PN-ABA-527

FINAL REPORT

DEVELOPMENT OF *PROSOPIS* SPECIES LEGUMINOUS TREES AS AN AGRICULTURAL CROP

S&T Small Activity Project #936-5542 (3.F32)

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Grantee Institution: United States Department of Agriculture
Agricultural Research Service
Western Regional Research Center
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Summary and recommendations

Two methods for processing mesquite (Prosopis species) pods were evaluated using pods from several species and populations. In the first process (Mexico) toasting, pin milling and sieving the milled pods produced an attractive flour with attributes similar to carob flour. The mesquite flour contains about 19% protein, 54% sugar, 6% fat and 21% dietary fiber. This product has been incorporated into commercial food products in mexico. A more complicated second process (USDA, Chile) which produced four mill fractions was also evaluated. Each of these fractions has unique compositions and industrial potential.

The overall conclusion is that pods from some Prosopis species offer potential for food utilization in developed and underdeveloped countries. When other characteristics of these species are considered such as their fast-growing nature, the ability to arrest desertification, environmental tolerance, and forage and firewood production, it becomes obvious that more serious attention should be devoted to Prosopis for Third World development.

Recommendation:

Mesquite flour as produced in Mexico is simply made, and is an attractive product with many positive attributes. To complete the developmental process, it is recommended that the economics of the process as developed in Mexico be evaluated to confirm its apparent low cost. Product acceptance in Mexico should be encouraged through official channels and by public relations activities. A portable milling system should be constructed and used to produce flour throughout Mexico to encourage acceptance. Similar systems could be established in other appropriate countries, for example Africa, the Caribbean and other South American countries. Promotional techniques used in Mexico should be applied in other countries.

The construction of a portable milling unit to separate pods into their four subfractions should be considered for small-scale use in developing countries. Blueprints for large-scale conversion of pods into the four subfractions are available now, and should be made available to interested parties.

1. Objectives and Approaches

The objectives of this study were to evaluate Prosopis species leguminous trees as an agricultural crop. Seeds, pods and foliage from different Prosopis species were investigated in collaborating LDC's and the USA. Chemical and physical properties of Prosopis protein, lipids, gums and mill fractions were studied to evaluate their nutritional and functional properties. Food and animal performance characteristics were assessed. Technology to separate the pods into useful mill fractions was developed and applications of those mill fractions in food products examined. Food products were organoleptically evaluated and those preferred by a taste panel were used as demonstration products for potential wholesalers in LDC's.

Because of LDC equipment limitations, two processing technologies were evaluated. In Mexico, the whole pods were finely milled and two mill fractions separated. In Chile, the pods were coarsely milled and four mill fractions separated.

2. MEXICO

2.1 Project, personnel, facilities

Mexico was selected as a target country because of its abundance of mesquite and its historical pattern of consumption and production of mesquite products. The principal collaborator, Dr. Francisco R. Del Valle is a PhD graduate of MIT. Del Valle led the project to manufacture soy-oats infant formula in Mexico which earned the 1983 Food Technology Industrial Achievement Award. This award is presented annually by the Institute of Food Technologists to honor those organizations developing an outstanding food process or product which represents a significant advance in the application of food technology (Mermelstein, 1983). Del Valle is president of Fundacion de Investigaciones en Ciencias Alimentarias y Nutricion (FICAN) and teaches at the Universidad de Chihuahua, as does his associate, Enrique Marco B., Professor of Chemistry. Both Del Valle and Marco have an ongoing favorable working relationship with Delicias Food Products, known as PADSA, and the PADSA general manager, Mario Vega P. which permits access to the Delicia. PADSA factory and processing equipment. PADSA personnel helped manufacture the mesquite products and participated in their evaluation and exposure to wholesalers.

The Delicias factory is about 60 miles south of Chihuahua. The processing line consists of a shaker to clean seeds, a gas fired oven for drying and toasting, a Brady Model 206 extruder, an Alpine pin mill (Model A400CW), and ancillary bagging and storage facilities. A simple kitchen laboratory is also available. Additional support analytical chemical laboratory facilities are available at the University in Chihuahua. Students from the University participated in several phases of this study.

2.2 Research approach

Because researchers in Chihuahua did not have access to a disk mill, initial experiments were performed to utilize the processing facilities in Delicias. Attempts to extrude mesquite pods using the Brady extruder were unsuccessful. The experimental procedure consisted of initially feeding soy beans to the extruder, then gradually adding increasing amounts of mesquite pods. Product was extruded until 50-70% mesquite pods were present. Then, because of the high fiber content of the mesquite, the product became too dry and the extruder jammed. Several processing conditions were tested with the same inevitable consequences. These results were consistent with experiments at the USDA using a Wenger laboratory extruder, so this approach was abandoned.

As part of the experiments utilizing the extruder, it was found that the Alpine mill could successfully mill mesquite pods. Further experiments demonstrated that oven dried pods milled better and produced a superior tasting product. An insect feeding bioassay demonstrated the optimum toasting conditions for nutritional availability were at 125°C for 20 or 40 minutes. Taste panels preferred toasting for 40 minutes.

Laboratory experiments indicated an improved product could be produced by removing the larger fiber particles from the pin milled flour. Consequently, the factory shaker, normally used to clean soy beans was modified by the addition of 45 and 100 mesh screens and the product screened. This resulted in two products; large fibrous particles that would not pass through the 100 mesh screen, and a fine flour that did go through the screen. The 45 mesh screen helped prevent the 100 mesh screen from becoming overloaded. The fine (100 mesh) flour, produced after toasting at 125°C for 40 minutes, became the product used in food applications.

2.3 Accomplishments

A significant result from the studies in Mexico was the demonstration that the bitter aftertaste component present in mesquite pods is eliminated by toasting. Almost all Prosopis pods are bitter to some degree, but even the most bitter were completely de-bittered by toasting. The chemical component that causes pod bitterness and the apparently related aftertaste has not been identified. It was our opinion that pod bitterness was a most important impediment to pod utilization. Obviously, bitter pods do not taste good, pods that are not bitter and have no aftertaste can be used as food adjuncts.

The mesquite flour contains about 19% protein, 54% sugar, 6% fat and 21% dietary fiber. The protein is high in lysine and limiting in methionine and cystine.

Several food products were prepared with the mesquite flour. A food manufacturing plant in Chihuahua City marketed a confection called Mazapan. These were prepared by mixing 29% ground peanuts, 10% mesquite flour, 60% powdered sugar and 1% salt. The mixture was pressed into a cylindrically shaped disk, wrapped and sold for 10 peso each (1986). These mazapans were well liked and apparently a successful product. Unfortunately, the manufacturing company went bankrupt in late 1986 due to the Mexican inflation crisis. A mesquite beverage base has also been tested. The powdery base was prepared with 69% sugar, 12% mesquite flour, 18% soy flour, salt and flavoring and used by mixing 1-2 tablespoons with milk or water in an 8 oz glass. Alternately, the toasted flour could be used as a beverage mix by itself or as a chocolate extender or replacement. The flour resembles carob flour in taste and appearance, but with its own unique character. It appears to have all the uses of carob, better in some cases, less so in others. For example, it makes

an attractive hot beverage by itself, but is not complementary to yogurt. It is an excellent chocolate replacement or extender. Economics would seem to favor this as the first commercial use of the flour.

In the last months of the project, large quantities of mesquite flour were produced and distributed with an informational handout to natural food stores in northern Mexico. Responses were very favorable, indicating the likely presence of a viable market.

3. CHILE

3.1 Project, personnel, facilities

The principal investigator in Chile, Srta. Maria Elena Torres and her parent organization Institute de Investigaciones Tecnologicas (INTEC) are well known to the USDA. In 1984, Srta Torres was awarded a National Academy of Science grant to study nitrogen fixation in Prosopis. She had demonstrated rapport with Dr. Orlando Balboa and his group at Universidad de Catolica de Chile who were studying propagation in Prosopis. During 1984, a PNUD(UNDP)/FAO program for development of semi-arid areas in Chile was initiated, which included further developmental work on Prosopis. She was also well known within the research community in Chile and interacted well with CORFO, CONAF, and Fundacion Chile.

The INTEC facility in Santiago had all the equipment needed for complete pod fractionation; a Rietz mill, Bauer disk mill and screening devices. They also had access to study trees near Santiago at Chincolco (about 150 km north of Santiago) and Peldehue (about 50 km North of Santiago) as well as trees in Pampa del Tamarugo (Habit, 1981, 1985).

Prosopis chilensis study trees near Santiago were taxonomically identified and their pods analyzed to detect compositional variations. A composite

collection of pods from many trees was used for the industrial process, which was also analyzed for compositional variations. These composites are referred to as P. chilensis and P. tamarugo, although it is understood that all trees in the composite sampling have not been critically identified.

3.2 Research approach

Since INTEC had the required equipment and facilities, they processed the pods using the procedure developed at USDA by Meyer et al (1987) (see Section 4.3). Prosopis pods were collected near Santiago and analyzed yearly for compositional variations. Large amounts of tamarugo pods from Pampa del Tamarugo were also processed and the fractions evaluated. Whole pod chemical composition, fraction composition and utilization of the fractions were studied. A companion investigation of nodulation of the study trees was unsuccessful.

3.3 Accomplishments

Analyses of pods from two Prosopis species grown in several locations in two consecutive years indicate little yearly compositional variations within species. This is in general agreement with other reports (De Lumen et al, 1986).

Nutritional evaluation by a rat feed experiment demonstrated the presence of a heat labile component(s) in P. chilensis pods. Toasting increased the PER from 0.03 to 0.87, compared to a high fiber casein control of 2.83. Uncooked tamarugo pods had a PER of 0.45 and exhibited toxicity. Algarrobo and tamarugo seeds had PER's of 1.27 and 1.47 respectively. Enzymatic in vitro digestibility assays gave similar results. Antinutrients such as cyanide, trypsin inhibitor, hemagglutinins, and urease activity were examined

and found to be present in levels less than what would appear to be responsible for the low nutritional value. No other antinutrients were detected. It seems likely that the poor nutritional performance is due in part to the high levels of fiber in the pods. The mesocarp flour from P. tamarugo was toxic to rats and should be investigated further. It was concluded that when using whole pods of P. chilensis and P. tamarugo as animal feed, the ration should be supplemented with other fodder.

A galactomannan gum was extracted from P. chilensis seed by dry milling or aqueous extraction followed by oven or spray drying. The spray dried preparation had a viscosity of only about 1/3 that of guar gum; the oven dried gum was even lower. [Analyses of this gum by the USDA laboratory indicated the presence of large amounts of free monosaccharides, indicating preparative contamination.] No mucilage gum was found in the P. tamarugo seeds.

Several food products using P. chilensis and P. tamarugo were formulated and evaluated. Dietary bread, cookies, and Chilean donuts called 'Berlines' were prepared in the laboratory and on an industrial scale using 5 kg dough. Doughs were evaluated with the farinograph and the final product judged by taste panels. It was found that bread and Berlines containing 10% P. chilensis flour were acceptable. Prosopis tamarugo was not acceptable above 5% substitution. All Prosopis products except the fried Berlines and products made from seeds were judged by INTEC personnel to be too bitter and to have too much of an aftertaste to be commercially useful.

Since P. chilensis pods contain as much as 50% sugar, utilization of the pods for alcohol production was investigated. It was found that a Saccharomyces cerevisiae yeast strain (Intec No. 131) adapted to produce ethanol at high sugar concentrations, yielded 92% of the theoretical yield of ethanol and consumed 97% of the total sugar.

4. USDA contributions

4.1 Collaboration with Mexico

The USDA supported the Mexican effort by actively participating in experimental design and recommending process modifications, providing many chemical analyses and all bioassays. Amino acid composition and proximate analyses were routinely performed on samples the Mexican researchers supplied. Bioassays using rats and red flour beetle larvae were performed to assist in the nutritional evaluation. All English language manuscripts were rewritten by USDA personnel before submission to journals.

4.2 Collaboration with Chile

Collaboration with Chile consisted of some proximate analyses, all amino acid analyses and all rat bioassays. Some chemical and computer supplies were provided. USDA actively participated in experimental design and interpretation of results, although experiments were frequently modified by the Chilean researchers. The principal investigator in Chile was ill during several months of this study. She anticipates publication of these results in the near future.

4.3 Accomplishments

The USDA collaborators developed a milling and separation process that produces four fractions with potential for different applications. The first fraction (50%) is a flour containing up to 60% sucrose, the second fraction (20%) a high fiber material, the third fraction (15%) principally a galactomannan gum, and the fourth fraction a high-protein flour (15%). These fractions were evaluated in numerous food applications, which included organoleptic appraisal by consumer panels. The economics of this process were

calculated for small and large scale cases in Mexico. A plant layout was designed and costed by Buehler.

Individual fractions show potential for use in snackfoods, baked products, sweetener (sirup) production, and as a substitute for guar gum.

Several chick-feeding experiments were carried out by personnel at the University of California, Davis. Their results showed that diets containing up to 20% whole pods from Prosopis chilensis, P. velutina, P. pubescens and P. tamarugo were satisfactory in promoting chick performance.

The forage quality of leaves from six Prosopis species was assessed. Four were satisfactory, but two showed toxicity (to mice). Further studies are needed to fully assess the suitability of leaves from Prosopis for ruminants.

4.4 USDA public relations

The Public Relations specialists at the USDA, WRRC, facility initiated press coverage for the project by preparing informational releases for distribution to US news services. This resulted in numerous articles in magazines and newspapers as well as radio interviews, some of which are listed (Appendix III.b). This has resulted in considerable domestic interest in the process, with several Texas companies discussing commercialization. Molokai Ranch in Hawaii has also indicated a commercial interest. As of this date however, there is no known large scale commercial production of mesquite pod products.

5. Publication List

5.1 Publication List. Mexico

Del Valle, F. R., Marco, E., Becker, R., Saunders, R. M. Preparation of a mesquite (Prosopis species) pod protein concentrate by a low cost process. 45th Annual IFT Meeting, Atlanta, GA. June 11, 1985. (Abstract)

Del Valle, F. R., Marco, E. B., Becker, R., Saunders, R. M., Escobedo, M. and Bourges, H. Estudios sobre el aprovechamiento de la vaina del mezquite para el cosumo humano. Presented at Asociacion de Tecnologos en Alimentos de Mexico. Mexico City. Nov. 15, 1985. (Abstract)

Del Valle, F. R., Marco, E. B., Becker, R., Saunders, R. M., Escobedo, M., and Bourges, H. Estudios sobre el aprovechamiento de la vaina del mezquite para consumo humono. Tecnologia de Alimentos. Mexico. (Accepted Mar. 1985)

Del Valle, F. R., Marco, E., Becker, R. and Saunders, R. M. Preparation of a mesquite (Prosopis spp) and pod enhanced protein reduced fiber fraction. J. Food Sci. 51:1215-1217. 1986.

Del Valle, F. R., Marco, E., Becker, R., Saunders, R. M. Further studies on production of a mesquite (Prosopis spp.) pod protein concentrate. 46th Annual IFT Convention. Dallas, TX, June 17, 1986. (Abstract)

Del Valle, F. R., Marco, E., Becker, R., Saunders, R. M. Evaluation of an industrial process for making mesquite pod (Prosopis spp) flour. 47th Annual IFT Convention. Las Vegas, June 1987. (Abstract)

Del Valle, F. R., Marco, E., Becker, R., Saunders, R. M. Development of low-cost nutritious food products utilizing a mesquite (Prosopis spp) pod flour. 7th International Congress Food Sci. technol. Singapore. Sept. 1987. (Abstract accepted)

Del Valle, F. R., Marco, E., Becker, R., Saunders, R. M. Studies on the production of a mesquite pod (Prosopis spp) protein concentrate. J. Food Pros. Pres. (Accepted, Feb. 1987)

Del Valle, F. R., Marco, E., Becker, R., Saunders, R. M. Evaluation of an industrial process for producing mesquite pod (Prosopis species) flour. J. Food Pros. Pres. (Submitted July, 1987).

5.2 Publication List. Chile.

NONE

5.3 Publication List. USDA

Meyer, D. Processing, utilization and economics of MESQUITE pods as a raw material for the food industry. Swiss Fed. Inst. Technol. Zurich Ph.D. Desertation ETH 7688. 1984. (Work conducted at USDA Grantee Institution).

Becker, R., Sayre, R. N. and Saunders, R. M. Semiarid crops as protein resources. J. Am. Oil Chem. Soc. 61:931-938. 1984.

Becker, R., Saunders, R. M. and Meyer, D. Farming the desert - Prosopis species (mesquite) pods as a food crop. LIFE Newsletter. 17(1):2. 1984.

Irving, D. W. and Becker, R. Seed structure and composition of potential new crops. Food Microstructure. 4:43-53. 1985.

Saunders, R. M., Becker, R., Meyer, D., Del Valle, F. R., Belestin, E. M., Torres, M. E. Identification of commercial milling techniques to produce high sugar, high fiber, high protein, and high galactomannan gum fractions from Prosopis pods. Symposium of Tree Planting in Semi-Arid Areas. April 29-May 3, 1985. Texas A&I University, Kingsville, Texas. (Abstract)

Becker, R., Meyer, D., Torres, M. E., Del Valle, F. R., Marco, E. B., Saunders, R. M. Development of Prosopis species Leguminous trees as an agricultural crop. In Arid Lands: Today and Tomorrow. October 20-25, 1985. Tucson, AZ. (Abstract)

Becker, R., Meyer, D., Torres, M. E., Del Valle, F. R., Marco, E. B., Saunders, R. M. Development of Prosopis species Leguminous trees as an agricultural crop. In Arid Lands: Today and Tomorrow. Proc. Intn'l. Res. Develop. Conf. October 20-25, 1985. Tucson, AZ. Whitehead, D. W., Hutchenson, C. F., Timmermann, D. N., Barady, R. G. (eds.) (Accepted Feb 1986)

Irving, D. W. and Becker, R. Microstructure and composition of potential new arid crops. In Arid Lands: Today and Tomorrow. October 20-25, 1985. Tucson, AZ. (Abstract)

Irving, D. W. and Becker, R. Microstructure and composition of potential new arid crops. In Arid Lands: Today and Tomorrow. Proc. Intn'l Res. Develop. Conf. October 20-25, 1985. Tucson, AZ. Whitehead, D. W., Hutchenson, C. F., Timmermann, D. N., Barady, R. G. eds. (Accepted Feb. 1986).

De Lumen, B. O., Becker, R. and Reyes, P. S. Legumes and a cereal with high methionine/cysteine contents. J. Agric. Food Chem. 34:361-364. 1986.

Saunders, R. M., Becker, R., Meyer, D., Del Valle, F. R., Belestin, E. M., Torres, M. E. Identification of commercial milling techniques to produce high sugar, high fiber, high protein, and high galactomannan gum fractions from Prosopis pods. For. Ecol. Manage. 16:169-180. 1986.

Meyer, D., Becker, R., Gumbmann, M. R., Vohra, P., Neukom, H., Saunders, R. M. Processing, composition, nutritional evaluation, and utilization of mesquite (Prosopis spp.) pods as a raw material for the food industry. J. Ag. Food Chem. 34:914-99. 1986.

Lyon, C. K., Gumbmann, M. R., Becker, R. Value of mesquite leaves as forage. J. Sci. Food Agric. 1987. (Accepted July, 1987)

Saunders, R. M., and Becker, R. Development of Prosopis Species Leguminous Trees as an Agricultural Crop. Intern. Symp. New Crops for Food and Industry. Southampton, England. 1987. (Accepted)

6. References

Mermelstein, NH. 1983. Soy-Oats Infant Formula Helps Fight Malnutrition in Mexico. Food Technol. August. pp 64-72.

Habit, MA. 1981. Prosopis tamarugo: Fodder tree for arid zones. FAO Plant Production and Protection Paper 25. FAO, Rome. 110p.

Habit, MA. 1985. The current state of knowledge on Prosopis tamarugo. FAO. 464 p.

APPENDIX

I. Mexico

I.a. Contract

I.b.1 Crops for production in marginal growing areas in Mexico. First Progress Report.

I.b.2 Crops for production in marginal growing areas in Mexico. Second Progress Report.

I.b.3 Development and evaluation of products containing lightly and highly toasted mesquite pod (*Prosopis* spp.) flours. Final Report

I.c Publications

APPENDIX

II. Chile

II.a.1 Contract
II.a.2 Background of the Technological Research Institute INTEC-Chile-1981
II.b.1 First Report-Maria Elena Torres-May/October 1986
II.b.2 First Annual Report: Crops for production in marginal growing areas in Chile (13 pages- no date)
II.b.3 Proximate Analysis of 1985 Prosopis spp samples (recd. 11-14-85)
II.b.4 Enzymatic evaluation of Prosopis spp fraction in vitro digestibility (recd. 11-14-85)
II.b.5 Informe de advance I: Formulacion de productos con Algarrobo y Tamarugo-Marso 1986
II.b.6 Informe de advance II: Evaluation sensorial productos de Algarrobo-Julio 1986
Part 1: Evaluation sensorial Pan Amasado
Part 2: Evaluation sensorial Berlines
II.b.7 Informe de advance III: Evaluacion sensorial productos de Algarrobo-Agosto 1986
II.b.8 Summary of activities during 1986: Crops for production in marginal growing areas in Chile- March 1987
II.b.9 Final Report: Crops for production in marginal growing areas in Chile- May 1987

II.c. Publications- none

APPENDIX

III. USDA

III.a Publications

III.b. News Releases:

1. Mesquite: The next health food? BUSINESS WEEK Science & Technology. June 16, 1986.

2. Washington UPI. Sagebrush gains value. Houston Chronicle. Pg. 4, Section 5. June 15, 1986.

3. Hillgren, S. (UPI). New process converts mesquite tree pods into food. News in agriculture, Washington UPI. 07:26. May 26, 1986.

4. Becker, R. and Del Valle, F. R. New Products from Mesquite Pods. BIOPROCESSING TECHNOLOGY 8(8):7. August 1986.

5. A nutritious, high-energy flour can be made from mesquite bean pods. Quarterly Report of Selected Research Projects, USDA. April 1, to June 30, 1986.

6. New process converts mesquite into nutritious foods. Scientific Research News, USDA..

7. Mesquite pods into nutritious foods. Agricultural Research AGNOTES USDA. 35(1):5. January 1987.

8. Becker, R. A profitable pest. AMARANTH TODAY 3(1):4. Winter 1987.

9. Research Progress in 1986. A Report of the Agricultural Research Service. Pg 38. May 1987.

APPENDIX I: MEXICO

UNITED STATES DEPARTMENT OF AGRICULTURE

RESEARCH AGREEMENT

TYPE OF RESEARCH AGREEMENT: COOPERATIVE AGREEMENT - SPECIFIC

AGENCY (Name and address)

AGRICULTURAL RESEARCH SERVICE
PACIFIC BASIN AREA
800 Buchanan St.
Albany, CA 94710

AGREEMENT NO.: 58-91H2-4-00010

TYPE OF ACTION: New

PERIOD OF AGREEMENT: 6-1-84 thru 6-1-87

FEDERAL OBLIGATION: $ 31,000.00 US

CHANGE IN FEDERAL OBLIGATI[illegible]: ☐+ ☐- $ N/A

CRIS NO.: 5390-20521-025A

AUTHORITY: 7 USC 2912, 3318, 31 USC 3600

PERFORMING ORGANIZATION (Name and address)

FUNDACION de INVESTIGACIONES en CIENCIAS ALIMENTARIAS Y NUTRICION, A. C.
Apartado Postal 1545, Sucursal C.
Chihuahua, Chih., Mexico

OBLIGATION DISTRIBUTION

Financial Data Code	Amount
4015390010	$31,000
ADVANCE PAYMENT - $13,000	

PRINCIPAL INVESTIGATOR (name and address)

Dr. Francisco P. del Valle
Principal Investigator
(Same address as above)

FINANCE OFFICE (Complete mailing address)

Chief, Accounting Services Branch
USDA-ARS-FMD
P. O. Box 53325
New Orleans, LA 70153

TITLE OF PROJECT

Crops for production in marginal growing area in Mexico

AUTHORIZED DEPARTMENTAL OFFICER'S DESIGNATED REPRESENTATIVE (Name and address)

Dr. R. Saunders and R. Becker (alternate)
USDA-ARS-Pacific Basin Area
Western Regional Research Center
800 Buchanan St., Albany, CA 94710

This Agreement includes the following:

- ☒ Statement of Work; *or*
- ☐ Project Summary; *or*
- ☐ Proposal; *and*
- ☒ General Provisions - 7 CFR 3015, Part U (by reference)
- ☐ Special Provisions
- ☐ Submit -
  - ☐ Technical Reports
  - ☐ Fiscal Reports,

  to: Authorized Departmental Officer's Designated Representative
- ☒ Other *(specify)*: EXHIBIT "A" - Scope of Work

BASIS FOR AWARD

FOR THE UNITED STATES DEPARTMENT OF AGRICULTURE

AUTHORIZED DEPARTMENTAL OFFICER	TYPED NAME	DATE
[signature]	T. J. CLARK Associate Deputy Administrator Administrative Management, ARS	JUN 21 1984

FOR THE PERFORMING ORGANIZATION

(Signature of person authorized by the governing body of the performing organization to incur contractual obligations.)

SIGNATURE	TYPED NAME AND TITLE	DATE
[signature]	Francisco P. del Valle President	6/10/84

Form ARS-451 (9/83)

CONTRACTORS COMPLETE CERTIFICATIONS ON REVERSE

WHEREAS, the United States Department of Agriculture, Agricultural Research Service, hereinafter referred to as ARS, and Fundacion de Investigaciones en Ciencias Alimentarias y Nutricion, A. C. (FICAN), hereinafter referred to as the Cooperator, desire to enter into this cooperative agreement for the research investigations set forth herein; and

WHEREAS, there is a need to assess potential of crops in Mexico which are tolerant of drought, salininty, and temperature stress; and

WHEREAS, the parties desire to investigate the food and feed potential of leguminous trees which are indigenous to marginal areas of known stress; and

WHEREAS, evaluation will include seed and pod yield and conversion to food and/or feed subfractions through conventional or innovative processing sequences; nutritional evaluation of plant parts by chemical factors; and incorporation and performance of seed fractions in food systems; and

WHEREAS, data generated will be related to economic justification of developing specific plants, and will be used to assist breeders in selection of tolerant plants; and

WHEREAS, it is the intention of the parties to this cooperative agreement that such research investigations shall be for their mutual benefit and for the benefit of the people of the United States and other countries; and

NOW, THEREFORE, for and in consideration of the promises and mutual covenants herein contained, the parties hereto do mutually agree with each other as follows:

A. The Cooperator Agrees:

1. The Cooperator will conduct research studies on the tasks listed below as detailed in the "Scope of Work" outlined in EXHIBIT "A" attached hereto and made a part hereof:

   a. Pod collection and selection from analysis.

   b. Milling and subfractionation of pods.

   c. Analysis of pod subfractions.

   d. Food, feed, and industrial evaluation of pods, pod subfractions, and foliage.

   e. Preliminary economic evaluation of *Prosopis*.

2. To provide the necessary personnel to conduct the research investigations, travel of the Cooperator's employees engaged in the project, and furnish the necessary facilities, equipment, and supplies as mutually agreed upon.

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3. To maintain current records of the investigations and provide semi-annual reports (4 copies) of the progress of the work to the Authorized Departmental Officer's Designated Representative (ADODR), including a final report (5 copies) setting forth in detail all work accomplished and results obtained. Upon receipt of these reports, copies will be sent to the following by the ADODR, Dr. R. Saunders or Dr. R. Becker:

Quarterly Letter Reports:	Area Director Western Region Deputy Administrator National Program Staff
Final Report:	Area Director National Agricultural Library Western Region Deputy Administrator National Program Staff

B. The Agricultural Research Service Agrees:

1. To provide the services of an ARS Representative to maintain close liaison with the Cooperator through frequent visits and other means to review and evaluate the research progress and to assist in the planning and coordination of the research to be undertaken.

2. To provide the necessary personnel to provide technical know-how on *Prosopis* pod processing technology, and define exact protocol to determine objectives listed under paragraph 4 of the Scope of Work.

3. a. To assist in defraying the cost of the project by reimbursing the Cooperator for salaries travel of the Cooperator's employees engaged in the project, expendable supplies and materials, including supplies and materials, in an amount not to exceed $31,000 during the period of this cooperative agreement. Indirect or overhead costs shall not be reimbursed by ARS.

   b. $13,000 ADVANCE PAYMENT will be issued by ARS Finance Office upon receipt of an executed copy of this cooperative agreement. At the time of each quarterly fiscal claim submitted to the ADODR, the Cooperator will be paid for actual expenses incurred and the initial advance will remain at $13,000. However, liquidation of the advance payment must take place before the ending date of this cooperative agreement.

C. It is Mutually Understood and Agreed:

1. Payment by ARS to the Cooperator will be made on a quarterly basis, for expenditures for each previous quarter as listed in on properly executed invoices or vouchers to be prepared by the Cooperator and submitted to the ADODR for approval and submission to the ARS Finance Office.

2. Items for which reimbursement will be claimed by the Cooperator shall not include capital improvement, non-expendable property, nor travel for ARS employees.

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3. Results of the research outlined herein may be published jointly by the Cooperator and ARS, or by either of these institutions separately, but manuscripts prepared for publication by either shall be submitted to the other party for suggestions and approval prior to publication. In the event of disagreement, either party may publish results on its own responsibility, giving proper acknowledgment of cooperation.

4. Results paterted by one party are to be made known to the other party and that the patenting party will give the other party a paid-up, royalty-free, world wide license to use the patent for government purposes.

5. This cooperative agreement may be amended or terminated upon 60 calendar 60 days notice in writing. Participation by ARS as cited in paragraphs B.1 and B.2 herein shall be subject to passage by the Congress of the United States of an appropriation of funds, from which expenditures may legally be made.

EXHIBIT "A"
SCOPE OF WORK

1. SUMMARY

This Agreement formally attests to a cooperative research venture between Fundacion de Investigaciones en Ciencias Alimentarias y Nutricion, A. C. (FICAN), Chihuahua, Chih., Mexico, hereinafter called the Cooperator, and ARS. The research objectives and plan of work are described herein.

Studies in Mexico, which will be financed by ARS, through funding originating from the Agency for International Development, Washington D.C., USA, will focus on a detailed examination of whole pods and pods subfractions of Mexican Prosopis species as a food, feed, and industrial resource. Technology will be developed to utilize the whole pods and/or rapidly separate the pods into subfractions with anticipated specific end uses. Properties of milled pods and pod subfractions will be monitored by chemical, biochemical, and functional techniques. Studies will include animal feeding. The work will be interfaced with Prosopis development work being carried out at the ARS facility, Western Regional Research Center (WRRC).

Project Duration: 3 years

Funds to the Cooperator: U.S. $31,000.00

Principal Investigators: Mexico, Cooperator: Dr. Francisco R. del Valle
Enrique Marco Belestin

USDA-ARS-WRRC: R. M. Saunders, ADODR
Robert Becker, ADODR

2. PROJECT OBJECTIVE

Define parameters required to exploit components of Prosopis species as food, feed, and industrial resources.

a. Define pod composition and relate to environmental factors.

b. Establish food, feed, and industrial potential of Prosopis pods and subfractionated pods.

3. BACKGROUND: PROSOPIS IN MEXICO

For several years workers in Mexico have been engaged in work relative to development of Prosopis. In 1983, a chemical and nutritional study on food mesquite beans (Prosopis juliflora) was published by del Valle, in which it was concluded that mesquite beans could be combined with cereals, legumes or mixtures of both to probably yield products of good nutritive value. In June, 1983, Dr. del Valle initiated discussions for collaborative Prosopis utilization research with ARS which led to a USDA visit to Chihuahua, Mexico in February 1984, and subsequently to this agreement.

4. WORK PLAN

a. Pod collection.
b. Selection of pods for analysis.
c. Milling and subfractionation of pods.
d. Analysis of pod subfractions.
e. Food, feed, and industrial evaluation of pods, pod subfractions, and foliage.
f. Preliminary economic evaluation of *Prosopis*.

4.a and 4.b - Pod collection and selection for analysis

Pod composition is known to vary widely due to poorly understood factors. To document this variation and efine the potential compositional range of a composite pod collection, five specific trees will be selected and tagged for a continuing study. Three selection will be based on pod taste and yield. A tree producing large amounts of sweet pods, a tree with sour pods, and three trees with typical yielding and tasting pods will be selected for the yield and pod composition study. If trees yielding sweet and sour pods cannot be obtained, 5 typical trees, seletected at random, or possibly from different elevations above sea level would be used. Pods which subsequently are shown to possess desirable economic value can thus be related to specific trees, which could become the germplasm for future development. Investigations in 1985 and 1986 would be expected to be carried out on pods from thos trees showing the most promise after examination in 1984. Other pods will be collected from random trees, combined and mixed to form a composite lot which will be used for experimentsd requiring large samples, such as processing and product formulations. Some preliminary studies will be performed on pods supplied by the ARS ADODR.

4.3 - Milling and subfractionation of pods

Milling characteristics of whole pods will be studied using existing mills and the mill products evaluated by standard screen analysis. The fractions from the milling procedure(s) judged best will be further analyzed for proximate composition. Milled pods or pod subfractions will be combined with other food products to achieve optimum nutritional benefits, extruded, milled, and evaluated as a food or food ingredient. Alternately, if whole pods are difficult to grind, they will be mixed with other food components and tests performed to determine if the mixture is easier to grind.

The ADODR will supply the Cooperator with at least 50 lbs. of *Prosopis* pods to permit preliminary evaluation of existing mills. If these mills are judged unsatisfactory, immediate efforts will be focused on obtaining a usable mill, purchased from funds allocated to Mexico. This evaluation of milling equipment will be the first research task.

4.4 - Analysis of pod subfractions

Whole pods or separated subfractions, and foliage which would be a crude fraction separable from collected pods during their initial cleaning, will be analyzed for nutrient content (portein, lipid, ash, fiber, sugars and moisture) using standard methods. A specific analysis for seed gum would be carried out on appropriate fractions. *In vitro* enzymatic digestion of *Prosopis* fractions will be carried out

to predict their potential digestibility for monogastric and ruminant animals. The ADODR will supply methods for seed gum analysis and in vitro engymatic digestion. Certain protein fractions would be sent to the ADODR for amino acid analyses.

4.5 - Food, feed, and industrial evaluation of pods, pod subfractions, and foliage

Based upon data generated in 4.4, a limited number of amino acid analysis and rat feeding experiments will be subcontracted by the Cooperator, to be carried out at Instituto Nacional de La Nutricion in Mexico City. These will be PER, NPU and if possible toxicity studies. If requested by ARS, the Cooperator will be responsible for ensuring that large quantities of pods are provided to the ADODR for chick and pig feeding to be carried out in the USA, shipping costs to be paid from funds provided to the Cooperator.

The Cooperator will carry out studies to separate the galactomannan gum from the Prosopis seed coat, using procedures recommended by the ADODR, and will compare the gum physical and chemical properties with those of guar gum. Such properties will include gelation and viscosity; the ADODR will supply a standard guar gum for comparison purposes.

Pods and pod subfractions will be tested as adjuncts in foods deemed appropriate for new and traditional Mexican and U. S. consideration. This will necessitate measurement of physicochemical attributes as commonly employed in food science to predict potential food characteristics, such as farinograph, amylograph, etc. as appropriate. The studies would include statistically correct consumer testing/ organoleptic appraisal in Mexico. Consumer acceptance of recommended products would be carried out in standard hedonic taste tests, by comparison of the Prosopis modified food with a nonmodified control, and by general reaction to new Prosopis-based foods. At least 8 Prosopis containing products will be evaluated. These products will be evaluated by proximate analysis, microbial analysis, large scale acceptance tests, and nutritional attributes. The best of these products would be evaluated with large scale market trials.

4.6 - Preliminary economic evaluation of Prosopis

To attract commercial interest in the production and processing of Prosopis species it is essential to demonstrate favorable economics. A preliminary determination will be made by the Cooperator of the value of the various fractions that are developed from the whole pods and the pod subfractions, and foliage. This will be done after work on pod subfraction, chemical analysis, and commercial products for which the various Prosopis materials can be substituted. The prices of these commercial products will be used to provide guides as to the value of the Prosopis fractions which are their potential substitute. The prices will be verified, discounted or increased depending on evaluations made by potential users who will have been provided product samples from the project. A written preliminary economic evaluation will be part of the final report.

5. - COLLABORATIVE ARRANGEMENTS

The Cooperator is encouraged to interact with others around the world engaged in Prosopis development, especially INTEC, Chile and P. Felker, USA. Cooperation with ARS will be maintained throughout the life of the project, which may include assignments of the Cooperator's staff at the ARS research facilities in USA.

6. BUDGET

The funds to be provided to the Cooperator by ARS (original source, Agency for International Development, USA) and their proposed distribution on an annual basis is outlined in Table 1.

Table 1. Cooperator staff effort and budget summary (U.S. dollars)[a]

	1984		1985		1986	
Principal Investigator Fernando R. del Valle	3m	($1,500)	3m	($1,500)	3m	($1,500)
Project Scientist Enrique Marco Belestin	12m	($4,500)	12m	($4,500)	12m	($4,500)
Salaries		$6,000		$6,000		$6,000
Travel[b]		$2,000		$2,000		-
Material, Supplies		$3,000		$2,000		-
Animal Feeding		$2,000		$2,000		-
Totals:		$13,000		$12,000		$6,000

Overall Total: $31,000

[a] Funds will be placed with the Cooperator by ARS. Funds can be interchanged within categories at the discretion of the Cooperator, but with prior written approval by the ADODR. Funds can be carried over from year to year. The first year funds can be expected June 1984, subject to signing of this cooperative agreement, and final approval of ARS Administration.

[b] Travel in Mexico is limited to pod collection. Travel to USA may be combined with attendance at meetings of recognized scientific societies with prior written approval by the ADODR.

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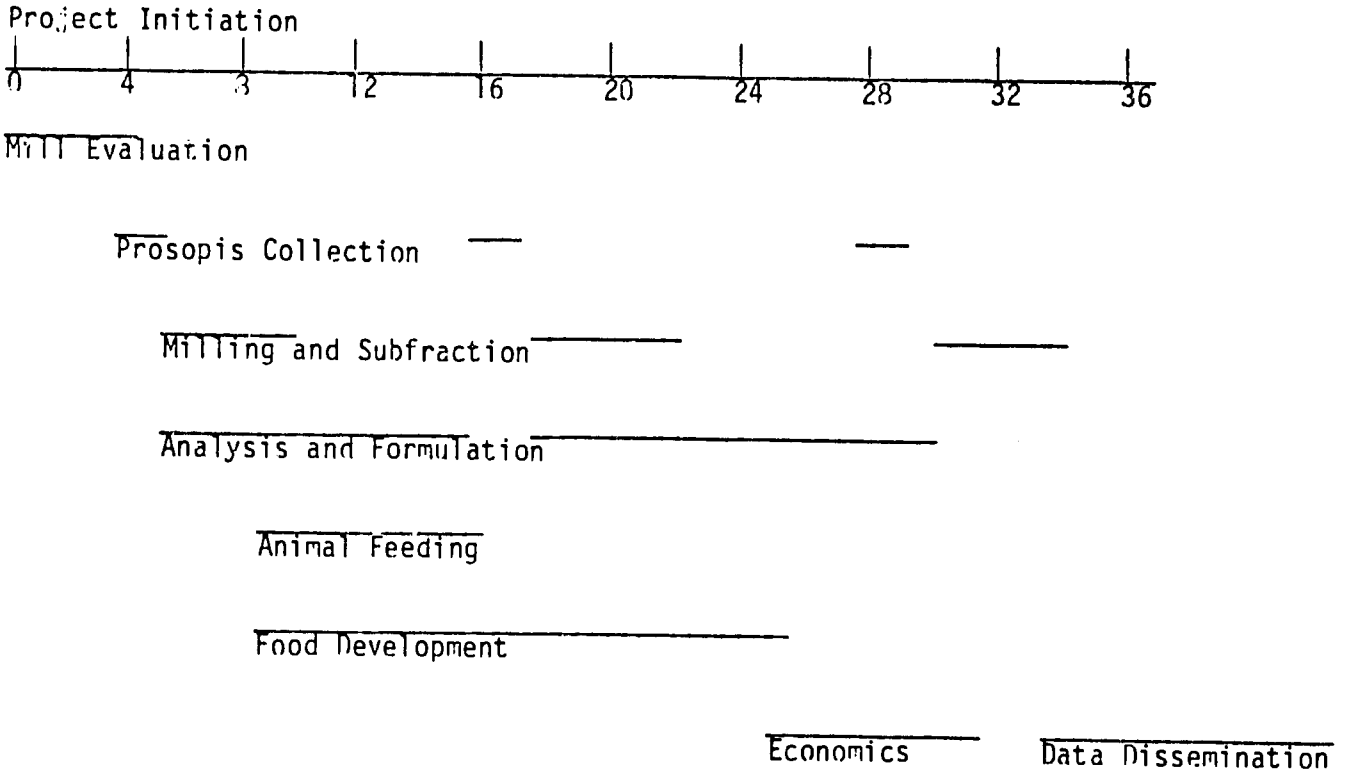
7. TIMEFRAME

The proposed timeframe in months is illustrated below:



8. REPORTS

A concise written report will be supplied to the ADODR by the Cooperator on a semiannual basis during the life of the project. Presentation of research results at meetings or in publications is permitted. Joint authorship between the Cooperator and ARS and/or other Mexican Investigators is encouraged, but not essential.

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DEVELOPMENT AND EVALUATION OF PRODUCTS CONTAINING LIGHTLY AND HIGHLY TOASTED MESQUITE POD (*Prosopis* spp.) FLOURS

Final report submitted to USDA - ARS, by
Fundación de Investigaciones en Ciencias Alimentarias y Nutrición, A. C., Apartado Postal 1545, Sucursal C, Chihuahua, Chih., Mexico

INTRODUCTION

Previous papers (Del Valle et al., 1986; Del Valle et al., 1987a, 1987b) have dealt with development and evaluation of processes for manufacture of mesquite pod (Prosopis spp.) flour. The best process, i.e., the one which gave flour of optimum organoleptic quality, yield and chemical and nutritional characteristics consisted of toasting of pods, followed by grinding in a pin mill, followed finally by screening in 45 and 100 mesh sieves (Del Valle et al., 1987b). The fines (-100 mesh material) constituted the final product. This process was carried out industrially with very good results (Del Valle et al., 1987b).

Once an industrial process for the manufacture of mesquite pod flour of good quality had been found, however, the next step was to develop uses for the flour. The purpose of this paper, therefore, was to study and evaluate different possible applications for the above product.

It might be noted that Del Valle et al. (1987b) obtained two types of mesquite pod flour utilizing their industrial process: lightly toasted and highly toasted products. Applications for both types of flour were therefore studied and evaluated.

MATERIALS AND METHODS

a) Development of products utilizing the lightly toasted flour.

Nine products were developed utilizing the lightly toasted mesquite pod flour. All were similar to products which are currently being manufactured in Mexico and which are extensively consumed by different population groups. These were as follows.

1) Powdered chocolate beverage base. A commercial powdered chocolate beverage base, manufactured by Productos Alimenticios Delicias, S. A. de C. V., Delicias, Chihuahua, Mexico, the composition of which is given in Table 1, was utilized. Four parts of the base were mixed with one part of mesquite pod flour to yield the final product. The beverage was prepared by blending 5 heaping teaspoonfuls of powdered base in 250 ml of milk.

2) Powdered strawberry beverage base. A commercial powdered strawberry beverage base, also manufactured by Productos Alimenticios Delicias, S. A. de C. V., Delicias, Chihuahua, Mexico, whose composition is given in Table 1, was utilized. As in the case of the powdered chocolate beverage base, four parts of the strawberry base were mixed with one part of mesquite pod flour to obtain the final product. Again, the beverage was prepared by blending 5 heaping teaspoonfuls of powdered base in 250 ml of milk.

3) Powdered base for "horchata" beverage. "Horchata" beverages are extensively consumed in Latin America and Spain. They are prepared by blending finely ground almond, rice grains, cantaloupe seeds and others in

water; the resulting blend is lightly sweetened and sometimes flavored with cinnamon). The powdered base for making "horchata"-type beverages utilizing mesquite pod flour was prepared by mixing 4 g powdered sugar, 5 g flour and 0.2 g powdered cinnamon. The beverage itself was prepared by blending 9 g base in 150 ml water.

4) Pinole. Pinole is corn which has been toasted and ground to a coarse powder. It is one of the staple foods of Tarahumara Indians, who live in the mountainous regions of the state of Chihuahua in Mexico. The same coarse powder, mixed with sugar (also called "pinole"), is extensively consumed by other low-income groups in northern Mexico. A pinole-type product, which incorporated toasted mesquite pod flour, was prepared by blending 40 parts of regular pinole (100% ground toasted corn), 30 parts sugar (sucrose) and 10 parts mesquite pod flour.

5) Pressed mesquite/peanut butter candy. Peanut butter marzipans or "mazapanes" are widely consumed by most, if not all population groups in Mexico. These products are manufactured by blending peanut butter with powdered sugar (approximately 60% of the former and 40% of the latter), followed by pressing to form round cakes (2 - 4 cm in diamter by 1 - 2 cm in depth). Marzipans containing mesquite pod flour were prepared as noted, with the following composition: 35% peanut butter, 55% powdered sugar and 10% toasted mesquite pod flour.

6) Mesquite pod butter. Peanut butter, originally developed, marketed and consumed in the U. S., is now being manufactured and consumed in many Latin American countries, including Mexico. Other like products, including almond, sesame seed and sunflower seed butters are available in the U.S. A mesquite pod butter, with characteristics similar to those of the latter products, was prepared by blending 5 parts toasted mesquite pod flour, 15 parts powdered sugar and 8 parts vegetable (safflower) oil.

7) Cooked blend of cream of wheat and mesquite pod flour. Cooked cream of wheat cereal is widely consumed by most population groups in Mexico. A cooked blend of cream of wheat and mesquite pod flour was prepared by mixing 46 g of regular dry cream of wheat cereal, 9 g of toasted mesquite pod flour and 2 g salt with 200 ml water and boiling until the usual consistency was attained.

8) Oatmeal cooked with mesquite pod flour. Like cream of wheat, oatmeal is also consumed by many population groups in Mexico, especially in the states of Chihuahua and Yucatan. Oatmeal cooked with mesquite pod flour was prepared by mixing 94 g of regular rolled oats with 19 g mesquite pod flour and 4 g salt, and boiling until the desired consistency was obtained.

9) Flavored yogurt blended with mesquite pod flour. Yogurt is increasingly becoming more popular in Mexico and other Latin American countries as inhabitants of these countries become more health conscious. Plain yogurt blended with mesquite pod flour was prepared by mixing 98 parts yogurt with 2 parts flour.

B) Organoleptic evaluation of products developed utilizing the lightly toasted flour and statistical analysis of results.

A 25-member untrained panel was utilized. Panelists were asked to assign a score to each of the following attributes for each product: 1) Aroma; 2) Flavor; 3) Color; 4) General Impression; and 5) Overall Acceptance. The grading scale was 1 (minimum score) to 9 (maximum score).

Average values and standard deviations were calculated for all assigned scores. Significance of differences in scores for the same attribute (i.e., aroma), between the different products was determined by application of Analysis of Variance Techniques (Snedecor, 1974).

C) Applications of highly toasted mesquite pod flour.

Two applications were studied and evaluated for the highly toasted mesquite pod flour: as an extender for cocoa and coffee. The cocoa extender application was evaluated by mixing regular (Hershey's brand) cocoa with the highly toasted flour in different proportions (0%, 25%, 50%, 75%, and 100%); 5 g of each of the mixtures were then blended (Waring blender) with 200 ml milk and 12 g sugar. The resulting "chocolate milks" were then evaluated as to cocoa flavor by a five-person untrained panel. The coffee extender application was similarly evaluated by mixing the highly toasted flour with instant coffee (Nescafe brand) in the same proportions. Coffee-like beverages were then prepared by mixing 1.5 g of blend plus 5 g sugar in 150 ml hot water. The resulting beverages were evaluated as to coffee flavor by the same five-person untrained panel.

D) Nutritional evaluation of the products developed utilizing the lightly toasted flour.

The nutritional advantages of utilizing mesquite pod flour are basically three: 1) Enrichment with a product which is high in dietary fiber (mesquite pod flour contains approximately 28% acid detergent fiber; Del Valle et al., 1986). This is believed to be perhaps the most important nutritional quality of mesquite pod flour. 2) Enrichment with a product which is fairly high in protein (mesquite pod flour contains approximately 18% protein). This feature is especially important in blends of mesquite pod flour with cereals, most of which contain less than 10% protein. 3) Utilization of mesquite pod flour as a natural sweetener, in partial or possibly total substitution of sucrose or other sweeteners (mesquite pod flour contains approximately 25% total sugars, mostly sucrose; Del Valle et al., 1988).

The developed products were nutritionally evaluated by comparing their protein and fiber contents before and after addition of mesquite pod flour. Protein and fiber contents of regular products (i.e., those without added mesquite pod flour) were obtained from nutritional composition tables given by Wilson et al. (1965), while corresponding values for mesquite pod flour were those reported by Del Valle et al. (1986).

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D) Cost estimates

Costs of the developed products containing mesquite pod flour were estimated, and compared with those of the same products without the flour.

E) Commercial applications of mesquite pod flours (lightly and highly toasted products.)

A survey of the 10 houses of nutrition existing in Chihuahua City, Mexico, was carried out, attempting to determine their willingess to buy and sell the lightly toasted mesquite pod flour as a nutritional (protein and fiber) fortifier. The questionnaire presented in Table 2 was utilized for each interview. Owners of the commercial establishments were also given a summary of the most important nutritional properties of the flour (Table 3).

Concerning the highly toasted flour, its use as a cocoa extender in the manufacture of a chocolate beverage base which is currently being produced and sold by Productos Alimenticios Delicias, Delicias, Chihuahua, Mexico (commercial name, "Tomi") was studied. This was done by substituting the cocoa component in the product formulation (Table 1) by the highly toasted flour at levels of 25%, 50% and 75%. Beverages were then prepared from the resulting dry powdered bases according to instructions given on the label (5 heaping teaspoonfuls in 200 ml milk), and evaluated as to chocolate flavor by a 5-person untrained panel.

RESULTS AND DISCUSSION

A,B) Development and sensory evaluation of products developed utilizing the lightly toasted mesquite pod flour.

Table 4 presents data on average scores (including standard deviations) assigned by the panelists to the different sensory attributes for the different products, while Table 5 presents results of analysis of variance calculations (F-values) performed on the data of Table 4

All products were significantly different from each other ($p < 0.01$) in all sensory attributes evaluated (Table 5). The products with the highest Overall Acceptance were the pressed mesquite/peanut butter candy (average score = [illegible]) and the chocolate beverage base (average scores for both were = 7.1); these were closely followed by the oatmeal cooked with mesquite pod flour (average score = [illegible]) and the pinole (average score = [illegible]). The mesquite butter and the cream of wheat cooked with mesquite pod flour were both assigned the same average score (6.5), while the [illegible] beverage base had an average score of 6.4. Least acceptable were the "Lonchera" beverage (average score = 4.4) and the yogurt blended with mesquite pod flour (average score = 5.4).

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Behavior similar to that observed with the attribute "Overall Acceptance" was reflected by the attribute "General Impression." Thus, concerning the latter, the highest average scores were again obtained by the chocolate beverage base (6.9) and the pressed peanut butter/mesquite pod flour candy (score = 6.8). In this case, however, the strawberry beverage base was assigned a score equal to that of the peanut butter/mesquite pod marzipan. As in the case of "Overall Acceptance", the highest average scores were followed by those assigned to pinole (6.7) and oatmeal cooked with mesquite pod flour (6.1). Similarly, the lowest average scores were those corresponding to yogurt blended with mesquite pod flour (5.6) and the "horchata" beverage (4.8).

Concerning the attribute "Color", products obtaining the highest average scores were both beverage bases (chocolate and strawberry) and the pressed mesquite pod/peanut butter candy (average score for all three = 7.0), followed by pinole (score = 6.8). In this respect, the behavior of the attribute "Color" was very similar to that of the attribute "General Impression". Interestingly, however, in this case, the yogurt blended with mesquite pod flour was assigned a relatively high score (6.0). Lowest scores were obtained by the "horchata" beverage (4.7) and also by the mesquite pod/peanut butter candy (4.4). Both cereal products cooked with mesquite pod flour (oatmeal and cream of wheat) were given relatively low and similar scores (5.8 and 5.9, respectively). It is evident that, although panelists generally accepted both of these products quite well (as noted previously, both were assigned relatively high "Overall Acceptance" and "General Impression" scores), they found the brownish color of both cooked cereal products somewhat objectionable.

Behavior of the attribute "Flavor" was somewhat different from that of the previous three attributes. As in the case of the latter, highest average scores were assigned to the chocolate beverage base (7.3) and the pressed mesquite/peanut butter candy (marzipan; 7.0). However, the second highest scores were those of the mesquite pod butter (6.4) and the cereal products cooked with mesquite pod flour (oats and cream of wheat; both of which scored 6.0). The strawberry beverage base, which had obtained scores nearly equal to those of the chocolate base in the cases of "Color" and "General Impression", was scored much below the latter in the case of "Flavor." Lowest scores were those of the "horchata" (4.8) and yogurt mixed with mesquite pod flour (5.4).

Surprisingly, the attribute "Aroma" behaved quite differently from the attribute "Flavor." In the first place, average scores assigned in the case of the latter considerably exceeded those assigned in that of the former. The highest score was that of the chocolate beverage base (6.7). All other scores, however, were below 6.0 and were as follows, in decreasing order: oatmeal cooked with mesquite pod flour, 5.9; cream of wheat cooked with mesquite pod flour, 5.6; strawberry beverage base, 5.5; pressed mesquite/peanut butter candy, 5.1; pinole and "horchata", 4.8; plain yogurt mixed with mesquite pod flour, 4.7; and mesquite butter, 2.4. As in the case of "Flavor", the strawberry beverage base was assigned a much lower score than the chocolate base. Interestingly, however, the lowest score was that of the mesquite

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butter (2.4); it might be recalled that this product was assigned a relatively high score in the case of "Flavor". The discrepancy between the "Flavor" and "Aroma" scores is probably best explained by noting that panelists were probably not very well aware of the sensory difference between both attributes.

Comparing the best product, i.e., that which consistently obtained the highest average scores in all quality attributes tested, was the chocolate beverage base. The next best products, i.e., those which obtained high scores in most attributes were, in descending score order, the creamed mesquite/peanut butter candy (marzipans), strawberry beverage base, "pinole", and both cereal products (oatmeal and cream of wheat) cooked with mesquite pod flour. The mesquite pod butter, although not among the worst products, was nevertheless assigned fairly low scores. The worst products were almost consistently (i.e., with respect to most attributes) the "horchata" and yogurt mixed with mesquite pod flour.

Reasons stated by panelists for liking the above best products were that the mesquite pod flour conferred a malt-like flavor and a pleasant sweetness. Thus, both beverage bases, as well as cereal products (pinole, oatmeal and cream of wheat), when blended with mesquite pod flour, were said to reflect a "malt-like" flavor which was much liked.

Reasons given by panelists for disliking the worst products were either lack of flavor (in the cases of both "horchata" and yogurt) or poor consistency (i.e., insufficient "body", in the case of the "horchata"). It is evident that mesquite pod flour, by itself, does not possess sufficient flavor; however, when it is blended with other flavorful foods such as those described in the previous paragraph, it appears to enhance and otherwise improve the flavor of the resulting blends.

C) Applications of the highly toasted mesquite pod flour.

Concerning the cocoa extender application, panelists unanimously agreed that no flavor difference could be detected, as far as cocoa flavor was concerned, in blends containing up to 50% toasted mesquite pod flour. Flavor differences which, in fact, were not unpleasant, could be detected in the 75% and 100% mesquite flour blends. It was concluded that the highly toasted mesquite pod flour could be satisfactorily used as a cocoa extender in blends containing as much as 50% of the flour. It was also concluded that beverages with a pleasant chocolate-like flavor (but different from regular chocolate), could also be prepared utilizing 100% of the highly toasted mesquite pod flour. These results are not surprising, in view of the fact that mesquite is a relative of carob, and it is known that toasted carob pods possess a distinct chocolate-like flavor.

Regarding the coffee extender application, panelists also unanimously agreed that no flavor difference with respect to regular coffee could be detected in blends containing up to 50% toasted mesquite pod flour.

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D) Nutritional evaluation of products developed utilizing the lightly toasted flour.

Protein and fiber contents of products with and without added mesquite pod flour are reported in Table 6. In all cases, the fiber content was considerably enhanced by enrichment with the flour. Most striking fiber increases were obtained with the flavored beverage bases (8.0% vs 2.0; "horchata" (4.9% vs 15.2%); and cream of wheat (8.0% vs 7.0%). And whereas regular sweetened peanut butter contained 0.8% fiber, sweetened mesquite pod butter contained 3.0% of this component. Least striking increases were observed with yogurt (0.0% vs 0.6%) and rolled oats (10.0% vs 12.9%); however, these increments in fiber are still believed to be important from as dietary point of view. Intermediate increases in fiber were obtained with "pinole" (0.8% vs 3.4%) and mesquite pod flour/peanut butter candy (marzipans; 1.2% vs 3.7%). All of these results indicate that mesquite pod flour would be a very useful vehicle for enrichment of different types of foods with dietary fiber.

Generally, addition of mesquite pod flour to the different products did not result in significant changes in protein content (Table 6). A substantial increase was observed in the case of "horchata" (4.3% vs 7.1%), while a substantial decrease was observed in the case of the sweetened butters (7.8% for peanut butter vs 2.3% for mesquite pod butter). These results indicate that addition of mesquite pod flour to foods of the type studied in this work would probably not significantly affect their protein content.

E) Cost estimates.

Costs of the different products studied, with and without added mesquite pod flour, are reported in Table 7 (U.S. Dollars). Both, the lightly and highly toasted flours would cost approximately $0.66 per kilo ($0.30 per pound). Table 7 shows that enrichment with the flour would not appreciably affect the cost of most products (beverage bases, pinole, marzipans, cream of wheat, rolled oats and yogurt). The "horchata" beverage base prepared from mesquite pod flour would be more expensive than that prepared from rice ($0.43/kg vs $0.29/kg). On the other hand, sweeted peanut butter would be appreciably more expensive than sweetened mesquite pod butter ($3.31/kg vs 1.68/kg). It may be concluded that addition of mesquite pod flour to products of the type studied in this work would probably not appreciably affect their cost

F) Commercial applications

Table 8 presents results of the survey carried out among the 10 houses of nutrition currently existing in Chihuahua City. It is evident that 8 of these considered the mesquite pod flour to be a good, novel and important nutritional product, and would be willing to buy the flour from the producer, and sell it to their customers. Currently, Productos Alimenticios Delicias, S. A. de C. V., in Delicias, Chihuahua, Mexico (the plant in which industrial production of the flour was carried out), is getting ready to manufacture both lightly

and heavily toasted mesquite pod flours. The lightly toasted flour will be sold to the 6 houses of nutrition in Chihuahua City which gave affirmative replies in the survey, while the heavily toasted flour will be offered to industrial users of cocoa as an extender for this product.

Concerning use of the highly toasted flour as a cocoa extender in the chocolate beverage base manufactured by Productos Alimenticios Delicias, preliminary results indicate that up to a 50% substitution of cocoa with the highly toasted flour is possible. If these results are verified, the company would immediately start using the latter product as a cocoa extender in the manufacture of its chocolate beverage base. It might be noted that Productos Alimenticios Delicias products are sold in many parts of Mexico, including all of the State of Chihuahua, Monterrey, Guadalajara and Mexico City. In this way, the highly toasted mesquite pod flour would be distributed, as part of a product, to many parts of Mexico.

SUMMARY AND CONCLUSIONS

From the foregoing, it is evident that there are multiple and varied applications for both, the lightly and highly toasted mesquite pod flours.

Applications for the lightly toasted flour are visualized as consisting mainly as a fiber fortifier and flavor enhancer. As a fiber fortifier, it has been seen that it is possible to duplicate, and in some cases, even triplicate the fiber content of a given product. This is highly desirable, given the value of dietary fiber in promoting general health and preventing a number of disease conditions. This fiber fortification, utilizing mesquite pod flour, has a number of advantages: 1) the fiber is found in a finely pulverized form which is easily incorporated into many different types of food products; 2) no "fibrous" or rough texture is apparent in the fortified products (such as is perceived when such products as wheat bran, for example are utilized); and 3) fortification with mesquite pod flour in most cases enhances flavor of the enriched products.

As a flavor enhancer, lightly toasted mesquite pod flour functions in a manner similar to malt; i.e., a pleasant toasted malt-like flavor is obtained. This flavor, as was seen, enhances the organoleptic quality of such products as beverage bases, pinole, peanut butter candy, oatmeal and cream of wheat.

Actually, lightly toasted mesquite pod flour accomplishes both functions--enrichment with fiber and flavor enhancement --simultaneously.

A third function of the lightly toasted mesquite product is its naturely sweetness, and hence its possibility as a total or partial substitute for sucrose or fructose in food product formulations.

Cost-wise, utilization of lightly toasted mesquite pod flour, in most cases, has little effect on prices.

The highly toasted flour has two clearly important potential applications: as a cocoa and also as a coffee extender. Both of these applications, although the former (i.e., cocoa extender) perhaps more so than the latter, would result in substantial savings to users of the product.

A number of important industrial and nutritional uses for heretofore unexploited product, therefore have been found.

And, as noted previously, industrial manufacture of both types of mesquite pod flour has already begun at Productos Alimenticios Delicias, S. A. de C. V. in Delicias, Chihuahua, Mexico.

It is hoped that this new and inexpensive technology for utilization of mesquite pods will become extended to other developing countries of the world

SUGGESTIONS FOR FURTHER RESEARCH

It is believed that the work carried out during the duration of this research grant could be optimally continued by carrying out the following research activities.

1) Design of a modular unit for the industrial manufacture of toasted mesquite pod flour. This unit is visualized as a simple package-type plant, consisting of a toaster, mill and sifter. This plant would be very inexpensive and could be easily set up in any location of a developing country. The package modular plant could also be transported to different mesquite-growing places in any given country, and be utilized there for manufacture of the flour [illegible]

2) Further nutritional evaluation of the mesquite pod flours. Since mesquite pod flours contain a large content of dietary fiber, it is felt that use of these as a fiber supplement could result in a number of important nutritional benefits, including lowering of blood cholesterol levels and decrease in glycemic response. The former would be of benefit to persons with hypercholesterolemia, while the latter would benefit diabetics. Research along these lines, therefore, appears to be highly recommended.

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TABLE 1: INGREDIENT FORMULAS OF CHOCOLATE AND STRAWBERRY BEVERAGE BASES, UTILIZED FOR ENRICHMENT WITH LIGHTLY TOASTED MESQUITE POD FLOUR

INGREDIENT	STRAWBERRY BEVERAGE BASE	CHOCOLATE BEVERAGE BASE
Sugar (sucrose)	61.098%	57.360%
Soy flour (full-fat)	18.865	18.865
Powdered oats (rolled, cooked)	15.435	15.435
Tricalcium phosphate	1.750	1.750
Salt (sodium chloride)	0.400	0.550
Vitamin and mineral mix	0.112	0.112
tificial strawberry flavor	1.800	--
Cocoa	--	4.725
Artificial chocolate flavor	--	1.000
Cinnamon flavor	--	0.180
Red coloring	0.0400	--
Brown coloring	--	0.0200
Cream flavor	0.500	--

TABLE 2: QUESTIONNAIRE UTILIZED IN SURVEY OF HOUSES OF NUTRION IN CHIHUAHUA CITY, MEXICO

1) DO YOU LIKE THIS PRODUCT?

_____

_____

2) DO YOU THINK THAT THIS PRODUCT WOULD BE WELL ACCEPTED BY YOUR CUSTOMERS?

_____

_____

3) WOULD YOU BUY THIS PRODUCT?

_____

_____

4) WHEN WOULD YOU BEGIN BUYING THE PRODUCT?

_____

_____

5) WHAT DO YOU THINK WOULD BE A SUITABLE PRICE FOR THE PRODUCT?

_____

_____

ADDITIONAL COMMENTS

_____

_____

TABLE 3: INFORMATION SHEET ON MESQUITE POD FLOUR GIVEN TO OWNERS OF HOUSES OF NUTRITION IN CHIHUAHUA CITY, MEXICO, ACCOMPANYING QUESTIONNAIRE GIVEN ON TABLE 2

INTRODUCTION

An industrial process that permits exploitation of mesquite pods (Prosopis spp.), by their conversion into a fine flour has been developed.

This process has been developed and evaluated jointly by Fundacion de Investigaciones en Ciencias Alimentarias y Nutricion, A. C., United States Department of Agriculture, and Productos Alimenticios Delicias, S. A. de C. V. (PADSA). PADSA is currently manufacturing the mesquite pod flour in an industrial scale.

CHEMICAL ANALYSIS

Moisture	8.8%
Protein	19.1%
Fat	6.3%
Ash	4.4%
Fiber (Acid Detergent)	21.6%
Carbohydrates (by difference)	45.4%
TOTAL	100.0%

NUTRITIONAL ADVANTAGES

Mesquite pod flour possesses a number of important nutritional advantages.

1) It is a totally natural product, with its complete content of naturally occurring vitamins and minerals.
2) It has a fairly high protein content (19.1%), which closely approximates that of common legumes such as beans, garbanzo, etc.
3) It has a high content of dietary fiber, consisting of both soluble and insoluble types. Its soluble fiber results from a gum, similar to guar gum. A number of recent research results indicate that both types of fiber play important roles in sustaining health, including lowering of blood cholesterol levels, reduced incidence of cancer and improved bowel movement.

4) High content of natural sugars. In this respect, mesquite pod flour may be considered to be a natural sweetener, with the same healthful properties of honey, molasses and brown sugar.
5) Toasted mesquite pod flour possesses an agreeable malt-like flavor.
6) In spite of the fact that mesquite pod flour is a healthful and tasty product, it is nevertheless quite inexpensive.

DOMESTIC USES OF MESQUITE POD FLOUR

Mesquite pod flour has many and varied uses, including:

1) It disperses easily in water, forming an horchata-like beverage.
2) It also disperses easily in hot or cold milk, forming pleasantly flavored malted-like products.
3) Mesquite pod flour may be added to sweet breads, cookies and other bakery products in total or partial substitution of sugar. The resulting products are also fortified with natural mesquite fiber.
4) It may be incorporated into peanut butter and other similar candies.
5) It may be added to both hot or cold cereals, such as oatmeal, cream of wheat, corn flakes, etc.
6) It may be blended with yogurt, especially flavored types.
7) It may also be dispersed on fruits such as melons, papaya, etc.

SUMMARY

We invite you to incorporate mesquite pod flour into your diet. Besides being manufactured from a native Mexican raw material, mesquite pod flour possesses excellent nutritional properties which would undoubtedly contribute to your better health.

TABLE 4: AVERAGE VALUES WITH STANDARD DEVIATIONS OF SCORES ASSIGNED BY PANELISTS TO THE DIFFERENT SENSORY ATTRIBUTES FOR THE DIFFERENT PRODUCTS

RODUCT	AROMA	FLAVOR	COLOR	GENERAL IMPRESSION	OVERALL ACCEPTANCE
HOCOLATE VERAGE ASE	6.7 ± 1.6	7.3 ± 1.2	7.0 ± 1.2	6.9 ± 0.9	7.1 ± 1.1
RAWBERRY VERAGE ASE	5.3 ± 2.0	6.3 ± 1.2	7.0 ± 1.4	6.8 ± 1.1	6.4 ± 1.4
RCHATA[a]	4.8 ± 1.1	4.8 ± 1.2	4.7 ± 1.4	4.8 ± 1.3	4.4 ± 1.1
NOLE[b]	4.8 ± 2.2	6.3 ± 2.0	6.8 ± 1.7	6.7 ± 1.7	6.6 ± 1.7
ESSED SQUITE/ ANUT TTER	5.1 ± 2.5	7.0 ± 1.3	7.0 ± 1.4	6.8 ± 1.5	7.1 ± 0.9
SQUITE/ ANUT TTER	3.4 ± 2.2	6.6 ± 2.0	4.4 ± 2.4	5.6 ± 1.8	6.5 ± 2.0
EAM OF EAT OKED WITH SQUITE OUR	5.6 ± 1.9	6.5 ± 1.3	5.9 ± 1.7	5.8 ± 1.5	6.5 ± 1.2
TMEAL OKED WITH SQUITE OUR	5.8 ± 2.1	6.5 ± 1.5	5.8 ± 2.0	6.1 ± 1.6	6.8 ± 1.2
AIN GURT TH SQUITE OUR	4.7 ± 2.2	3.6 ± 1.9	6.0 ± 1.8	5.6 ± 1.8	5.4 ± 1.4

Horchata" is a beverage prepared from raw rice dispersed in water, which is i[illegible]ly sweetened and cinnamon flavored; the product reported here was enriched with mesquite flour, as mentioned in the text.
Pinole" is a toasted corn flour, mixed with sugar; the product reported here as enriched with mesquite flour, as mentioned in the text.

TABLE 5: RESULTS OF ANALYSIS OF VARIANCE CALCULATIONS PERFORMED ON THE DATA OF TABLE 4

SENSORY ATTRIBUTE	AROMA	FLAVOR	COLOR	GENERAL IMPRESSION	OVERALL ACCEPTANCE
F-VALUE[a]	3.57+++	12.22+++	8.08+++	7.96+++	9.22+++

[a]Degrees of freedom for numerator = 8; degrees of freedom for denominator = 180

++Significant at $p < 0.01$ level.

PRODUCT	PERCENT PROTEIN	PERCENT FIBER
BEVERAGE BASE WITHOUT MESQUITE	17.5	3.0
BEVERAGE BASE WITH MESQUITE	16.6	8.0
RICE "HORCHATA" (DRY BASIS)	4.3	4.9
MESQUITE "HORCHATA" (DRY BASIS)	7.1	15.2
PINOLE WITHOUT MESQUITE	3.8	0.8
PINOLE WITH MESQUITE	4.2	3.4
PEANUT BUTTER CANDY WITHOUT MESQUITE	12.0	1.2
PEANUT BUTTER CANDY WITH MESQUITE	10.3	3.7
ANUT BUTTER, SWEETENED	7.8	0.8
MESQUITE POD BUTTER, SWEETENED	2.3	5.0
CREAM OF WHEAT WITHOUT MESQUITE (DRY BASIS)	14.0	3.0
CREAM OF WHEAT WITH MESQUITE (DRY BASIS)	13.8	7.0
ROLLED OATS WITHOUT MESQUITE (DRY BASIS)	12.0	10.0
ROLLED OATS WITH MESQUITE (DRY BASIS)	12.2	12.9
YOGURT WITHOUT MESQUITE	3.5	0.0
YOGURT WITH MESQUITE	3.7	0.6

TABLE 6: PROTEIN AND FIBER CONTENTS OF PRODUCTS WITH AND WITHOUT ADDED MESQUITE POD FLOUR

PRODUCT	PRICE, U.S.$
BEVERAGE BASE WITHOUT MESQUITE	1.01/KG
BEVERAGE BASE WITH MESQUITE	0.94/KG
RICE "HORCHATA" (DRY BASIS)	0.29/KG
MESQUITE "HORCHATA (DRY BASIS)	0.43/KG
PINOLE WITHOUT MESQUITE	0.37/KG
PINOLE WITH MESQUITE	0.39/KG
PEANUT BUTTER CANDY WITHOUT MESQUITE	0.11/25-GRAM PORTION
PEANUT BUTTER CANDY WITH MESQUITE	0.10/25-GRAM PORTION
PEANUT BUTTER, SWEETENED	3.31/KG
MESQUITE POD BUTTER, SWEETENED	1.68/KG
CREAM OF WHEAT WITHOUT MESQUITE (DRY BASIS)	1.15/KG
CREAM OF WHEAT WITH MESQUITE (DRY BASIS)	1.07/KG
ROLLED OATS WITHOUT MESQUITE (DRY BASIS)	0.94/KG
ROLLED OATS WITH MESQUITE (DRY BASIS)	0.90/KG
YOGURT WITHOUT MESQUITE	1.11/L
YOGURT WITH MESQUITE	1.10/L

TABLE 7: COST ESTIMATES FOR PRODUCTS WITH AND WITHOUT ADDED MESQUITE POD FLOUR

TABLE 8: RESULTS OF SURVEY CONDUCTED AMONG 10 HOUSES OF NUTRITION IN CHIHUAHUA CITY, MEXICO, UTILIZING QUESTIONNAIRE IN TABLE 2

1) DO YOU LIKE THIS PRODUCT?

Yes, 80%
No , 20%

Additional comments given in reply to this question:

a) I like it because of its agreeable flavor, 10%
b) I like it because it is a natural product, 20%
c) I like it because of its nutritive properties, 30%

2) DO YOU THINK THAT THIS PRODUCT WOULD BE WELL ACCEPTED BY YOUR CUSTOMERS?

Yes, 80%
Maybe, 20%
No, 0%

Additional comments given in reply to this question:

a) The product is easily utilized, 10%

3) WOULD YOU BUY THIS PRODUCT?

Yes, 70%
Yes if it is liked by my family, 10%
Yes if it is flavored, 10%
No, 10%

4) WHEN WOULD YOU BEGIN BUYING THE PRODUCT?

As soon as it is available, 80%
If it is sold in peanut marzipans, 10%
No reply to this question, 10%

5) WHAT DO YOU THINK WOULD BE A SUITABLE PRICE FOR THE PRODUCT?

1000 pesos per kilo (calculated price, 890 pesos per kilo) 30%
Do not know 10%
No reply to this question, 30%
A reasonable price, 10%
560 pesos per kilo, 10%
400 pesos per kilo, 10%

ADDITIONAL COMMENTS

a) Should be sold in combination with chocolate and other products; I also like it alone.
b) Everybody in the store liked the flavor.
c) It is a good product; also, it is a Mexican product with

TABLE 8 (CONTINUED)

ADDITIONAL COMMENTS (CONTINUED)

c) excellent nutritive properties.
d) Ideal for use with malnourished persons.
e) When taken alone, it leaves a slightly unpleasant after-taste; however, this after-taste is not perceived when mixed with other products.
f) The manufacturer should give extensive information on uses for the product.
g) Should prepare a brochure with extensive nutritional and applications information.
h) It is a good nutritious product which should be marketed as soon as possible; its high fiber content would be very beneficial to persons with diabetes, constipation and colitis.

CROPS FOR PRODUCTION IN MARGINAL GROWING AREAS IN MEXICO

First progress report submitted to the U. S. Agricultural Research Service, Pacific Basin Area, by Fundación de Investigaciones en Ciencias Alimentarias y Nutrición, A. C., Chihuahua, Chih., Mexico, October 31, 1984.

Dr. Francisco R. del Valle

Ing. Enrique Marco Belestin

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ABSTRACT

Mesquite pods were ground in an Alpine pin mill either raw, extruded or toasted; in blends with soybeans and oat groats, they were extruded and also ground in the Alpine mill, in all cases, 1 - 4 times. Fraction of fines (-100 mesh material) increased with number of passes through the mill and also by blending with other materials; processing of raw and extruded 100% mesquite gave similar results, but toasting obtained fewer fines than the other two processes. Protein concentration was highest in the fines, increasing, in that fraction with blending with other materials, but being unaffected by number of passes through the mill. Acid detergent fiber was lowest in the fines, decreasing, in that fraction, by blending with other materials, but being unaffected by number of passes through the mill. Recovery of total protein was highest in the fines; in that fraction, protein recovery was approximately equal for raw and extruded mesquite, but was lowest for the toasted product; generally, protein recovery in the fines tended to increase with number of passes through the mill. A mesquite protein concentrate, containing twice as much protein as whole mesquite pods, may be prepared by grinding followed by separation of fines. All products were found to be contaminated with mesophilic aerobes, coliform organisms and yeasts and molds, to an intermediate degree.

INTRODUCTION

Fundación de Investigaciones en Ciencias Alimentarias y Nutrición, A. C., has entered into a research contract with the U. S. Agricultural Research Service, Pacific Basin Area, to study the possibility of utilizing pods from Prosopis species, found in Mexico, as a food and feed source.

This report covers work performed from initiation of the contract, June 1, 1984, through October 31, 1984.

MATERIALS AND METHODS

The work was divided into three parts.

1) Pod collection. A total of 150 kilograms of pods was collected from mesquite trees in the area within and adjoining Chihuahua, Mexico. Only mature pods were collected. Collection was carried out between June 15 and August 15, with most material being obtained during the month of July. Before June 15 pods were too green; after August 15 pods began to rot due to excessive rainfall. Most pods were picked from trees; however, those of acceptable quality were also collected from the ground.

Five trees were marked and pods therefrom collected and identified as follows: one tree bearing sweet tasting pods; one tree bearing sour tasting pods; and three trees bearing typical yielding and tasting pods.

2) Tests with pods supplied by Mr. Robert Becker. Approximately 50 pounds of pods were shipped to Chihuahua by Mr. Robert Becker. These were processed as follows.

a) Grinding of raw pods in an Alpine pin mill. Raw pods were

passed 1, 2, 3 and 4 times through an Alpine pin mill with both discs rotating, and the resulting ground samples were subjected to a screen analysis utilizing U.S. Standard sieves. Raw pods were also passed one time through the same mill with one of both discs rotating and the other disc stationary, and the resulting ground materials were also subjected to a screen analysis utilizing U.S. Standard sieves. Purposes of the latter tests were: 1) break whole pods down to a size suitable for feeding into the Brady extruder; and 2) evaluate the possibility of separating seeds (including seed coats) from pericarp.

b) Extrusion of pods in a Brady extruder, followed by grinding in an Alpine pin mill. Pods which had been broken down to a smaller size by passing one time trhough the Alpine mill with the door disc rotating were cooked in the Brady extruder (60 sec at 310°F) and the resulting material passed 1, 2, 3 and 4 times through the Alpine mill with both discs rotating. The ground samples were subjected to a screen analysis utilizing U.S. Standard sieves. The purpose of these tests was to determine if extrusion affected grinding of the pods in the Alpine mill.

c) Extrusion of mesquite with other products, followed by grinding in the Alpine mill. The following blends of mesquite pods (broken down in size by passing one time through the Alpine mill with the door disc rotating and the other stationary) with other materials were prepared and extruded (Brady extruder, 60 sec at 310°F): 1) 50% mesquite/50% cracked soybeans; 2) 50% mesquite/50% polished oat groats; 3) 33 1/3% mesquite/33 1/3% cracked soybeans/33 1/3% polished oat groats. The extruded products were passed 1, 2, 3 and 4 times through the Alpine mill with both discs rotating, and the resulting materials

subjected to a screen analysis utilizing U.S. Standard sieves. Again, the purpose of this work was to determine if grinding of mesquite pods would be affected by extruding blends of these with other materials.

d) Toasting of mesquite pods, followed by grinding in the Alpine mill. Raw mesquite pods were toasted 20 min at 310°F, under a butane flame, utilizing a rotary toaster. The toasted product was passed 1, 2, 3 and 4 times through the Alpine mill with both discs rotating, and the resulting material was subjected to a screen analysis. This work was carried out to determine if grinding of mesquite pods would be affected by toasting.

3) Tests with pods collected in Chihuahua. Pods collected in Chihuahua were processed in the same manner as those supplied by Mr. Becker, i.e. a) grinding of raw pods in the Alpine mill; b) extrusion of pods in a Brady extruder, followed by grinding in the Alpine mill; c) extrusion of pods with other products, followed by grinding in the Alpine mill; and d) toasting of pods, again followed by grinding.

In addition to determining screen analyses of the ground products, proximate chemical analyses of the +45, +100 and -100 sieve samples were obtained for the following materials: 1) raw pods passed 1 and 4 times through the Alpine mill; 2) extruded pods passed 1 and 4 times through the mill; 3) 50/50 mesquite/soybean blend, extruded and passed 1 and 4 times through the mill; 4) 50/50 mesquite/oat blend, extruded and passed 1 and 4 times through the mill; and 5) toasted mesquite pods passed 1 and 4 times through the Alpine mill. This work was done in order to determine if screening would enrich protein and decrease concentration of crude fiber.

Microbiological analyses of the following materials (total plate,

coliform and yeast and mold counts] were determined: 1) raw pods; 2) extruded pods; 3] extruded 50/50 blend of mesquite with soybeans; and 4) extruded 50/50 blend of mesquite with oat groats. This was done in order to obtain a measure of the degree of contamination of the raw mesquite pods, and also to determine if blending with other materials and extrusion lowered contamination, as much by destruction of microorganisms by heat (applied in the extruder), as by blending with other, presumably less contaminated materials.

RESULTS AND DISCUSSION

1) Pod collection. No trouble was experienced at any time during pod collection. Pods were placed in polypropylene fiber bags and stored at room temperature. In order to avoid insect infestation the storage room is being fumigated with malathion once per month.

2) Tests with pods supplied by Mr. Robert Becker. Table 1 reports results of the grinding tests carried out with raw mesquite. The Alpine mill with either disc rotating and the other stationary produced essentially the same results, although the door disc probably yielded more whole material. Visual inspection of both of these ground products (i.e., produced with one disc stationary and the other rotating) revealed that fairly good separation of seeds from pericarp was possible, although some grinding of the former occurred; generally, more whole seeds were obtained with the door disc rotating and the other stationary.

The mill worked much better at pulverizing the raw pods when both discs were rotating and, as shown in Table 1, 4 passes through the mill obtained considerably more fines than 1 pass under these conditions.

b) Extrusion of pods in a Brady extruder, followed by grinding in the Alpine mill. Difficulty was experienced in passing whole raw mesquite pods through the Brady extruder, due to their geometrical configuration. However, after the pods had been passed one time through the Alpine mill with the door disc rotating and the other stationary, extrusion was easily accomplished.

Results of the grinding tests carried out with the extruded material are reported in Table 2. Comparison of the screen analysis of this material passed one time through the Alpine mill (Table 2) with that of raw mesquite, also passed one time through the mill (Table 1) shows that the former yielded more coarse fraction, but approximately the same amount of fines as the latter. It appears, therefore, that extrusion makes grinding of mesquite more difficult. A possible explanation for this observation is that gum, released from seeds during extrusion, acted as an agglutinant thus hindering grinding, or making grinding more difficult.

c) Extrusion of mesquite with other products, followed by grinding in the Alpine mill. Results of these tests are reported in Tables 3 and 4. Comparison of the data in Table 3, for the extruded blends, with that in Table 2, for extruded 100% mesquite, shows that all of the former possessed more fines (-100 mesh fraction) than the latter. This is reasonable, since soybeans and oats are definitely easier to grind than mesquite. Interestingly, Table 3 shows that while the 50/50 blends of mesquite with soybeans and oats gave essentially the same results, the ternary mesquite/soybeans/oats blend produced fewer fines. No explanation for this observation is apparent at this time.

Table 4 shows that the 50/50 mesquite/soybean blend was nearly completely pulverized after passing 4 times through the Alpine mill, since its content of fines approached 90%, compared with 78% for the material passed one time through the mill.

d) Toasting of mesquite pods, followed by grinding in the Alpine mill. No problem was experienced in toasting the pods. As is usually the case with other materials, flavor of mesquite was improved by toasting, which brought out pleasant nutty notes.

Table 5 shows that, contrary to what was found in the cases of raw and extruded mesquite, as well as extruded blends of mesquite with other products, passing 4 times through the Alpine mill caused no change in screen analysis. This effect could have been due to hardening of mesquite seed gum by toasting, which prevented size reduction.

3) Tests with pods collected in Chihuahua. a) Grinding tests. Results of grinding tests with raw pods are reported in Table 6. Comparison of these data with those for U.S. mesquite, reported in Table 1, show interesting differences and similarities. For one thing, grinding with one disc rotating and the other stationary produced fewer coarse material and more fines with Chihuahua than with U.S. mesquite; this was especially true when grinding with the body disc, which gave nearly four times more fines with Chihuahua than with U.S . mesquite. When grinding was carried out with both discs rotating, however, more fines were obtained with U.S. mesquite, the latter effect being especially notable after four passes through the mill.

Comparison of Tables 2 and 7 show that grinding of extruded 100% mesquite gave essentially the same results for Chihuahua as for U. S. mesquite.

When extruded blends of mesquite with other materials were ground in the Alpine mill with both discs rotating, Chihuahua mesquite appeared to be harder to grind than U.S. mesquite, since it gave fewer fines. This effect was especially apparent in Tables 4 and 9 (grinding of 50/50 mesquite/soybean blends): passing four times through the mill obtained 88% fines with U.S. mesquite, but only 66% fines with Chihuahua mesquite.

When the toasted samples were ground, on the other hand, no appreciable difference was detectable between Chihuahua and U.S. pods (Tables 5 and 10, respectively).

Summarizing, no consistent differences between Chihuahua and U.S. mesquite were apparent. This probably means that, as far as grinding of raw, extruded and toasted materials in the Alpine mill is concerned, no real difference probably existed between Chihuahua and U.S. mesquite. One important observation, however, was made when both materials were extruded: Chihuahua mesquite was considerably harder to extrude than U.S. mesquite. This difference was probably due to the higher gum content of the former with respect to the latter, since Chihuahua mesquite formed a compact mass inside the extruder which, in a given moment, cuased the extruder to "plug up". This effect, of course, could also have been due to the higher moisture content of Chihuahua mesquite, since the extruded sample, having been recently collected, was fresher than the U.S. sample, which was several months old. However, it is the feeling of all persons who participated in the extrusion tests, that the problem of extrusion of Chihuahua mesquite was due to its high gum, and not its high moisture content.

b) Proximate chemical analyses. Tables 11 through 15 present results of the proximate chemical analyses carried out on the different sieve fractions for the different mesquite samples. Studying the tables, the following trends become evident.

1) Protein was most concentrated in the fines (-100 mesh fraction) in all cases, with average concentration for the 100% mesquite samples being of the order of 25%. Considering that whole mesquite contains roughly 13% protein, this means that grinding and separation of fines doubles protein concentration, and may therefore be considered to be an inexpensive and simple process for obtaining a mesquite protein concentrate. In fact, Del Valle et al. (1983) obtained, by a considerably more complex procedure, a mesquite protein concentrate with approximately the same protein concentration.

2) In some cases, the +100 mesh fraction had more protein than the +45 mesh fraction, while in other cases it did not.

3) Ether extract showed no clear trends; in some cases the fines (-100 mesh fraction) contained more of this substance, while in others, ether extract was more concentrated in the coarse material (+45 mesh fraction).

4) Acid detergent fiber, on the other hand, was always minimum in the fines (-100 mesh fraction), and tended to be maximum in the coarse material (+45 mesh fraction).

5) In all cases, the sum of cellulose and lignin approximately equalled acid detergent fiber.

6) Generally, cellulose and lignin followed the same trend as acid detergent fiber; i.e., both tended to be minimum in the fines and maximum in the coarse material.

7) In all cases, passing a sample four times through the mill did not appreciably increase protein content, nor appreciably decrease acid detergent fiber in the different fractions.

8) The raw and extruded 100% mesquite samples, passed one and four times through the mill, showed no appreciable difference in proximate chemical analysis. Interestingly, however, the toasted 100% mesquite sample exhibited lower protein content than the other two. These results indicate that, if concentration of protein by grinding and separation of fines were desired, no advantage would be gained by extruding before grinding. Toasting, on the other hand, would be unfavorable results. Raw mesquite would, therefore, be the most suitable raw material for this process; it would also be the least expensive.

9) Blending of mesquite with soybeans gave the highest protein and lowest acid detergent fiber contents of all samples.

10) Blending of mesquite with oat groats gave approximately equal protein content, but lower fiber content than 100% mesquite.

c) Protein recovery among the different sieve fractions, for different products. The percentage recovery of total protein among the different sieve fractions, for the different mesquite products is reported in Table 16. The following observations may be made.

1) The maximum amount of protein recovered occurred, in all cases except one (toasted mesquite, passed one time through the mill), in the fines (-100 mesh fraction).

2) Grinding of any given product 4 times usually increased protein recovery in the fines, with respect to grinding 1 time.

3) Protein recovery, in the fines, was approximately the same for the raw and extruded samples passed one time through the mill; however,

in samples passed four times through the mill, protein recovery in the fines was much higher for the extruded product.

4) The toasted mesquite product exhibited considerably lower protein recovery, in the fines, than the other two 100% mesquite products (raw and extruded), when passed one time through the mill; however, this recovery was considerably increased after passing four times through the mill.

5) The extruded 50/50 mesquite/soybean product exhibited very high protein recoveries, in the fines, after one pass through the mill; this recovery, however, was not increased by passing four times through the mill.

6) The extruded 50/50 mesquite/oat groats and 1/3 mesquite/1/3 soybeans/1/3 oat groats samples both exhibited very high protein recoveries in the fines.

7) Highest protein recoveries, in the fines, were obtained in the following samples: a) exturded 1/3 mesquite, 1/3 soybeans, 1/3 oat groats, passed one time through the mill (83.61% recovery); b) extruded 100% mesquite, passed 4 times through the mill (80.37% recovery); c) extruded 50% mesquite, 50% oat groats, passed one time through the mill (76.87% recovery); d) extruded 50% mesquite, 50% soybeans, passed one time through the mill (73.77% recovery).

8) These results verify the fact that grinding, followed by separation of fines, would be an inexpensive and simple procedure for producing a mesquite protein concentrate, with excellent protein recovery. Incidentally, protein recoveries obtained by this procedure exceed by much those obtained by Del Valle et al. (1981) in preparation of mesquite protein concentrate by a complex chemical technique, involving isoelectric leaching.

d) Results of microbiological determinations. Results of these tests are summarized in Table 17. Again, some important observations may be made.

1) All samples exhibited relatively low total plate counts.

2) Coliform counts, however, were high in the raw, extruded and toasted samples, with the exception of the 50/50 mesquite/oat groats extruded product.

3) Passing of raw mesquite through the extruder did not appreciably lower its total and coliform counts; however, a small decrease in the yeast and mold count was apparently obtained.

4) Yeast and mold counts of the different samples were neither too high nor too low; they were intermediate.

5) Dilution of mesquite with soybeans and oat groats, followed by extrusion did not apparently lower any one of the microbiological indices.

6) The above results indicate that contamination probably occurred after blending, extrusion and grinding, or at least simultaneously with these operations.

7) Interestingly, although the 50/50 mesquite/oat groats sample exhibited minimum contamination, the 1/3 mesquite, 1/3 soybeans, 1/3 oat groats sample was as contaminated as the others.

8) Summarizing, although the mesquite samples were contaminated to a medium extent (neither too high nor too low), it is believed that any product designed for human consumption should definitely be less contaminated, so that means should be sought for lowering contamination of any products developed utilizing mesquite, either alone or in blends with soybeans and oat groats.

9) A study, designed to detect the source or sources of contamination should be carried out.

SUMMARY AND CONCLUSIONS

1) Mesquite may be extruded, either alone or in blends with soybeans and oat groats.
2) Mesquite, either alone or in combination with soybeans and oat groats is easily ground in an Alpine pin mill with both discs rotating.
3) Passing any sample through the mill four times generally increases fines and decreases coarse material.
4) Protein concentration of any sample is generally highest in the fines and tends to be lowest in the coarse material.
5) Acid detergent fiber, cellulose and lignin contents of any sample tend to be lowest in the fines and highest in the coarse material.
6) Protein recovery of any sample tends to be highest in the fines; it is increased by passing more times through the mill.
7) The process of grinding, followed by separation of fines, appears to be a simple and inexpensive procedure for obtention of a mesquite protein concentrate which contains tiwce as much protein as whole mesquite pods.
8) Although protein concentration of fines is approximately equal when utilizing raw or extruded 100% mesquite, utilization of the former obtains higher protein recovery in the fines. On the other hand, toasted mesquite gives minimum protein concentration and minimum protein recovery in the fines, for equivalent processing conditions.
9) Blending of mesquite with other materials (soybeans and oat groats) generally increases protein concentration and protein recovery in the fines, and decreases acid detergent fiber concentration in the same fraction.

10) Most mesquite products studied in this work were contaminated with coliforms and yeasts and molds. Although contamination with these organisms was not too high (total plate count was also not too high), means for reducing these contaminations should be sought before developing products, containing mesquite, for human consumption.

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MESH NUMBER	PERCENT MATERIAL			
	DOOR DISC ROTATING[b]	BODY DISC ROTATING[b]	BOTH DISCS ROTATING 1 PASS	BOTH DISCS ROTATING 4 PASSES
+ 45	88.1	74.9	23.9	14.6
+ 60	4.8	11.3	14.9	
+ 80	2.4	6.0	11.6	
+100	1.2	1.9	7.1	12.5[a]
-100	3.5	5.9	42.5	72.9

[a] In this case, the +100 mesh fraction also contained the +60 and +80 fractions.
[b] Passed one time through the mill.

TABLE 1: SCREEN ANALYSES OF RAW U.S. MESQUITE GROUND IN AN ALPINE PIN MILL UNDER DIFFERENT CONDITIONS

COMPONENT, PERCENT	PERCENT MATERIAL ONE PASS
+ 45	42.1
+ 60	3.0
+ 80	3.9
+100	2.2
-100	48.8

TABLE 2: SCREEN ANALYSIS OF EXTRUDED U.S. MESQUITE (BRADY EXTRUDER, 1 PASS, 60 SEC AT 300°F) IN AN ALPINE PIN MILL, BOTH DISCS ROTATING

MESH NUMBER	PERCENT MATERIAL		
	50% SOYBEANS 50% MESQUITE	50% OAT GROATS 50% MESQUITE	33 1/3% SOYBEANS 33 1/3% OAT GROATS 33 1/3% MESQUITE
+ 45	16.1	17.8	30.3
+100	6.2	6.7	9.6
-100	77.7	75.5	60.1

TABLE 3: SCREEN ANALYSES OF EXTRUDED U.S. MESQUITE WITH OTHER MATERIALS (BRADY EXTRUDER, 1 PASS, 60 SEC AT 300°F) IN AN ALPINE PIN MILL, ONE PASS, BOTH DISCS ROTATING

MESH NUMBER	PERCENT MATERIAL ONE PASS	FOUR PASSES
+ 45	13.8	4.5
+100	8.4	7.1
-100	77.6	88.4

TABLE 4: SCREEN ANALYSES OF AN EXTRUDED 50/50 U.S. MESQUITE/SOYBEAN BLEND, GROUND IN AN ALPINE PIN MILL WITH BOTH DISCS ROTATING

MESH NUMBER	PERCENT MATERIAL ONE PASS	FOUR PASSES
+ 45	24.3	23.9
+100	8.6	10.2
-100	67.1	65.9

TABLE 5: SCREEN ANALYSES OF TOASTED (20 MIN AT 310°F) U. S. MESQUITE, GROUND IN AN ALPINE PIN MILL WITH BOTH DISCS ROTATING

MESH NUMBER	PERCENT MATERIAL			
	DOOR DISC ROTATING[b]	BODY DISC ROTATING[b]	BOTH DISCS ROTATING 1 PASS	BOTH DISCS ROTATING 4 PASSES
+ 45	72.9	45.4	42.9	45.6
+ 60	4.5	13.9	4.2	
+ 80	3.2	11.5	13.3	
+100	1.5	3.8	3.2	8.6[a]
-100	17.9	25.9	36.4	45.8

[a] In this case, the +100 mesh fraction also contained the +60 and +80 fractions.
[b] Passed one time through the mill.

TABLE 6: SCREEN ANALYSES OF RAW CHIHUAHUA MESQUITE GROUND IN AN ALPINE PIN MILL UNDER DIFFERENT CONDITIONS

MESH NUMBER	PERCENT MATERIAL ONE PASS	FOUR PASSES
+ 45	36.3	20.8
+ 60	5.5	
+ 80	1.9	
+100	4.6	6.8[a]
-100	51.7	73.2

[a] In this case, the +100 mesh fraction also contained the +60 and +80 fractions.

TABLE 7: SCREEN ANALYSES OF EXTRUDED CHIHUAHUA MESQUITE (BRADY EXTRUDER, 1 PASS, 60 SEC AT 300°F) FOLLOSED BY GRINDING IN AN ALPINE PIN MILL, ONE PASS, BOTH DISCS ROTATING

MESH NUMBER	PERCENT MATERIAL		
	50% SOYBEANS 50% MESQUITE	50% OAT GROATS 50% MESQUITE	33 1/3% SOYBEANS 33 1/3% OAT GROATS 33 1/3% MESQUITE
+ 45	23.5	23.6	15.[illegible]
+100	15.2	8.5	11.1
-100	61.3	67.9	73.7

TABLE 8: SCREEN ANALYSES OF EXTRUDED CHIHUAHUA MESQUITE WITH OTHER MATERIALS (BRADY EXTRUDER, 1 PASS, 60 SEC AT 300°F) IN AN ALPINE PIN MILL, ONE PASS, BOTH DISCS ROTATING

MESH NUMBER	PERCENT MATERIAL ONE PASS	FOUR PASSES
+ 45	23.5	20.5
+100	15.2	12.9
-100	61.3	66.5

TABLE 9: SCREEN ANALYSES OF AN EXTRUDED 50/50 CHIHUAHUA MESQUITE/SOYBEAN BLEND, GROUND IN AN ALPINE PIN MILL WITH BOTH DISCS ROTATING

MESH NUMBER	PERCENT MATERIAL ONE PASS	FOUR PASSES
+ 45	27.1	17.8
+100	7.9	5.8
-100	65.0	76.4

TABLE 10: SCREEN ANALYSES OF TOASTED (20 MIN AT 310°F) CHIHUAHUA MESQUITE, GROUND IN AN ALPINE PIN MILL WITH BOTH DISCS ROTATING

COMPONENT, PERCENT	ONE PASS			FOUR PASSES		
	+45	+100	-100	+45	+100	-100
MOISTURE	6.02	6.93	6.90	4.27	5.98	6.84
PROTEIN	9.93	14.41	23.68	8.06	10.69	17.24
ETHER EXTRACT	4.12	5.57	7.38	5.80	5.36	5.34
ACID DET. FIBER	47.1	36.20	26.81	52.77	23.14	13.19
CELLULOSE	37.82	30.37	20.88	44.48	19.55	10.34
LIGNIN	9.10	6.10	5.96	8.39	3.67	2.67

TABLE 11: PROXIMATE CHEMICAL ANALYSES OF DIFFERENT SIEVE FRACTIONS OF RAW CHIHUAHUA MESQUITE PASSED ONE AND FOUR TIMES THROUGH THE ALPINE PIN MILL WITH BOTH DISCS ROTATING

COMPONENT, PERCENT	ONE PASS +45	ONE PASS +100	ONE PASS -100	FOUR PASSES +45	FOUR PASSES +100	FOUR PASSES -100
MOISTURE	5.75	6.23	6.13	6.10	5.57	5.87
PROTEIN	13.63	7.99	24.96	17.20	13.07	24.91
ETHER EXTRACT	10.12	4.28	7.81	11.56	9.13	11.44
ACID DET. FIBER	36.89	24.03	12.81	31.63	28.93	12.72
CELLULOSE	29.56	31.00	9.79	27.40	25.11	10.01
LIGNIN	7.36	4.11	2.92	5.01	4.98	2.70

TABLE 12: PROXIMATE CHEMICAL ANALYSES OF DIFFERENT SIEVE FRACTIONS OF EXTRUDED 100% CHIHUAHUA MESQUITE PASSED ONE AND FOUR TIMES THROUGH THE ALPINE PIN MILL WITH BOTH DISCS ROTATING

COMPONENT, PERCENT	ONE PASS +45	ONE PASS +100	ONE PASS -100	FOUR PASSES +45	FOUR PASSES +100	FOUR PASSES -100
MOISTURE	4.06	4.48	4.71	5.80	5.40	5.39
PROTEIN	20.38	14.62	32.13	24.66	23.43	29.25
ETHER EXTRACT	18.37	6.10	5.88	16.10	6.71	7.20
ACID DET. FIBER	23.78	27.28	8.22	16.29	18.66	10.40
CELLULOSE	19.48	22.94	6.48	13.34	14.14	7.76
LIGNIN	4.08	5.00	1.51	2.94	4.41	2.55

TABLE 13: PROXIMATE CHEMICAL ANALYSES OF DIFFERENT SIEVE FRACTIONS OF EXTRUDED 50/50 CHIHUAHUA MESQUITE/ SOYBEANS, PASSED ONE AND FOUR TIMES THROUGH THE ALPINE PIN MILL WITH BOTH DISCS ROTATING

COMPONENT, PERCENT	ONE PASS[a] +45	+100	-100	ONE PASS[b] +45	+100	-100
MOISTURE	4.43	4.91	4.95	5.10	5.50	5.72
PROTEIN	13.88	15.89	22.63	14.34	15.03	26.67
ETHER EXTRACT	10.10	10.15	10.38	9.93	9.16	10.52
ACID DET. FIBER	32.09	20.36	9.10	38.72	18.19	8.14
CELLULOSE	26.41	15.14	6.56	32.42	14.02	6.38
LIGNIN	5.64	5.27	2.44	6.50	3.87	1.93

[a]50/50 extruded mesquite/oat groats blend.
[b]1/3 mesquite/1/3 soybeans/1/3 oat groats extruded blend.

TABLE 14: PROXIMATE CHEMICAL ANALYSES OF DIFFERENT SIEVE FRACTIONS OF DIFFERENT EXTRUDED BLENDS, PASSED ONE TIME THROUGH THE ALPINE MILL WITH BOTH DISCS ROTATING

COMPONENT, PERCENT	ONE PASS +45	ONE PASS +100	ONE PASS -100	FOUR PASSES +45	FOUR PASSES +100	FOUR PASSES -100
MOISTURE	5.35	5.33	6.13	6.65	5.18	5.52
PROTEIN	7.68	6.32	19.13	11.35	7.55	18.12
ETHER EXTRACT	3.01	3.60	5.85	6.89	6.78	5.99
ACID DET. FIBER	53.20	38.45	17.33	49.19	50.72	20.13
CELLULOSE	42.39	30.04	13.19	39.51	41.77	16.30
LIGNIN	10.83	8.29	4.09	9.66	8.20	3.81

TABLE 15: PROXIMATE CHEMICAL ANALYSES OF DIFFERENT SIEVE FRACTIONS OF TOASTED CHIHUAHUA MESQUITE, PASSED ONE AND FOUR TIMES THROUGH THE ALPINE PIN MILL WITH BOTH DISCS ROTATING

TABLE 16: DISTRIBUTION OF TOTAL PROTEIN AMONG DIFFERENT SIEVE FRACTIONS, FOR DIFFERENT MESQUITE PRODUCTS

PRODUCT[a]	PERCENT OF TOTAL PROTEIN IN FRACTION +45	+100	-100
RAW MESQUITE, 1 PASS	26.83	18.81	54.35
RAW MESQUITE, 4 PASSES	30.81	7.15	62.02
EXTRUDED MESQUITE, 1 PASS	18.01	34.93	47.04
EXTRUDED MESQUITE, 4 PASSES	15.74	3.88	80.37
EXTRUDED 50/50 MESQUITE/SOYBEANS, 1 PASS	16.90	8.31	73.77
EXTRUDED 50/50 MESQUITE/SOYBEANS, 4 PASSES	18.35	10.97	70.67
EXTRUDED 50/50 MESQUITE/OAT GROATS, 1 PASS	16.36	6.75	76.87
EXTRUDED 1/3 MESQUITE/ 1/3 SOYBEANS/1/3 OAT GROATS, 1 PASS	9.28	7.10	83.61
TOASTED MESQUITE, 1 PASS	54.43	13.05	32.51
TOASTED MESQUITE, 4 PASSES	9.94	21.51	68.53

[a]Passed one and four times through the Alpine pin mill, both discs rotating.

ORGANISM[b]	SAMPLE[a] A	B	C	D	E	F
PRESUMPTIVE COLIFORMS	200	500	0	40	500	500
CONFIRMED COLIFORMS	200	90	0	40	90	200
FECAL COLIFORMS	4	7	0	0	0	0
TOTAL COUNT	8.1×10^4	7.0×10^4	1.0×10^2	1.1×10^3	3.9×10^3	7.5×10^4
YEASTS AND MOLDS	8.7×10^3	1.7×10^3	1.0×10^2	2.4×10^3	3.6×10^3	4.3×10^3

[a] Key to samples: A = raw mesquite, passed one time through mill, both discs; B = extruded mesquite, passed one time through mill, both discs; C = extruded 50/50 mesquite/soybean blend, passed one time through mill, both discs; D = extruded 50/50 mesquite/oat groats blend, passed one time through mill, both discs; E = exturded 1/3 mesquite/1/3 soybeans/1/3 oat groats blend, passed one time through mill, both discs; F = toasted mesquite, passed one time through mill, both discs.

[b] All results reported as count per gram sample.

TABLE 17: MICROBIOLOGICAL ANALYSES OF DIFFERENT MESQUITE PRODUCTS

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CROPS FOR PRODUCTION IN MARGINAL GROWING AREAS IN MEXICO.

Second progress report submitted to the U. S. Agricultural Research Service, Pacific Basin Area, by Fundación de Investigaciones en Ciencias Alimentarias y Nutrición, A. C., Chihuahua, Chih., Mexico, June 31, 1985.

Dr. Francisco R. del Valle

Ing. Enrique Marco Belestin

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ABSTRACT

This report covers worked carried out from November 1, 1984 through June 30, 1985. A scientific paper entitled "Production of a mesquite (Prosopis sp.) protein concentrate by a low-cost process" was presented at the 1985 Annual Convention of the Institute of Food Technologists in Atlanta, Ga, based on experimental results obtained in the first report. Concerning experimental work, four processes were studied attempting to obtain a batter mesquite pod protein concentrate. Extrusion was not considered in any process because serious difficulties were encountered in the first part of the work in attempting to extrude Chihuahua mesquite. All processes studied involved grinding in the Alpine pin mill, followed by screening. The optimum one was found to be as follows: toasting of raw pods, followed by passing one time through the Alpine mill with both discs rotating, followed by screening through 45 and 100 mesh sieves; a mesquite pod protein concentrate, consisting of the -100 mesh fines, was obtained with an 88% protein recovery. This process was considered to be of relatively low cost. Grinding with new pins in the Alpine mill increased yield of fines and also protein recovery in the fines, but had no effect on fines protein content. Relatively low protein contents obtained in this work were probably due to insect infestation. In vitro digestibility of coarse (+45) and intermediate (+100) fractions were rather low, of the order of 35 - 55%; this parameter was higher in the +100 mesh fractions. Two nutritious low-cost food products for humans were developed and preliminarily evaluated: a mesquite/soy/peanut butter pressed candy, called "mazapán" in Spanish, and a flavored, sweetened, powdered base for preparation of "horchata" beverages. Typical portions of these products would supply 3 - 4 grams of protein, 110 - 160 calories, and 0.5 - 0.8 grams of fiber. Both were prepared utilizing the mesquite protein concentrate from the optimum process, and both had good acceptance.

INTRODUCTION

This is the second report pertaining to the research contract entitled "Crops for Production in Marginal Growing Areas in Mexico", signed by Fundación de Investigaciones en Ciencias Alimentarias y Nutrición, A. C. and the U. S. Agricultural Research Service, Pacific Basin area.

The report covers work performed between November 1, 1984 through June 30, 1985.

MATERIALS AND METHODS

The work was divided into four parts.

1) Presentation of results obtained in the first report at the Institute of Food Technologists' Meeting in Atlanta, GA. A paper entitled "Preparation of a mesquite pod (*Prosopis sp.*) protein concentrate" by F. R. Del Valle, E. Marco, R. Becker and R. Saunders was presented at the 45th Annual Convention of the Institute of Food Technologists in Atlanta, GA, on Tuesday, June 11 at 1:30 P.M. in the technical session on "Proteins." Presentation of the paper required carrying out of a number of preliminary activities, including preparation of short and extended summaries for review by the congress Scientific Program Committee and preparation of art work for slides, as well as of the slides themselves. The paper was submitted in November, 1984 and was accepted for presentation in February, 1985; it was presented at the convention by E. Marco.

Preparation of the manuscript of a scientific research paper with the same title and authors as that presented at the IFT Meeting, is nearly complete. It will be submitted for consideration for publication in "Journal of Food Science."

2) Further studies on preparation of a mesquite pod protein concentrate

In the work covered by the first report, it was found that a mesquite pod protein concentrate could be prepared by extruding pods, followed by passing 4 times through the Alpine pin mill, followed finally by screening in a U.S. Std. 100-mesh sieve. The concentrate, consisting of the fines, contained approximately 25% protein, with an 80% protein recovery.

The purpose of the second part of the work was to attempt to verify the above results, and also to evaluate other alternative processes for production of the concentrate.

Altogether, 4 processes were studied, as summarized in Figs. 1 through 4. It should be noted that all work was carried out with Chihuahua mesquite, collected June - August, 1984, stored at room temperature, and fumigated periodically in order to avoid insect infestation.

It should also be noted that in the work covered by the first report, considerable difficulty was experienced in passing Chihuahua mesquite through the Brady extruder; the latter tended to plug up so that it was necessary to disassemble it a number of times in order to remove adhering material. Interestingly, no such difficulty was encountered when extruding California mesquite. The problem with Chihuahua mesquite was believed to be due to is high seed gum content. For this reason, extrusion was not considered in any of the processes studied.

PROCESS 1 (verification of the process utilized in preparing the protein concentrate in the first report, except that the extrusion step was omitted for reasons noted above; Fig. 1): Raw mesquite pods were passed one time through the Alpine pin mill with the door disc rotating, after which the resulting material was ground 4 times in the same mill with both discs rotating. The ground material was screened in a

U. S. Std. 100-mesh sieve. Yields as well as proximate chemical analyses (moisture, ash, ether extract, crude protein, acid detergent fiber, lignin, cellulose and silica) of both fines (-100 mesh) and coarse (+100 mesh) materials were determined. Protein recoveries in both materials were calculated by carrying out materials balances, based on results of sieve and proximate analyses. Analytical procedures employed were as follows: AOAC (1980) for moisture, ash, ether extract and crude protein; Goering and Van Soest (1975) for acid detergent fiber, lignin, cellulose and silica. All analyses were run in triplicate.

PROCESS 2 (Fig. 2): Raw mesquite pods were passed one time through the Alpine mill with the door disc rotating, after which they were ground one time in the same mill with both discs rotating. The ground material was screened in a U.S. Std. 45 mesh sieve. The resulting coarse material (+45 mesh) was saved; the fines, however were further screened in a U.S. Std. 100 mesh sieve. Products resulting from the second screening were denominated as follows: +100 mesh, "intermediate fraction"; -100 mesh, "fines." As before, yields, proximate chemical analyses and protein recoveries in all three fractions (i.e., coarse and intermediate materials and fines) were determined by previously described methods.

The purpose of this run was to separate the oversize material (as distinguished from fines) into two fractions (+45 mesh and +100 mesh) in order to determine if any difference in *in vitro* digestibility existed between these fractions (please see Part 3, below).

PROCESS 3 (Fig. 3): Raw mesquite pods were fed directly to the Alpine mill with both discs rotating, after which the ground material was screened utilizing a U.S. Std. 45 mesh sieve. The resulting coarse

material (+45 mesh) as well as that passing through the screen were processed in exactly the same manner as corresponding materials obtained in Process 2.

The purpose of this run was to determine if the preliminary grinding step, utilizing the Alpine mill with the door disc rotating, was necessary or could be omitted.

PROCESS 4 (Fig. 4): Raw mesquite pods were toasted (155°C, 20 min) utilizing the toaster described in the first report (Del Valle and Marco, 1984). The toasted product was ground one time in the Alpine mill with both discs rotating, after which the ground material was screened utilizing a U.S. Std. 45 mesh sieve. The resulting oversize (+45 mesh) and undersize (-45 mesh) materials were again processed in exactly the same manner as corresponding materials obtained in Process 2.

The purpose of this run was to determine if toasting would produce a mesquite pod protein concentrate of good quality (protein content and protein recovery).

3) Evaluation of mesquite pod coarse and intermediate materials as possible rumminant feeds. As noted previously, coarse and intermediate materials (+45 mesh and +100 mesh, respectively) were obtained from mesquite pods in all four processes studied in Part 2. The suitability of these materials as components of rumminant feeds was evaluated by carrying out *in vitro* digestibility determinations on all samples, according to the method of Tilley and Terry (1963).

4) Preliminary development of low-cost nutritious human food products utilizing mesquite pod protein concentrate. The mesquite pod protein concentrate of best quality, obtained from the processes studied in Part 2, was utilized in the preliminary development of two low-cost

nutritious foods for humans: a) a sweetened, cinnamon-flavored powdered beverage base, and b) a sweetened mesquite-peanut butter pressed candy (called "mazapán" in Spanish).

Two additional runs were carried out as follows. 1) The complete proximate chemical analysis of whole raw mesquite pods was determined, utilizing previously described. This was done in order to establish a basis for comparing corresponding analytical data for coarse, intermediate and fines fractions obtained in Processes 1 - 4. 2) Since protein contents of all fines fractions (-100 mesh) from Processes 1 - 4 were low as compared with values obtained in the first report, an explanation for this difference was sought. It was believed that one possible cause might be the degree of wearing of the Alpine mill pins. As a result, Process 1 was repeated utilizing new pins, and the resulting coarse and fines fractions analyzed as previously described, except that <u>in vitro</u> digestibility of the coarse fraction was not determined.

RESULTS AND DISCUSSION

1) <u>Presentation of results obtained in the first report at the Institute of Food Technologists' Meeting in Atlanta, GA</u>.

Figs. 5 and 6 present copies of the listings in the Congress booklet, showing the Technical Session in which the paper was presented, and also the abstract of the paper.

Approximately 20 - 25 persons attended the presentation, including Dr. Daniel Meyer. A number of persons expressed interest in the work and requested further information.

2) <u>Further studies on preparation of a mesquite protein concentrate</u>.

In most processes studied (2 - 4) all materials were passed only one time through the Alpine mill, and not four times as was done in

first report, for cost reasons: each pass through the mill costs approximately 0.08 U.S. cents per pound, and a minimum cost process was desired. Only in Process 1, which was intended to duplicate and verify results obtained in the first report, was the material passed 4 times through the mill. Also, materials were not extruded in any process for reasons noted previously (see "Materials and Methods" section).

Comparing yields of fines, a number of interesting observations may be made from Tables 1 - 4.

1) As might have been expected, Process 1 (Table 1), with four passes through the mill, gave the maximum yield (75.4%). If this figure is compared with the corresponding one from the first report (45.8%, Table 6), it may be seen that a considerable increase in yield was obtained in the second report. This was probably due to the fact that in the first report mesquite pods were still quite fresh and hence more moist than in the second report. Indeed, typical moisture contents were of the order of 5 - 7% in the first report (Tables 11 - 15), and of the order of 2 - 4% in the second report (Tables 4 - 8).

2) Yields of fines were approximately equal in Processes 2 and 3, showing that the preliminary pass through the Alpine mill with one disc rotating was ineffective in increasing yields. Again, comparing corresponding yield values from the first report (36.4%, Table 6 and second report (41 - 42%, Tables 2 and 3), it may be seen that greater values were obtained in the second report, due to the greater dryness of the pods.

3) Interestingly, however, yields of fines of toasted mesquite pods were quite similar in both reports (65.0%, Table 10, first report, and 69.0%, Table 4, second report). This was probably due to the fact

that the process of toasting dried the pods in both cases, facilitating their grinding.

4) Summarizing, it may be concluded that, from the point of view of obtaining maximum yield of fines at minimum cost (one pass through the mill), Process 4 was optimum.

Considering now proximate chemical analyses (Tables 5 - 8), again a number of interesting observations may be made.

1) Protein contents of all fractions in the second report were considerably lower than corresponding values in the first report. It was believed that this could have been due to two factors: a) Degree of wearing of the mill pins: older, more blunt pins should be expected to give less pulverization of pods, with lesser separation of protein, than new pins; b) insect infestation: pods utilized in the first report had not been attacked by insects, while those utilized in the second report had been infested, despite efforts at preventing this by fumigation; infested pods should be expected to possess lower protein contents than fresh pods, since it is known that insects consume especially this component. In order to test hypothesis a), mesquite pods from the second report were ground in the Alpine mill according to Process 1, except that the material was passed through the mill only once, with both discs rotating, and the mill was equipped with new pins. Table 15 shows that protein content of the fines was not increased by utilization of new pins. As a result, hypothesis a) was disproved, leaving hypothesis b) as the only plausible explanation.

2) Tables 4 - 8 show that protein contents of the fines were not much different for the different processes studied, being of the order of 13.5 - 14.5%. Unfortunately, Table 13 shows that the latter values were not much greater than that for whole pods, which was 11.2%.

These results are in striking contrast with those obtained in the first report, in which protein content of the fines was nearly doubled with respect to that of whole pods. The explanation for these results could lie in the insect infestation hypothesis.

3) In all cases, protein content increased with increasing fraction mesh number. The same results were obtained in the first report.

4) Concerning acid detergent fiber and fiber components, values obtained in the second report were somewhat higher than those obtained in the first report. This was probably due to the fact that, since protein contents were decreased in the second report, fiber and fiber components were proportionately increased. As in the case of the first report, all of these parameters decreased with increasing fraction mesh number.

5) Interestingly, ether extract values were lower in the second report, as compared with the first report. A possible explanation for this observation could be that, due to their long storage period, extensive lipid peroxidation as well as fatty acid polymerization had occurred in samples utilized in the second report. Both changes would result in reduced ether extract. As was the case in the first report, ether extract increased with increasing fraction mesh number in the second report.

6) In all cases (Tables 6 - 8), ash content decreased and subsequently increased with increasing fraction mesh number, with minimum values corresponding to the +100 mesh samples. An explanation for this observation is not apparent at this time.

With regard to protein recoveries in the fines (Tables 8 - 11), it may be seen that minimum values corresponded to Processes 2 and 3, while the maximum value was that of Process 4. It appears, therefore

that, under similar conditions, grinding in the Alpine mill 4 times with both discs rotating resulted in considerably greater recover than grinding one time; this same effect was noted in the first report. Also, pregrinding in the mill with the door disc rotating also produced a small increase in protein recovery, as is apparent by comparing Tables 10 and 11. Interestingly, however, grinding toasted mesquite pods once with both discs rotating obtained a considerably higher recovery (88%, Table 12) than grinding raw pods four times under the same conditions (Table 8). It appears, therefore, that Process 4, utilizing toasted pods, was optimum in this respect.

As noted previously, whole raw mesquite pods possessed 11.2% protein (Table 13). This value was somewhat lower than that obtained by Del Valle et al. (1983) in previous work (1983). Acid detergent fiber and cellulose were also lower in this work, and lignin was approximately the same as in the previous one.

Tables 2, 3 and 14 show that using new pins in the Alpine mill did appreciably increase yield of fines (from approximately 42% to 56%), with respect to using older, more blunt pins. On the other hand, Tables 6, 7 and 15 show that fines protein content was not appreciably affected by the type of pins utilized. Protein recovery in the fines was somewhat increased by use of new pins (Tables 10, 11 and 16), reflecting the increased yield of fines previously noted.

Summarizing, of all processes studied in this, as well as in the first work, the optimum one appears to be Process 4 (toasting, Fig. 4), for the following reasons: 1) extrusion, which caused many problems, was not employed; 2) pregrinding in the Alpine mill with the door disc rotating was not required; 3) only one pass through the mill with both discs rotating was required; 4) yield of fines was adequate (approximately 70%); 5) protein content of the fines was high

(14.33%) and fiber content low (16.25%); 6) protein recovery in the fines was very high (88.2%); and 7) the process was simple and inexpensive to carry out.

3) Evaluation of mesquite pod coarse and intermediate fractions as possible rumminant feeds. Tables 17 - 20 present results of *in vitro* digestibility determinations carried out on the coarse (+45 mesh) and intermediate (+100 mesh) fractions of the different processes studied. The following observations may be made regarding these data.

1) Digestibilities were generally low, varying from approximately 30% to approximately 57%. Corresponding values for good forages usually vary from 70 to 90% (Mugerwa and Bwabye, 1974). Interestingly, however, Carvantes (1984) obtained digestibility values of 57 - 59% for fresh amaranth forage.

2) In all cases, digestibility increased with increasing fraction mesh number.

3) Most fractions did not differ much in digestibility, with average values being of the order of 35 - 40%.

4) Maximum values were obtained with fractions from Process 3. This is interesting, since Processes 2 and 3 were essentially the same, except that in Process 2 raw pods were pre-ground in the Alpine mill with the door disc rotating, while in Process 3 this step was omitted.

5) Digestibility values obtained in Process 4, which appears to be the optimum from protein yield and recovery points of view, were average.

6) It may be concluded that oversize fractions from utilization of mesquite pods by the processes herein described, would not be extraordinarily good rumminant feeds; on the other hand, they would probably represent by products of acceptable quality for this purpose.

4) Preliminary development of low-cost nutritious human food products utilizing a mesquite pod protein concentrate. As noted previously, the prototypes of two products were developed, utilizing mesquite pod protein concentrate (the fines, -100 mesh, from Process 4): 1) a mesquite/soy/peanut butter pressed candy, called "mazapán" in Spanish; and 2) a powdered, flavored, sweetened basee for preparation of an "horchata" type beverage. Both types of products are very popular in Mexico.

It might be noted that the "mazapán" was prepared at Productos Alimenticios DYN, S. A. de C. V. in Chihuahua City, while the "horchata" base was prepared at Productos Alimenticios Delicias, S. A. de C. V. in Delicias.

Tables 21 and 23 present the ingredient formulas for the above products, while Tables 22 and 24 give nutritional avaluation data for the same products.

Informal organoleptic evaluations of the products by personnel from each plant revealed that both were of good quality and good acceptance. In both products the flavor of toasted mesquite was considered to be an asset.

It might be added that in calculating the ingredient formulas given in Tables 20 and 23, the protein, sucrose and fiber contents of the mesquite component were considered. In this way the mesquite pod protein concentrate contributed protein, sucrose and fiber in the final products.

Tables 22 and 24 reveal that typical portions of both products would supply approximately 3 - 4 grams of protein and 110 and 160 calories, respectively. Thus, both products would contribute to improving the protein-calorie nutrition of persons utilizing them. The high sucrose content of both products might appear to be a dis-

advantage; however, it is this sweetness which makes both products attractive to all age groups, especially children.

It might be noted that the reconstituted "horchata" beverage (Table 24) contains 1.4% protein. This is equivalent to 40% the protein content of milk. The beverage, however, is considerably cheaper and more appealing than milk due to its sweetness and cinnamon flavor. The "horchata" beverage, therefore would be an inexpensive and at -tive form for supplying protein nutrition to low income groups.

An additional advantage of utilizing mesquite protein concentrate in the preparation of both products would be its fiber content. Besides supplying protein and calories, both products would also supply much needed dietary fiber.

SUGGESTED NEW RESEARCH

1) Evaluation of the insect infestation hypothesis as the cause of the low protein values obtained in the second report. The protein content of new mesquite pods--currently being collected--would be determined. The same pods would also be utilized in Process 4, and the protein contents of all fractions would also be determined. If higher values than those obtained in this report were found, the insect infestation hypothesis would have been verified.
2) Verification of Process 4 as being the optimum one for preparation of a mesquite pod protein concentrate. Process 4 as described in this report would be repeated, with the purpose of verifying yields, proximate analyses and protein recoveries in the different fractions (coarse, intermediate and fines), obtained in this report.
3) Determination of the protein quality of mesquite pods and mesquite pod protein concentrate. Once Process 4 had been verified

as being the optimum one, the Protein Efficiency Ratio (P.E.R.) and Net Protein Utilization (N.P.U.) of whole pods as well as of mesquite pod protein concentrate would be determined.

4) Determination of in vivo digestibility of coarse and intermediate fractions from Process 4. The in vitro digestibility of these fractions was determined in this report. In vivo determinations, utilizing goats as test animals, would be carried out at Facultad de Zootecnia of Universidad Autónoma de Chihuahua in Chihuahua City. The same determination could also be carried out with whole mesquite pods.

5) Development and evaluation of nutritious low-cost products for humans utilizing mesquite pod protein concentrate. The products whose prototypes were developed in this report would be further studied and perfected, with the purpose of assuring maximum nutritional quality at minimum cost. Formal sensory evaluation tests would be carried out. The Protein Efficiency Ratio (P.E.R.) and Net Protein Utilization (N.P.U.) of the products would also be determined.

6) Determination of yields of typical trees. As noted in the first report, five mesquite trees were marked since last year. This trees bear sweet pods, sour pods and typically tasting pods. The total yields of these trees will be determined this year.

7) New mesquite pod collection. Mesquite pods from the current harvest are being collected. It is hoped that 200 kilos will be obtained. If it is found that insect infestation was the cause of the low protein contents obtained in this report, other means for preserving the pods, other than storage at room temperature with periodic fumigation, would have to be found.

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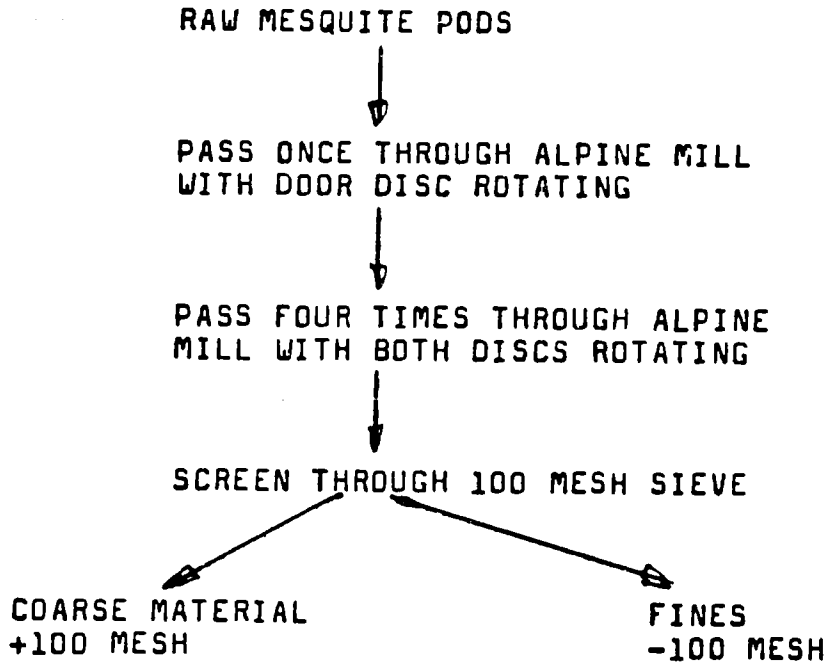

FIG. 1: FLOW DIAGRAM FOR PROCESS 1

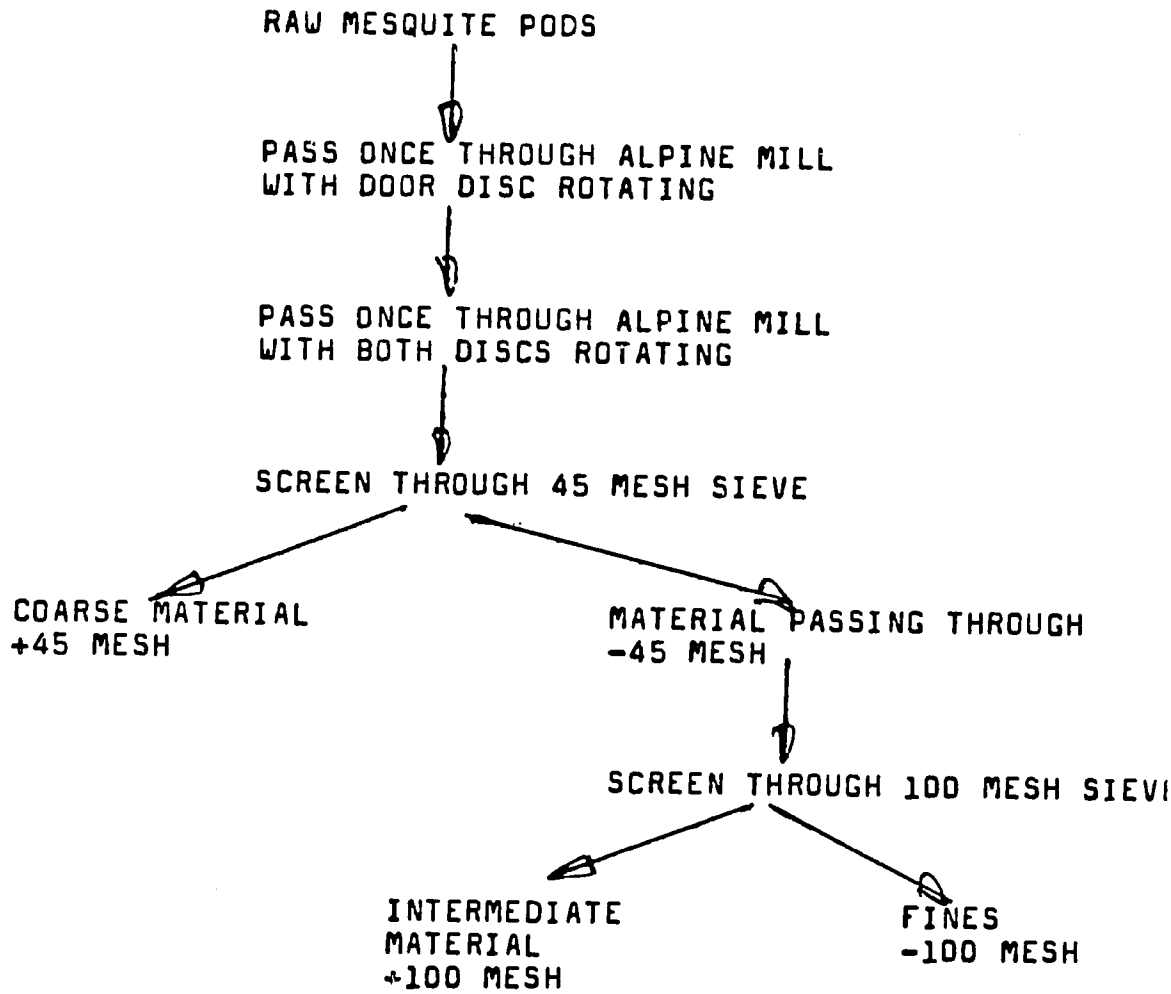

FIG. 2: FLOW DIAGRAM FOR PROCESS 2

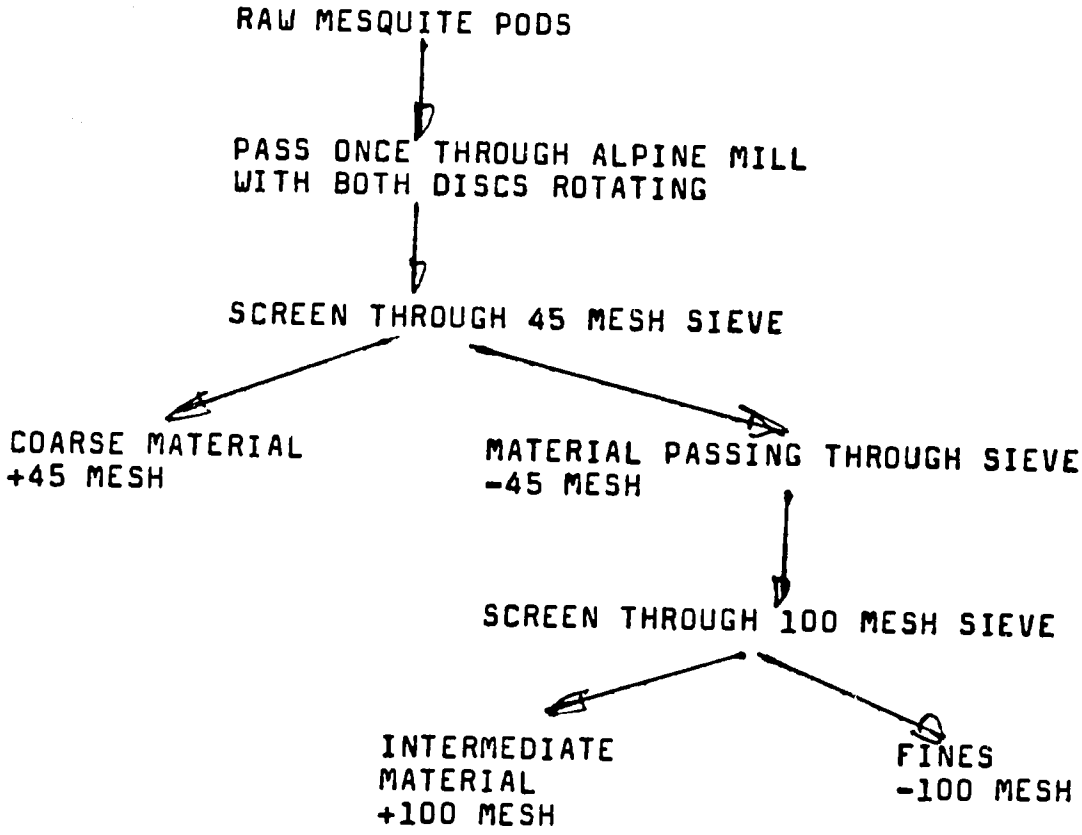

FIG. 3: FLOW DIAGRAM FOR PROCESS 3

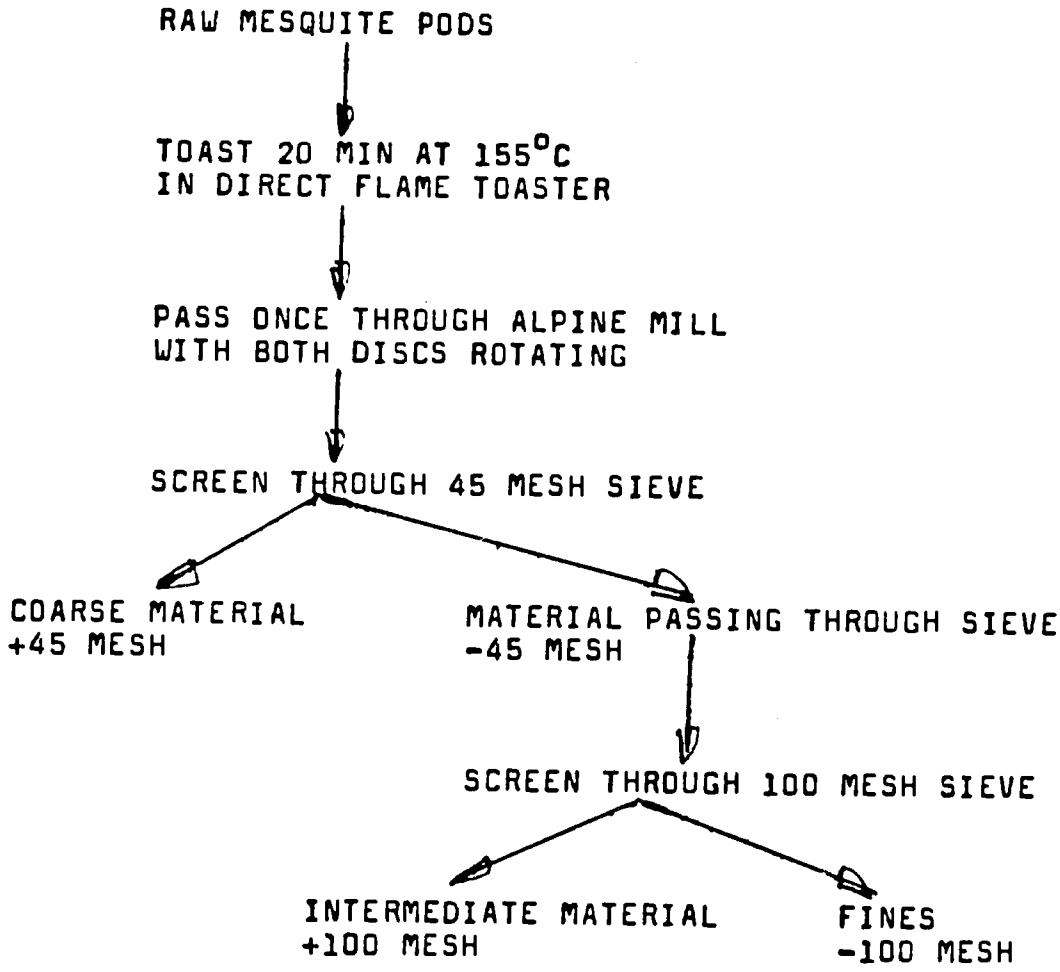

FIG. 4: FLOW DIAGRAM FOR PROCESS 4

ift 85

PROGRAM & ABSTRACTS

45th ANNUAL IFT MEETING/ATLANTA—JUNE 9–12, 1985

SESSION 34 • ROOM 256
Dairy Technology STG Program
Ultrafiltration of Milk for Cheese Making

Chairmen: A.J. LUKSAS, Dairy Research Inc.
V. HOLSINGER, USDA-Philadelphia

1:30 Introductory Remarks

1:35 (323) On-farm ultrafiltration of milk: A national study—R.R ZALL, Cornell U.-Ithaca

2:05 (324) Requirements for sanitary construction and maintenance of ultrafiltration equipment for dairy processing—R.G. SEMERAD, USDA-AMS-Washington, DC

2:35 (325) New cheese making procedures utilizing ultrafiltration—F.V. KOSIKOWSKI, Cornell U.-Ithaca

3:05 (326) New dairy products from ultrafiltered whole milk—C.A. ERNSTROM, Utah State U.

3:35 (327) Review of equipment capabilities for ultrafiltration of milk—B.S. HORTON, Horton International, Inc.

4:05 (328) Legal concerns related to ultrafiltration and cheese standards—G.M. BURDITT, Burditt, Bowles & Radzius, Ltd.

4:35 Dairy Technology STG Business Meeting

SESSION 35 • ROOM 257
Technical Session: Proteins—General

Chairmen: R.L. ANDERSON, USDA-Peoria
F.C. PARRISH Jr., Iowa State U.

1:30 Introductory Remarks

1:35 (329) Preparation of a mesquite (*Prosopis* sp.) pod protein concentrate by a low-cost process—F.R. Del Valle, E. MARCO, R. Becker & R. Saunders, FICAN, Mexico

1:50 (330) Inhibition of chymosin and the coagulation of paracasein micelles by anions—N.A. BRINGE & J.E. Kinsella, Cornell U.-Ithaca

2:05 (331) Studies on the effect of protein hydrophobicity on the functional properties of food proteins—C.H. LEE & S.K. Kim, Korea U., Seoul

2:20 (332) Interaction of procyanidin and protein—W.E. ARTZ, P. Bishop, A.K. Dunker, E.G. Schanus & B.G. Swanson, U. of Illinois-Urbana

2:35 (333) Tryptophan oxidation catalyzed by light or oxidizing lipids—M.K. Krogull, J.D. Kanner & O. FENNEMA, U. of Wisconsin-Madison

2:50 (334) Structure function relationships as they affect

FIG. 6

foaming of soy proteins—
sella, Cornell U.-Ithaca

3:05 (335) Interaction of carbonyls
Thermodynamic and conf
O'NEILL & J.E. Kinsella, C

3:20 (336) Factors influencing develc
cutting beef muscle—W.I
FORTH, Utah State U.

3:35 (337) Active site determinatior
probe analysis of heat
GILBERT & S. Tanaka, Ru

3:50 (338) Effects of postmortem
muscle structure and me
Y.B. Lee, U. of California-I

4:05 (339) Comparative studies on a
and from thin filament of
K-C. CHANG & D.E. Goll,

4:20 (340) Proportion of collagen typ
muscles—M.C. HUNT & D
U.

4:35 (341) Investigations into the rc
resolution of rigor mortis
D.A. ZDANIS, S. Matoba
ifornia-Davis

SESSION 36 • ROO
Technical Session: Nutrie
of Foods

Chairmen: C.M. WEAVER, Purdue U.
G. FRONING, U. of Nebra

1:30 Introductory Remarks

1:35 (342) Development of an acce
sessing a reduced sodi
DESSO & D.H. Kleyn, Rut

1:50 (343) Relationship of specific g
sensory quality and fat
chips—D.K.W. JAHNER &
sin-Stout

2:05 (344) Light-induced changes in
flavin content of chee
Ashoor, Arizona State U.

2:20 (345) Effect of further processi
tention of thiamin and r
deboned chicken—C.Y.W
Athens

2:35 (346) Vitamin C loss in vegeta
foodservice cycle—B.L. (

e of fiber in treatment of disease—J.W. ANDERSON, Medical vice, Veterans Administration Medical Center, Univ. of Ken- ry, Lexington, KY 40511

ary fiber intake offers many health advantages. Fiber-deficient diets been linked to the high prevalence of diabetes, hypertension, obes- eart disease and colon cancer. High fiber diets are useful for treating etes, hyperlipidemia, hypertension or obesity. They lower insulin re- ements of diabetics and lower blood pressure. Low energy dense ls from high-fiber foods promote weight loss and maintenance. Sol- -fiber rich foods such as oat and legume products can lower serum sterol by 20%. High fiber foods not only reduce the risks for many mon diseases but can also help to reverse these conditions.

grate research findings, consumer attitudes, and regulatory itions for new marketing strategies for dietary fiber—H.D. RT, The Quaker Oats Company, 617 W. Main St., Barrington, 0010

relationship between diet and health (with special emphasis on di- y fiber), that is based on scientific research and advocated by health essionals, science writers and food editors, is now being exploited he private sector to meet the real and/or perceived needs of the umer. The direct use of nutrition/health information derived from ce presents new approaches to marketing that will create new op- unities as well as identify responsibilities for the academic, industrial regulatory communities. This presentation will examine the relation- of the current state of knowledge concerning dietary fiber, consumer ides, and regulatory positions in presenting the implications of in- iting nutritional issues into marketing strategies.

arm ultrafiltration of milk—A national study—R.R. ZALL, . of Food Science, Cornell Univ., Stocking Hall, Ithaca, NY 3

pr involves the installation and operation of an ultrafiltration m ... a large dairy farm in California where about 800 cows are d twice daily. Retentate was transported to different cheese facto- where four separate varieties of cheese were made. Permeate was on the farm and used in an experimental program to supplement al feeds. Key objectives were: to determine whether or not a fully nated membrane plant can be successfully integrated into the milk sting system on a day to day basis; to determine if commercially table cheese can be made from ultra-filtered milk; to determine added worth to the farmer; and economics of the process.

irements for sanitary construction and maintenance of ul- itration equipment for dairy processing—R.G. SEMERAD, A-AMS, Dairy Grading Section, Dairy Grading & Standard- on Branch, Washington, DC 20250

brane systems for dairy use must be designed for sanitary process- horough cleaning, and effective sanitization. Criteria for sanitary n are outlined and discussed. Progress with development of 3A lards for membrane equipment is reviewed. USDA experience with ction of dairy membrane systems is summarized

cheese making procedures utilizing ultrafiltration—F.V. KOWSKI, Dept. of Food Science, Cornell Univ., Ithaca, NY)

e making by ultrafiltration (UF) utilizing highly concentrated milk ates originated in France during 1969 through a concept called MMV. then use of ultrafiltered milk retentates for cheese making has steadily and assumed new forms such as low concentrated reten- CR) methodology. Advantages of using ultrafiltration for cheese g include attainment of higher yields, improved efficiency, contin- production, new cheeses and better quality and nutrition of prod- quipment firms have designed and installed large turn-key molecular ition membrane plants in Europe and the United States. A revo- lution in the manufacture of important cheeses is underway, and its char- acter and ratifications are discussed.

New dairy products from ultrafiltered whole milk—C.A. ERN— 326
STROM, Dept. of Nutrition & Food Sciences, Utah State Univ. - UMC 87, Logan, UT 84322

Ultrafiltration of whole milk for cheese making may increase yields due to improved recovery of fat and protein in curd. Whether it does depends on the amount of syneresis during curd making following ultrafiltration. Ultrafiltration (5x) followed by fermentation and evaporation (36% moisture) increased yields by 18% (no syneresis). Curd from ultrafiltered milk (2x) that is set and cooked in the traditional way has no yield advantage (excess syneresis). Heating retenate (60% moisture) to 83°C for 30 min results in a smooth curd that does not expel whey, gives maximum yield and has good keeping quality.

Review of equipment capabilities for ultrafiltration of milk— 327
B.S. HORTON, Horton International, Inc., 238 Main St., Cambridge, MA 02142

The evolution of ultrafiltration equipment for processing milk since 1967 is reviewed with respect to the interest in manufacturing cheese and other dairy products with membrane processes. The designs in the U.S. resulting from early attempts to meet sanitary construction and even 3-A standards are compared to those which have emerged since closed CIP systems became a reality. Performance of equipment on whole and skim milk are presented to show the influence of membrane materials and design. The fact that widely differing designs are functioning commercially on milk suggests that costs play as important role as technical features.

Legal concerns related to ultrafiltration and cheese standards— 328
G.M. BURDITT, Burditt, Bowles & Radzius, Ltd., 135 South LaSalle St., Chicago, IL 60603

Food standards are often criticized as hindrances to the use of new procedures made possible by advances in technology. To the detriment of consumers, food standards can impose a ceiling on nutrition and quality, and prevent the utilization of improved manufacturing techniques. But cheese standards do not labor under this handicap. The alternate make procedure clause which appears in many cheese standards was designed to facilitate the utilization of modern techniques, such as ultrafiltration, developed by dairy scientists for the benefit of consumers, dairy farmers and cheese producers.

Preparation of a mesquite (*Prosopis* sp.) pod protein concen- trate by a low-cost process— 329
F.R. Del Valle, E. MARCO, R. Becker & R. Saunders, FICAN, Apartado Postal 1545, Sucursal C, Chihuahua, Chih., Mexico

Mesquite pods were ground in al Alpine mill raw, extruded (alone and a 50/50 soybean blend) or toasted. The resulting products were separated into coarse, intermediate and fines fractions, and protein and fiber contents determined. Protein concentration and recovery were maximum, and fiber content minimum, in the fines. A protein concentrate, containing 25% protein and 12% fiber, with 80% protein recovery was prepared by extrusion, followed by grinding and separation of fines. Protein content was raised to 32%, and fiber content lowered to 8% in the soybean blend, with approx. equal protein recovery.

Inhibition of chymosin and the coagulation of para-casein mi- celles by anions— 330
N.A. BRINGE & J.E. Kinsella, Dept. of Food Science, Cornell Univ., Ithaca, NY 14853

The independent effect of anion type on coagulation was determined by monitoring light transmission after adding 40 mM calcium salt to partially hydrolyzed casein micelles. The release of macropeptide by chymosin was quantified using fluorescamine. Chymosin activity and the coagu-

FIG. 7

MESH NO.	PERCENT MATERIAL
+100	24.6
-100	75.4

TABLE 1: YIELDS OF COARSE MATERIAL AND FINES IN PROCESS 1

MESH NO.	PERCENT MATERIAL
+ 45	37.6
+100	20.8
-100	41.6

21
42
63

42/63 = 67%

TABLE 2: YIELDS OF COARSE, INTERMEDIATE AND FINES FRACTIONS IN PROCESS 2

MESH NO.	PERCENT MATERIAL
+ 45	40.5
+100	16.9
-100	42.6

TABLE 3: YIELDS OF COARSE, INTERMEDIATE AND FINES FRACTIONS IN PROCESS 3

MESH NO.	PERCENT MATERIAL
+ 45	22.0
+100	8.9
-100	69.1

TABLE 4: YIELDS OF COARSE, INTERMEDIATE AND FINES FRACTIONS IN PROCESS 4

COMPONENT, PERCENT	+100 MESH	-100 MESH
MOISTURE	3.60	4.06
PROTEIN	11.30	12.50
ETHER EXTRACT	1.83	3.45
ASH	3.58	4.64
ACID DETERGENT FIBER	47.17	26.61
CELLULOSE	37.97	16.79
LIGNIN	11.75	5.11

TABLE 5: PROXIMATE CHEMICAL ANALYSES OF THE DIFFERENT FRACTIONS FOR PROCESS 1

COMPONENT, PERCENT	+45 MESH	+100 MESH	-100 MESH
MOISTURE	3.72	3.60	3.62
PROTEIN	6.00	6.[illegible]0	14.40
ETHER EXTRACT	1.42	1.65	4.45
ASH	4.11	3.02	4.52
ACID DETERGENT FIBER	59.74	43.73	16.69
CELLULOSE	48.34	33.31	13.34
LIGNIN	13.29	11.56	4.79
	121.37	88.6	34.82
	131.12	103.77	[illegible]

TABLE 6: PROXIMATE CHEMICAL ANALYSES OF THE DIFFERENT FRACTIONS FOR PROCESS 2

COMPONENT, PERCENT	+45 MESH	+100 MESH	-100 MESH
MOISTURE	3.42	4.31	3.23
PROTEIN	8.50	9.43	13.99
ETHER EXTRACT	1.98	2.16	5.50
ASH	4.82	3.72	5.06
ACID DETERGENT FIBER	37.38	35.06	14.24
CELLULOSE	30.27	27.54	10.44
LIGNIN	10.40	7.19	4.33

TABLE 7: PROXIMATE CHEMICAL ANALYSES OF THE DIFFERENT FRACTIONS FOR PROCESS 3

COMPONENT, PERCENT	+45 MESH	+100 MESH	-100 MESH
MOISTURE	2.70	3.33	3.06
PROTEIN	3.65	5.89	14.33
ETHER EXTRACT	1.44	1.55	2.37
ASH	4.05 11.84 / 82.16	2.64 86.59 / 13.41	4.89 / 21.65
ACID DETERGENT FIBER	64.46	46.31	16.25
CELLULOSE	52.42	38.11	10.77
LIGNIN	13.31	12.13	4.16

TABLE 8: PROXIMATE CHEMICAL ANALYSES OF THE DIFFERENT FRACTIONS FOR PROCESS 4

MESH NO.	PERCENT OF TOTAL PROTEIN
+100	22.8
-100	77.2

TABLE 9: DISTRIBUTION OF TOTAL PROTEIN AMONG THE DIFFERENT MESH FRACTIONS FOR PROCESS 1

MESH NO.	PERCENT OF TOTAL PROTEIN
+ 45	23.3
+100	14.9
-100	61.8

TABLE 10: DISTRIBUTION OF TOTAL PROTEIN AMONG THE DIFFERENT MESH FRACTIONS FOR PROCESS 2

MESH NO.	PERCENT OF TOTAL PROTEIN
+ 45	31.3
+100	14.5
-100	54.2

TABLE 11: DISTRIBUTION OF TOTAL PROTEIN AMONG THE DIFFERENT MESH FRACTIONS FOR PROCESS 3

MESH NO.	PERCENT OF TOTAL PROTEIN
+ 45	~~7.1~~ 15.3
+100	~~4.7~~ 24.7
-100	~~88.2~~ 60.0

TABLE 12: DISTRIBUTION OF TOTAL PROTEIN AMONG THE DIFFERENT MESH FRACTIONS FOR PROCESS 4

COMPONENT	PERCENT
MOISTURE	4.90
PROTEIN	11.20
ETHER EXTRACT	1.68
ASH	4.60
ACID DETERGENT FIBER	28.61
CELLULOSE	20.13
LIGNIN	9.05

TABLE 13: PROXIMATE CHEMICAL ANALYSIS FOR WHOLE CHIHUAHUA MESQUITE PODS

COMPONENT	PERCENT MATERIAL
+100 MESH	44.0
-100 MESH	56.0

TABLE 14: YIELDS OF COARSE AND FINES FRACTIONS FOR MESQUITE PODS, PROCESS 1, GROUND WITH NEW PINS IN ALPINE MILL

COMPONENT, PERCENT	+100 MESH	-100 MESH
MOISTURE	1.43	2.13
PROTEIN	9.05	13.62
ETHER EXTRACT	1.80	1.99
ASH	3.58	4.57
ACID DETERGENT FIBER	38.78	23.44
CELLULOSE	29.41	16.53
LIGNIN	9.37	6.91

TABLE 15: PROXIMATE CHEMICAL ANALYSES OF DIFFERENT SIEVE FRACTIONS FOR MESQUITE PODS, PROCESS 1, GROUND WITH NEW PINS IN ALPINE MILL

MESH NO.	PERCENT OF TOTAL PROTEIN
+100	34.3
-100	65.7

TABLE 16: DISTRIBUTION OF TOTAL PROTEIN AMONG DIFFERENT SIEVE FRACTIONS FOR RAW MESQUITE PODS, PROCESS 1, GROUND WITH NEW PINS IN ALPINE MILL

SAMPLE	IN VITRO DIGESTIBILITY	
	DRY MATTER	ORGANIC MATTER
+100 MESH	38.42%	36.83

TABLE 17: IN VITRO DIGESTIBILITY OF COARSE MATERIAL FROM PROCESS 1

SAMPLE	IN VITRO DIGESTIBILITY	
	DRY MATTER	ORGANIC MATTER
+ 45 MESH	35.02%	32.65%
+100 MESH	46.81%	44.43%

TABLE 18: IN VITRO DIGESTIBILITIES OF MEDIUM AND COARSE FRACTIONS FROM PROCESS 2.

SAMPLE	IN VITRO DIGESTIBILITY	
	DRY MATTER	ORGANIC MATTER
+ 45 MESH	44.08%	43.56%
+100 MESH	55.69%	52.77%

TABLE 19: IN VITRO DIGESTIBILITIES OF MEDIUM AND COARSE FRACTIONS FROM PROCESS 3

SAMPLE	IN VITRO DIGESTIBILITY	
	DRY MATTER	ORGANIC MATTER
+ 45 MESH	28.96%	27.71%
+100 MESH	39.45%	38.87%

TABLE 20: IN VITRO DIGESTIBILITIES OF MEDIUM AND COARSE FRACTIONS FROM PROCESS 4

INGREDIENT	PARTS
GROUND PEANUTS OR PEANUT BUTTER	29
MESQUITE PROTEIN CONCENTRATE, PROCESS 4	10
POWDERED SUCROSE	60
SALT	1

TABLE 21: INGREDIENT FORMULA FOR MESQUITE-PEANUT BUTTER PRESSED CANDY ("MAZAPAN")

COMPONENT	PERCENT
PROTEIN	11
FAT	16
SUCROSE	60
OTHER CARBOHYDRATES	7
FIBER	2
WEIGHT PER UNIT, GRAMS	25
GRAMS PROTEIN PER UNIT	3
GRAMS FAT PER UNIT	4
GRAMS SUCROSE PER UNIT	15
GRAMS OTHER CARBOHYDRATES PER UNIT	2
GRAMS FIBER PER UNIT	0.5
TOTALCALORIES PER UNIT	108

TABLE 22: CALCULATED PROXIMATE ANALYSIS AND OTHER NUTRITIONAL DATA FOR MESQUITE-PEANUT BUTTER CANDIES

INGREDIENT	PARTS
MESQUITE PROTEIN CONCENTRATE, PROCESS 4	12.00
FULL-FAT SOY FLOUR	18.00
SUCROSE	68.65
SALT	1.00
CINNAMON FLAVOR, POWDERED, ARTIFICIAL	0.35

METHOD OF PREPARATION: DISPERSE TWO TABLESPOONFULS (40 GRAMS) IN ONE GLASS OF WATER (250 ML) AND BLEND

TABLE 23: INGREDIENT FORMULA FOR POWDERED MESQUITE-SOYA FLAVORED AND SWEETENED BEVERAGE BASE

COMPONENT, PERCENT	POWDERED BLEND	DISPERSED IN WATER AS INDICATED IN TABLE 23
PROTEIN	8.6	1.4
FAT	4.7	0.8
SUCROSE	70.9	11.5
OTHER CARBOHYDRATES	8.4	1.4
FIBER	2.0	0.3
GRAMS NUTRIENT PER GLASSFUL OF BEVERAGE:		
PROTEIN	3.5	
FAT	1.9	
SUCROSE	27.5	
OTHER CARBOHYDRATES	4.3	
FIBER	0.3	
CALORIES	158	

TABLE 24: CALCULATED PROXIMATE COMPOSITION FOR POWDERED MESQUITE-SOY BEVERAGE BLEND AND BEVERAGE, AND OTHER NUTRITIONAL INFORMATION

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UTILIZACION DE LA VAINA DE MEZQUITE (*Prosopis spp*) EN LA ALIMENTACION HUMANA

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RESUMEN

Se obtuvo la composición bruta de la vaina de mezquite (*Prosopis spp.*: pericarpio, semillas y cascarilla) así como la composición proximal de cada una de las fracciones. También se obtuvieron los contenidos de sacarosa y azúcares reductores de la vaina entera así como de la fracción denominada "pericarpio". En lo referente a las proteínas de la vaina entera, se obtuvo el perfil de aminoácidos esenciales, la curva de solubilidad como función del pH, la Razón de Eficiencia Proteíca (R.E.P.) y la Utilización Neta de Proteínas (N.P.U.). Aunque se elaboraron concentrados y aislado proteínicos por métodos químicos conocidos, se encontró que ambos procesos eran muy complicados y resultarían caros en la práctica. Consecuentemente, se acudió a métodos físicos para concentrar la proteína y disminuir la fibra cruda de la vaina entera. En este respecto, se estudiaron 4 métodos: 1) molienda directa de la vaina entera, con cernido posterior; 2) extrusión de la vaina, con molienda y cernidos posteriores; 3) ya que hubo problemas para extruir la vaina entera, se intentó extruirla en combinación con soya, en proporción de 1:1; la mezcla extruida fue molida y cernida; y 4) tostado de la vaina, seguido de molienda y cernido. En todos los casos se obtuvieron fracciones de +45, +100 y -100 mallas, así como los rendimientos y análisis proximales de cada fracción. Se encontró que en todos los casos, el contenido de proteínas aumentaba, y el contenido de fibra disminuía, al aumentar la finura de la fracción; la fracción de malla -100 era un producto pulverizado, de muy buen aspecto. El proceso que obtuvo la mayor concentración de proteínas y mayor disminución de fibra, así como mayor recuperación de proteínas, con respecto a la vaina entera en los finos fue el de tostado, molido y cernido. Se elaboraron dos productos nutritivos de bajo costo utilizando el concentrado proteínico del mezquite elaborado por tostado: un mazapán de cacahuate/mezquite/soya y una base en polvo, endulzada y saborizada con canela, para la preparación de horchata. Ambos productos tuvieron muy buena aceptación, notándose que el sabor de mezquite tostado mejoraba la calidad. En ambos productos la sacarosa del mezquite contribuyó a su dulzura total. Las fracciones de malla +45 y +100 reflejaron valores intermedios de digestibilidad *in vitro* para rumiantes.

ABSTRACT

The gross composition of mesquite pods (Prosopis spp.: pericarp, seeds and seed envelopes) was obtained, as was the proximate composition of each fraction. The sucrose and reducing sugar contents of whole pods and pericarp were also determined. Concerning whole mesquite proteins, the following were determined: essential amino acid profile, solubility curve as a function of pH, Protein Efficiency Ratio (P.E.R.) and Net Protein Utilization N.P.U.). Although a protein concentrate and isolate were prepared utilizing established chemical methods, it was found that both procedures would be costly and hence impractical. Consequently, physical methods were sought for concentrating protein and decreasing crude fiber content of whole pods. In this respect, 4 methods were studied: 1) direct grinding of whole pods, followed by screening; 2) extrusion of whole pods, followed by grinding and screening; 3) since many problems were experienced when attempting to extrude mesquite pods, extrusion was accomplished by blending mesquite with soybeans (1:1 w/w); the extruded blend was subsequently ground and screened; and 4) toasting pods, followed by grinding and screening. In all cases, +45, +100 and -100 mesh fractions were obtained, as were yield and proximate composition of each fraction. It was found that in all cases, protein content increased and fiber content decreased, all with increasing degree of fineness; the -100 mesh fractions were finely powdered products of excellent appearance The process which resulted in maximum concentration of proteins, maximum decrease in fiber content, and maximum protein recovery consisted of toasting, followed by grinding and screening. Two low cost nutritious products were prepared utilizing the toasted mesquite protein concentrate: a peanut/soybean/mesquite "mazapan" (powdered, compacted candy) and a powdered, sweetened, cinnamon flavored base for preparation of "horchata" beverages. Both products had very good acceptance, and it was noted that in both cases the toasted mesquite flavor contributed to overall quality. In both products, the sucrose from mesquite contributed to total sweetness. The +45 and +100 mesh fractions reflected intermediate *in vitro* digestibility values for ruminants.

UTILIZACION DE LA VAINA DE MEZQUITE (Prosopis spp) EN LA ALIMENTACION HUMANA.

INTRODUCCION

El mezquite (Prosopis spp) es una planta leguminosa que se encuentra en muchas de las zonas áridas y semiáridas del planeta, incluyendo las áreas subtropicales del Norte y Sudamérica, Africa y Asia. Aunque estas plantas se encuentran en todos los tipos de suelos, predominan sin embargo en ecosistemas áridos que reciben menos de 8 cm. de precipitación pluvial por año. También se encuentran en pastizales y valles de los ríos (Allen y Allen, 1981). Como es el caso con otras leguminosas las plantas del mezquite poseen raíces que contienen nódulos con bacterias que fijan el nitrógeno, y el fruto de la planta se dá en forma de vainas. Rendimientos típicos de las vainas verían aproximadamente de 30 a 40 Kg. por Ha. en el caso de las plantas silvestres (Ludwig y Whitford, 1981) (McDaniel, 1982) hasta aproximadamente 3000 Kg. por Ha. en áreas con población densa de mezquite (Harden et. al., 1981). Se conocen varios usos alimenticios de las vainas del mezquite. En nuestro país se elabora un dulce denominado "mezquitamal" a base de harina de mezquite prensada; los niños tambien acostumbran chupar las vainas de mezquite. Como consecuencia de su alto contenido de azúcar, las vainas del mezquite se utilizan en la preparación de diversas bebidas fermentadas (vinos y cervezas de mezquite y también un producto destilado denominado "mezcal") y no fermentadas ("mezquitatole") en México y Centroamérica. En el suroeste de Estados Unidos los indios Pima molían las vainas para producir una harina denominada "pinole" que se utilizaba en la elaboración de un pan nutritivo.

Las vainas del mezquite, desde luego también se utilizan como forraje para los rumiantes (Allen y Allen, 1981).

COMPOSICION BRUTA DE LA VAINA

La vaina del mezquite consiste de dos componentes básicos: el "pericarpio" que incluye al "epicardio" o cubierta externa y es un material dulce y pulposo que se adhiere a las semillas; y las semillas. Estas últimas consisten de almendras, que contienen la mayor parte de las proteínas y las grasas, y que son pequeñas duras y de superficie lisa; y las cascarillas, que recubren a las almendras y que son duras y fibrosas.

En lo referente a la proporción de cada fracción en la vaina total del mezquite, la Table 1 muestra que el pericarpio constituye el 58%, las semillas el 14% y la cascarilla 28%, todo de la vaina total (Del Valle et. al., 1983).

Por otra parte las Figuras 1 a 4 muestran las vainas enteras del mezquite, las semillas enteras con cascarilla, las semillas abiertas mostrando las almendras dentro de las cascarillas y las almendras solas, respectivamente.

COMPOSICION QUIMICA

La Table 2 presenta la composición química delas vainas enteras así como de las distintas fracciones: pericarpio, cascarilla y almendras (del Valle et. al., 1983).

De un punto de vista químico las almendras serían las más adecuadas para consumo humano ya que reflejan alto contenido de proteínas (37%) y bajo contenido de fibra (8%); sin embargo debido a su baja proporción dentro de la vaina y dificultad de separación de la misma, las almendras serían demasiado caras.

El pericarpio, aunque presente en buena proporción y es de fácil separación, también tendría valor limitado debido a su bajo contenido de proteínas (10.5%) y alto contenido de fibra (20%). La cascarilla prácticamente no tendría valor debido a su baja proporción, dificultad de separación, bajo contenido protéico y alto contenido de fibra. Así se concluye que la vaina entera sería la única opción viable para utilización para consumo humano.

La Tabla 2 muestra que los carbohidratos son el constituyente principal de todas las fracciones exceptuando las almendras; también, las vainas enteras y todas las fracciones, incluyendo las almendras, muestran bajo contenido de grasas. En este aspecto las vainas de mezquite se asemejan a las leguminosas comunes cuyo contenido de grasa varía de 1 a 4% (Fleck, 1971).

Con la excepción de las almendras, todas las otras fracciones así como las vainas enteras muestran muy altos contenidos de fibra, del orden del 20 al 30%, valores que exceden a los del salvado de trigo, que contiene del 10 al 12% de esta sustancia (Baker et. al., 1979, Saunders Hustala, 1979). Este alto contenido de fibra sin embargo no excluye el uso de la vaina del mezquite para consumo humano; por el contrario, se sabe que cuando se utiliza en niveles adecuados la fibra dietética aporta diversos efectos benéficos (Anónimo, 1979). Así la vaina del mezquite se puede utilizar en combinación con materias primas de bajo contenido de fibra, tales como cereales, leguminosas comunes, etc.; en este caso además de aportar proteína y carbohidratos la vaina del mezquite también aportaría fibra dietética.

La Tabla 2 muestra que la sacarosa y los azúcares reductores constituyen el 50% o más de los carbohidratos totales de la vaina del mezquite y el pericarpio, y que éste último contiene más azúcares reduc

tores que la vaina completa. La sacarosa es el componente más abundante, lo que explica la fuerte dulzura de la vaina del mezquite. Esta alta concentración de sacarosa aumentaría la utilidad del mezquite en la formulación de alimentos nutritivos y de bajo costo del tipo dulce, tales como bebidas, atoles y dulces. En estos casos, además de suplir proteínas y fibras, el mezquite también aportaría sacarosa, lo que repercutiría en el ahorro de endulcorantes externos. Así, la vaina de mezquite se perfila como una buena fuente de calorías.

La figura 5 muestra la curva de solubilidad de proteínas para la vaina entera del mezquite (Del Valle et. al., 1983) e incluye la curva correspondiente para la proteína de soya como comparación (Smith y Circle, 1978). Cabe notar que ésta última es prácticamente idéntica a las de las leguminosas comunes tales como frijoles y chícharos (Wolf, 1977; Hang et. al., 1970). El punto isoeléctrico de la proteína de mezquite es aproximadamente de pH 4.5 lo que también es el caso para la proteína de soya. Aunque la forma general de ambas curvas es semejante, la solubilidad en el punto isoeléctrico es mucho mayor para el mezquite; por otro lado la solubilidad en los extremos de pH es mucho menor para el mezquite. Este comportamiento del mezquite, tan distinto al de las leguminosas comunes, sin embargo es semejante al de ciertas leguminosas silvestres, por ejemplo Phaseolus mungo que se encuentra en la India (Hang Y.D., Steinkkraus, K.H., Hackler, L.R. 1970).

VALUACION NUTRICIONAL

El contenido de inhibidor de tripsina de la vaina entera de mezquite se ha reportado en 1.4 U.I.T. (unidades de inhibidor de tripsina) por miligramo, base seca, Liener (1979) es un valor sumamente bajo

para cualquier alimento. En comparación el contenido del inhibidor de tripsina para el frijol de soya crudo es de 90 a 100 U.I.T. por miligramo (Rackis, 1974).

La Tabla 3 muestra el patrón de aminoácidos para la proteína de la vaina del mezquite entero e incluye los patrones FAO/OMS (1973) recomendados para niños y adultos en comparación. Los aminoácidos limitantes del mezquite son los siguientes: sulfurados, treonina e isoleucina. La lisina casi iguala a la del patrón para niños. Por otra parte el patrón de aminoácidos de la proteína del mezquite excedió el patrón recomendado para adultos en todos los casos.

La Tabla 4 presenta los valores reportados para la Razón de Eficiencia Protéica (R.E.P.) y Utilización Neta de Proteínas (N.P.U.) incluyendo valores correspondientes para la caseína como proteína de referencia (Del Valle et. al., 1983). El valor del R.E.P. de 1.4 para la proteína de mezquite es semejante al reportado para las leguminosas comunes (1.3-1.5; FAO, 1970), pero menor que el valor reportado para la proteína de soya (2.0; Wolf y Cowan, 1971). Los valores del R.E.P. y N.P.U. para la proteína de mezquite fueron del 54% y el 74% de los valores correspondientes obtenidos para la caseína.

CONCENTRADO Y AISLADO PROTEICO

Se han preparado un concentrado y un aislado proteínico de la vaina del mezquite entero utilizando procesos químicos establecidos (Rhee et. al., 1972 y 1973) con modificaciones descritas por Del Valle et. al. (1983). Los resultados obtenidos se muestran en la Tabla 5. Se puede apreciar que el concentrado proteínico duplicó el contenido protéico con respecto a la vaina entera. Por otro lado el aislado proteínico casi triplicó la concentración protéica.

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El rendimiento del concentrado fue típico para esta clase de productos (Wolf, 1977). Sin embargo el rendimiento del aislado fue sumamente bajo.

Se concluyó que, dada la dificultad de elaborar tanto el concentrado como el aislado, ya que la concentración de proteínas no fue muy elevada, la elaboración industrial de estos productos sería impráctica.

PROCESAMIENTO DE LA VAINA DE MEZQUITE POR MOLIENDA DIRECTA Y CERNIDO

Ya que se encontró que la concentración de proteínas y disminución de fibras de la vaina del mezquite por métodos químicos no era práctica, se recurrió a procesos físicos incluyendo molienda, extrusión, tostado y cernido.

El primer proceso que se estudió fue el de molienda y cernido (Del Valle et. al., 1983). Con este fin se quebró el mezquite pasándolo por un molino de pernos solamente con el disco de la puerta girando. El producto resultante fue molido en el mismo molino con ambos discos girando, haciéndolo pasar una y cuatro veces. El material molido fue cernido por mallas +45 y +100, obteniéndose los porcentajes y los análisis proximales (AOAC, 1970) correspondientes.

Los resultados obtenidos se muestran en las Tablas 6 y 7. La Tabla 6 muestra que la proporción de finos (malla -100) aumentó ligeramente al aumentar el número de pasadas por el molino; también muestra que este incremento se debió a un decremento correspondiente en la fracción de malla +100. Por otro lado, la proporción de finos obtenida por este proceso se consideró baja.

La Tabla 7 muestra claramente que la concentración de proteínas aumentó y la concentración de fibra disminuyó, ambos al aumentar la

finura de la fracción.

Por otro lado la concentración de proteínas no fue afectada por el número de pasadas por el molino, pero para los finos la concentración de fibra sí disminuyó al aumentar el número de pasadas por el molino.

Se concluyó que, debido a los bajos rendimientos de finos obtenidos por moliendo directo de la vaina de mezquite, este proceso no se consideraba adecuado para obtener un concentrado proteínico de mezquite.

PROCESAMIENTO DE LA VAINA DEL MEZQUITE POR EXTRUSION

a) Mezquite solo.

Se intentó extruir la vaina del mezquite sola por un extrusor de marca Brady, después de haberla quebrado pasándola por el molino de pernos Alpine con el disco puerta girando. Sin embargo no fue posible hacer ésto, ya que el extrusor se "amarró" de manera que fue necesario desarmarlo para limpiarlo. Se cree que este problema fue debido al contenido excesivo de pana de la vaina.

b) Mezquite con soya.

Ya que fue imposible extruir el mezquite sólo, se intentó extruir la vaina del mezquite quebrada de la manera indicada anteriormente en combinación con soya en proporción de 1:1. En este caso se logró la extrusión con éxito (150°C, 60 seg.). El producto extruído fue molido una y cuatro veces en el molino de pernos Alpine y el producto molido resultante fue cernido en mallas +45 y +100. Se obtuvieron las proporciones y los análisis proximales (AOAC, 1970) de las diferentes fracciones.

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Los resultados obtenidos se muestran en las Tablas 8 y 9.
La Tabla 8 indica que aún utilizando este procedimiento no hubo suficiente producción de finos (malla -100), ya que el valor máximo, obtenido con cuatro pasadas por el molino, fue solamente de 66.5%. Los demás datos (proporción, contenido de proteínas, contenido de fibras, etc.) mostraron la misma variación con el número de pasadas por el molino que la que fue observada en el caso de la molienda directa de las vainas del mezquite solas. Como es de suponerse, los contenidos de proteínas de todas las fracciones fueron mayores que los valores correspondientes para el mezquite solo debido a la presencia de la soya, cuyo contenido protéico es apreciablemente mayor que el del mezquite.
Se concluyó que este proceso funciona, pero que la necesidad de añadir soya le restaría valor, ya que la meta es la obtención de un concentrado protéico de mezquite puro.

PROCESAMIENTO DE LA VAINA DEL MEZQUITE POR TOSTADO

Se estudió un proceso más, intentando obtener un concentrado proteínico con buen rendimiento de finos y buena recuperación de proteínas. El proceso estudiado a continuación fue el de tostado. Las condiciones de tostado fueron las siguientes: llama directa, 155°C, 20 min.. Nuevamente, el producto tostado fue pasado una y cuatro veces por el molino de pernos Alpine, obteniéndose las proporciones y los análisis bromatológicos (AOAC, 1970) de las diferentes fracciones. Los resultados obtenidos se presentan en las Tablas 10 y 11.
La Tabla 10 muestra que el proceso de tostado y molienda con 4 pasadas por el molino obtuvo un rendimiento muy alto de finos (malla -100): 76.4%. Este valor excedió considerablemente a los valores correspondientes obtenidos en los otros procesos estudiados.

La Table 11 muestra que el contenido de proteínas de los finos obtenidos por el proceso de tostado seguido por molienda, fue del orden del 18 al 19%.

Nuevamente las fracciones se comportaron de la misma manera ya vista en los casos anteriores en lo referente a la variación de rendimiento, contenido de proteínas, contenido de fibras, etc., con grado de finura (número de malla) y número de pasadas por el molino.

Se concluyó que el proceso de tostado, seguido por molienda y cernido sería el más adecuado para la obtención de un concentrado proteínico de mezquite, con buen rendimiento de finos y buena recuperación de proteínas en los mismos. De hecho, se calculó que para el proceso de tostado con cuatro moliendas y cernido, la recuperación de la proteína total en los finos fue casi del 70%.

RESUMEN DE TODOS LOS PROCESOS ESTUDIADOS Y ELECCION DEL MEJOR

Se han estudiado los siguientes procesos para concentrar las proteínas del mezquite y disminuir el contenido de fibra:

1) Concentrado proteínico por proceso químico.
2) Aislado proteínico por proceso químico.
3) Concentrado proteínico por molienda directa de la vaina de mezquite y cernido.
4) Concentrado proteínico por extrusión de la vaina de mezquite.
5) Concentrado proteínico por extrusión de la vaina de mezquite en combinación con soya en proporción de 1:1, seguido por molienda y cernido.
6) Tostado de la vaina del mezquite seguido por molienda y cernido.

Como se indicó anteriormente, el proceso que obtiene el mayor rendimiento de finos con la mayor recuperación de proteínas es el No. 6.

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DESARROLLO DE PRODUCTOS NUTRITIVOS UTILIZANDO HARINA DE MEZQUITE (CONCENTRADO PROTEINICO) POR EL PROCESO DE TOSTADO, COCCIONES Y CORNICO

Se desarrollaron dos productos utilizando el concentrado proteínico del mezquite:

a) Una base en polvo endulzada con sabor a canela para la preparación de horchata; y

b) Un mazapán de mezquite/cacahuate/soya

Las tablas 12 y 13 reportan datos nutricionales para los dos productos desarrollados. Cabe notar que ambos productos fueron elaborados en plantas industriales localizadas en el estado de Chihuahua.

Se efectuaron valuaciones organolépticas informales de los productos por el grupo de los investigadores y por el personal de ambas plantas. En ambos casos se encontró que la calidad organoléptica era muy buena y la aceptación muy alta. En los dos productos se consideró que el sabor del mezquite tostado mejoraba el producto.

Cabe notar que en el cálculo de las fórmulas de los ingredientes se tomaron en cuenta los contenidos de proteína, sacarosa y fibra del concentrado proteínico del mezquite. De esta manera este producto aportó proteína, sacarosa y fibra a los productos finales.

Las tablas 12 y 13 muestran que las porciones típicas de ambos productos suplirían aproximadamente 3 a 4 gramos de proteína y 110 y 160 calorías respectivamente. Así, ambos productos mejorarían la nutrición de proteínas-calorías de las personas que los consumieran. El alto contenido de sacarosa podría aparecer como una desventaja; sin embargo la dulzura es la que hace a ambos productos atractivos a todas las edades, especialmente a los niños.

Cabe notar que la horchata reconstituída (Tabla 13) contiene 1.4% de proteínas. Esto equivale al 40% del contenido protéico de la leche. La horchata sin embargo sería apreciablemente más barata y más atrac-

tiva que la leche, debido a su dulzura y sabor a canela y mezquite tostado. Esta bebida, entonces, representaría una forma barata y agradable de aportar proteínas y calorías a los grupos de bajos recursos económicos.

Una ventaja adicional de la utilización del concentrado proteínico de mezquite en la preparación de ambos productos sería su contenido de fibra. Además de aportar proteínas y calorías, los dos productos aportarían fibra dietética, tan importante y tan necesaria.

VALOR NUTRITIVO DE LAS FRACCIONES GRUESAS DE LA VAINA DE MEZQUITE PARA RUMIANTES

En los procesos estudiados para la elaboración del concentrado proteínico de mezquite por molienda directa y cernido, así como por tostado, molienda y cernido, además de obtener los finos o concentrado proteínico (malla -100) también se obtuvieron fracciones intermedias (malla +100) y gruesas (malla +45).

El producto utilizado para el consumo humano fueron finos (malla -100). Los productos intermedios y gruesos (malla +100 y +45 respectivamente), sin embargo, no tendrían utilidad para humanos. Consecuentemente, se estudió la posibilidad de aprovechar estos productos en formulaciones para rumiantes determinando su digestibilidad *in vitro* utilizando el método de Tilley y Terry (1963).

La Tabla 14 presenta los resultados obtenidos. Se puede notar aproximadamente del 30 al 57%. En general, se considera que un buen valor de digestibilidad para forrajes es del orden del 70 al 90% (Mugerwa y Gwebye, 1974). Por otro lado, se observa también que la digestibilidad aumentó al aumentar el número de malla, dando que las fracciones gruesas fueron menos digeribles que las de las fracciones intermedias.

Se concluyó que tanto las fracciones gruesas como las finas obtenidas por los procesos anteriormente descritos no serían extraordinariamente buenas como componentes de raciones para rumiantes. Por otro lado, sin embargo, los valores no son tan bajos como para excluir su uso para esta aplicación. En general, se piensa que con un precio adecuado ambos productos probablemente tendrían mercado como componentes de raciones para rumiantes.

RESUMEN Y CONCLUSIONES

Se ha encontrado que la proteína de la vaina de mezquite posee un valor nutritivo (P.E.R.) que es semejante al de las leguminosas comunes. Esta proteína se encuentra más concentrada en la almendra de la vaina. Sin embargo resultaría impráctico separar la vaina en sus diferentes fracciones por lo que la manera más recomendable de utilizar la vaina es en forma entera. Por otro lado, la proteína de la vaina del mezquite es mucho más soluble en el punto isoeléctrico y mucho menos soluble en los extremos de pH que la proteína de soya y otras leguminosas comunes.

Lo anterior elimina el método químico como medio para la preparación de concentrado y aislado proteínico, dejando los procesos mecánicos como medios para lograr una concentración de las proteínas y una disminución del contenido de fibra.

De los métodos mecánicos estudiados, el que obtuvo mejores resultados (mayor rendimiento de finos y mayor recuperación de proteínas en los finos) fue el de tostado, seguido por molienda (molino de pernos) y cernido. La fracción malla -100 se obtiene en este caso con un 76% de rendimiento y aproximadamente 70% de recuperación de la proteína total de la vaina entera. Este es el proceso recomendable para su industrialización. Se han preparado dos productos

nutritivos y de bajo costo utilizando esta fracción.

Por otro lado los productos intermedios (malla +100) y grueso (malla +45) obtenidos por el proceso anterior podían tener aplicación como componentes de raciones de alimentos balanceados para rumiantes con un precio adecuado, dada su digestibilidad *in vitro* no muy alta.

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TABLA 1

COMPOSICION DE LA VAINA DE MESQUITE

Componente	Porcentaje[a]
Pericarpio	58.0
Cascarilla	28.1
Semillas	13.9

[a]Tamaño de la muestra, 100 gramos; variabilidad ± 3%

TABLA 2

ANALISIS PROXIMAL, COMPONENTES FIBROSOS Y CONTENIDO DE AZUCAR DE LA VAINA DE MESQUITE Y SUS FRACCIONES, BASE SECA

Componente[a]	Vaina	Pericarpio	Cascarilla	Semillas
Humedad	9.0	10.1	5.4	8.3
Materia seca	91.0	89.9	94.6	91.7
Proteina cruda	14.7	10.5	11.3	37.2
Grasa	3.2	2.7	1.8	6.3
Cenizas	5.5	6.4	4.2	7.6
Fibra cruda	21.3	20.4	31.6	8.5
Carbohidratos, por diferencia	46.3	49.9	45.7	32.1
Fibra ácido detergente	34.9	27.8	37.5	13.6
Lignina	8.3	8.2	8.3	4.2
Celulosa	26.6	19.6	29.2	9.4
Azucares reductores[b]	1.7	6.5	-	-
Sacarosa[b]	21.3	21.3	-	-

a Tamaño de la muestra para todas las determinaciones exepto azucares reductores: 1.5-2.0 gr.;variabilidad para las mismas determinaciones, ± 2%.

b Tamaño de la muestra para determinaciones de azucares: 5 gr. variabilidad, ± 6%.

TABLA 3

COMPOSICION DE LOS AMINOACIDOS DE LA PROTEINA DE MESQUITE

Aminoácido	Mesquite[a,b]	FAO/WHO Niños	Recomendación Adultos
Ac. Aspártico	11.20	-	-
Treonina	3.33	4.0	1.4
Serina	5.32	-	-
Ac. Glutámico	15.10	-	-
Prolina	7.43	-	-
Glicina	4.62	-	-
Alanina	4.21	-	-
Cisteina	1.54	-	-
Valina	4.99	5.0	2.0
Metionina	1.26	-	-
Isoleucina	3.77	4.0	2.0
Leucina	7.48	7.0	2.8
Tirosina	2.81	-	-
Fenilalanina	3.95	-	-
Histidina	2.44	1.4	-
Lisina	5.01	5.5	2.4
Arginina	7.37	-	-

[a] Contenido de aminoácido expresado en gramos por 16 gr. de nitrogeno.

[b] Tamaño de la muestra, 2 gr.; variabilidad ± 2%

TABLA 4

CALIDAD NUTRICIONAL DE LA PROTEINA DE MESQUITE

Proteina	P.E.R.[a,b]	P.E.R.[c] Corregido	N.P.U.[d]
Mesquite entero	1.48±0.19	1.4	39.8±3.8
Caseina	2.76±0.23	2.5	56.7±5.3

a Resultados reportados con su desviación estandar.

b P.E.R. razón de eficiencia proteica que es igual al peso ganado dividido por el peso de proteina consumida (Osborn et. al., 1919).

c P.E.R. corregido ajustado al P.E.R. de la caseina de 2.5

d N.P.U. Utilización Neta de la Proteina que es igual al nitrogeno retenido dividido entre el nitrogeno ingerido según el método de Bender y Miller (1953).

TABLA 5

PREPARACION DEL CONCENTRADO PROTEINICO Y AISLADO DE LA VAINA DE MESQUITE

Parametro[a]	Concentrado	Aislado
Rendimiento con respecto a la vaina de mesquite, base seca[b]	48%	10%
Contenido de proteina base seca	27%	38%
Rendimiento con respecto a la proteina de la vaina de mesquite[c] base seca	88%	26%

[a] Tamaño de la muestra, 50 gr.; variabilidad ± 10%

[b] Rendimiento igual al peso del concentrado seco o al aislado dividido por el peso de las vainas secas, multiplicado por 100.

[c] Rendimiento igual al contenido proteico en gramos en el concentrado o aislado dividido por el contenido de proteina de la vaina en gramos, multiplicado por 100.

TABLA 6

PORCENTAJE DEL PESO TOTAL EN LAS FRACCIONES CERNIDAS

Producto	Una Pasada[a]			Cuatro Pasadas[a]		
	+45	+100	-100	+45	+100	-100
Vaina Entera	49.2	20.7	36.4	45.6	8.6	45.8

[a] A través del molino Alpine

TABLA 7

ANALISIS PROXIMAL DE LAS DIFERENTES FRACCIONES DE LA VAINA DE MESQUITE PASADAS UNA Y CUATRO VECES POR EL MOLINO ALPINE CON AMBOS DISCOS ROTANDO

Componente en porcentaje	Una Pasada			Cuatro Pasadas		
	+45	+100	-100	+45	+100	-100
Humedad	6.02	6.93	6.90	4.27	5.98	6.84
Proteina	9.93	14.41	23.68	8.06	10.69	17.24
Extracto Etereo	4.12	5.57	7.38	5.80	5.36	5.34
Fibra acido detergente	47.10	36.20	26.81	52.77	23.14	13.19
Celulosa	37.82	30.37	20.88	44.48	19.55	10.34
Lignina	9.10	6.10	5.96	8.39	3.67	2.67

TABLA 8

PORCENTAJE DEL PESO TOTAL EN LAS FRACCIONES CERNIDAS

Producto	Una Pasada[a]			Cuatro Pasadas[a]		
	+45	+100	-100	+45	+100	-100
Mesquite/Soya[b] 1:1 Extruido	23.5	15.2	61.3	20.5	12.9	66.5

[a] A través del molino Alpine

[b] Extrusor Brady, 60 seg. a 150 °C

TABLA 9

ANALISIS PROXIMAL DE LAS DIFERENTES FRACCIONES DE MESQUITE/SOYA EXTRUIDO (1:1) PASADAS UNA Y CUATRO VECES POR EL MOLINO ALPINE CON AMBOS DISCOS ROTANDO

Componente en porcentaje	Una Pasada			Cuatro Pasadas		
	+45	+100	-100	+45	+100	-100
Humedad	4.06	4.48	4.71	5.80	5.40	5.39
Proteina	20.38	14.62	32.13	24.66	23.43	29.25
Extracto Etereo	18.37	6.10	5.88	16.10	6.71	7.20
Fibra ácido detergente	23.78	27.28	8.22	16.29	18.66	10.40
Celulosa	19.48	22.94	6.48	13.34	14.14	7.76
Lignina	4.08	5.00	1.51	2.94	4.41	2.55

TABLA 10

PORCENTAJE DEL PESO TOTAL EN LAS FRACCIONES CERNIDAS

Producto	Una Pasada[a]			Cuatro Pasadas[a]		
	+45	+100	-100	+45	+100	-100
Tostado[b]	27.1	7.9	65.0	17.8	5.8	76.4

[a] A través del molino Alpine

[b] Usando un tostador rotatorio, 20 min. a 155 °C

TABLA 11

ANALISIS PROXIMAL DE LAS DIFERENTES FRACCIONES DE MESQUITE TOSTADO PASADAS UNA Y CUATRO VECES POR EL MOLINO ALPINE CON AMBOS DISCOS ROTANDO

Componente en porcentaje	Una Pasada			Cuatro Pasadas		
	+45	+100	-100	+45	+100	-100
Humedad	5.35	5.33	6.13	6.65	5.18	5.52
Proteina	7.68	6.32	19.13	11.35	7.55	18.12
Extracto Etereo	3.01	3.60	5.85	6.89	6.78	5.99
Fibra ácido detergente	53.20	38.45	17.33	49.19	50.72	20.13
Celulosa	42.39	30.04	13.19	39.51	41.77	16.30
Lignina	10.83	8.29	4.09	9.66	8.20	3.81

TABLA 12

COMPOSICION PROXIMAL DE UNA BASE EN POLVO ENDULZADA CON SABOR A CANELA (HORCHATA) Y OTRA INFORMACION NUTRICIONAL

Componente en porcentaje	Base en Polvo
Proteina	8.6
Grasa	4.7
Sacarosa	70.9
Otros Carbohidratos	8.4
Fibra	2.0
Gramos de nutriente por vaso de bebida	
Proteina	3.5
Grasa	1.9
Sacarosa	27.5
Otros Carbohidratos	4.3
Fibra	0.8
Calorias	158

TABLA 13

ANALISIS PROXIMAL Y OTRA INFORMACION NUTRICIONAL DE UN MAZAPAN DE MESQUITE/CACAHUATE/SOYA

Componente	Porcentaje
Proteina	11
Grasa	16
Sacarosa	60
Otros Carbohidratos	7
Fibra	2
Peso por unidad, gramos	25
Gramos de proteina por unidad	3
Gramos de grasa por unidad	4
Gramos de sacarosa por unidad	15
Gramos de otros carbohidratos por unidad	2
Gramos de fibra por unidad	0.5
Total de calorias por unidad	108

TABLA 14

DIGESTIBILIDAD *in vitro* DE LAS FRACCIONES INTERMEDIA Y GRUESA DE LA VAINA DE MESQUITE CRUDA Y TOSTADA, MOLIDA Y CERNIDA

Muestra	No. de Malla	Materia Seca	Materia Orgánica
Molido Diracto y Cernido	+45	44.08	43.56
	+100	55.69	52.77
Tostado Molido y Cernido	+45	25.96	27.71
	+100	39.45	38.87

Preparation of a Mesquite (*Prosopis* spp.) Pod Enhanced Protein Reduced Fiber Fraction

F. R. DEL VALLE, E. MARCO, R. BECKER, and R. M. SAUNDERS

ABSTRACT

Raw, extruded (alone and a 50/50 blend with soybeans) or toasted mesquite (*Prosopis* spp.) pods were passed 1 and 4 times through an Alpine pin mill, and the resulting ground products separated into different sieve fractions. Protein concentration and recovery were maximum, and fiber content minimum, in the fines. Maximum protein concentration and recovery were obtained in both extrusion runs; of the remaining two runs, toasted pods gave higher protein recovery, but lower protein concentration in the fines, than raw pods.

INTRODUCTION

MESQUITE (*Prosopis* spp.) is a leguminous plant which grows wild in many desert and semi-desert areas of the world (Allen and Allen, 1981). It bears fruit in the form of pods, which are known to contain approximately 13% protein, 21% mono- and disaccharides (mostly sucrose), and also 19% crude fiber (Del Valle et al., 1983). Whole pod protein was limiting in sulfur amino acids and threonine, and borderline in lysine with respect to the FAO/WHO (1973) pattern for children (Becker, 1984), and possessed a corrected PER of 1.4 (Del Valle et al., 1983), which is approximately equal to that for common legumes (FAO, 1970). Mesquite pods were almost devoid of trypsin inhibitor (1.4 TIU/mg; Del Valle et al., 1983).

Since mesquite trees grow abundantly in many developing countries in Asia, Africa, and Latin America, their pods could possibly become a good, low-cost food for inhabitants of these countries. However, some inexpensive means for concentrating protein and decreasing fiber content of pods would have to be found.

The purpose of this work was to develop a low-cost process for producing a mesquite fraction containing higher protein and lower fiber content than whole pods.

MATERIALS & METHODS

MESQUITE (*Prosopis* spp.) pods were collected in the area within and adjoining Chihuahua City, Mexico, and stored in polyethylene bags in a shaded area at room temperature (25–30°C) until used.

A protein-rich low-fiber mesquite fraction was prepared by grinding pods, pretreated as described below, followed by separation of the ground materials into sieve fractions U.S. Std. Mesh Nos. +45 (coarse); +100 (intermediate); and −100 (fines). Yields of the different fractions were determined by screen analyses of the ground materials, utilizing screens of the same mesh numbers (45 and 100), according to AOAC (1970) procedures. Protein (AOAC, 1970) and acid detergent fiber (Goering and Van Soest, 1975) contents of whole pods were determined. All determinations were carried out in triplicate.

Prior to grinding, the pods were treated as follows: (1) Raw pods (no treatment); (2) pods passed once through a Brady low-cost extruder (150°C, 60 sec; manufactured by the Brady Extruder Corp., 23535 Telo Ave., Torrance, CA 90505); (3) pods toasted at 155°C for 20 min (toaster described below); and (4) a blend of mesquite pods and cracked dehulled soybeans (50:50), passed one time through the Brady extruder (150°C, 60 sec).

The toaster consisted of a perforated rotating drum equipped with two rows of equally spaced (2 in. or 5.1 cm) butane gas burners placed 5.1 cm from the drum surface. Each row contained 14 burners and the distance between rows was 5.1 cm. Burner diameter was 0.9 cm (3/8 in). Perforations on the surface of the drum were uniformly spaced on a 2.5 cm (1 in) square pattern; each perforation was 0.5 cm (3/16 in) in diam. The drum was 40.6 cm (16 in.) in diam and 69.9 cm (27.5 in) long; its rotation speed was 26 rpm. Temperature inside the drum, measured with a thermocouple placed in the middle of the drum axis, was adjusted to the desired value by varying gas flow rate into the burners. Preliminary tests indicated that 10 kg mesquite pods loaded into the drum permitted good circulation of solids, and, hence, good heat transfer from hot gases to solids.

Pods were ground by passing 1 or 4 times through an Alpine pin mill (Model A400Cw, Alpine American Corporation, 5 Michigan Drive, Natick, MA 01760).

To determine protein yields, distribution of total protein among the different sieve fractions was calcu[illegible] based upon weight yield of a given fraction (from screen anal[illegible]) and protein concentration in that fraction.

Data were statistically analy[illegible]d in two ways: (1) the significance of the overall effect of independent variables on dependent variables was determined by application of Analysis of Variance techniques (Spiegel, 1975); and (2) individual mean values were compared by means of t-tests (Spiegel, 1975).

The anticipated cost of whole raw mesquite pods as well as of the protein-enriched product considered to be the optimum were calculated. Costs of other common foods available in Mexico (e.g., corn, tortillas, beans, etc.) were obtained and expressed as relative costs with respect to costs of the two mesquite products previously mentioned.

RESULTS & DISCUSSION

THE PROTEIN and acid detergent fiber contents of whole mesquite pods were 14.2% and 34.4%, respectively. These results are in agreement with those obtained by Del Valle et al. (1983).

Results of the screen analyses performed on the different pretreated and ground samples, as well as results of analysis of variance calculation performed on the same data, are reported in Table 1. Yields of the different mesh fractions were significantly different from each other ($p < 0.01$). Type of process significantly affected yield of fines ($p < 0.05$), with the toasted and extruded samples producing the maximum amount, and the untreated sample producing the minimum amount of this fraction. Passing a given sample four times through the mill significantly increased ($p < 0.05$) its yield of fines. Considerable difficulty was encountered in passing 100% mesquite through the Brady extruder; due, possibly, to the gum and sugar contents of the pods, the extruder tended to "plug up". On the other hand, no such difficulty was experienced with the mesquite/soybean blend.

Application of t-tests to increase in yield of fines obtained between 1 and 4 passes through the mill revealed that the sample which exhibited the maximum increase was the extruded 100% product (21.5%, $p < 0.01$), followed by the toasted and raw samples, for which increases in yield were 11.4% ($p < 0.01$) and 9.4% ($p < 0.01$), respectively. The

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Table 1—Screen analyses of mesquite products after grinding in an alpine pin mill

Type of process	Percent of total weight in sieve fraction[a,b]					
	One pass through mill			Four passes through mill		
	+45	+100	−100	+45	+100	−100
Untreated (Raw)	42.9	20.7	36.4	45.6	8.6	45.8
Extruded[c]	46.3	12.8	51.7	20.8	6.6	73.2
Toasted[d]	27.1	7.9	65.0	17.8	5.8	76.4
Extruded 50/50 mesquite/soybean blend[c]	23.5	15.2	61.3	20.5	12.9	66.5

Results of analysis of variance: significant main effects

Type of process[e]
Number of passes through mill[e]
Mesh size[f]

[a] U.S. Standard Mesh Number.
[b] Results in this work reported as means of three determinations.
[c] Brady extruder, one pass, 60 sec at 150°C.
[d] Rotary drum toaster, 20 min at 155°C.
[e] Significant at $p < 0.05$ level.
[f] Significant at $p < 0.01$ level.

minimum increase in yield of fines occurred with the extruded blend (5.2%), which was also significant ($p < 0.01$).

Protein and acid detergent fiber contents of the sieve fractions for the different processes are shown in Tables 2 and 3, respectively. For both parameters, type of process and mesh number were significant at the $p < 0.01$ level, while number of passes through the mill was not significant. Protein was most concentrated in the fines, with average concentrations for the 100% mesquite samples being about 25%, and that of the mesquite/soybean blend exceeding 32%. Acid detergent fiber, on the other hand, was minimum in the fines, with values varying from approximately 13% to 17% in most samples. In the case of the extruded and toasted products, protein was lowest in the +100 mesh fraction. The toasted sample exhibited the lowest protein content of all 100% mesquite products, while blends of mesquite with soybeans exhibited the highest protein and lowest fiber of all samples, as expected. Concerning the latter (mesquite/soybean blends), Table 3 shows that the sieve fraction containing the maximum amount of fiber was the intermediate, or + 100 mesh, material.

Percent distribution of total protein among the different sieve fractions, as well as corresponding results of analysis of variance calculations are shown in Table 4. Whereas type of process was not significant, number of passes through the mill and mesh number were both significant at the $p < 0.10$ and $p < 0.01$ levels, respectively. The maximum amount of protein was always recovered in the fines, and protein recovery in this fraction was significantly increased by increasing the number of passes through the mill ($p < 0.10$). The highest recovery in the fines after 1 and 4 passes through the mill corresponded to the extruded 50/50 mesquite/soybean blend (73.8% and 70.7%, respectively) and the extruded 100% mesquite product (47.0% and 80.4%, respectively). The highest increases in recovery, resulting from increasing the number of passes through the mill from 1 to 4, were exhibited by the toasted and 100% mesquite extruded products (36.0% and 33.4%, respectively, $p < 0.01$), whereas raw mesquite exhibited only a small, but significant, increase under the same conditions (7.6%, $p < 0.01$). Protein recovery in the fines was not significantly ($p > 0.10$) affected in the extruded 50/50 mesquite/soybean blend by increasing the number of passes through the mill from 1 to 4.

Extrusion of 100% mesquite gave maximum protein concentration and protein recovery in the fines. As noted previously, however, considerable difficulty was experienced in extruding 100% mesquite, so this process would probably not be a practical option. Of the remaining two processes utilizing 100% mesquite, raw pods gave higher protein concentration, but lower protein recovery, in the fines than toasted pods. The process utilizing extruded 50/50 mesquite/soybeans gave excellent protein concentration and protein recovery in the fines. This process would be ideal for applications involving extension or fortification of mesquite with soybeans.

It might be noted that more sophisticated procedures for utilization of mesquite pods than those described in this work have been developed; these include separation of seeds and other fractions from whole pods (Mayer, 1984). Due to their high cost, however, these procedures would probably not be suitable for use in developing countries.

SUMMARY & CONCLUSIONS

IF MESQUITE PODS are ground, either raw or after different pretreatments, and the ground material is separated into +45, +100 and −100 mesh fractions, protein is concentrated and fiber reduced in the fines (−100 mesh) with respect to the other fractions. Although yield of fines and protein recovery in the fines were appreciably increased, neither protein nor

Table 2—Protein content of mesquite products after grinding in an alpine pin mill and screening to different mesh fractions

Type of process	Percent protein in sieve fraction[a,b]					
	One pass through mill			Four passes through mill		
	+45	+100	−100	+45	+100	−100
Untreated (Raw)	9.9	14.4	23.7	8.1	10.7	17.2
Extruded[c]	13.6	8.0	25.0	17.2	13.1	24.9
Toasted[d]	7.7	6.3	19.1	11.4	7.6	18.1
Extruded 50/50 mesquite/soybean blend[c]	20.4	14.6	32.1	24.7	23.4	29.3

Results of analysis of variance: significant main effects[e]

Type of process[f]
Mesh size[f]

[a] U.S. Standard Mesh Number.
[b] Results on this work reported as means of three determinations.
[c] Brady extruder, one pass, 60 sec at 150°C.
[d] Rotary drum toaster, 20 min at 155°C.
[e] Number of passes through the mill not significant at $p < 0.10$ level.
[f] Significant at $p < 0.01$ level.

Table 3—Acid detergent fiber content of mesquite products after grinding in an alpine pin mill and screening to different mesh fractions

Type of process	Percent acid detergent fiber in sieve fraction[a,b]					
	One pass through mill			Four passes through mill		
	+45	+100	−100	+45	+100	−100
Untreated (Raw)	47.1	36.2	26.8	52.8	23.1	13.2
Extruded[c]	36.9	24.0	12.8	31.6	28.9	12.7
Toasted[d]	53.2	38.5	17.3	49.2	50.7	20.1
Extruded 50/50 mesquite/soybean blend[c]	23.8	27.3	8.2	16.3	18.7	10.4

Results of analysis of variance, significant main effects[e]

Type of process[f]
Mesh size[f]

[a] U.S. Standard Mesh Number.
[b] Results in this work reported as means of three determinations.
[c] Brady extruder, one pass, 60 sec at 150°C.
[d] Rotary drum toaster, 20 min at 155°C.
[e] Number of passes through mill not significant at $p < 0.10$ level.
[f] Significant at $p < 0.01$ level.

Table 4—Distribution of total protein in sieve fractions for mesquite products, after grinding in alpine pin mill and screening to different mesh fractions

Type of process	Percent of total protein in sieve fraction[a,b]					
	One pass through mill			Four passes through mill		
	+45	+100	−100	+45	+100	−100
Untreated (Raw)	26.8	18.2	54.4	30.8	7.2	62.0
Extruded[c]	18.0	34.9	47.0	15.7	3.9	80.4
Toasted[d]	54.4	13.1	32.5	9.9	21.5	68.5
Extruded 50/50 mesquite/soybean blend[d]	16.9	8.3	73.8	18.4	11.0	70.7

Results of analysis of variance: significant main effects[e]

Number of passes through mill[f]
Mesh number[g]

[a] U.S. Standard Mesh Number.
[b] Results in this work reported as means of three determinations.
[c] Brady extruder, one pass, 60 sec at 150°C.
[d] Rotary drum toaster, 20 min at 155°C.
[e] Type of process not significant — $p > 0.10$.
[f] Significant at $p < 0.10$ level.
[g] Significant at $p < 0.01$ level.

fiber in the fines were appreciably changed by increasing the number of passes through the mill from 1 to 4.

Of the different pretreatments studied, extrusion, either of whole pods or of pods in a 50/50 blend with soybeans, resulted in maximum protein concentration and recovery in the fines; serious difficulties, however, were encountered when extruding 100% pods. Toasted pods gave greater protein recovery, but lower protein concentration in the fines than did raw pods.

The process most suitable for industrial exploitation appears to be that which utilizes 100% raw pods passed one time through the mill, for the following reasons: (1) the fines contain high protein and low fiber, approximately 24% and 27%, respectively; (2) a reasonably good protein recovery in the fines is obtained, approximately 55% of the total protein found in the original whole pods; (3) processing costs would be minimum, since no pretreatment, and only one pass through the mill would be required; (4) raw material cost would be minimum, since blending with soybeans would not be required; (5) since the finished product (the fines or −100 mesh fraction) would only contain mesquite, and not soybeans, it would reflect maximum flexibility in applications; and (6) the process would not involve extrusion.

Given the abundance and low cost of mesquite pods and the simplicity of the recommended process, there appear to be excellent possibilities for the utilization of this previously underexploited raw material in developing countries.

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7/8/87

EVALUATION OF AN INDUSTRIAL PROCESS FOR PRODUCING MESQUITE POD (*PROSOPIS* SPECIES) FLOUR.

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ABSTRACT

Mesquite pods (Prosopis spp) from two species of mesquite trees were industrially processed by toasting, grinding and screening to produce three fractions (large, intermediate and fine). The fine (-100 mesh) flour was enriched in protein and reduced in fiber compared to the other fractions and the starting material. Of the processing conditions studied, toasting at 125°C for 40 minutes was found to result in a maximum yield of fines and maximum protein availability (measured by red flour beetle larva growth). The final product was a fine (-100 mesh) cream colored low cost flour with many potential applications in the food industry.

INTRODUCTION

Efforts aimed at obtaining enhanced protein, reduced fiber fractions from mesquite (Prosopis spp) pods have been reported in previous papers (Del Valle et al., 1986, 1987). The optimum process found (Del Valle et al., 1987) involved grinding toasted mesquite pods in an Alpine mill and screening the resulting flour through 45 and 100 mesh screens. The fraction passing through the 100 mesh screen (-100 mesh) was enhanced in protein and reduced in fiber with respect to whole pods as well as the other fractions. Screening of pod fractions in both of the above publications, however, was carried out utilizing laboratory screens. Also, only one type of mesquite, that obtained in the area adjoining Chihuahua City, Mexico, was utilized.

The studies reported here were designed to optimize the processing conditions and equipment to produce the maximum quantity of the protein enriched, reduced fiber fraction of optimal protein quality. In addition, processing characteristics of two different species of mesquite pods were compared; those obtained from the area near Chihuahua City, Mexico, and those obtained from the area near Irapuato, Guanajuato, Mexico. Species from the Irapuato area were investigated because this area produces large amounts of pods which could serve as raw material for future industrial exploitation of mesquite.

MATERIALS AND METHODS

Pod collections in the Chihuahua City area were from Prosopis glandulosa trees and in the Irapuato area from P. juliflora. The whole mesquite pods of both species were processed by toasting followed by milling in an *Alpine Pin Mill operated with both discs rotating. The milled material was sieved through an industrial screen equipped with U.S. Standard 45 and 100 mesh sieves so that three fractions were obtained: oversized (retained on the 45 mesh screen); intermediate (passing through the 45 mesh screen but retained on the 100 mesh screen); and fines (passing through the 100 mesh screen).

The toaster and pin mill used in this work have been described elsewhere (Del Valle et al., 1986). The industrial screen was a grain cleaner (scalper) (Harper and Del Valle, 1987) to which the 45 and 100 mesh screens were adapted. Toasting temperature-time conditions studied were: 100°C for 40 or 80 minutes, 125°C for 20 or 40 minutes, and 150°C for 10 minutes.

In each industrial screening run, total weight of material fed to the screen and weights of the three resulting fractions were determined. The fractions were analyzed for particle size by laboratory screen analyses (+45, +100, -100 mesh) and for proximate chemical analyses (moisture, ash, fat, protein, and acid detergent fiber) using AOAC (1970) methods. All determinations were run in triplicate and reported as means. The fines fractions resulting from the industrial screening runs were analyzed for protein quality utilizing red flour beetle (Tribolium castaneum) larvae according to the method of Vohra et al. (1978).

All results were statistically analyzed utilizing Analysis of Varience and Student's t-Test techniques (Spiegel, 1975).

*Reference to a company and/or product named by the Department is only for purposes of information and does not imply approval or recommendation of the product to the exclusion of others which may also be suitable.

RESULTS AND DISCUSSION

The proximate chemical compositions of the pods from Chihuahua and Irapuato are shown in Table 1. The Irapuato pods contained significantly more ash and acid detergent fiber ($p<0.05$, t test) than Chihuahua pods. Fat and protein contents were not significantly different (t test). The pod moisture content is affected by ambient humidities, so these differences are not critical. These results are consistent with analyses of pods from similar Prosopis species (Becker and Grosjean, 1980; Meyer et al, 1986).

The yields and compositions of the different process fractions are shown in Tables 2 and 3. The higher toasting temperatures tested resulted in generally higher yields of -100 mesh material, the desired product, and correspondingly lower yields of +45 and +100 mesh material. The material lost during processing was primarily from the +45 and +100 mesh fractions. Minor equipment modifications are expected to reduce this amount in future runs.

Laboratory screen analyses of the industrially produced fraction demonstrated that the process successfully produced a fine fraction with only small amounts of larger pieces. The +45 and +100 mesh fractions contained some -100 mesh material which could probably be recovered. Toasting at 125°C for 40 minutes or 150°C for 10 minutes gave both the highest yield of -100 mesh material and fewer large (+45 and +100) comtaminants in the fine fraction.

Toasting at 125°C for 40 minutes resulted in fines with higher levels of protein, ash and fat and lower ADF. Lower toasting temperatures (100°C for 40 or 80 minutes) resulted in higher protein levels but reduced yields.

Comparison of the pods from Chihuahua and Irapuato showed little difference in yield (Tables 2 and 3). Processing the Irapuato pods resulted in less net loss, due to improvements and experience with the process.

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As with the pods from Chihuahua, toasting the pods from Irapuato at lower temperatures resulted in higher protein levels but lower yields. Toasting at 150°C for 10 minutes gave high protein and high yield but created off flavors.

Growth of red flour beetle larvae indicated that toasting at 125°C for 40 minutes optimized protein availability (Table 4). This assay has been found to be a good measure of protein quality, especially when similar products are being compared (Vohra, et al. 1978).

Organoleptic evaluation by a taste panel (data not shown) indicated a strong panel preference for the sample toasted at 125°C for 40 minutes. Because of the agreement between the panel and the insect assay, the preferred toasting conditions were judged to be 125°C for 40 minutes.

The above observations support the following conclusions: Prosopis species pods from different sources and of different varieties can be successfully processed on an industrial scale by toasting at 125°C for 40 minutes, pin milling with both discs rotating, and sieving through 45 and 100 mesh screens. Three fractions are produced; the fibrous material is concentrated in the +45 and +100 mesh fractions; the fine (-100 mesh) fraction is high in protein and minerals, contains reduced amounts of fiber, has optimum protein availability, and is preferred by a taste panel. This process appears to be highly economical and produces a flour with many possible applications in the food industry.

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Table 1: Proximate chemical analyses of whole Chihuahua and Irapuato mesquite pods.

Proximate Analyses, %	Chihuahua Mesquite Pods	Irapuato Mesquite Pods
Moisture*	0.79	4.12
Ash**	3.0	4.09
Fat***	1.63	1.84
Protein*** (N x 6.25)	11.33	10.76
Acid Detergent Fiber**	28.30	30.95

*Differences between the two mesquite types significant at $P<0.01$ level (t test).

**Differences between the two mesquite types significant at $P<0.05$ level (t test)

***No significant differences between the two types of mesquite (t test).

Table 2. Characteristics of fractions derived from pods harvested near Chihuahua City, Mexico

Roasting Conditions	Yield +45	Yield +100	Yield -100	Net Loss	Screen Analyses[a] +45	Screen Analyses[a] +100	Screen Analyses[a] -100	Proximate Composition (%) H_2O	Protein[b]	Ash	Fat	ADF[c]
100°C/40 min.	23.5	-	-	7.9	92.5	0.4	6.7	2.9	9.1	4.1	2.1	49.1
		24.1	-		59.7	36.1	3.9	3.3	9.5	3.9	2.4	37.3
	-	-	45.0		2.0	7.2	90.7	4.3	15.2	4.3	4.0	23.2
100°C/80 min.	42.0	-	-	6.7	90.9	1.5	7.2	3.5	9.6	4.1	2.8	43.6
	-	12.3	-		40.4	54.5	4.8	3.9	9.8	3.5	3.0	36.7
	-	-	39.0		3.7	9.0	87.2	3.5	15.6	4.0	4.3	21.2
125°C/20 min	19.0	-	-	17.4	57.2	2.0	38.7	1.5	9.6	4.0	2.6	44.4
	-	13.6	-		54.3	29.5	15.4	2.7	7.4	3.7	2.6	47.2
	-	-	50.0		2.0	6.7	90.3	3.1	14.5	4.0	3.4	29.2
125°C/40 min.	19.4	-	-	7.3	69.7	1.7	27.6	3.0	10.4	3.7	2.4	48.9
	-	19.4	-		57.9	29.1	12.6	3.7	9.2	3.5	3.9	48.9
	-	-	53.9		0.9	3.2	95.7	3.8	19.1	4.4	6.3	21.0
150°C/10 min.	16.1	-	-	16.2	67.7	1.9	29.7	3.8	11.9	3.8	3.9	46.2
	-	14.0	-		79.0	9.8	11.0	2.6	13.6	4.3	3.8	33.0
	-	-	53.7		3.0	4.1	93.3	6.0	13.8	3.6	4.6	24.9

a. U.S. Standard Mesh, Laboratory Analyses

b. N X 6.25

c. Acid Detergent Fiber

Table 3. Characteristics of fractions derived from pods harvested near Irapuato, Mexico

Toasting Conditions	Yield +45	Yield +100	Yield -100	Net Loss	Screen Analyses[a] +45	Screen Analyses[a] +100	Screen Analyses[a] -100	Proximate Composition (%) H_2O	Protein[b]	Ash	Fat	ADF[c]
100°C/40 min.	18.7	-	-	3.3	95.1	0.2	4.7	2.6	6.2	2.0	1.5	50.4
	-	31.6	-		62.6	35.6	1.8	2.8	8.7	3.3	1.5	33.5
	-	-	46.9		10.1	22.9	67.3	3.6	15.2	4.3	2.4	23.6
100°C/80 min.	26.2	-	-	10.4	89.5	1.4	9.1	3.3	7.7	2.7	1.5	51.8
	-	32.4	-		48.5	50.6	1.2	4.0	8.3	3.0	1.8	39.0
	-	-	31.8		6.6	28.0	66.1	4.8	14.0	4.0	2.9	25.5
125°C/20 min.	12.5	-	-	6.2	86.7	0.2	13.1	1.7	7.4	2.0	0.8	54.0
	-	31.3	-		5o.5	30.3	11.2	3.1	8.0	3.5	1.9	40.5
	-	-	50.0		2.3	6.3	91.2	3.3	10.7	4.0	2.6	24.2
125°C/40 min.	12.9	-	-	2.9	88.7	0.4	10.9	2.0	6.5	2.2	0.9	55.6
	-	29.6	-		68.6	19.7	11.7	3.4	7.1	3.1	1.9	46.2
	-	-	55.1		4.1	7.3	88.6	3.6	11.6	4.3	2.4	28.4
150°C/10 min.	8.8	-	-	8.8	90.3	0.3	9.4	2.8	5.9	2.3	1.6	57.4
	-	24.0	-		71.7	14.2	14.1	3.9	12.4	3.5	2.9	35..9
	-	-	58.4		4.9	7.1	88.0	2.9	14.4	1.9	1.4	20.3

a. U.S. Standard Mesh, Laboratory Analyses

b. N X 6.25

c. Acid Detergent Fiber

Table 4. Protein quality of different Chihuahua mesquite samples, determined by weight gain of Red Flour Beetle (*Tribolium castaneum*) larvae

Toasting Conditions	Weight Gain Per Larva, mg[b,c]	Mean Weight Gain Per Larva ± Std. Deviation
CONTROL SAMPLE, Whole wheat flour[a]	2.90 3.05 2.93	2.96 ± 0.6
100°C/40 min*	1.21 1.21 1.01	1.18 ± 0.12
100°C/80 min.*	1.24 1.24 1.25	1.24 ± 0.01
125°C/20 min.**	1.34 1.25 1.18	1.24 ± 0.05
125°C/40 min.**	1.18 1.58 1.67	1.71 ± 0.13
150°C/10 min.***	1.12 0.90 0.86	0.97 ± 0.11
150°C/20 min.***	1.38 1.19 1.36	1.31 ± 0.09

[a]Control sample according to method of Vohra et al. (1978).

[b]Red flour beetle (*Tribolium castaneum*), according to method of Vohra et al. (1978).

[c]F-value between type of process (5/12 degrees of freedom) = 14.99, significant, $p<0.01$ level.

*Difference in weight gain due to change in toasting time at 100°C not significant (t test).

**Difference in weight gain due to change in toasting time at 125°C significant at $p<0.05$ level (t test).

***Difference in weight gain due to change in toasting time at 150°C significant at $p<0.01$ level (t test).

APPENDIX II: CHILE

UNITED STATES DEPARTMENT OF AGRICULTURE

RESEARCH AGREEMENT

TYPE OF RESEARCH AGREEMENT: COOPERATIVE AGREEMENT - SPECIFIC

AGENCY (Name and address)

AGRICULTURAL RESEARCH SERVICE
PACIFIC BASIN AREA
800 Buchanan St.
Albany, CA 94710

AGREEMENT NO.: 58-91H2-4-00005

TYPE OF ACTION: New

PERIOD OF AGREEMENT: 5-1-84 thru 5-1-87

FEDERAL OBLIGATION: $ 35,300

CHANGE IN FEDERAL OBLIGATION: ☐ + ☐ − $

CRIS NO.: 5390-20522-026A

AUTHORITY: 7 USC 3318, 41 USC 505

PERFORMING ORGANIZATION (Name and address)

INSTITUTO de INVESTIGACIONES TECNOLOGICAS
(INTEC)
Av. Santa Maria 06500 Lo Curro
Casilla 667 - Santiago de Chile

OBLIGATION DISTRIBUTION

Financial Data Code	Amount
4015390005	$35,300
ADVANCE PAYMENT -	- $15,600

PRINCIPAL INVESTIGATOR (name and address)

Maria E. Torres, Principal Investigator
(same address as above)

FINANCE OFFICE (Complete mailing address)

Chief, Accounting Services Branch
USDA-ARS-FMD-ASB
P. O. Box 53326
New Orleans, LA 70153

TITLE OF PROJECT

Crops for production in marginal growing areas in Chile

AUTHORIZED DEPARTMENTAL OFFICER'S DESIGNATED REPRESENTATIVE (Name and address)

Dr. R. Saunders and R. Becker (alternate)
USDA-ARS-Pacific Basin Area
Western Regional Research Center
800 Buchanan St., Albany, CA 94710

This Agreement includes the following:

- ☐ Statement of Work; *or*
- ☐ Project Summary; *or*
- ☐ Proposal; *and*
- ☐ General Provisions - 7 CFR 3015, Part U (by reference)
- ☐ Special Provisions
- ☐ Submit -
  - ☐ Technical Reports
  - ☐ Fiscal Reports, to: Authorized Departmental Officer's Designated Representative
- ☒ Other *(specify)*: EXHIBIT "A" - Scope of Work

BASIS FOR AWARD

FOR THE UNITED STATES DEPARTMENT OF AGRICULTURE

AUTHORIZED DEPARTMENTAL OFFICER	TYPED NAME	DATE

FOR THE PERFORMING ORGANIZATION
(Signature of person authorized by the governing body of the performing organization to incur contractual obligations.)

SIGNATURE	TYPED NAME AND TITLE	DATE

SIGNATURE	TYPED NAME AND TITLE	DATE

Form ARS-451 (9/83)

CONTRACTORS COMPLETE CERTIFICATIONS ON REVERSE

USDA-A

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WHEREAS, the United States Department of Agriculture, Agricultural Research Service, hereinafter referred to as ARS, and Instituto de Investigaciones Tecnologicas (INTEC), hereinafter referred to as the Cooperator, desire to enter into this cooperative agreement for the research investigations set forth herein; and

WHEREAS, there is a need to assess potential of crops in Chile which are tolerant of drought, salininty, and temperature stress; and

WHEREAS, ARS is interested in mesquite, a native U.S. Prosopis species, for reasons of its drought tolerance, its yield of pods (sugar and protein) and biomass (wood); and

WHEREAS, the parties desire to investigate the food and feed potential of leguminous trees which are indigenous to marginal areas of known stress; and

WHEREAS, evaluation will include seed and pod yield and conversion to food and/or feed subfractions through conventional or innovative processing sequences; nutritional evaluation of plant parts by chemical factors; and incorporation and performance of seed fractions in food systems; and

WHEREAS, data generated will be related to economic justification of developing specific plants, and will be used to assist breeders in selection of tolerant plants; and

WHEREAS, it is the intention of the parties to this cooperative agreement that such research investigations shall be for their mutual benefit and for the benefit of the people of the United States and other countries; and

NOW, THEREFORE, for and in consideration of the promises and mutual covenants herein contained, the parties hereto do mutually agree with each other as follows:

A. The Cooperator Agrees:

1. The Cooperator will conduct research studies on the tasks listed below as detailed in the "Scope of Work" outlined in EXHIBIT "A" attached hereto and made a part hereof:

   a. Pod collection.

   b. Selection of pods for analysis.

   c. Subfractionation of pods.

   d. Analysis of pod subfractions.

   e. Food, feed, and industrial evaluation of pods, pod subfractions, and foliage.

   f. Preliminary economic evaluation for Prosopis.

2. To provide the necessary personnel to conduct the research investigations, travel of the Cooperator's employees engaged in the project, and furnish the necessary facilities, equipment, and supplies as mutually agreed upon.

3. To maintain current records of the investigations and provide semi-annual reports (4 copies) of the progress of the work to the Authorized Departmental Officer's Designated Representative (ADODR), including a final report (5 copies) setting forth in detail all work accomplished and results obtained. Upon receipt of these reports, copies will be sent to the following by the ADODR, Dr. R. Saunders or Dr. R. Becker:

Quarterly Letter Reports:	Area Director Western Region Deputy Administrator National Program Staff
Final Report:	Area Director National Agricultural Library Western Region Deputy Administrator National Program Staff

B. The Agricultural Research Service Agrees:

1. To provide the services of an ARS Representative to maintain close liaison with the Cooperator through frequent visits and other means to review and evaluate the research progress and to assist in the planning and coordination of the research to be undertaken.

2. To provide the necessary personnel to provide technical know-how on *Prosopis* pod processing technology, and define exact protocol to determine objectives listed under paragraph 4 of the Scope of Work.

3. To conduct the following experiments during the period of performance:

   a. Determine salt tolerance of Chilean *Prosopis* species.

   b. Provide conclusive evidence that *Prosopis* species can or cannot utilize moisture in the air through leaf absorption and transfer to the root system (contrary to normal plant physiology).

   c. Obtain N-fixing rhizobia from Chilean Principal Investigator for ongoing work at the ARS Western Regional Research Center (WRRC) concerning N-fixation in *Prosopis*.

   d. Carry out controlled chick, and possibly sheep feeding experiments in cooperation with the University of California, Davis, California. *Prosopis* pod fractions will be prepared at WRRC from donated Chilean material.

   e. Carry out tests on *Prosopis* galactomannan gum as a mud for oilwell drilling.

4. a. To assist in defraying the cost of the project by reimbursing the Cooperator for salaries (which includes 30% fringe benefits on salaries), travel of the Cooperator's employees engaged in the project, expendable supplies and materials, including supplies and materials, in an amount not to exceed $35,300 during the period of this cooperative agreement. Indirect or overhead costs shall not be reimbursed by ARS.

   b. $15,600 ADVANCE PAYMENT will be issued by ARS Finance Office upon receipt of an executed copy of this cooperative agreement. At the time of each quarterly fiscal claim submitted to the ADODR, the Cooperator will be paid for actual expenses incurred and the initial advance will remain at $15,600. However, liquidation of the advance payment must take place before the ending date of this cooperative agreement.

C. It is Mutually Understood and Agreed:

1. Payment by ARS to the Cooperator will be made on a quarterly basis, for expenditures for each previous quarter as listed in on properly executed invoices or vouchers to be prepared by the Cooperator and submitted to the ADODR for approval and submission to the ARS Finance Office.

2. Items for which reimbursement will be claimed by the Cooperator shall not include capital improvement, non-expendable property, nor travel for ARS employees.

3. Results of the research outlined herein may be published jointly by the Cooperator and ARS, or by either of these institutions separately, but manuscripts prepared for publication by either shall be submitted to the other party for suggestions and approval prior to publication. In the event of disagreement, either party may publish results on its own responsibility, giving proper acknowledgment of cooperation.

4. Results patented by one party are to be made known to the other party and that the patenting party will give the other party a paid-up, royalty-free, world wide license to use the patent for government purposes.

5. This cooperative agreement may be amended or terminated upon 60 calendar 60 days notice in writing. Participation by ARS as cited in paragraphs B.1 thru B.3 herein shall be subject to passage by the Congress of the United States of an appropriation of funds, from which expenditures may legally be made.

EXHITIB "A" C/A No. 58-91H2-4-00005

SCOPE OF WORK

1. SUMMARY

This Agreement formally attests to a cooperative .esearch venture between INTEC, Chile, and WRRC-USDA, USA. The research objectives and plan of work are described herein.

Studies in Chile, which will be financed by WRRC-USDA through funding originating from the Agency for International Development, Washington, D.C., USA, will focus on a detailed examination of Chilean Prosopis species as a food, feed, and industrial resource. Seeds, pods, and foliage from different Prosopis species will be investigated. Technology will be developed to rapidly separate the pods into sub-fractions with anticipated specific end uses. Properties of pod subfractions will be monitored by chemical, biochemical, and functional techniques. Studies will include animal feeding. The work will be interfaced with Prosopis development work being carried out by CONAF (PNUD/FAO Grant), the Univ. Catolica de Chile (NAS/USA Grant), and INTEC (NAS/USA Grant), and with work at WRRC-USDA. CORFO and Fundacion Chile will be kept apprised of research progress. Fundacion-Chile will provide input into economic assessment of any processes or products recommended as being exploitable from Prosopis species.

Project Duration: 3 Years

Funds to INTEC: U.S.$ 35,300

Principal Investigators:

Chile, INTEC: Maria Elena Torres

USA, WRRC-USDA: Robert Becker

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2. PROJECT OBJECTIVE

Define parameters required to exploit components of Prosopis species as food, feed, and industrial resources.

1. Define pod composition and relate to environmental factors

2. Establish food, feed, and industrial potential of Prosopis pods and subfractionated pods.

3. BACKGROUND: PROSOPIS IN CHILE

For several years Chile has been engaged in work relative to development of Prosopis, principally P. tamarugo and P. chilensis. Considerable data are available from CORFO concerning this work. Recently, grants have been made by the National Academy of Sciences, USA, to INTEC concerning nitrogen fixation in Prosopis, and to Univ. Catolica de Chile concerning propagation in Prosopis. During 1984, a PNUD(UNDP)/FAO program for development of semi-arid areas in Chile will be initiated; this work includes further development research on Prosopis. In order to develop this crop, it is essential that the final product (tree, foliage, pod, etc) has an economic utility. The aforementioned projects do not address this critical element. The project herein is designed to provide the means whereby the Prosopis "product(s)" can be assessed for utilization potential. This information will be made available to CORFO and CONAF in Chile, and to other institutions around the world interested in Prosopis development.

4. WORK PLAN

1. Pod collection
2. Selection of pods for analysis
3. Subfractionation of pods
4. Analysis of pod subfractions
5. Food, feed, and industrial evaluation of pods, pod subfractions, and foliage.
6. Preliminary economic evaluation of Prosopis

4.1 and 4.2. Pod collection and selection for analysis

A variety of pods collected from P. tamarugo and P. chilensis will be provided to INTEC by CORFO (L. Zelada) or CONAF (B. Husch and R. Romero), and the Univ. Catolica de Chile (O. Balboa and M. Jordon). In addition, INTEC is encouraged to find other sources of Chilean pods if they appear to have potential. Since there is a wide variation in pod characteristics, the pods selected for further study will represent such diversity, but should be limited in number (but at least five) to avoid overtaxing research facilities. It is essential that pods should be derived from known tagged trees, and if possible with defined or determinable ecological parameters. Furthermore it would be beneficial if pods could be obtained from those trees which are under investigation for nitrogen fixation and propagation in other research projects. Pods which subsequently are shown to possess desirable economic value can thus be related to specific trees, which would then become the germplasm for future development. Investigations in 1985 and 1986 would be expected to be carried out on pods from those same trees showing the most promise after examination in 1984.

4.3. Subfractionation of pods

With advisory input from WRRC-USDA, selected pods would be separated (milled) into seeds, endocarp amd exocarp subfractions. The seeds would be further fractionated into seed coat (including gum) and cotyledon. The other fractions may be further milled into flours.

4.4. Analysis of pod subfractions

Whole pods or separated subfractions, and foliage which would be a crude fraction separable from collected pods during their initial cleaning, will be analyzed for nutrient content (protein, lipid, ash, fiber, sugars and moisture) using standard methods to be supplied by WRRC-USDA. A specific analysis for gum would be carried out using a method to be supplied by WRRC-USDA. *In vitro* enzymatic digestion of these *Prosopis* fractions will be carried out to predict their potential digestibility for monogastric and ruminant animals, using procedures to be supplied by WRRC-USDA. Certain protein fractions would be sent to WRRC-USDA for amino acid analyses.

4.5. Food, feed, and industrial evaluation of pods, pod subfractions, and foliage.

Based upon data generated in 4.4, a limited number of rat feeding experiments will be subcontracted by INTEC, to be carried out in Chile. These will be PER measurements. If requested by WRRC-USDA, INTEC will be responsible for ensuring that CONAF or CORFO provides large quantities of pods to WRRC-USDA for chick and pig feeding to be carried out in the USA. CORFO (L. Zelada) has indicated that there would be no charge for such pods, although shipping costs may have to be paid from funds provided to INTEC.

In addition, CONAF and CORFO expect to carry out further sheep feeding trials at Pampa del Tamarugo. Data from these studies will be made available to this project. WRRC-USDA and INTEC will advise on processing of pods prior to such sheep feeding trials. It is expected that no charge would be made to INTEC funds concerning these animal trials.

In addition, if INTEC believes that further animal feeding trials could be contracted with other institutions in Chile at an acceptable cost, they are encouraged to do so. Prior to such trials, WRRC-USDA should be contacted for design input.

Pods and pod subfractions will be tested as adjuncts in foods deemed appropriate for new and traditional Chilean and U.S. consideration. This will necessitate measurement of physicochemical attributes as commonly employed in food science to predict potential food characteristics, such as farinograph, amylograph, etc, incorporation of the materials into foods (anticipated to be mainly baked bread type foods). CORFO has suggested that such food product tests may also include fishmeal and/or dried milk products indigenous to the Pampa Del Tamarugo region; INTEC is encouraged to act on this suggestion. The studies would include statistically correct consumer testing/organoleptic appraisal in the INTEC facility. In the final year, it would be advantageous if similar testing could be carried out with the local Pampa Del Tamarugo population. Consumer acceptance of recommended products would be carried out in standard hedonic taste tests, by comparison of the *Prosopis* modified food with a nonmodified control, and by general reaction to new *Prosopis*-based foods.

INTEC will carry out studies to separate the galactomannan gum from the Prosopis seed coat, using procedures recommended by WRRC-USDA, and will compare the gum physical and chemical properties with those of guar gum. Such properties will include gelation and viscosity; WRRC-USDA will supply a standard guar gum for comparison purposes.

INTEC will carry out fermentation studies on selected pod subfractions to test their value as a substrate for ethanol (energy) production.

INTEC will supply WRRC-USDA pod subfractions to be tested for toxic antinutrients. The procedures used by WRRC-USDA will be subsequently provided to INTEC so that their facility could become skilled in this assay in foods and feeds.

4.6. Preliminary economic evaluation of Prosopis

To attract commercial interest in the production and processing of Prosopis species it is essential to demonstrate favorable economics. A preliminary determination will be made by INTEC with input from Fundacion-Chileon the value of the various fractions that are developed from the pod pericarp and seeds, and foliage. This will be done after work on pod subfractionation, chemical analysis, and food and feed evaluations have progressed sufficiently to identify potential commercial products for which the various Prosopis materials can be substituted. The prices of these commercial products will be used to provide guides as to the value of the Prosopis fractions which are their potential substitute. The prices will be verified, discounted or increased depending on evaluations made by potential users who will have been provided product samples from the project.

INTEC must hold meetins with Fundacion-Chile at frequent intervals during the life of the project to fully apprise them of developments, but especially to solicit their early input into the economic assessment of Prosopis; this has been agreed to by A. Wylie and F. Sanchez of Fundacion-Chile.

5. COLLABORATIVE ARRANGEMENTS

It is essential that INTEC collaborate with other Chilean investigators re Prosopis, including CONAF, CORFO, Univ. Catolica de Chile (section 4.1) and Fundacion-Chile (section 4.6). INTEC is also encouraged to interact with others around the world engaged in Prosopis development, and especially P. Felker, USA. Cooperation with WRRC-USDA will be maintained throughout the life of the project, which will include assignments of INTEC staff at the WRRC-USDA research facility in USA.

6. BUDGET

The funds to be provided to INTEC by WRRC-USDA (original source, Agency for International Development, USA) and their proposed distribution on an annual basis is outlined in Table 1.

Table 1. INTEC staff effort and budget summary (U.S. dollars)[a]

	1984	1985	1986
Principal investigator (Maria Elena Torres)	1.5m ($1,500)	1.5m ($1,500)	1.5m ($1,500)
Graduate technician 1	12m ($2,400)	12m ($2,400)	12m ($2,400)
Graduate technician 2	6m ($1,200)	6m ($1,200)	6m ($1,200)
Salaries	$5,100	$5,100	$3,900
INTEC overhead, 30%	$1,500	$1,500	$1,200
Travel[b]	$4,000	$4,000	-
Material, supplies	$3,000	$2,000	-
Animal feeding	$2,000	$2,000	-
Totals:	$15,600	$14,600	$5,100

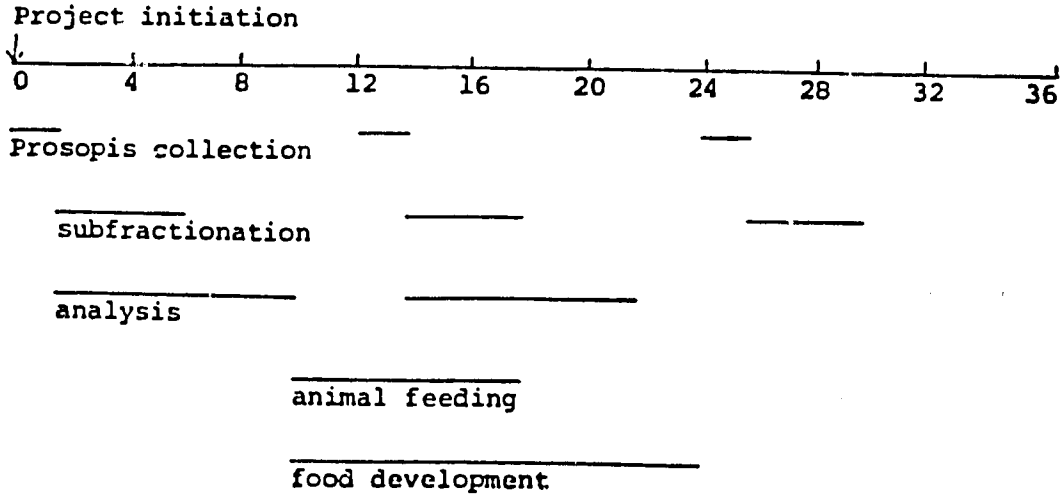
Overall total: $35,300

[a] Funds will be placed at INTEC by WRRC-USDA. Funds can be interchanged within catagories at the discretion of INTEC, but with prior written approval of WRRC-USDA. Funds can be carried over from year to year, and will be provided at the beginning of each work year. The first year funds could be expected April-May 1984, subject to signing of this Agreement, and final approval of USDA Administration.

[b] Travel to USA, and travel in Chile limited to pod collection form tagged trees, and attendance at the 1984 International Prosopis Meeting, Chile. Travel to USA may be combined with attendance at the National Academy of Sciences' meetings for NAS funded researchers.

7. TIMEFRAME

The proposed timeframe in months is illustrated below:



8. REPORTS

A concise written report should be supplied to WRRC-USDA by INTEC on a semiannual basis during the life of the project. Presentation of research results at meetings or in publications is permitted. Joint authorship between INTEC and WRRC-USDA and/or other Chilean investigators is encouraged, but not essential.

BACKGROUND OF THE TECHNOLOGICAL RESEARCH INSTITUTE INTEC - CHILE

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INTEC - CHILE

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BACKGROUND OF THE TECHNOLOGICAL RESEARCH INSTITUTE (INTEC-CHILE)

INTEC-CHILE is a non profit institute of industrial research, created as a Committee of the Chilean Development Corporation (CORFO) at the end of 1968.

INTEC-CHILES'S objetive is to support industry, public and private productive enterprises, and CORFO, in every aspect related to the process of technological creation, innovation, adaptation or substitution, by means of technical information, technology transfer and experimental development, at its own laboratories and pilot plants.

INTEC-CHILE has been organized as an Applied Research Institute, whose orientation and evaluation of operations is controlled by a Board of Directors, for which members are nominated by the Executive Vicepresident of CORFO.

The Board appoints an Executive Director to manage the research and development activities and who is responsible for the general administration of the institution.

The action of INTEC-CHILE is fundamentally geared to satisfy the requirements of technological research and development of the productive sector of the economy, especially those of privately owned industry and state productive enterprises. From these sectors the Institute obtains an important fraction of its financing, by means of r & d contracts that are treated on a confidential basis.

In addition, INTEC has been also working for the State, mainly for the Chilean Development Corporation (CORFO) and for Regional Governments analizing local natural resources and experimenting in different ways to utilize them.

Since 1968, INTEC-CHILE has represented a truly national solution to the problems of improving production processes, making use of natural local resources and optimizing the utilization of available labor force, through an adequate selection and optimal use of appropiate technology.

A. Type of activities carried out by INTEC-CHILE

To comply with its objectives of technologically assisting the Chilean entrepreneural sector, INTEC-CHILE performs the following tasks:

- Provide information on technical alternatives required by industrial development.

- Carry out studies on searching, evaluation and selection of technologies.

- Serve as a link between world technology producers and owners, and potential clients of Chilean industry, by means of an adequate transfer and tecnology broker service.

- Provide adaptation of technology to local conditions, conducting an performing the necessary studies.

- Carry out research to obtain new products and develop new processes, improve existing ones and facilitate innovation, according to demand of private companies or government.

- License products and processes developed internally at INTEC-CHILE.

- Market studies and technical and/or economic feasibility studies of new activities or expansion of existing ones, related to research and development work contracted.

- Render technical services that lead to technology applications, such as analysis services, trouble shooting, startup and tuning of industrial processes.

- Pilot technology - intensive production.

- Active participation in interdisciplinary groups, with engineering firms, universities or other research organizations, either in joint ventures or as subcontractor, in studies to implement technology application and make possible the innovation processes.

- INTEC-CHILE'S field of action covers all geographical regions of the country, and the Institute is capable and well-staffed for operating abroad, under request. Our organization is preferentially serving the needs of the food, chemical, metallurgical, mining, energy, metal-mechanical and electrical industries. INTEC'S involvement also includes some agricultural activities.

B. Human Resources

Permanent Personnel

Doctors of Science	3
Masters of Science	3
Engineers of differents expertises (6 years of study)	27
Business Administrators	1
Chemists	8
B.S. Engineers (4 years of studies)	7
Other University Graduates	2
Librarians	3
Technicians	15
Skilled workers and operators	10
Administratives and services	27
T O T A L	106

C. Organization of INTEC-CHILE

INTEC-CHILE comprises several division, namely:

- INFORMATION DIVISION

It answers specific enquires coming from the industry, local or foreign organizations and privates. A library with about 9,000 books and 150 periodicals is available. The division is also part of the Lockheed Information Network (Palo Alto, California), through a satellite connection.

- METALLURGY AND CHEMICAL INDUSTRIES

The division deals with the Chilean Mining Industry and Chemical Industry. Its main involvement is in the field of set-up and control of processes in general.

- FOOD INDUSTRIES, AGRO-INDUSTRIES AND INDUSTRIAL MICROBIOLOGY

It offers services on development, formulation and analysis of foodstuffs, technology transfer, process development applied to Agroindustry and Food Industry. Its field of work also includes some agricultural activities.

- DIVISION OF PROJECTS AND ALLIED INDUSTRIES

Its main objectives are the development of particular projects in the fields of mechanical design, industrial refrigeration, energy, electronics, process optimization and automation, environment pollution and metal products.

- TECHNO-ECONOMICS STUDIES

This division provides a supporting service to the activities of the Institute as well as serving the requirements of the industry in the technoeconomical field, particularly feasibility and market studies and assistance in selection/purchase of technologies.

D. Material Resources

INTEC-CHILE is located in the Municipality of Las Condes, Santiago, Chile, 06500 Santa María Avenue. This location, about 15 kms, from downtown Santiago, has easy access, the general site having been selected subsequently for the establishment of other similar research and development organizations, and also business companies. INTEC-CHILE owns a lot covering 90.000 m2. The buildings all recently constructed and in excellent shape, totalize 9.600 m2., with the following aproximate distribution:

Offices and laboratories	4.600 m2
Pilot Plants	4.000 m2
Machinery rooms and workshop	300 m2
Warehouses	700 m2

The following is a list of the laboratories, pilot plant, and other existing installations:

a. Laboratories

- Electronics (circuit and systems development, electromedicine, professional electronics).

- Control and instrumentation Systems
- Metallography
- Minerals microscopy
- Thermal treatment
- Powder metallurgy (obtention of metallic powder by diverse methods, powder characterization)
- Chemical analysis (organic and inorganic)
- Instrumental chemical analysis (infrared spectrophotometry, UV, visible, atomic absorption; gas chromatographs, thermobalance, differential calorimeter, porosity meter, etc).
- Extractive metallurgy
- Coal technology
- Mineral reducibility
- Foundry
- Biochemistry
- Food analysis
- Food technology
- Sensorial evaluation
- Experimental kitchen
- Bacteriological analysis

b. Pilot Plants

- Extractive metallurgy (mineral dressing, mineral concetration, solvent extraction)

- Coal technology
- Obtention of metallic powder (atomization, electrolysis, reduction)
- Foundry
- Chemical reactors
- Solid and liquid food technology (milling, sifting, mixing, extrusion, dehydration, roasting, centrifugation, homogenization, pasteurization, evaporation, freezing, etc.)

c. Workshops

- Printed circuits assembly workshop
- Mechanical workshop
- Electrical workshop
- Electronics workshop
- Carpenters' shop

d. Machine Rooms

- Boilers (1.500 kg/hour)
- Compressors (150 lb/in2)

e. Additional Services

There is adequate infraestructure for INTEC'S needs in technical drawing, photography, reproduction and printing.

E. SUMARY OF PROJECTS CARRIED OUT BY INTEC-CHILE

Listed below are some of the most important projects carried out by INTEC-CHILE. Some of the titles of the list correspond to more than one individual study.

1. Precooking of cereals and legumes by extrusion.
2. Development of foodstuffs to be used as cold school meals.
3. Experimental development and feasibility study of producing texturized vegetable protein by extrusion.
4. Feasibility study of utilization Chilean rose hip.
5. Production of essential oils and oleoresins at laboratory and pilot plant level.
6. Development of products and processes for obtaining milk substitutes. License to a local company and a international organization.
7. Utilization of lupine as a replacer for soybean.
8. Alternatives of red meat supply for the city of Iquique (located in the north of Chile).
9. Development of products from "chañar" (small fruit grown wild in northern Chile).
10. Sun drying of grapes and other fruits.
11. Fresh water fish farming and processing in Chile (salmón, trout).

12. Design, construction and start up of fruit fumigation chambers using methil bromide (several projects for private companies).
13. International course of food extrusion.
14. Utilization of oat.
15. Production of goat cheese.
16. Use of agricultural and forestry wastes.
17. Development of fish protein concentrates.
18. Milk substitutes to be used as feedstuffs.
19. Development of minced meats of animal origin and products derived from it.
20. Processing and preservation of avocado fruit.
21. Drying and dehydration of vegetables, fruits and spices.
22. Efficiency improvement of rhizobium in white and red clover.
23. Alternatives of apple processing.
24. Texturization of vegetable protein other than soybean
25. Experimental production of pasta enriched with legume.
26. Development of a soluble coffee substitute.
27. Hydrolysis of wheat flour at low moisture level.
28. Design, construction and start up of fruit cold stores (several projects, private industry and government).
29. Feasibility study of shellfish processing plant (several projects, private companies)
30. Determination of the impact on the environment of a copper refining plant.

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31. Set up of a data file on environmental pollution.

32. Characterization and quantification of chemical and biological contaminants.

33. Precooling - fumigation systems for export fruit.

34. Picking and processing of chilean filbert.

35. Post-harvesting handling of fresh vegetables.

36. Production of ethanol from sugar beet; feasibility study.

37. Effect of rhizobium on the development of prosopis species (Prosopis tamarugo and prosopis chilensis)

38. Nitrogen fixation related to mineral nutrition and salinity in Prosopis tamarugo and Prosopis chilensis.

RBecker

First Report

(May through October 1984)

Maria Elena Torres
INTEC

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Milling and Separation of *Prosopis* pods Components

Mature pods of *Prosopis chilensis* were collected from beneath trees from two populations: Chincolco (about 150 Km north of Santiago), and Peldehue (about 50 Km north of Santiago). Pods were collected from three separate trees, and also 300 Kg were gathered from different trees.

The pods were dried to about 4% H_2O in a hot air dryer. The pods were broken and then milled with disk 8504 (Mill:
with a gap of 4 mm, 4.5 mm, and 3.8 mm. The Table 1 shows the different yields with the different gap of the disks, and the four fractions obtained.

Pods of *Prosopis tamarugo* were collected from beneath trees of Pompa del Tamarugal.

The pods were processed the same way as *Prosopis chilensis*, three fractions were obtained. With 100 kg of pods were gotten the following: 9.5 Kg of seeds, 13 Kg of flour, and 71 Kg of endocarp.

Table 1. MILLING CONDITIONS FOR PROSOPIS CHILENSIS AND YIELDS OF THE FRACTION

PROCEDENCIA	DISC GAP ABERTURA DISCO	INITIAL TOTAL WEIGHT PESO TOTAL INICIAL	SEEDS SEMILLA	ENDOCARP ENDOCARPIO	MIXTURE CASCARILLA	FLOUR HARINA	FINAL WEIGHT PESO TOTAL FINAL	LOST (%) PERDIDA
US - 1	4,5 mm	500 g	58 g	129.0 g	176.2 g	74.0 g	437.2 g	12.6%
Chincolco	90		11.6%	25.8%	35.2%	14.8%		
3 Peldehue	3.8 mm	500 g	41.0 g	68.4 g	241.9 g	65.0 g	416.3 g	16.7%
	63		8.2%	13.7%	48.4%	13.0%		
5 Peldehue	4.5 mm	500 g	58.1 g	99.4 g	203.4 g	45.5 g	406.4 g	18.7%
	90		11.6%	19.92%	40.7%	9.1%		
Pull Various trees	4.0 mm	500 g	79.8 g	71.4 g	231.7 g	72.4 g	455.3 g	8.4%
Peldehue	75		16.0%	14.3%	46.3%	14.5%		
Pooled Chincolco		58 kg	8 kg	13 kg	18 kg	19 kg		
			13.8%	22.4%	31%	32.8%		

The proximate composition of *Prosopis* pods are shown in Table 2.

The enzymatic evaluation of digestibility of the different fractions obtained are now being assayed.

Work for the next period.

- Continuing the "*in vitro*" digestibility of the different fractions obtained by the milling of the *Prosopis* pods.
- Separation of the seed-coat and cotyledons.
- Obtain gum. Analysis and evaluation of the quality of the gum.
- Rat feeding assays (PER).

Table 2. PROXIMATE COMPOSITION OF PROSOPIS PODS (1)

FRACTION FRACCION	TOTAL SOLIDS SOLIDOS TOTALES	ASH CENIZAS %	PROTEINS PROTEINAS (N x 6, 25)	FAT EXTRACTO ETEREO %	FIBER FIBRA %	NNE E.N.N. %
P. CHILENSIS ALGARROBO						
Semilla pooled Seed pooled	92,62	3,50	30,75	2,30	7,91	55,54
Semilla US 1 Ch Seed US 1 Ch	90,76	3,28	29,06	2,02	8,33	57,31
Semilla 3P Seed 3P	92,17	3,53	33,95	2,26	7,37	52,82
Semilla 5P Seed 5P	93,14	3,45	30,93	2,63	6,85	56,14
Endocarpio #5 pooled	95,36	1,93	6,49	0,88	41,07	49,63
Endocarpio #5 US 1 Ch	93,86	2,43	8,23	0,54	27,52	61,28
Endocarpio #5 3P	95,71	1,83	6,28	0,53	52,31	39,05
Endocarpio #5 5P	95,52	2,63	9,23	1,12	37,05	49,97
#20 pooled	96,22	2,92	6,89	1,64	11,50	77,05
#20 US1 Ch	93,50	2,97	7,05	0,48	9,45	80,05
#20 3P	96,27	3,23	9,82	0,92	13,11	72,92
#20 5P	96,76	3,16	6,60	1,18	9,06	80,00
Harina #40 pooled Flour #40 pooled	95,97	3,24	7,64	2,73	3,86	82,53
Harina #40 US 1 Ch Flour #40 US 1 Ch	93,54	3,12	8,60	0,59	7,62	80,07
Harina #40 3P Flour #40 3P	96,89	3,79	10,60	0,91	3,62	81,08
Harina #40 5P Flour #40 5P	96,32	3,48	7,30	1,21	4,92	83,09
P. TAMARUGO						
Semilla T1 PT Seed T1 PT	91,73	3,85	31,20	2,80	10,96	51,19
Semilla T2 PT Seed T1 PT	91,96	3,82	31,15	2,50	11,26	51,27
Fibra T1 PT Endoc. T1 PT	89,81	4,24	7,36	0,24	39,65	48,51
Fibra T2 PT Endoc.T2 PT	89,29	3,89	8,16	0,53	37,24	50,18
Harinilla T1 PT Flour T1 PT	88,52	6,27	17,50	0,95	19,16	56,12
Harinilla T2 PT Flour T2 PT	88,36	6,09	17,37	1,14	19,05	56,35

(1) AS DRIED WEIGHT

Table 3. ENZYMATIC DIGESTIBILITY OF PROSOPIS CHILENSIS AND P. TAMARUGO FRACTIONS

	DIGESTION WITH PEPSIN, TRIPSIN, AND CELLULASE			DIGESTION WITH PEPSIN, TRIPSIN, CELLULASE AND PRONASE		
SAMPLE	TSAE WITH E	TSAE NO E	REFERENCE CELL	TSAE WITH E	TSAE NO E	REFERENCE CELL
1	38.92	25.10	13.82	39.70	24.04	15.66
2	72.2	66.11	6.09	74.06	67.46	6.60
3	80.89	-	-	84.18	82.43	1.75
4	-	-	-	-	-	-
5	71.08	67.34	3.74	72.96	68.35	4.61
6	-	-	-	-	-	-
7	84.22	57.59	26.63	87.96	59.52	28.44
8	32.02	-	-	33.92	30.56	3.36
9	85.54	58.22	27.32	87.04	54.71	32.33
10	30.61	20.04	10.57	32.15	17.75	14.40

SAMPLES

1. P. chilensis, tree No 3, Peldehue ENDOC.
2. P. chilensis, tree No 3, Peldehue, MIXTURE.
3. P. chilensis, tree No 3, Peldehue, FLOUR.
4. P. chilensis, pooled, ENDOCARP.
5. P. chilensis, pooled, MIXTURE
6. P. chilensis, pooled, FLOUR
7. P. chilensis, pooled, SEED
8. P. Tamarugo, FLOUR.
9. P. Tamarugo, SEED.
10. P. Tamarugo, ENDOCARP.

Samples 4 & 6 under analysis. Blank lost in 358 (To be repeated)

Table 4. ENZYMATIC DIGESTIBILITY (NITROGEN ANALYSIS) OF THE DIGESTED FRACTIONS OF P. CHILENSIS AND P. TAMARUGO

SAMPLES	NITROGEN TOTAL	NITROGEN FRACTION INSOLUBLE	NITROGEN BLANK	TOTAL SOLIDS %
1	0.96	0.36	0.51	95.71
2	1.51	0.48	0.75	96.27
3	1.64	0.34	0.55	96.89
4	0.99	0.35	0.62	95.36
5	1.06	0.38	0.61	96.22
6	-	-	-	-
7	4.56	0.71	2.56	92.62
8	2.78	0.69	0.88	88.36
9	4.58	0.67	2.40	91.96
10	1.31	0.42	0.51	89.22

SAMPLES

1. P. chilensis, tree No 3, Peldehue ENDOC.
2. P. chilensis, tree No 3, Peldehue, MIXTURE.
3. P. chilensis, tree No 3, Peldehue, FLOUR.
4. P. chilensis, pooled, ENDOCARP.
5. P. chilensis, pooled, MIXTURE
6. P. chilensis, pooled, FLOUR
7. P. chilensis, pooled, SEED
8. P. Tamarugo, FLOUR.
9. P. Tamarugo, SEED.
10. P. Tamarugo, ENDOCARP.

FIRST ANNUAL REPORT

CROPS FOR PRODUCTION IN MARGINAL GROWING AREAS IN CHILE

INTEC - CHILE

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CROPS FOR PRODUCTION IN MARGINAL GROWING AREAS IN CHILE

The objective of this project is to define parameters required to exploit components of *Prosopis* species, principally *P. tamarugo* and *P. chilensis*, as food, feed and industrial resources.

Pod Collection

Mature pods of *Prosopis chilensis* were collected beneath the trees out of two populations: Chincolco (about 150 km north of Santiago), and Peldehue (about 50 km north of Santiago).

Pods were collected from three different trees, 300 additional kg were also gathered from other trees.

Pods of *P. tamarugo* were collected from beneath the trees of the Pampa del Tamarugal.

Separation of fractions

The pods of P. chilensis were dried to about 4% water in a hot air dryer, broken and then milled with a Bauer disc Mill (148 - C 8"), using disk Nr 8504.

The gaps setting were 3,8; 4,0 and 4,5 mm. Table 1 shows the yields of the four fractions obtained, as a function of gap setting.

TABLE 1. MILLING CONDITIONS FOR PROSOPIS CHILENSIS AND YIELDS OF THE FRACTIONS

ORIGIN	DISC GAP	INITIAL TOTAL WEIGHT	SEED	ENDOCARP	MIXTURE	FLOUR	FINAL WEIGHT	LOS S(%)
PROCEDENCIA	ABERTURA DISCO	PESO TOTAL INICIAL	SEMILLA	ENDOCARPIO	CASCARILLA	HARINA	PESO TOTAL FINAL	PERDIDA
US - 1	4.5 mm	500g	58 g	129.0 g	176.2 g	74.0 g	437.2 g	12,6 %
Chincolco	90	-	11.6%	25.8%	35.2%	14,8%	-	-
3 Peldehue	3.8 mm	500g	41.0 g	68.4 g	241.9 g	65.0 g	416.3 g	16.7 %
	63	-	8,2%	13,7%	48.4%	13.0%	-	-
5 Peldehue	4.5 mm	500 g	58.1 g	99.4 g	203.4 g	45.5 g	406.4 g	18.7 %
	90	-	11.6 %	19.92%	40.7%	9.1%	-	-
Pooled (various trees)	4.0mm	500 g	79.8	71.4 g	231.7 g	72.4 g	455.3 g	8.4 %
Peldehue	75	-	16.06 %	14.3 %	46.3 %	14.5 %	-	-
Pooled Chincolco	-	58 kg	8 kg	13 kg	18 kg	19 kg	-	-
			13,8%	22.4%	31.0%	32.8%		

The fractions obtained by the milling process of the P. chilensis are the following:

- Seeds
- Endocarp
- Mesocarp (Flour)
- Exocarp and mesocarp (mixture)

The process for P. tamarugo was the same as with P. chilensis, three fractions were obtained. The yields with 100 kg of pods was the following: 9,5 kg of seeds, 13 kg of exocarp and mesocarp (flour) and 71 kg of exocarp (fiber).

Chemical Composition of the pods

The proximate composition of P. tamarugo whole pods from different populations, and foliage are shown in Table 2 and the different fractions from P. chilensis and P. tamarugo are shown in Table 3. Standard methods (AOAC) supplied by WRRC - USDA were used.

The analysis were performed from representative samples. About 20 different trees for the pooled samples, and one special from each population. (Chincolco and Peldehue were gathered).

TABLE 2. PROXIMATE COMPOSITION OF PROSOPIS TAMARUGO PODS AND FOLIAGE (1)
(PERCENTAGE)

POPULATION	TOTAL SOLIDS SOLIDOS TOTALES	ASH CENI-ZAS	PROTEINS PROTEI-NAS	FAT EXTRACTO ETEREO	FIBER FIBRA	NNE ENN
Bellavista(pods)	95.8	4.15	7.76	-	-	-
Pintados(pods)	97.5	5.51	9.24	-	-	-
Pillalla(pods)	93.8	4.01	11.16	-	-	-
Pillalla(foliage)	95.6	18.06	9.14	-	-	-

(1) As dried weight

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TABLE 3. PROXIMATE COMPOSITION OF PROSOPIS TAMARUGO AND PROSOPIS CHILENSIS FRACTIONS (1

FRACTION FRACCION	TOTAL SOLIDS SOLIDOS TOTALES	ASH CENIZAS %	PROTEINS PROTEINAS (N x 6,25)	FAT EXTRACTO ETEREO %	FIBER FIBRA %	NNE E.N.N. %
P. CHILENSIS ALGARROBO						
Semilla (varios) Seed pooled	92,62	3,50	30,75	2,30	7,91	55,54
Semilla US 1 Ch Seed US 1 Ch	90,76	3,28	29,06	2,02	8,33	57,31
Semilla 3P Seed 3P	92,17	3,53	33,95	2,26	7,37	58,82
Semilla 5P Seed 5P	93,14	3,45	30,93	2,63	6,85	56,14
Endocarpio # 5 pooled	95,36	1,93	6,49	0,88	41,07	49,63
Endocarpio # 5 US 1 Ch	93,86	2,43	8,23	0,54	27,52	61,28
Endocarpio # 5 3P	95,71	1,83	6,28	0,53	52,31	39,05
Endocarpio # 5 5P	95,52	2,63	9,23	1,12	37,05	49,97
# 20 pooled	96,22	2,92	6,89	1,64	11,50	77,05
# 20 USI Ch	93,50	2,97	7,05	0,48	9,45	80,05
# 20 3P	96,27	3,23	9,82	0,92	13,11	72,92
# 20 5P	96,76	3,16	6,60	1,18	9,06	80,00
Harina # 40 (varios) Flour # 40 pooled	95,97	3,24	7,64	2,73	3,86	82,53
Harina # 40 US 1 Ch Flour # 40 US 1 Ch	93,54	3,12	8,60	0,59	7,62	80,07
Harina # 40 3P Flour # 40 3P	96.89	3,79	10,60	0,91	3,62	81,08
Harina # 40 5P Flour # 40 5P	96,32	3,48	7,30	1,21	4,92	83,09
P. TAMARUGO						
Semilla T1 PT Seed T1 PT	91,73	3,85	31,20	2,80	10,96	51,19
Semilla T2 PT Seed T 2 PT	91,96	3,82	31,15	2,50	11,26	51,27
Fibra T1 PT Endoc. T1 PT	89,81	4,24	7,36	0,24	39,65	48,51
Fibra T2 PT Endoc. T2 PT	89,29	3,89	8,16	0,53	37,24	50,18
Harinilla T1 PT Flour T1 PT	88,52	6,27	17,50	0,95	19,16	56,12
Harinilla T2 PT Flour T2 PT	88,36	6,09	17,37	1,14	19,05	56,35

(1) AS DRIED WEIGHT

INTEC - CHILE

Digestibility of the Pod Fractions

The availability of proteins in the pod fractions obtained by milling P. tamarugo and P. chilensis will be established by rat feeding trials, but in vitro methods for evaluating the protein digestibility were performed because of their rapidity; this will permit to predict the potential as feed for those different fractions.

The methodology used was the pepsin-trypsin system described by Saunders et al (J. Nutr. 103 (4) 530-535 (1973). This method measures total digestible nitrogen rather than solubilized amino acids as other methods.

The results for the digestibility assays are shown in Table 4.

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TABLE 4. ENZYMATIC DIGESTIBILITY OF PROSOPIS CHILENSIS AND P. TAMARUGO FRACTIONS

SAMPLE	DIGESTION WITH PEPSIN, TRIPSIN AND CELLULASE			DIGESTION WITH PEPSIN, TRIPSIN CELLULASE AN PRONASE		
	TSAE WITH E	TSAE NO E	REFERENCE CELL	TSAE WITH E	TSAE NO E	REFERENCE CELL
1	38.92	25.10	13.82	39.70	24.04	15.66
2	72.2	66.11	6.09	74.06	67.46	6.60
3	80.89	80.19	0.70	84.18	82.43	1.75
4	(*)	-	-	-	-	-
5	71.08	67.34	3.74	72.96	68.35	4.61
6	80.34	79.93	0.41	83.23	80.63	2.60
7	84.22	57.59	26.63	87.96	59.52	28.44
8	34.41	33.26	1.15	33.92	30.56	3.36
9	85.54	58.22	27.32	87.04	54.71	32.33
10	30.61	20.04	10.57	32.15	17.75	14.40

(*) Sample 4 under analysis

1. P. chilensis, tree Nº 3, Peldehue ENDOC.
2. P. chilensis, tree Nº 3, Peldehue, MIXTURE
3. P. chilensis, tree Nº 3, Peldehue, FLOUR
4. P. chilensis, pooled, ENDOCARP
5. P. chilensis, pooled, MIXTURE
6. P. chilensis, pooled, FLOUR
7. P. chilensis, pooled, SEED
8. P. tamarugo, FLOUR
9. P. Tamarugo, SEED
10. P. Tamarugo, ENDOCARP

Gum extraction from Proscpis chilensis seed

The seeds of the Prosopis have o seed coat without o nutritional value, but beneath this lies directly o fraction that could be of considerable economical volue; this part probably o galactomannan could have different industrial uses as o gum.

Dry Milling

The separation of the endosferm-splits from the cotyledon was not possible with the Bauer mill; for this reason the quality of the gum as o thickening agent was first measured by just milling the whole seed. Two ways of mlling were tried.

a. The wohole seed was milled in an A. H. Thomas laboratory mill, Model ED-5. The powder was clasified into the size $<$ 40 mesh.

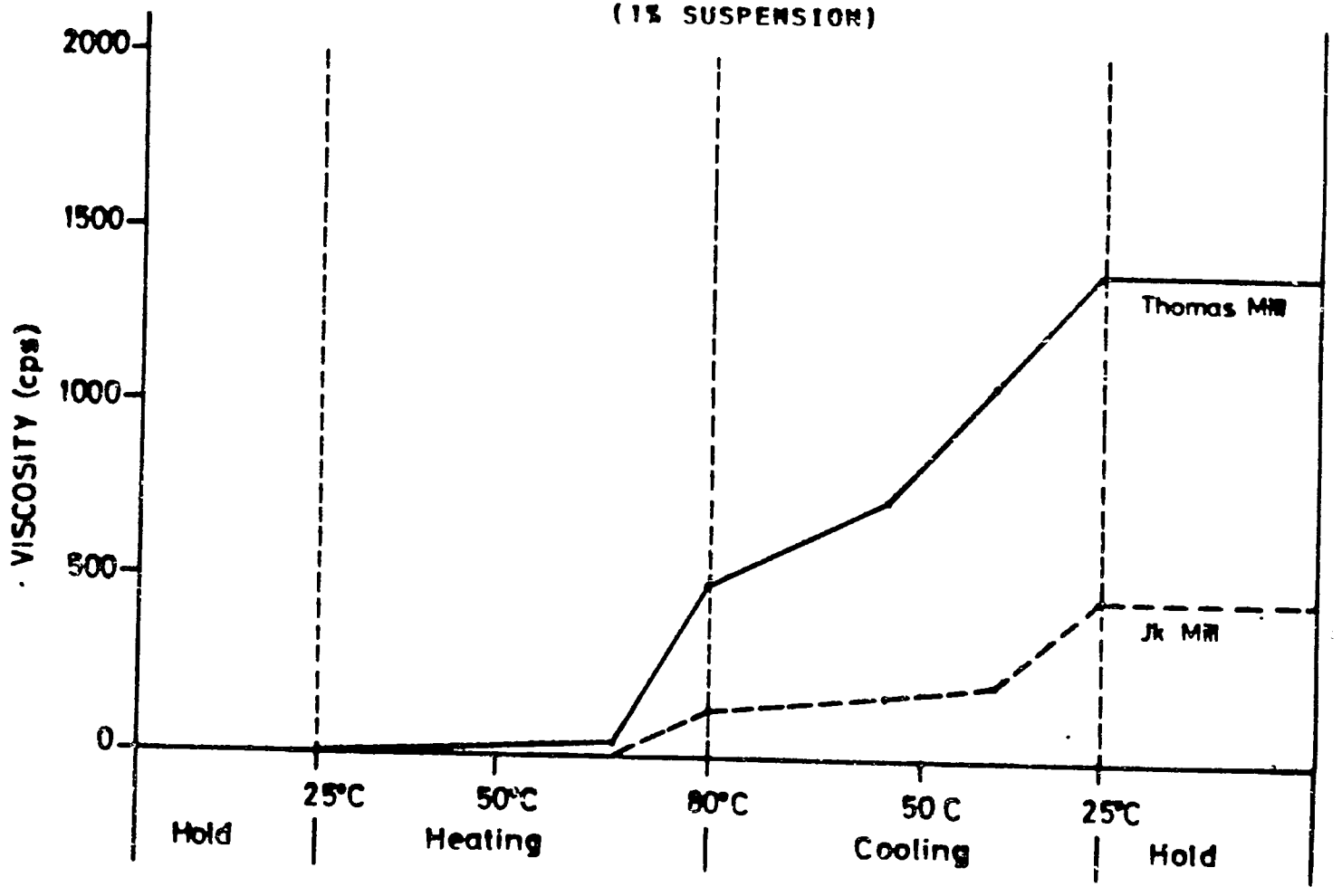
   A 1% suspension of the powder was prepared by agitation during two hours,at room temperature.

   The apparent viscosity was measured with a Brookfield Sychro-Lectric Viscometer, model RUF, spindle # 3 (Figure 1). Temperature was slowly raised from 25º C to 80º C at a rate of 1º C/min. During all the heating period, apparente viscosity was dinamically measured. After reaching 80º C, the solution was cooled down naturally, and apparent viscosity was also recorded through 25ºC. Results are shown in Figure 1.

b. Another alternate way of milling was tried, by using a Jenke laboratory mill (Jenke and Kunkel K.G., Byp A-10), obtaining a powder size $<$ 40 mesh, after which the procedure was similar to (a).
   The results are shown in Figure Nº 1.

FIGURE Nº 1

APPARENT VISCOSITY OF PROSOPIS CHILENSIS GUM.
EXTRACTION BY MILLING IN A THOMAS LABORATORY MILL AND A J.K. MILL
(1% SUSPENSION)



For the purpose of comparing the behaviour of P. chilensis gum with other known gum, the viscosity of a 1% solution of guar gum (prepared in a similar way to P. chilensis) was measured at 25º C, after heating to 80º C and with further cooling to 25º C. Results are shown in Table Nº 5.

TABLE Nº 5 : APPARENT VISCOSITY OF P. CHILENSIS GUM AND GUAR GUM AS A FUNCTION OF TEMPERATURE

T (º C)	Guar gum Apparent viscosity (cps)	P.chilensis gum Apparent viscosity (cps)
25	3.075	20
80	1.955	550
25	5.300	1.550

Wet process

As an alternative to the dry milling, this process was studied in order to obtain a pure gum fraction.

The whole seeds were broken into pieces in a mill, then soaked in water, at room temperature during 24 hours, The gum fraction swells up and all the fractions (germ, endosperm with the gum, and the seed coat) were separated by passing through a pulping machine.

After the separation process the gum fraction was dried by two ways:

- In an oven at 45º C, durint 24 hours

- In a spray drier; this operation was carried out in a pilot plant size spray drier (Niro Atomizer), with an inlet air temperature of 130º C, and an outlet air temperature of 80º C.

The characteristics of the gums obtained by oven drying and spray drying, were assessed by measuring the apparent viscosity of a 1% solution at different temperatures. Results are shown in Figure 2. Where it can be seen that the viscosity behaviour of spray dried gum is different compared to the oven dried one; ther former exhibits a much higher apparent viscosity at 25º C, indicating that oven dried gum has suffered an irreversible structure breakdown.

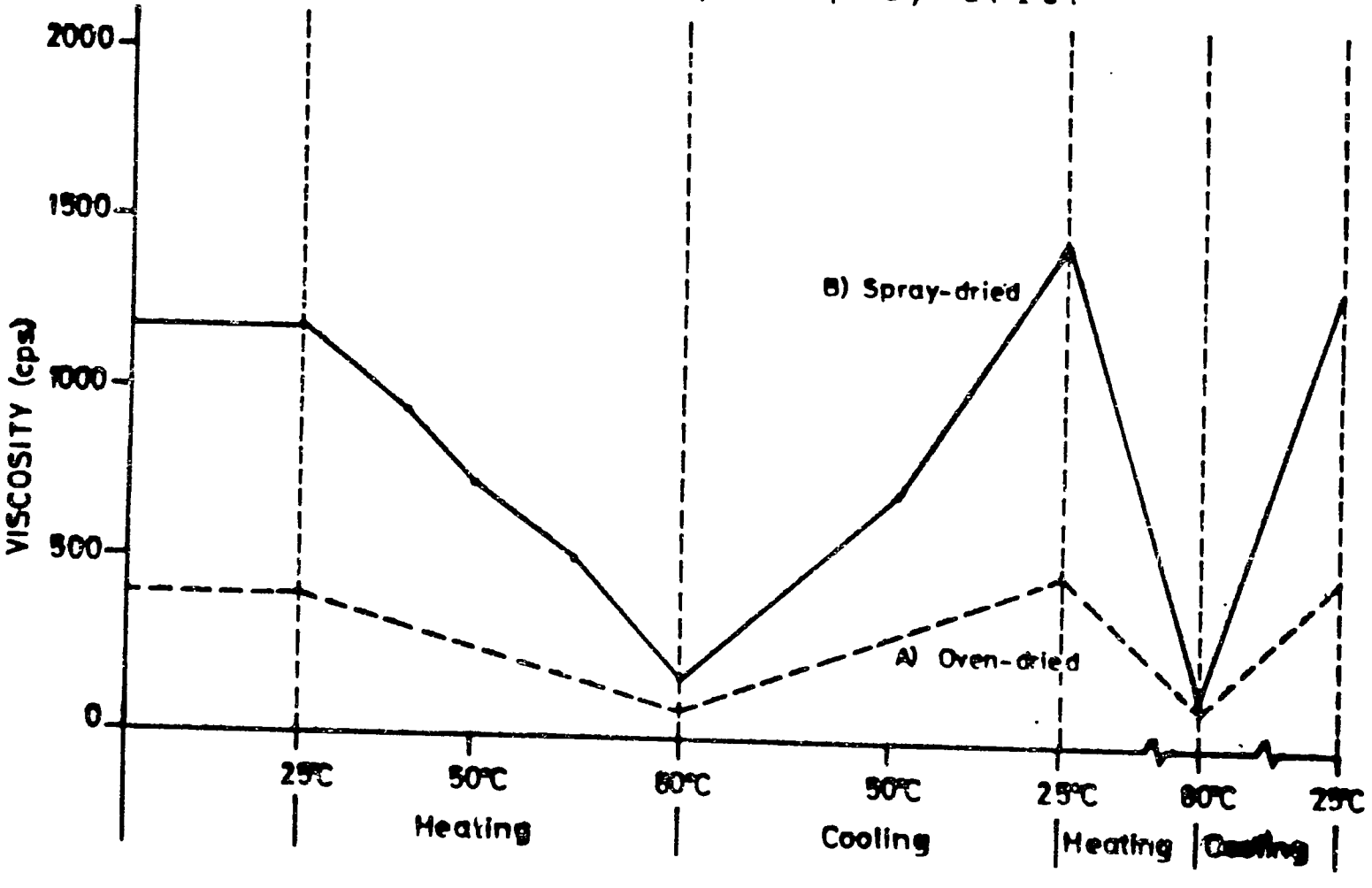
On the other hand, on heating both gum solutions, some degree of breakdown can also be observed in the spray dried products after two heatings to 80º C and further cooling to 25º C.

FIGURE Nº 2

APPARENT VISCOSITY OF PROSOPIS CHILENSIS GUM. (1% SUSPENSION)

a. Dried by oven (45º C)

b. Dried by a spray drier



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Gum extraction from P. tamarugo

Whole seeds of P. tamarugo were treated as above, but the procedure failed for this species, since it does not produce gum.

Work fot the nex period

All the assays already performed with samples from 1984 will be repeated with the material harvested during this year.

The toxic and antinutrients characteristics will be assayed in the material, and at the same time fermentation studies are being carried out in the fraction with the higher sugar content.

PROXIMATE ANALYSIS OF 1985 PROSOPIS spp SAMPLES

SAMPLE	MOISTURE (%)	PROTEIN (%Nx6,25)	FAT (%)	FIBER (%)	ASH (%)	N.N.E. (%)
P. CHILENSIS						
SEED 3P	9,27	33,80	2,97	7,41	3,35	52,47
SEED 5P	9,33	40,42	3,04	7,62	3,29	45,63
SEED POOLED P	7,54	32,93	3,54	6,44	3,40	53,69
ENDOCARPS # 5						
3P	6,54	6,39	1,21	35,05	2,43	54,92
5P	6,04	6,15	1,10	32,96	2,41	57,38
POOLED P	6,22	9,68	0,99	33,48	2,21	53,64
FINES #20						
3P	6,95	13,11	1,51	9,80	3,23	72,35
5P	7,22	13,99	1,97	9,85	3,02	71,17
POOLED P	6,12	8,24	0,97	11,45	2,32	77,02
FLOUR # 40						
3P	6,85	9,21	1,11	7,62	3,14	78,92
5P	6,39	8,40	1,37	11,02	3,04	76,17
POOLED P	5,65	9,09	1,02	8,91	2,40	78,58
WHOLE POD	8,07	9,81	1,34	9,64	2,67	76,54
P. TAMARUGO						
SEED	7,01	32,04	3,95	21,35	3,54	39,12
FIBER	9,35	9,87	0,49	42,08	4,16	43,40
FLOUR	9,48	16,35	2,77	10,72	6,20	63,96
WHOLE POD	10,19	11,30	0,99	31,85	4,42	51,44

ANTINUTRIENTS IN PROSOPIS spp.

PODS AND FRACTIONS

PROSOPIS CHILENSIS

SAMPLE	TRYPSIN INHIBITOR(1)	HEMAGGLUTININ	UREASE (2)	HCN (mg/100g)
WHOLE POD	2,3	NEGATIVE	0	0,04
SEED	4,9	NEGATIVE	0-0,02	
ENDOCARP	1,4	NEGATIVE	0-0,03	
FLOUR	3,6	NEGATIVE	0-0,02	
FIBER	1,3	NEGATIVE	0-0,2	

PROSOPIS TAMARUGO

WHOLE POD	1,4	NEGATIVE	0,02	0,11
SEED	1,2	NEGATIVE	0,08-0,10	
FLOUR	1,1	NEGATIVE	0	
FIBER	16,2	NEGATIVE	0	

(1) mg trypsin inhibited/mg sample

(2) AOCS Method - UPH

Prosopis chilensis Peldehue gives urease +

UREASE (Method : AOCS-Ba 9 -58 - Third Edition)

SAMPLES	U.P.H.
# 1 - Algarrobo Penldehue # 3 seed	0
# 2 - Algarrobo Peldehue endocarp	0
# 3 - Algarrobo Peldehue flour	0
# 4 - Algarrobo Peldehue fiber	0,02
# 5 - Algarrobo NN Peldehue seed	0,02
# 6 - Algarrobo NN Peldehue endocarp	0,03
# 7 - Algarrobo NN Peldehue flour	0,02
# 8 - Algarrobo NN Peldehue fiber	0,02
# 9 - Tamarugo seed	0,08 - 0,10
# 10 - Tamarugo flour	0
# 11 - Tamarugo endocarp	0
# 12 - Tamarugo whole pod	0,02
# 13 - Algarrobo Peldehue # 5 seed	0,02
# 14 - Algarrobo Peldehue endocarp	0
# 15 - Algarrobo Peldehue # 5 flour	0
# 16 - Algarrobo Peldehue # 5 fiber	0,03
# 18 - Algarrobo whole pod NN	0
beans (ground)	0

ENZYMATIC EVALUATION OF PROSOPIS spp FRACTIONS
IN VITRO DIGESTIBILITY

SAMPLES	DIGESTIBILITY (%)	
	1984	1985
MESQUITE FRACTIONS		
Seed 3P	--	80,20
Endocarp 3P	62,00	80,48
Fiber (#20) 3P	68,79	72,44
Flour (#40) 3P	79,29	71,88
Seed Pooled P	84,35	83,49
Endocarp Pooled P	64,42	69,68
Fiber Pooled P (# 20)	63,64	66,67
Flour Pooled (# 40)	74,59	71,03
TAMARUGO		
Seed	85,34	85,19
Endocarp	68,00	65,82
Fiber	75,24	70,23
Whole Pod	--	61,33

3-10-87

INFORME DE AVANCE

FORMULACION DE PRODUCTOS CON ALGARROBO Y TAMARUGO

Santiago, Marzo de 1986.-

INTEC — CHILE

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TRABAJO REALIZADO PROYECTO Nº1376

I. Ensayo preliminar de mezclas compuestas por endocarpio de algarrobo + harina de trigo + agua

% de sustitución

5% : Ligazón fácil, buen color aroma y amasado, homogéneo, no queda residuo.

8% : Buen color, leve aumento de pecosidad, sin residuo, buena ligazón, buen aroma

10% : Buena apariencia, leve problema de ligazón, pequeño residuo, mayor trabajo mecánico, buen aroma

15% : Buena apariencia, aumento pecosidad, mayor dificultad de amasado, más trabajo mecánico, pequeños residuos, aroma levemente herbáceo.

20% : Apariencia más oscura, pero agradable; masa inestable, residuos se incrustan en la masa que se van soltando, difícil amasado, aroma herbáceo leve

Resultados

A medida que se aumenta el % de sustitución se detecta:

1. Aumento de la corteza y disminución de la miga
2. Cocción dificultosa y prolongada
3. Aumento de dulzor
4. Menor volumen
5. Aroma a caramelo (leve)
6. Apariencia similar pan centeno

- A 10% de sustitución se detecta claramente el gusto dulce.
- Hay un sabor posterior herbáceo a partir del 15% de sustitución.

Enad

II. Ensayo preliminar de mezclas compuestas por: harinilla + harina de trigo + agua (endosperm)

% de sustitución

5% : Amasado compacto y contínuo, existe cierta cantidad de pecas absorbe menos agua que al trabajar con endoscarpio.

10% : Aumento de pecas, pequeña dificultad en amasado, se liga fácilmente, buen aroma

15% : Buena ligazón, masa blando, buen manejo, mayor proporción de pecas

20% : Buen acoplamiento, fácil manejo de la masa, buena apariencia, color oscuro y presencia de pecas.

Resultados

- Mejor manejo de la masa que al utilizar endoscarpio.
- Más intensidad de sabor "herbáceo"
- menos volumen
- Menos intensidad de dulzor

III. Determinación de la calidad del producto

a. Se utilizó el farinógrafo para determinar el rendimiento probable de pan que puede dar una harina midiendo la absorción de agua, asi como el acondicionamiento de la masa y la resistencia que presenta a su fermentación.

Variables

Absorción	>	mejor calidad
Desarrollo	>	mejor calidad
Decaimiento	<	mejor calidad
Valor W	>	mejor calidad

b. Color

c. Humedad

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A continuación se detallan los valores obtenidos en las mezclas analizadas:

Análisis	Harinilla Algarrobo % sustitución			Endoscarpio Algarrobo % sustitución		
	10%	15%	20%	10%	15%	20%
% Absorción	55,3	55,4	55,4	67,8	68,3	68,2
Desarrollo	2'	2'30"	2'	6'	5'	13'30"
Decaimiento	90	100	160	120	110	40
W	44	42	48	57	54	86
Color	12,2	14,3	17,4	13,6	15,9	Fuera escala
% Humedad	12,7	12,5	12,1	12,35	12,2	11,65

Resultados

Fueron positivos hay un aumento de la fuerza de la harina al aumentar el % de sustitución de algarrobo en particular al utilizar el endoscarpio.

El color es más alto que el normal y la cantidad de pecas va en aumento en relación a mayor sustitución.

El comportamiento de la masa es mejorado con el % de algarrobo en la mezcla.

Una harina normal registra valores de absorción de 58-60%, una humedad de 14% y un color que va entre 5,4 a 6,8

El comportamiento de amasado es bueno, sin problemas mayores de homogenización, después de un amasado contínuo.

Su apariencia, textura y aroma son satisfactorios después de la cocción.

IV. Ensayos productos de panificación (tipo casero)

Mezcla base

100 partes harinas (con diferentes % sustitución)
3 partes manteca vegetal
2 partes sal
4 partes azúcar
3 partes levadura
59 partes agua

	Mezcla con algarrobo	Mezcla con tamarugo
5%	- Buen color café claro - Corteza buena - Buen comportamiento - Sin residuo - Calidad sensorial buena	- Buena apariencia oscura - Corteza dura - Buen volumen - Calidad sensorial buena
8%	- Buen color café claro - Corteza buena - Migo blanda - Calidad sensorial buena	- Buena apariencia oscura - Corteza dura - Buen volumen - Levemente herbáceo (final)
10%	- Buen color - pecos - Esponjoso, suave - Buena corteza - Se nota dulce (leve)	- Buena apariencia, oscura - Corteza dura - Sin residuo - Leve dejo herbáceo final
15%	- Buen color - Corteza dorada - café - Se percibe dulce leve acaramelado - Dejo herbáceo final	- Apariencia pan centeno - Corteza duro - Buen color miga - Esponjoso. Color muy oscuro - Olor, sabor herbáceo leve, moderado
20%	- Buen color corteza dorada - Dulce acaramelado - Leve dejo herbáceo	- Apariencia desagradable. Oscuro - Corteza dura - Difícil cocción - Olor y sabor intenso. Herbáceo

Resultados

La sustitución máxima en algarrobo está en un 10% y en tamarugo 5%.

Las características de panificación son más alentadoras para la mezcla con algarrobo. En tamarugo predomina el sabor herbáceo penetrante tanto en aroma como en sabor desarrollado en forma posterior a la degustación, la apariencia se ve objetada por el desarrollo de la tonalidad café oscura y pecas.

V. Ensayo galletería (tipo casero)

Con fracción de algarrobo.

a. Harinilla
b. Endoscarpio

Fórmula base

100 g harina (sustitución por fracción a o b)
112 ml agua
9 g manteca
2 g goma guar o de algarrobo

Resultado

Con endoscarpio: una sustitución del 10% dió un sabor agradable, pero leve aroma herbáceo, crujiente. Se detecta el dulzor.

Con harinilla: la apariencia es más oscura, leve aroma herbáceo, crocante

La adición de goma de algarrobo presentó mejor resultado. La textura es más crocante comparada con las galletas preparadas con goma guar.

Hay que pensar en niveles de sustitución inferiores al 10% en ambas fracciones de algarrobo.

VI. Ensayo Productos Pastelería: elaboración de berlines

Fórmula base

100 g harina (sustitución endoscarpio de algarrobo o harinilla)
30 g azúcar
30 g margarina
2,5 g sal
2,5 g levadura
0,5 ml Panetone (saborizante)
2 ml solución 1% de tartrazina
115 ml de agua

Resultados

Fueron alentadores, se puede trabajar con sustitución de 10 a 15% de endoscarpio y menos de 10% de harinilla (leve dejo herbáceo posterior).

EL producto tiene buena apariencia, sin problemas de amasado, buena eludación con 15% se debilita un poco, sabor agradable, se detecta más dulce el producto elaborado con endoscarpio, textura buena.

ENZYMATIC EVALUATION OF PROSOPIS spp FRACTIONS
IN VITRO DIGESTIBILITY

SAMPLES	DIGESTIBILITY (%)	
	1984	1985
MESQUITE FRACTIONS		
Seed 3P	--	80,20
Endocarp 3P	62,00	80,48
Fiber (#20) 3P	68,79	72,44
Flour (#40) 3P	79,29	71,88
Seed Pooled P	84,35	83,49
Endocarp Pooled P	64,42	69,68
Fiber Pooled P (# 20)	63,64	66,67
Flour Pooled (# 40)	74,59	71,03
TAMARUGO		
Seed	85,34	85,19
Endocarp	68,00	65,82
Fiber	75,24	70,23
Whole Pod	--	61,33

ANTINUTRIENTS IN PROSOPIS spp.

PODS AND FRACTIONS

PROSOPIS CHILENSIS

SAMPLE	TRYPSIN INHIBITOR(1)	HEMAGGLUTININ	UREASE (2)	HCN (mg/100g)
WHOLE POD	2,3	NEGATIVE	0	0,04
SEED	4,9	NEGATIVE	0-0,02	
ENDOCARP	1,4	NEGATIVE	0-0,03	
FLOUR	3,6	NEGATIVE	0-0,02	
FIBER	1,3	NEGATIVE	0-0,2	

PROSOPIS TAMARUGO

WHOLE POD	1,4	NEGATIVE	0,02	0,11
SEED	1,2	NEGATIVE	0,08-0,10	
FLOUR	1,1	NEGATIVE	0	
FIBER	16,2	NEGATIVE	0	

(1) mg trypsin inhibited/mg sample

(2) AOCS Method - UPH

Prosopis chilensis Peldehue gives urease +

UREASE (Method : AOCS-Ba 9 -58 - Third Edition)

SAMPLES	U.P.H.
# 1 - Algarrobo Penldehue # 3 seed	0
# 2 - Algarrobo Peldehue endocarp	0
# 3 - Algarrobo Peldehue flour	0
# 4 - Algarrobo Peldehue fiber	0,02
# 5 - Algarrobo NN Peldehue seed	0,02
# 6 - Algarrobo NN Peldehue endocarp	0,03
# 7 - Algarrobo NN Peldehue flour	0,02
# 8 - Algarrobo NN Peldehue fiber	0,02
# 9 - Tamarugo seed	0,08 - 0,10
# 10 - Tamarugo flour	0
# 11 - Tamarugo endocarp	0
# 12 - Tamarugo whole pod	0,02
# 13 - Algarrobo Peldehue # 5 seed	0,02
# 14 - Algarrobo Peldehue endocarp	0
# 15 - Algarrobo Peldehue # 5 flour	0
# 16 - Algarrobo Peldehue # 5 fiber	0,03
# 18 - Algarrobo whole pod NN	0
beans (ground)	0

GLUSIDOS CIANOGENICOS

MUESTRA Nº	mg HCN % g muestra (base seca)
1 - Algarrobo Peldehue , árbol 3, semilla	N.D.
2 - Algarrobo Peldehue, árbol 3 endocarpio	6,18
3 - Algarrobo Peldehue, árbol 3, harinilla	4,75
4 - Algarrobo Peldehue, árbol 3, fibra	8,32
5 - Algarrobo Peldehue, NN, semilla	2,39
6 - Algarrobo Peldehue, NN, endocarpio	0,28
7 - Algarrobo Peldehue, NN, harinilla	1,46
8 - Algarrobo Peldehue, NN, fibra	1,91
9 - Tamarugo, semilla	2,93
10 - Tamarugo harinilla	5,68
11 - Tamarugo, corteza (endocarpio)	2,61
12 - Tamarugo, fruto completo	5,38
13 - Algarrobo, Peldehue, arból Nº 5, semilla	ND
14 - Algarrobo Peldehue, árbol Nº 5, endocarpio	4,14
15 - Algarrobo Peldehue, árbol Nº 5 harinilla	4,73
16 - Algarrobo Peldehue, árbol Nº 5, fibra	5,78
17 - -----	
18 - Algarrobo Peldehue, NN, fruto completo	5,22

(*) ND = No se determinó por no contar con suficiente muestra

Método

Hydrocyanic Acid in Beans - Titrimetric Method - Acid Titration Method. AOAC, (26.150). Fourteenth Edition, 1984

Fundamento del método

Los glucósidos son hidrolizados mediante remoja en agua y posterior destilación, el HCN desprendido es atrapado en $AgNO_3$ acidificado con HNO_3, el pp formado es filtrado a través de un gooch y luego el exceso de $AgNO_3$ es titulado con NH_4SCN usando alumbre férrica como indicador.

Santiago, Marzo de 1986.-

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July 86

INFORME

EVALUACION SENSORIAL

PRODUCTOS DE ALGARROBO

Santiago, Julio de 1986.-

INTEC CHILE

INFORME DE AVANCE II

EVALUACION SENSORIAL DE PRODUCTOS ELABORADOS CON ALGARROBO

1. ANTECEDENTES

El objetivo de este estudio fue el de determinar el comportamiento de el endoscarpio de algarrobo en la sustitución de la harina de trigo en la elaboración de pan amasado en forma industrial, las pruebas se realizaron en una amasandería de Santiago bajo la supervisión de INTEC/CHILE.

Se trabajó en las pruebas de evaluación sensorial con 24 jueces de INTEC/CHILE de ambos sexos.

2. ELABORACION DEL PRODUCTO

Se empleó la fracción de endoscarpio con las mismas especificaciones que el utilizado en la elaboración de berlín.

Se utilizó una fórmula base. Ver Apéndice, Cuadro Nº 1.

Los tratamientos ensayados fueron los siguientes:

A. Muestra control vs sustitución del 10% de harina por endoscarpio sin mejorador.

B. Muestra control vs sustitución del 8% de harina por endoscarpio sin mejorador

C. Muestra control vs sustitución del 10% de harina por endoscarpio con mejorador

D. Muestra control vs sustitución del 8% de harina por endoscarpio con mejorador

Todos los tratamientos se realizaron siguiendo un control riguroso del proceso. Ver Apéndice. Cuadro Nº 3.

3. EVALUACION SENSORIAL

Se realizaron las siguientes pruebas:

- Prueba de comparación en pares dirigida a Preferencia del producto
- Prueba de Escala Hedónica de cinco intervalos para determinar el nivel de agrado de las muestras
- Sistema de clasificación de cinco puntos (Buena a Mala) para determinar el nivel de calidad del pan

Con el objeto de completar la información cuantitativa se caracterizó el producto en sus factores más relevantes.

3.1. Análisis Estadístico

Se emplearon tablas estadísticas específicas y análisis de χ^2.

4. PRESENTACION DE RESULTADOS

A continuación se presentan tablas con los valores obtenidos.

EVALUACION SENSORIAL PAN AMASADO

TRATAMIENTO : A

PRUEBAS REALIZADAS	MUESTRAS CONTROL	MUESTRAS ESTUDIO
COMPARACION PARES - Juicios a favor (Preferencia)	23	1
SIGNIFICACION ESTADISTICA - Calculada - Tabulada	18,375 0,1% 0,1%	0,1%
CALIDAD DE LA MUESTRA Escala 1 - 5	4,6	3,2
GRADO DE CALIDAD	Satisfactoria Buena	Aceptable
NIVEL DE AGRADO %		
- Agrada mucho	33,3	0
- Agrada	58,3	37,5
- Me es indiferente	8,3	25,0
- Me desagrada	0	37,5
- Me desagrada mucho	0	0
CARACTERIZACION CALIDAD SENSORIAL GENERAL	Buena apariencia Sabor típico agradable Textura blanda esponjosa, suave	Apariencia pan centeno Sabor extraño, levemente dulzón presencia de grumos

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EVALUACION SENSORIAL PAN AMASADO

TRATAMIENTO : B

PRUEBAS REALIZADAS	MUESTRA CONTROL	MUESTRA ESTUDIO
COMPARACION PARES - Juicios a favor (Preferencia)	21	3
SIGNIFICACION ESTADISTICA - Calculada - Tabulada	12,041 0,1% 0,1%	0,1%
CALIDAD DE LA MUESTRA Escala 1 - 5	4,2	3,0
GRADO DE CALIDAD	Satisfactoria	Aceptable
NIVEL DE AGRADO % - Agrada mucho - Agrada - Me es indiferente - Me desagrada - Me desagrada mucho	 20,8 62,5 12,5 4,1 0	 8,3 25,0 20,8 37,5 8,3
CARACTERIZACION CALIDAD SENSORIAL GENERAL	Buena apariencia sabor típico, agradable Buena textura suave, esponjosa	Apariencia similar pan centeno sabor no es típico, se desarrolla sabor posterior herbáceo, ácido. Buena textura

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EVALUACION SENSORIAL PAN AMASADO

TRATAMIENTO : C

PRUEBAS REALIZADAS	MUESTRA CONTROL	MUESTRA ESTUDIO
COMPARACION PARES		
- Juicios a favor (Preferencia)	19	5
SIGNIFICACION ESTADISTICA		
- Calculada	7,041 1%	1%
- Tabulada	1%	
CALIDAD DE LA MUESTRA		
Escala 1 - 5	4,3	3,6
GRADO DE CALIDAD	Satisfactoria	Aceptable Satisfactoria
NIVEL DE AGRADO %		
- Agrada mucho	37,5	4,1
- Agrada	41,6	45,8
- Me es indiferente	16,6	29,1
- Me desagrada	4,1	12,5
- Me desagrada mucho		8,3
CARACTERIZACION CALIDAD SENSORIAL GENERAL	Buena apariencia Sabor agradable típico Textura crujiente esponjoso, blanda, homogénea, suave	Apariencia similar al pan centeno Sabor leve dejo amargo, extraño Textura esponjosa

EVALUACION SENSORIAL PAN AMASADO

TRATAMIENTO : D

PRUEBAS REALIZADAS	CONTROL	MUESTRA ESTUDIO
COMPARACION PARES - Juicios a favor (Preferencia)	19	4
SIGNIFICACION ESTADISTICA - Calculada - Tabulada	8,521 1% 0,5%	1% 0,5%
CALIDAD DE LA MUESTRA Escala 1 - 5	4,3	3,6
GRADO DE CALIDAD	Satisfactoria	Aceptable Satisfactorio
NIVEL DE AGRADO % - Agrada mucho - Agrada - Me es indiferente - Me desagrada - Me desagrada mucho	 34,8 56,5 4,3 4,3	 13,0 39,1 30,4 17,4
CARACTERIZACION CALIDAD SENSORIAL GENERAL	Buen color Sabor agradable Textura blanda	Color oscuro Similar al pan centeno Sabor agradable se detecta buen nivel de sal. Textura se nota mucho la fibra áspero

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CONCLUSIONES

1. Se prefiere el pan sin reemplazo de la harina de trigo por el endoscarpio de algarrobo. Las diferencias son estadísticamente significativas para los niveles de 8 y 10% de sustitución.

2. Es necesario adicionar mejorador de pan para obtener una calidad panadera superior.

3. La calidad sensorial del pan con niveles de 8% a 10 % de endoscarpio de algarrobo más mejorador se define de aceptable a satisfactoria.

4. El rechazo sensorial del pan fabricado con un 8 a 10% de endoscarpio más mejorador es bajo, no supera al 20%.

OBSERVACIONES

Con el propósito de llegar a definir el nivel más aconsejable de sustitución y poder determinar si tenemos diferencias menores, se hará una formulación con un 5% de reemplazo de harina de trigo por endoscarpio.

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A P E N D I C E

CUADRO Nº 2

CONTROL DE PROCESO

EXPERIENCIA Nº _____ FECHA : _____

HORA INICIO: _____ HORA TERMINO: _____

INGREDIENTES	grs
Harina	____
Margarina	____
Levadura	____
Mejorador	____
Sal	____
Agua	____
Endoscarpio	____
Harinilla	____

Tiempo amasado	10 minutos
Tiempo fermentación	95 minutos
Temperatura horno	300º C
Tiempo cocción	7 minutos

Nº panes _____

OBSERVACIONES

_____

_____

_____

_____

CUADRO Nº 1

FORMULA BASE

Harina	2000 grms
Margarina	66,6 grms
Levadura	16,0 grms
Mejorador	66,6 grms
Sal	22,5 grms
Agua	1600 cc
Endoscarpio	
Harinilla	

INFORME

EVALUACION SENSORIAL
PRODUCTOS DE ALGARROBO

Santiago, Julio de 1986.-

INTEC - CHILE

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INFORME DE AVANCE

EVALUACION SENSORIAL DE PRODUCTOS ELABORADOS CON ALGARROBO

1. Antecedentes

El objetivo de ete estudio fue el complementar los ensayos realizados en forma artesanal del año 1985 en los cuales se vislumbró con buenas perspectivas la utilización de endoscarpio y harinillo de algarrobo como extensor de la harina de trigo tanto en productos de panificación como de repostería.

La elaboración de los productos se hizo a escala industrial, en una amasandería de Santiago bajo la supervisión de INTEC/CHILE durante todo el proceso. Se eligió en la línea de repostería el berlín por ser de consumo masivo y de un precio conveniente a la población.

Las pruebas de evaluación sensorial se realizaron utilizando 24 jueces de INTEC/CHILE de ambos sexos.

2. Elaboración de Productos

Se utilizó algarrobo de la cosecha del año, separando las dos fracciones endoscarpio y harinilla, para cumplir con una buena especificación en cuanto al tamaño de partícula, se empleó el molino RIZT y se pasó por malla # 40.

Se le hizo el control microbiológico a la materia prima. Ver Apéndice Cuadro Nº 1 y Nº 2. (Producto terminado).

2.2. Elaboración de Berlín

Se utilizó una fórmula base, Apéndice Cuadro Nº 3.
Los tratamientos ensayados fueron los siguientes:

A. Muestra Control vs Sustitución 10% de harina por endoscarpio sin mejorador, sin esencia y sin colorante

B. Muestra Control vs Sustitución 10% de harina por endoscarpio, sin mejorador, con esencia, con color.

C. Muestra Control vs Sustitución 10% de harina por endoscarpio sin mejorador, con color con esencia Givaudan.

D. Muestra Control vs Sustitución 10% de harina por endoscarpio con mejorador, con color con esencia de vainilla

E. Muestra Control vs Sustitución 10% de harina por endoscarpio con mejorador con color y con esencia Givaudan.

F. Muestra Control vs Sustitución 8% de harina por endoscarpio, sin mejorador con esencia y con color.

G. Muestra Control vs Sustitución 8% de harina por endoscarpio, con mejorador con color y con esencia.

H. Muestra Control vs Sustitución 8% de la harina por endoscarpio sin mejorador, con color y con esencia Givaudan

I. Muestra Control vs Sustitución 8% de harina por endoscarpio con mejorador con color y con esencia Givaudan.

Todos los tratamientos se realizaron siguiendo un control riguroso del proceso. Apéndice Cuadro Nº 4.

2.3. Evaluación Sensorial

Se utilizaron las siguientes pruebas:

- Prueba de Comparación en Pares para determinar la preferencia de las muestras.
- Prueba de Escala Hedónica de cinco intervalos para determinar el nivel de agrado de las muestras.
- Sistemas de clasificación de cinco puntos (Buena a Mala) para determinar el nivel de calidad de las muestras

Con el propósito de complementar la información cuantitativa, se caracterizó el producto en sus factores más sobresalientes.

2.4. Análisis Estadístico

Se emplearon tablas estadísticas específicas y análisis de χ^2.

3. Presentación de Resultados

A continuación se presentan tablas con los valores obtenidos.

EVALUACION SENSORIAL BERLINES

TRATAMIENTO : A

PRUEBAS REALIZADAS	Muestras CONTROL	ESTUDIO
COMPARACION PARES		
- Juicios a favor (Preferencia)	20	4
SIGNIFICACION ESTADISTICA		
- Calculada	9,375 1%	1%
- Tabulada	0,5%	0,5%
CALIDAD DE LA MUESTRA		
Escala 1 - 5	4,0	3,1
GRADO DE CALIDAD	Satisfactoria	Aceptable
NIVEL DE AGRADO %		
- Agrada mucho	29,2	4,1
- Agrada	54,1	37,5
- Me es indiferente	4.1	8,3
- Me desagrada	12,5	50,0
- Me desagrada mucho	0	0
CARACTERIZACION CALIDAD SENSORIAL GENERAL	Buena apariencia color y tamaño sabor agradable blanda, suave	Falta color masa tonalidad oscura, falta sabor típico, desarrollo sabor posterior, herbáceo

EVALUACION SENSORIAL BERLINES

TRATAMIENTO : B

PRUEBAS REALIZADAS	Muestra CONTROL	Muestra ESTUDIO
COMPARACION PARES		
- Juicios a favor (Preferencia)	22	2
SIGNIFICACION ESTADISTICA		
- Calculada	15,041 0,1%	0,1%
- Tabulada	0,1%	
CALIDAD DE LA MUESTRA		
Escala 1 - 5	4,2	3,6
GRADO DE CALIDAD	Satisfactoria	Aceptable Satisfactoria
NIVEL DE AGRADO %		
- Agrada mucho	20,8	8,3
- Agrada	66,6	37,5
- Me es indiferente	8,3	41,6
- Me desagrada	4,1	8,3
- Me desagrada mucho	0	4,1
CARACTERIZACION CALIDAD SENSORIAL GENERAL	Buena apariencia color tamaño Buen sabor Textura suave esponjosa	Color oscuro sabor predomina gusto harina integral, leve Textura áspera

EVALUACION SENSORIAL BERLINES

TRATAMIENTO : C

PRUEBAS REALIZADAS	Muestras CONTROL	Muestras ESTUDIO
COMPARACION PARES		
- Juicios a favor (Preferencia)	16	8
SIGNIFICACION ESTADISTICA		
- Calculada	2,041 N.S.	N.S.
- Tabulada	N.S.	
CALIDAD DE LA MUESTRA		
Escala 1 - 5	4,6	4,0
GRADO DE CALIDAD	Satisfactoria Buena	Satisfactoria
NIVEL DE AGRADO %		
- Agrada mucho	33,3	20,8
- Agrada	58,3	45,8
- Me es indiferente	4,1	20,8
- Me desagrada	4,1	12,5
- Me desagrada mucho	0	0
CARACTERIZACION CALIDAD SENSORIAL GENERAL	Buena apariencia Mejor sabor Agradable Textura esponjosa	Color oscuro con pintas. Diferente volumen Buen sabor Textura más seca, áspera, masa más apretada

N.S. = no significativas las diferencias

EVALUACION SENSORIAL BERLINES

TRATAMIENTO : D

PRUEBAS REALIZADAS	Muestras CONTROL	Muestras ESTUDIO
COMPARACION PARES		
- Juicios a favor (Preferencia)	14	9
SIGNIFICACION ESTADISTICA		
- Calculada	0,695 N.S.	N.S.
- Tabulada	N.S.	
CALIDAD DE LA MUESTRA		
Escala 1 - 5	4,1	3,7
GRADO DE CALIDAD	Satisfactoria	Aceptable Satisfactoria
NIVEL DE AGRADO %		
- Agrada mucho	17,4	8,7
- Agrada	47,8	60,8
- Me es indiferente	30,4	21,7
- Me desagrada	4,3	8,7
- Me desagrada mucho	0	0
CARACTERIZACION CALIDAD SENSORIAL GENERAL	Buena apariencia Sabor agradable típico Textura esponjosa	Color de la masa más oscuro Buen sabor, sabroso, mejor dulzor Textura: se disuelve con facilidad

N.S. = no significativa las diferencias

EVALUACION SENSORIAL BERLINES

TRATAMIENTO : E

PRUEBAS REALIZADAS	Muestras CONTROL	ESTUDIO
COMPARACION PARES - Juicios a favor (Preferencia)	19	8
SIGNIFICACION ESTADISTICA - Calculada - Tabulada	3,703 N.S. N.S.	N.S.
CALIDAD DE LA MUESTRA Escala 1 - 5	4,6	3,9
GRADO DE CALIDAD	Satisfactoria Buena	Satisfactoria Aceptable
NIVEL DE AGRADO %		
- Agrada mucho	45,8	29,1
- Agrada	54,1	45,8
- Me es indiferente	0	12,5
- Me desagrada	0	12,5
- Me desagrada mucho	0	0
CARACTERIZACION CALIDAD SENSORIAL GENERAL	Buena apariencia Buen sabor, agradable, tradicional Textura esponjosa	Apariencia deteriorada, harina gruesa Sabor típico Textura esponjosa

N.S. = no significativa las diferencias

EVALUACION SENSORIAL BERLINES

TRATAMIENTO : F

PRUEBAS REALIZADAS	Muestra CONTROL	Muestra ESTUDIO
COMPARACION PARES - Juicios a favor (Preferencia)	17	10
SIGNIFICACION ESTADISTICA - Calculada - Tabulada	1,333 N.S. N.S.	N.S.
CALIDAD DE LA MUESTRA Escala 1 - 5	4,4	3,8
GRADO DE CALIDAD	Satisfactoria	Satisfactoria Aceptable
NIVEL DE AGRADO % - Agrada mucho - Agrada - Me es indiferente - Me desagrada - Me desagrada mucho	 29,1 62.5 8,3 0 0	 20,8 45.8 12,5 20,8 0
CARACTERIZACION CALIDAD SENSORIAL GENERAL	Buen color y tamaño Sabor típico Textura suave esponjosa	Color más oscuro. Sabor agradable, buen dulzor Textura: menos esponjosa y menos suave

N.S. = no significativas las diferencias

EVALUACION SENSORIAL BERLINES

TRATAMIENTO : G

PRUEBAS REALIZADAS	Muestras CONTROL	ESTUDIO
COMPARACION PARES		
- Juicios a favor (Preferencia)	21	4
SIGNIFICACION ESTADISTICA		
- Calculada	10.240 1%	1%
- Tabulada	0,1%	0,1%
CALIDAD DE LA MUESTRA		
Escala 1 - 5	4,5	3,5
GRADO DE CALIDAD	Satisfactoria	Aceptable
NIVEL DE AGRADO %		
- Agrada mucho	36	8
- Agrada	60	48
- Me es indiferente	4	28
- Me desagrada	0	16
- Me desagrada mucho	0	0
CARACIERIZACION CALIDAD SENSORIAL GENERAL	Buena apariencia buen color, tamaño, sabor agradable Textura buena, suave, esponjosa	Buena apariencia, mas más oscura Sabor bueno, agradable, buen dulzor Textura esponjosa

EVALUACION SENSORIAL BERLINES

TRATAMIENTO : H

PRUEBAS REALIZADAS	CONTROL	ESTUDIO
		Muestras
COMPARACION PARES - Juicios a favor (Preferencia)	20	5
SIGNIFICACION ESTADISTICA - Calculada - Tabulada	7,840 1% 1%	1% 1%
CALIDAD DE LA MUESTRA Escala 1 - 5	4,5	3,6
GRADO DE CALIDAD	Satisfactoria	Satisfactoria Aceptable
NIVEL DE AGRADO % - Agrada mucho - Agrada - Me es indiferente - Me desagrada - Me desagrada mucho	 50,0 37,5 8,3 4,1 0	 8,3 58,3 20,8 12,5 0
CARACTERIZACION CALIDAD SENSORIAL GENERAL	Buena apariencia buen color Sabor agradable típico Textura buena esponjosa	Color más oscuro Sabor agradable, limón rico, buen dulzor, buen aroma

EVALUACION SENSORIAL BERLINES

TRATAMIENTO : I

PRUEBAS REALIZADAS	Muestras CONTROL	ESTUDIO
COMPARACION PARES		
- Juicios a favor (Preferencia)	15	10
SIGNIFICACION ESTADISTICA		
- Calculada	0,640 N.S.	N.S.
- Tabulada	N.S.	
CALIDAD DE LA MUESTRA		
Escala 1 - 5	4,2	4,0
GRADO DE CALIDAD	Satisfactoria	Satisfactoria
NIVEL DE AGRADO %		
- Agrada mucho	25,0	33,3
- Agrada	58,3	41,6
- Me es indiferente	16,6	25,0
- Me desagrada	0	0
- Me desagrada mucho	0	0
CARACTERIZACION CALIDAD SENSORIAL GENERAL	Buena apariencia Sabor agradable típico Textura esponjosa suave, blanda	Color más oscuro. Sabor agradable, limón buen dulzor y aroma Textura blanda esponjosa algo más áspera

N.S. = no significativa las diferencias

4. Conclusiones

1. Los resultados obtenidos son altamente satisfactorios. Es factible utilizar endoscarpio de algarrobo como sustituto de la harina de trigo en proporciones que van entre un 8 y 10% en la fabricación de berlines.

2. Se logró un producto de similares características a la muestra control 100% harina de trigo, tanto en su calidad sensorial como en el nivel de aceptabilidad, siempre que se utilice mejorador colorante y esencia en la fabricación.

3. La adición del mejorador es fundamental para obtener un producto similar al control. Las fórmulas que no llevaban dicho aditivo, sus diferencias son estadísticamente significativas.

4. Para obtener un buen sistema de cocción del berlín es necesario utilizar 180º C y 3 minutos por lado, se dora la superficie y se cuece por dentro.

5. Observaciones

- Por razones obvias como es el evitar todo tipo de enmascaramiento del sabor se trabajo con berlín sin relleno.

- El tipo de masa del berlín es muy frágil, pero se pudo trabajar sin problemas, su acoplamiento es mediano, requiere de un poco más de trabajo.

APENDICE

CUADRO Nº 1

ANALISIS MICROBIOLOGICO

Muestra : Harina de Algarrobo

RESULTADOS

	MUESTRA
Recuento de gérmenes viables/g	3×10^3
Coliformes, NMP/g	93
Coliformes fecales	s.d.(1)
S. aureus	s.d.
Salmonella	s.d.
Hongos y levaduras/g	1×10^3

(1) s.d. = sin desarrollo

CUADRO Nº 2

ANALISIS MICROBIOLOGICO

Muestra : Berlines

RESULTADOS

	Berlín de Algarrobo	Berlín Control
Recuento total de gérmenes viables/gr	20	50
Hongos y levaduras/gr	20	70
Coliformes NMP/gr	s.d.(1)	s.d.
Coliformes fecales NMP.g	s.d.	s.d.
S. aureus/gr	s.d.	s.d.
Salmonella/25 g	s.d.	s.d.

(1) s.d. = sin desarrollo

CUADRO Nº 3

FORMULA BASE BERLIN

Harina	1000 gr
Levadura	60 gr
Mejorador S-500 LEFERSA	46 gr
Azúcar	150 gr
Margarina	150 gr
Huevo	2 unidades
Sal	10 gr
Vainilla "La Habanera"	16 cc
Amarillo Vegetal Michelson 10% p/p	8 cc
Esencia 79460 Givaudan	2,5 cc
Agua	400 cc

CUADRO Nº 4

CONTROL DE PROCESO

EXPERIENCIA Nº : _____ FECHA : _____

HORA INICIO: _____ HORA TERMINO: _____

INGREDIENTES

	grs.	c.c.
Harina	___	___
Levadura	___	___
Mejorador	___	___
Azúcar	___	___
Margarina	___	___
Huevos	___	___
Sal	___	___
Vainilla	___	___
Amarillo Veb.	___	___
Esencia 79460	___	___
Harinilla o endoscarpio	___	___
Otros (H20)	___	___
Tiempo amasado	_____	
Tiempo ovillado	_____	
Tiempo fermentación	_____	
Temperatura aceite	_____	
Tiempo cocción	_____	

Nº berlines: _____

OBSERVACIONES _____

_____

_____

3-10-87

INFORME

EVALUACION SENSORIAL PRODUCTOS DE ALGARROBO

Santiago, Agosto de 1986.-

INTEC – CHILE

INFORME DE AVANCE III

EVALUACION SENSORIAL DE PRODUCTOS ELABORADOS CON ALGARROBO

1. ANTECEDENTES

El objetivo de este estudio fue el de determinar el comportamiento de la fracción de algarrobo denominada harinilla, en la sustitución de la harina de trigo en la elaboración de berlines en forma industrial, las pruebas se realizaron en una amasandería de Santiago bajo la supervisión de INTEC/CHILE.

Se trabajó en las pruebas de evaluación sensorial con 24 jueces de INTEC/CHILE de ambos sexos.

2. ELABORACION DEL PRODUCTO

Se utilizó la fracción (harinilla) con las especificaciones dadas en el primer informe de avance, ajustándose a la misma fórmula tipo y al control riguroso de todo el proceso de fabricación.

De acuerdo a los resultados obtenidos empleando endoscarpio de algarrobo en la fabricación de berlín, el número de ensayos se disminuyó realizándose los siguientes:

A. Muestra control vs sustitución de 8% de harina por harinilla, con mejorador, color y esencia de vainilla.

B. Muestra control vs sustitución del 10% de harina por harinilla con mejorador, con color y esencia de vainilla.

C. Muestra control vs sustitución del 10% de harina por harinilla con mejorador, con color y con esencia Givaudan.

3. EVALUACION SENSORIAL

Se realizaron las siguientes pruebas:

- Prueba de comparación en pares dirigida a Preferencia del producto.
- Prueba de Escala Hedónica de cinco intervalos para determinar el nivel de agrado de las muestras.
- Sistema de clasificación de cinco puntos (Buena a Mala) para determinar el nivel de calidad del berlín.

Con el objeto de complementar la información cuantitativa se caracterizó el producto en sus factores más relevantes.

3.1. Análisis estadístico

Se emplearon tablas estadísticas específicas y análisis del χ^2

4. PRESENTACION DE RESULTADOS

A continuación se presentan tablas con los valores obtenidos.

EVALUACION SENSORIAL DE BERLIN

TRATAMIENTO : A

Pruebas realizadas	Control	Estudio
Comparación Pares (Juicios a favor, Preferencia)	15	10
Significación estadística		
- Calculada	0,640 x N.S.	N.S.
- Tabulada	N.S.	N.S.
Calidad de la muestra Escala (1 - 5)	4,5	3,8
Grado de calidad	Satisfactoria	Satisfactoria Aceptable
Nivel de agrado %		
. Agrada mucho	34,8	34,7
. Agrada	60,8	30,4
. Me es indiferente	4,3	26,1
. Me desagrada	0	8,7
. Me desagrada mucho	0	0
Caracterización Calidad Sensorial General	Buena apariencia Agradable sabor Típico Textura esponjosa suave	Buen sabor, aroma agradable, Textura crujiente, le falta un poco de esponjosidad

N.S. - no significativas las diferencias.

EVALUACION SENSORIAL DE BERLIN

TRATAMIENTO : B

Pruebas realizadas	Control	Estudio
Comparación Pares (Juicios a favor preferencia)	16	7
Significación estadística		
. Calculada	2,782 N.S.	N.S.
. Tabulada	N.S.	N.S.
Calidad de la muestra Escala (1-5)	4,3	3,6
Grado de calidad	Satisfactoria	Aceptable Satisfactoria
Nivel de agrado %		
. Agrada mucho	26,1	18,2
. Agrada	59,1	36,3
. Me es indiferente	9,1	31,8
. Me desagrada	4,5	13,6
. Me desagrada mucho	0	0
Caracterización Calidad Sensorial General	Buena apariencia Buen sabor, agrable, textura blanda esponjosa	Color adecuado Sabor agradable buen dulzor, leve dejo amargo posterior, Textura blanda crujiente, algo seca, leve aspereza final

N.S. No significativas las diferencias

EVALUACION SENSORIAL DE BERLIN

TRATAMIENTO C

Pruebas realizadas	Control	Estudio
Comparación en pares (Juicios a favor Preferencia)	16	11
Significación estadística		
. Calculda	0,592 N.S.	N.S.
. Tabulada	N.S.	N.S.
Calidad de la muestra Escala (1-5)	4,5	3,9
Grado de calidad	Satisfactoria	Satisfactoria Aceptable
Nivel de agrado %		
. Agrada mucho	29,1	33,3
. Agrada	62,5	33,3
. Me es indiferente	8,3	20,8
. Me desagrada	0	12,5
. Me desagrada mucho	0	0
Caracterización Calidad Sensorial General	Buena apariencia Sabor agradable Textura esponjosa blanda	Color adecuado pero más oscuro Sabor agradable a limón, más rico, aromática leve dejo amargo posterior. Textura crujiente blanda, algo fibrosa

N.S. = no significativas las diferencias

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CONCLUSIONES

1. Los resultados obtenidos son altamente satisfactorios. Es posible utilizar harinilla de algarrobo como sustituto de la harina de trigo en proporciones que van entre un 8 y un 10% en la fabricación de berlines. Las diferencias entre los tratamientos en Preferencia no fueron estadísticamente satisfactorios.

2. Se logró un producto de características muy parecidas al control 100% harina de trigo tanto en su calidad sensorial como en el nivel de aceptabilidad, utilizando colorante y esencia en su fabricación.

3. El producto experimenta un realce de sus características sensoriales al emplear la esencia Givaudan # 79460.

4. Se observó un mejor volumen en el producto comparado con las muestras elaboradas con endoscarpio de algarroba.

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CROPS FOR PRODUCTION IN MARGINAL GROWING AREAS IN CHILE

SUMMARY OF ACTIVITIES DURING 1986

Introduction

INTEC-CHILE has a research contract with the U.S. Agricultural Research Service, Pacific Basin Area, since May 1984.

This summary of activities covers the period March through December 1987.

The aim of this project is to define parameters required to exploit components of *Prosopis* species pods, as food, feed, and industrial resources.

Activities during 1986

1. Pod Collection

   Pods of *P. tamarugo* were collected from trees of the Pampa del Tamarugal.

   Pods of *P. chilensis* were collected out of only one population this year: Peldehue. Chincolco's trees did not produce fruits this season. About 50 kg of pods were harvested this year. Some of the fruits were damaged.

2. Separation of fractions

   The pods of *P. chilensis* and *P. tamarugo* were separated as the described conditions in the First Annual Report.

   With this process were obtained the following fractions:

   Prosopis chilensis :

   - Seeds
   - Endocarp
   - Mesocarp (Flour)
   - Exocarp and Mesocarp (fiber, mixture)

   Recd from Torres
   Mar 9, 1987.

   Prosopis tamarugo

   - Seeds
   - Exocarp and mesocarp (flour)
   - Exocarp (fiber)

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3. Proximate analysis

The proximate analysis for the pods harvested during the 1986 season were performed.

4. Digestibility assay

The protein digestibility by an enzimatic methodology was used for assaying some of the fraction pods. This was a repetition of various samples collected during the season 1986.

5. Fermentation trials

Two fractions of P. chilensis: were treated as substrate for fermenting with yeast, in order to obtain an alcoholic beverage.

The results showed that alcoholic fermentation is possible by utilizing the mesocarp (flour) and exocarp plus mesocarp fractions.

6. Products formulation with two different fractions of Prosopis pods

P. chilensis and P. tamarugo were used for formulating some products as bread (dietary fiber bread), cookies, and a special type of chilean doughnuts, called "berlines".

The fractions used for sustitution of flour are: endocarp (P. chilensis), mesocarp (P. chilensis) and exocarp (fiber) and exocarp plus mesocarp (flour) of P. tamarugo

The levels of sustitution for this fractions, in the mixture wheat flour, water and additives, is around 8 to 10% for P. chilensis and about 5% for P. tamarugo

From the laboratory level this was afterwards, performed at an industrial level. Some of the products got a good acceptance level, with a sensory evaluation panel. This was specially truth for the products formulated with P. chilensis fractions.

A microbiological analysis for the raw fractions and for the final products was also performed.

December, 1986.-

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Fermentation of the fractions of Prosopis.

The assays have been done with two fractions of P. chilensis; endocarp and flour.
These were ground to mesh 40 and then leached during one hour at 30°C with agitation (200 RPM)
The leached was separated by centrifugating (4,000 RPM × 10 minutes).

50 g flour + 200 ml water produced after centrifugation 94 ml of leached, which was inoculated with 1 ml of yeasts (10^6 cells/ml,

The flasks were incubated 48 hours at 26-28°C in a rotatory shaker (180 RPM)

The fermentation is followed by:
soluble solids (refractometer)
sugar contents (DNS method: 2 OH-3,5-dinitrobenzo
number of cells/ml
final alcohol content (distilled)

content of
galactomanose
analysis

Pit on Rice Bran extension
NRRC microorganisms
Thanks for Cook-Tamayo

FAO - PNUD - CONAF (3 años)

INFOR: V. José Aguirre.

P. chilensis
P. alba
P. tamarugo. (4)

Region I → Metropolitan.
17 procedencies

plague resistent
good food production * pods
straight (Trunk)

Trial assays for detecting the best characteristics (genetics) accordingly to the above mentioned

1986-1987: Pod collections.
1987. Trials Pampa del Tamarugal
Metropolitan Region.

Defined media for growing Saccharomyces cerevisiae (strain 131, obtained from an industrial operation)

Composition /100 ml

Sacharose (comercial sugar)	6 through 30 g
$(NH_4)_2SO_4$	0.7
KH_2PO_4	0.3
yeast extract	0.7
water	100 ml

This media was utilized for adapting the yeast strain to increasing sugar concentration.

Conditions:

Incubation temperature 28-30°c

Initial concentration of inoculum 10^6 yeast/ml

At the final point of the fermentation the yeasts stop to produce CO_2 and they sett down.

The fermentation was followed by:

- soluble solids (refractometer)
- sugar content (DNS)
- number of cells/ml
- final alcohol content (distilled)

FINAL REPORT

CROPS FOR PRODUCTION IN MARGINAL GROWING AREAS IN CHILE

SANTIAGO, MAY 1987.-

INTEC — CHILE

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CROPS FOR PRODUCTION IN MARGINAL GROWING AREAS IN CHILE

1. OBJECTIVES

The objective of this project is to define parameters required to exploit components of *Prosopis* species, principally *P. tamarugo* and *P. chilensis* as food, feed and industrial resources.

In order to get this goal the following tasks were accomplished:

- Pod collection.
- Pod chemical composition.
- Subfractionation of pods and establishing food and feed potential of those fractions.
- Proximate composition of the fractions.
- Industrial uses of pods, other than feed and food, as extraction of gums.

This study is part of a collaborative project with the Agriculture Research Service (WRRC) of the United States Department of Agriculture.

2. INTRODUCTION

About one third of the land area of the earth are arid and semi-arid regions, in Chile this kind of climates comprises about 40% of the whole country.

Prosopis trees are also used as timber and fuel.

3. EXPERIMENTAL WORK

In order to get the main objective of this study many tasks were accomplished; which will be described separately in the following chapters.

3.1. Pod Collection

As described in Chile there are 5 identified species of Prosopis, with very different type of pods, regarding the morphological and chemical composition of the fruits.

This study have been restricted to Prosopis tamarugo (tamarugo) and Prosopis chilensis (algarrobo).

The pods used in the whole study were collected during three different seasons 1984, 1985 and 1986 from different regions.

Pods of P. tamarugo were harvested from trees of the Pampa del Tamarugal, at the Refresco farm, poperty of the National Forestry Corporation (CONAF), during the month of April. In 1984, 300 kg were gathered from different trees, plus 5 kg from three different identified trees. During the secsons of 1985 and 1986 pods were harvested only from the three identified trees, in order to perform the composition analysis of the fruits.

Mature pods of P. chilensis were collected beneath the trees out of two populations: Chincolco (about 150 km north of Santiago), and Peldehue (about 50 km north of Santiago).

The seeds consist of: the seed coat (brown color), the endosperm, just beneath the seed coat, and the cotyledon with the germplasm.

The Prosopis seedsare very hard and generally small.

The pericarp of the Prosopis pod is different, varying accordingly with the species, it is composed of three layers:

- the exocarp, the outer layer, it is light brown or yelow
- the mesocarp, the medium layer, it is soft and the thickness depending of the species.
- the endocarp, the inner layer, it is enveloping the seed, it is very hard and fibrous.

Separation process

The pods of Prosopis were previously dried, to about 4% moisture in a hot air dryer at 70ºC for at least 6 hours. This operation can not be avoided, because the pods can not go through the milling process with less than 4% moisture.

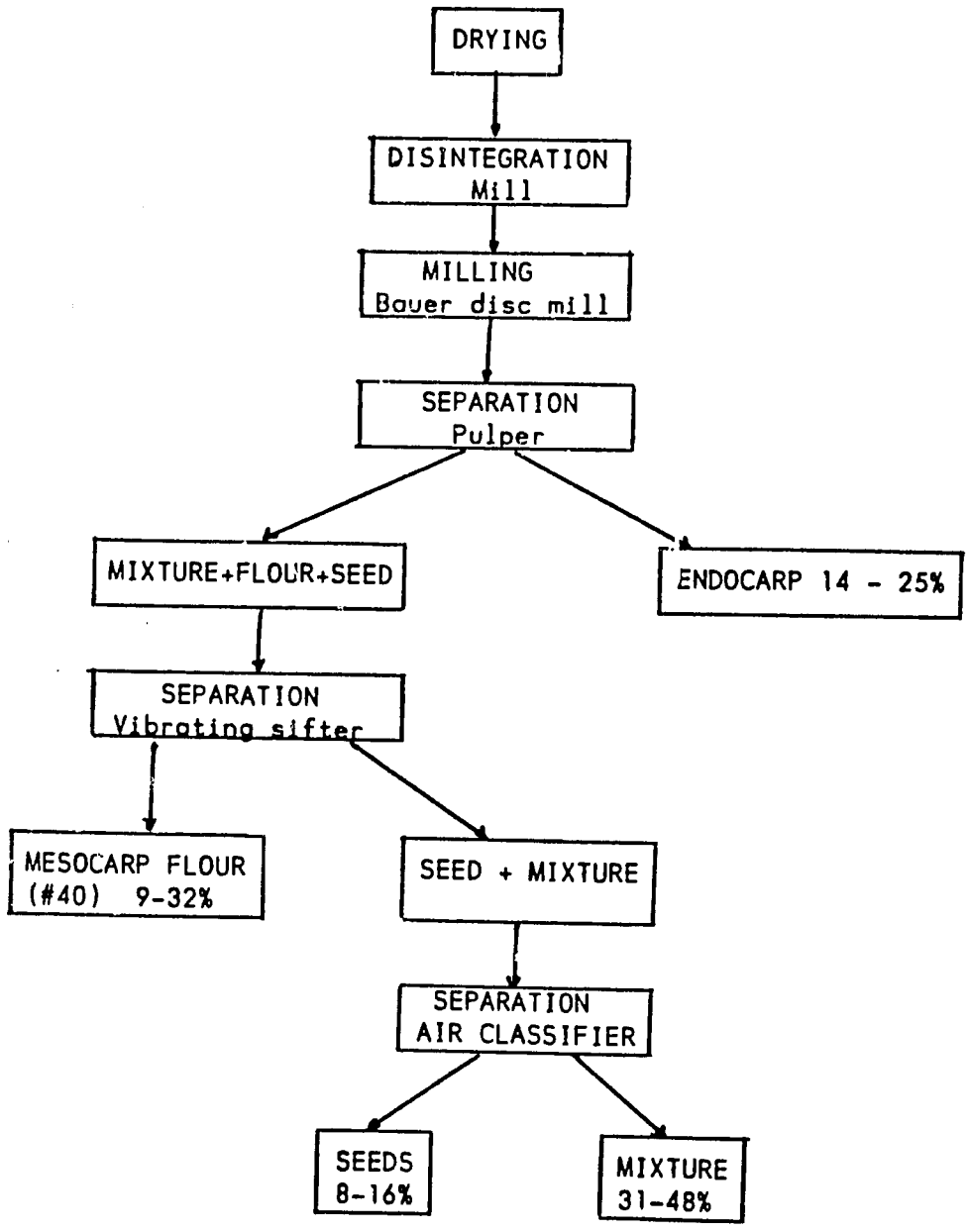
The dried pods are inmediately broken with a Rietz mill into 2-4 cm pieces in order to facilitate the separating process, then milled in a vertical disc mill with corrugated discs; a Bauer disc mill (Model 148, size 8, disc 8504).

TABLE 1. MILLING CONDITIONS FOR PROSOPIS CHILENSIS AND YIELDS OF THE FRACTIONS

ORIGIN	DISC GAP	INITIAL TOTAL WEIGHT	SEED	ENDOCARP	MIXTURE	FLOUR	FINAL WEIGHT	LOSS (%)
1-Chincolco	4.5 mm	500g	58 g	129.0 g	176.2 g	[illegible] g	437.2 g	12,6 %
	90	-	11.6%	25.8%	35.2%	14,8%	-	-
3-Peldehue	3.8 mm	500g	41.0 g	68.4 g	241.9 g	65.0 g	416.3 g	16.7 %
	63	-	8.2%	13.7%	48.4%	13.0%	-	-
5-Peldehue	4.5 mm	500 g	58.1 g	99.4 g	203.4 g	45.5 g	406.4 g	18.7 %
	90	-	11.6 %	19.92%	40.7%	9.1%	-	-
Pooled (various trees)	4.0mm	500 g	79.8	71.4 g	231.7 g	72.4 g	455.3 g	8.4 %
Peldehue	75	-	16.06 %	14.3 %	46.3 %	14.5 %	-	-
Pooled Chincolco	-	58 kg	8 kg	13 kg	18 kg	19 kg	-	-
			13,8%	22.4%	31.0%	32.8%		

FIGURE 1

SEPARATION OF SUB-FRACTIONS OF P. CHILENSIS PODS



With the process just described seeds are separated from the other subfractions. About 80% of the seeds are obtained without breaking the seed coat, in this way, those can be used for reforestation.

3.3. Chemical Composition of the Pods and Sub-fractions

The proximate composition of P. tamarugo and P chilensis whole pods from different populations, and foliage obtained by the separation process were analyzed by standard methods (AOAC), the results are shown in Table 2 and 3.

The analysis were performed from representative samples. About 20 different trees for the pooled samples, and one special tree from each population were gathered (Chincolco, Peldehue, Bellavista, Pintados, and Pillalla).

TABLE 3

PROXIMATE COMPOSITION OF PROSOPIS CHILENSIS PODS AND FOLIAGE (PERCENTAGE) (1)

POPULATION	TOTAL SOLIDS	ASH	PROTEINS	FAT	FIBER	SUGARS
1984						
Peldehue (foliage)	91,7	9,7	13,1	1,3	19,0	-
Peldehue (pods) 3	92,6	2,6	9,8	1,6	9,4	-
Peldehue (pods) 5	93,8	2,4	11,1	1,7	13,0	-
Average	93,2	2,5	10,5	1,65	11,2	-
1985						
Peldehue (foliage)	90,9	8,5	12,9	1,4	18,5	-
Peldehue (pods) 3	93,5	2,8	10,2	1,3	9,5	31,4
Peldehue (pods) 5	91,9	2,9	10,6	1,5	10,5	32,7
Average	92,7	2,85	10,4	1,4	10,0	32,1
1986						
Peldehue (pods) 3	90,8	1,9	9,5	1,4	9,7	30,5
Peldehue (pods) 5	93,1	2,3	10,5	1,7	10,1	33,1
Average	91,9	2,2	10,05	1,55	9,9	31,8

(1) as dried weight

TABLE 4

PROXIMATE COMPOSITION OF PROSOPIS TAMARUGO AND PROSOPIS CHILENSIS (1)
(PERCENTAGE)

1984

FRACTION	TOTAL SOLIDS	ASH	PROTEINS	FAT	FIBER	NNE
P. CHILENSIS						
SEED						
Chincolco pooled	92,6	3,5	30,8	2,3	7,9	55,5
Chincolco 1	90,8	3,3	29,1	2,0	8,3	57,3
Peldehue 3	92,2	3,5	33,9	2,3	7,4	58,8
Peldehue 5	93,1	3,4	30,9	2,6	6,9	56,1
Average	92,2	3,4	31,2	2,3	7,5	56,9
ENDOCARP						
Chincolco pooled	95,4	1,9	6,5	0,9	41,0	49,6
Chincolco 1	93,9	2,4	8,2	0,5	27,5	61,3
Peldehue 3	95,7	1,8	6,3	0,5	52,3	39,0
Peldehue 5	95,5	2,6	9,2	1,1	37,0	49,9
Average	95,1	2,2	7,6	0,75	39,5	50,0
MIXTURE(# 20)						
Chincolco pooled	96,2	2,9	6,9	1,6	11,5	77,1
Chincolco 1	93,5	2,9	7,1	0,5	9,5	80,1
Peldehue 3	96,3	3,2	9,8	0,9	13,1	72,9
Peldehue 5	96,8	3,2	6,6	1,2	9,1	80,0
Average	95,7	3,05	7,6	1,05	10,8	77,6
FLOUR(# 40)						
Chincolco pooled	95,9	3,2	7,6	2,7	3,8	82,5
Chincolco 1	93,5	3,1	8,6	0,6	7,6	80,0
Peldehue 3	96,8	3,7	10,6	0,9	3,6	81,0
Peldehue 5	96,3	3,4	7,3	1,2	4,9	83,0
Average	95,6	3,35	8,5	1,35	5,0	81,6
P. TAMARUGO						
Bellavista Seed T1	91,7	3,8	31,2	2,8	10,9	51,1
Bellavista Seed T2	91,9	3,8	31,1	2,5	11,2	51,2
Average	91,8	3,8	31,15	2,65	11,05	51,15
Bellavista Exoc. T1	89,8	4,2	7,3	0,2	39,6	48,5
Bellavista Exoc. T2	89,2	3,8	8,1	0,5	37,2	50,1
Average	89,5	4,0	7,7	0,35	38,4	49,3
Bellavista Flour T1	88,5	6,2	17,5	0,9	19,1	56,1
Bellavista Flour T2	88,3	6,0	17,3	1,1	19,0	56,3
Average	88,4	6,1	17,4	1,0	19,05	56,2

(1) as dried weight

The tables 4 and 5 present the chemical composition of the fractions as obtained by the separation process, regarding their potential uses, for algarrobo and tamarugo pods.

The sub-fractions of P. chilensis obtained are: seed, endocarp, mixture of flour that passes through mesh # 20 (mesocarp + exocarp) and flour that passes through mesh # 40.

The seed of P. chilensis is composed of the seed coat, a very thin fibrous layer of brown color; the endosperm a transparent layer that covers the seed coat, and the cotyledons plus the germ, very soft and yellow.

The principal constituent of the seed are protein (29-40%) from the cotyledons and the germ, fiber (6.4 - 8.3%) from the seed coat, and carbohydrate from the endosperm (not analyzed quantitatively), which is a polysaccharide, a galactomannan type, that acts as thickening agent (similar to locust bean).

The results of the analysis shows that the composition of the seed does vary significantly in the proteins content from different trees, even during the same harvesting season (32.9 - 40.4%, year 1985). The fat content shows differences between the seasons 1984 and 1985, 2.3 and 3.25% (average) respectively.

Fiber and ash content do not present large variation from season to season.

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The average protein content of seeds are 33.9% and 31.6% for P. chilensis and P. tamarugo, its average aminoacid composition are shown in Table 6 and 7. Those were analyzed with a Durram aminoacid analyzer, Model D-500, at the Western Regional Research Laboratory (WRRC) of the USDA, in Berkeley.

TABLE 6

AMINO ACID COMPOSITION OF P. CHILENSIS SEEDS (1984)

AMINO ACID	GRAMS PER 100 g of seeds	mg per gram nitrogen	Provisional score(FAO) mg/g N
Aspartic acid	3.123	498	
Threonine	0.966	154	250
Serine	1.713	273	
Glutamic acid	6.845	1.091	
Proline	1.996	318	
Glycine	2.050	327	
Alanine	1.471	235	
Cysteine	0.446	71	
Valine	1.532	244	310
Methionine	0.494	79	220(MET+CYS)
Isoleucine	1.127	180	250
Leucine	2.273	362	440
Tyrosine	0.927	148	
Phenylalanine	1.436	229	380(PHE+TYR)
Hystidine	0.942	150	
Lysine	1.664	265	340
Arginine	4.640	740	

This demonstrates that Prosopis protein from seeds has a nutritive value similar to other common legumes.

Other researchers checked different fractions as cotyledons and germs and whole seeds, in P. velutina and P. juliflora, respectively. They found the same type of amino acids present in the seed from P. chilensis and P. tamarugo.

The analysis of different types of fiber were performed, for the various sub-fractions of P. chilensis and P. tamarugo, at the Western Regional Research Laboratory (WRRC) of the USDA, in Berkely. The results are shown in Table 8.

TABLE 8

TYPES OF FIBER OF FRACTIONS OF P. CHILENSIS (1984)
(PERCENTAGE)

FIBER	SEED	MIXTURE (#20)	FLOUR (# 40)	ENDOCARP
Crude fiber	5,3	10,0	2,6	33,0
Neutral detergent fiber	22,0	36,6	20,6	14,2
Acid detergent fiber	8,7	30,7	15,2	11,7
Lignin	2,5	6,7	5,2	3,4
Cellulose	6,2	23,9	10,0	8,1

3.4.1. Feeding experiments

The protein efficiency ratio (PER) was determined using AOAC methods, with diets containing 10% protein, as indicated on Table 10, two samples were lower than 10% in protein. Diets were fed *od libitum* to groups of five, 21 day old male sprague-Dawley rats. Digestibility of the diet and apparent nitrogen digestibility were determined (data not available yet). The PER were determined at the WRRC from USDA.

TABLE 10

WEIGHT GAIN AND PER IN RATS FED P. CHILENSIS AND P. TAMARUGO (1)

DIET (2)	WEIGHT GAIN	PER
1. Soybean/cottonseed	107 cB	2.57 cC
2. Toasted *P. chilensis* flour	28 fgEF	0.87 fF
3. *P. chilensis* seed	37 fE	1.27 eE
4. *P. chilensis* pod	1 hG	0.03 hH
5. *P. tamarugo* seed	63 eD	1.46 eE
6. *P. tamarugo* flour	-	-
7. *P. tamarugo* pod	19 gF	0.45 gG
8. ANRC casein, high fiber (3)	144 aA	2.83abABC
9. ANCR casein, normal fiber	123 bB	3.02 aA

(1) Means with no letter in common are significantly different ($P < 0,03$, lower case, $P < 0.01$ upper case)
(2) Diets contained 10% protein, except diet 4, 8,9%
(3) Non nutritive fiber (alphacel) was increased to equal fiber of diet # 7; 28.2%.

All fractions resulting of the milling operation (pooled samples and from one tree, Peldehue population) from 1984 and 1985 harvesting seasons, and the whole pods were analyzed with this "in vitro" digestibility enzymatic assays. The results for the determination are shown in Table 1.

TABLE 11

ENZYMATIC DIGESTIBILITY OF P. CHILENSIS AND P. TAMARUGO WHOLE PODS AND FRACTIONS

SAMPLES	DIGESTIBILITY %	
	1984	1985
PROSOPIS CHILENSIS		
Peldehue population (pooled)		
Whole pods	N.a. (1)	63.8
Seed	84,4	83,5
Endocarp	64.4	69.7
Mixture (#20)	63.6	66.7
Flour (# 40)	70.6	71.0
Peldehue pop. tree # 3		
Seed	N.a.	80.2
Endocarp	62.0	70.5
Mixture (#20)	68.8	72.4
Flour (# 40)	69.3	71.9
PROSOPIS TAMARUGO		
Whole pods	N.a.	61.3
Seed	85.3	85.2
Flour	75.2	70.2
Exocarp	63.0	65.8

(1) N.a. = not analyzed

Considering the values obtained, the whole pods present a low digestibility even lower than the more fibrous fractions as the endocarp.

Trypsin inhibition was determined using a substrate of BAPA (Benzoyl - DL Arginine-p-nitroanilide hydrochloride), and bovine trypsine. (Method of Kakade et al, Cereal Chem. 51, 376 (1974).

The following tables show the values obtained in the determination of the antinutrients factors above mentioned.

TABLE 12

CYANOGENICS GLUCOSIDES IN PROSOPIS spp. PODS AND FRACTIONS

HCN mg/100 g sample (dried weight)

PROSOPIS CHILENSIS

Samples	1985			1986
	Peldehue pooled	Peldehue 3	Peldehue 5	Peldehue 9
Whole pod	5,2	N.A. (1)	3,2	2,1
Seed	2,4	N.A.	N.A.	1,3
Endocarp	0,3	-	4,1	0,9
Flour	1,4	4,7	4,7	1,3
Mixture	1,9	-	5,8	0,6

PROSOPIS TAMARUGO (Bellavista)

	1985	1986
Whole pod	5,4	1,6
Seed	2,9	1,5
Exocarp	2,6	0,8
Flour	5,7	2,9

(1) N.A. = not analyzed

The results indicate a great variation between samples from different trees and harvesting seasons.

All the fractions and the whole pods of P. chilensis and P. tamarugo exhibit the presence of antitryptic factor.

Table 14 shows the values obtained for the urease determinations.

TABLA 14

INDEX OF UREASE ACTIVITY IN PROSOPIS spp. PODS AND FRACTIONS (1)

PROSOPIS CHILENSIS

Sample	SEED	ENDOCARP	FLOUR	MIXTURE	WHOLE POD
Peldehue pooled	0,02	0,03	0,02	0,02	0
Peldehue 3	0	0	0	0,02	-
Peldehue 5	0,02	0	0	0,03	0
PROSOPIS TAMARUGO	0,09	0	0	-	0,02

(1) The determination is based on the difference between the pH of the test and the pH of the blank.

Urease and trypsin inhibitor are enzymes usually present in soybean; based in the presence of the antitrypsin factor in the fractions and whole pod of Prosopis, urease was also determined in those samples.

The values obtained with raw soybean are about the ranges 1.7.5 - 1.90 , and with treated coocked soybean the pH difference is about 0.2 units; accordingly with these results we could conclude that the Prosopis samples analyzed did not contain urease in amounts considered to be toxic.

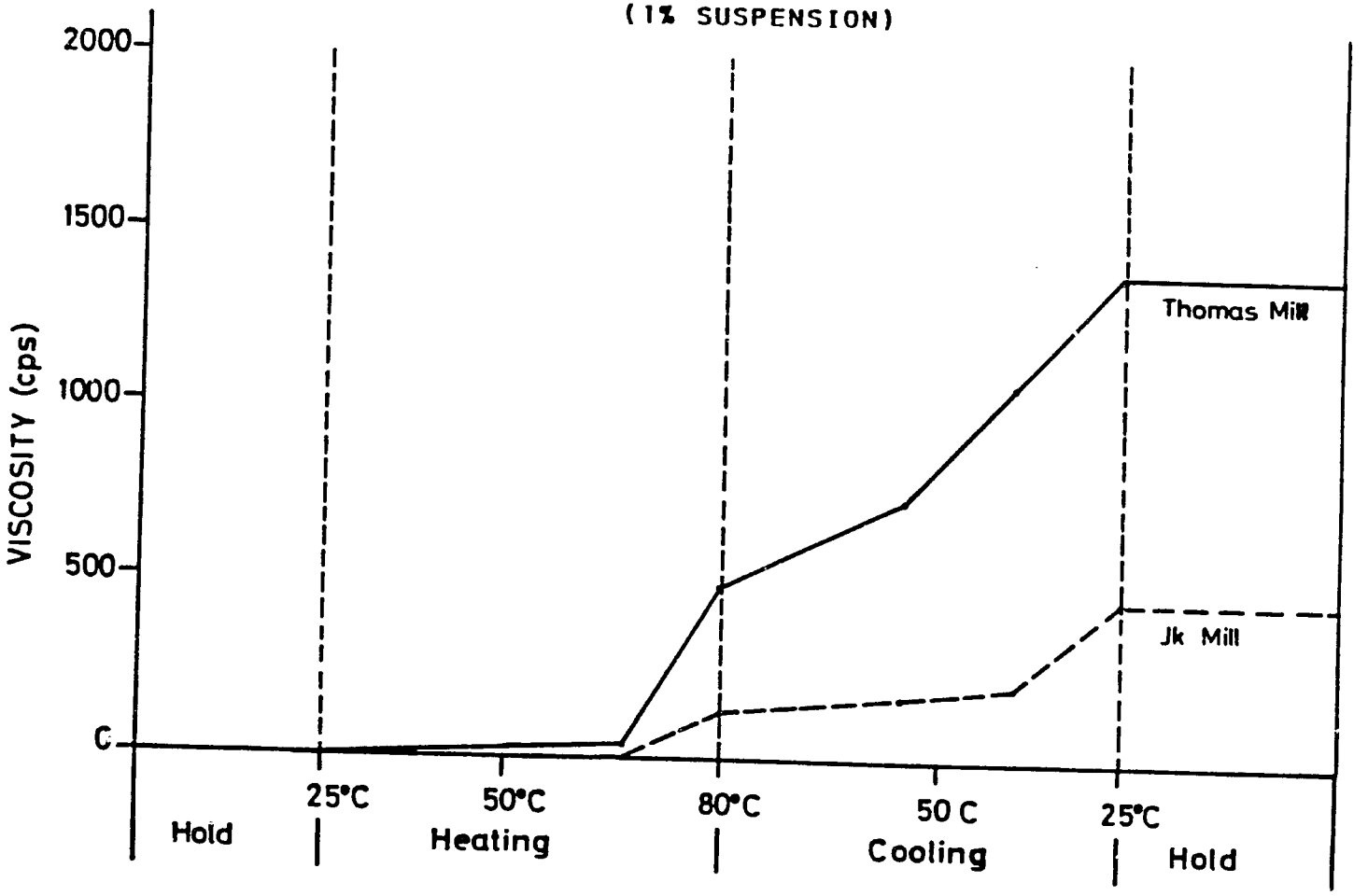
industry in order to fortificate and balance the amino acid composition of other foods.

The seeds could be used also for reforestation and for feeding purposes.

The endosperm of some Prosopis pods contains a polysaccharide, a galactomannan, which could be used as a thickening agent. P. tamarugo do not have this carbohydrate, P. chilensis does.

FIGURE Nº 1

APPARENT VISCOSITY OF PROSOPIS CHILENSIS GUM.
EXTRACTION BY MILLING IN A THOMAS LABORATORY MILL AND A J.K. MILL
(1% SUSPENSION)



- In a spray drier; this operation was carried out in a pilot plant size spray drier (Niro Atomizer), with an inlet air temperature of 130º C, and an outlet air temperature of 80º C.

The characteristics of the gums obtained by oven drying and spray drying, were assessed by measuring the apparent viscosity of a 1% solution at different temperatures. Results are shown in Figure 2. Where it can be seen that the viscosity behaviour of spray dried gum is different compared to the oven dried one; ther former exhibits a much higher apparent viscosity at 25º C, indicating that oven dried gum has suffered an irreversible structure breakdown.

On the other hand, on heating both gum solutions, some degree of breakdown can also be observed in the spray dried products after two heatings to 80º C and further cooling to 25º C.

The process of the gum extraction at the pilot plant level, working with some kilograms of seeds, at different temperatures of extraction give a yield in mucilage of: 15% at room temperature and 24% at 50ºC.

As a comparison, the mucilage fraction accounts in average 30% of the seed.

Other methods of extraction of gum were assayed: as alcali and/or acid treatment, but they proved to be unconvenient for an industrial or semi-industrial process.

3.6.2. Food products formulated with different fractions of Prosopis pods

3.6.2.1. Fractions utilized

P. chilensis and P. tamarugo fractions obtained by the separation and milling operation were utilized for formulating some food products, as bread (dietary bread), cookies, and a special type of chilean doughnuts, called "berlines".

The fractions lack starch and gluten so the application are restricted to the sustitution of the wheat flour, in a low percentage of the various formulated products.

The fractions are employed thinking to obtain a type of dietetic product, because of the high fiber content of the raw material.

The fractions obtained from P. chilensis and utilized in baked products are:

- Endocarp (14 - 26% of pods)
- Mescocarp flour (30% of pods)
- Mixture (31-48% of pod) is a mixture of flour, broken seeds and endocarp.

P. tamarugo fractions:

- Exocarp (70% of pods)
- Flour (13% of pods)

TABLE 16

LEVEL OF SUSTITUTION OF PROSOPIS FLOURS IN WHEAT BAKED PRODUCTS

	Fraction	Sustitution(1)(%)
P. chilensis	Endocarp	10 - 15
	Flour	10
	Mixture	8
P. tamarugo	Exocarp	< 5
	Flour	5

(1) Maximum percentage of Prosopis flour added to wheat flour, at which no unpleasant or reduced baking quality occurs.

The results show that tamarugo flours from exocarp amd mesocarp (flour) do not produce acceptable products, due to an unpleasant bitter after taste; and a hard crust formed. Algarrobo flours can replace wheat flour to a level of 10 to 15%, obtaining good quality products; being the better fractions flour and endocarp. The fraction named "mixture" is good only to an 8% sustitution.

The quality of the baking capacity of the wheat flour with different percentage of sustitution of the endocarp and the flour from P. chilensis were measured in a pharinograph. The results are shown in Table 17.

levels of Prosopis fractions. The final products were evaluated by a sensory panel, and determined the sustitution percentage at which the Prosopis fraction was detectable, and the level of rejection.

This preliminary work was performed at the laboratory level.

a. Bread

Basic recipe:

100 parts flour (wheat flour with different sustitution % of Prosopis fractions)
3 parts shortening
2 parts salt
4 parts sugar
3 parts yeast
59 parts H_2O

Results

The maximun sustitution level were the same as shown in Table 16, 10-15% and 10%, respectively for endocarp and flour of P. chilensis were the better results. P. tamarugo did show bad baking characteristics. The absorption was worse than normal, the crumb firmness was too high, the color too dark and a bitter after taste with more than 5% of sustitution level was developped.

TABLE 18

FORMULATION OF BERLINES AND BREAD

PRODUCTS	BERLINES	BREAD
Flour	1000 g	1000 g
Sugar	150 g	-
Shortening	150 g	34 g
Improver S-500 Lefersa	46 g	34 g
Yeast	60 g	8 g
Egg	2 units	-
Salt	10 g	11 g
Vanilla	16 cc	-
Coulour (Vegetal Yellow)	8 cc	-
Flavoring 79460, Givaudan	2,5 cc	-
Water	400 cc	1600 cc

A microbiological control of the raw material was analyzed, the values obtained are shown in Table 19.

- Berlines can be prepared with wheat flour containing up to 10% of endocarp and flour of P. chilensis pods. This product was accepted regarding all organoleptical characteristics, but without statistical significance.

- Berlines did not present off-flavor, nor bitter aftertaste with the 10% of sustitution for both fractions (endocarp and flour).

- The utilization of the dough improver is necessary for getting o product similar to the control (formulated with 100% wheat flour plus dough improver). The formulation without this additive showed a high rejection with statistical significance.

- In order to get a good final product, the frying process have to be done at 180ºC to 200ºC and 3 minutes frying each side.

- Bread can be prepared with wheat flour containing up to 10% of endocarp and flour of P. chilensis pods. The formulations need to be added with dough improver in order to get a good product.

- Bread with 10% of endocarp sustitution had a 20% of rejection.

- Bread with 10% of flour sustitution was accepted regarding the organoleptical criterias, but without statistical significance.

- Extraction with different particle size (20 and 40 mesh), various shaking conditions (100, 200 and 250 rpm), different temperatures (20, 30, 60º C, boiling water), and time of treatment (30 minutes, 1 and 2 hours) did not present great differences in the extracted content of sugar.

- Extraction of sugar with different levels of solid content (10, 20, 25 and 30% relation solid: liquid) did not present differences in the amount of extracted sugar, at room temperature. The percentage of the sugar extraction is about the 96.3% of the total content of sugar present in the different fractions.

Fermentation assays

The microorganism used is a Saccharomyces cerevisiae, a special strain (Intec Nº 131) adapted to produce ethanol at high concentrations of sugar. This yeast was obtained from an industrial alcohol production, employing molasses from sugar beets as substrate.

The yeast is maintained in a malt extract agar. The basal media for adaptation of the S. cerevisiae to high concentration of sugar was performed in the following media:

The results showed that with 15% of sugar in the substrate, with the leaching (a) process or directly, without any extraction procedure (b). the yield in alcohol production is the about 92% of the theoretical yield, and with the 97% of the total content of sugar consumed.

The seeds can be used into animal diets, because they do have high protein content and lower fiber content than the other fractions.

P. chilensis seeds contains a mucilage in the endosperm, which is a polysacharide a galactomannan with good viscosity characteristics. This fraction was separated by a wet process, producing a yield of 15% and 24% by the extraction at room temperature, and 50ºC, respectively. This type of gum can be used in the oil-well drilling, food and pet-food and also for pharmaceutical applications if the mucilage can be purified properly.

Hemagglutinin were not detected in any of the samples, urease was only found in very low percentages in some of the samples from. P. chilensis, but is was not detected in whole pods.

The high urease content was present in seeds of P. tamarugo (0,09 units).

Cyanogenetic glucosides and antitryptic factor were present in all the fractions and whole pods of P. chilensis and P. tamarugo (0.3 - 0.5 mg HCN/100 g sample and 0.8 - 6.1 Trypsin inhibited units/mg samples).

All the figures of toxic substances in the analyzed fractions are low, compared with the values found in other forrages commonly consumed.

The fractions obtained through the separation process described for P. chilensis: flour, endocarp and mixture, permit to formulate some food products as doughnuts, bread, and cookies. The fractions are employed with wheat flour in different sustitutions levels (8 - 10%).

The tamarugo fractions do not result in acceptable products, because of the bitter aftertaste.

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APPENDIX III: USDA

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Processing, Utilization and Economics of MESQUITE pods as a Raw Material for the Food Industry

A dissertation submitted to the
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A WEED IS A PLANT, WHOSE VIRTUES
HAVE NOT YET BEEN DISCOVERED

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"I left my heart in San Francisco....."

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1. INTRODUCTION

1.0. Overview

MESQUITE (Prosopis spp.) is a leguminous plant that occurs all around the world in arid and semi-arid zones. The plant grows wild, requires very little water and is capabable to fix nitrogen.

Depending on the specie, as well as the specific climatic situation, MESQUITE develops as a small brush or as a tree of a height of several meters.

MESQUITE produces an annual crop of pods which fall to the ground when ripe. The pods were an important staple food for former cultures in North- and South-America as well as in Asia. The pods were usually ground in mortars and the flour processed into several different products, such as flatbreads or fermented drinks.

In modern times the importance of MESQUITE as a food or feed became nil, due to several reasons:
a) MESQUITE is a weed that -if not controled- can infest grassland in semiarid regions.
b) MESQUITE pods have a very complex and tough morphological structure; no attempts have ever been made to develop a milling and separation process for the pods.
c) MESQUITE pods as an agricultural crop could never match the purely economical criterias of a modern crop.

Only in the last couple of decades man has begun to look at plants (and animals) as part of a complete ecological system where a "weed" suddenly becomes an important factor in the system.

When chemical studies revealed that MESQUITE pods contain a very high amount of sucrose as well as high-protein and galactomannan-rich seeds, some researchers started to consider its use as a food crop again. The increasing under-supply of food in lesser developed countries in arid zones also led to incresed efforts to the establishment of local crops.

Therefore, this work concentrated on the development of a milling and separation process for MESQUITE pods, and on its utilization as a food raw-material. It has been the intention to come up with a immediately realizable model for MESQUITE processing and utilzation along with the consideration of the economical aspects.

1.1. Botany of MESQUITE

1.1.1. Taxonomy, patterns of variation

Among the legumes, the genus Prosopis (common name: MESQUITE) belongs to the subfamily of Mimosideae. There are 44 known species, but only one still exists in tropical Africa, where MESQUITE possibly originated. From there,the ancestors of present day Prosopis may have migrated to east and west during the continental drift at the end of the Mesozoic or the beginings of tertiary times (1).

To identify the correct Prosopis species in the field can be an extremely difficult task, even for someone who thinks he knows MESQUITE, since Prosopis plants can be small shrubs or short trunked trees but can even develop into 20 m tall trees, all depending on the species and/or the availability of water (2).

There are not only differences in size or shape of the tree; even more astounding may be the differences of the pods. They may be 2 cm long curled pods with the characteristic name "screwbean" (P.pubescens) or up to 13 cm long brown pods of P.chilensis, which might almost be confused with the fruit of a carob tree (Ceratonia siliqua).

The thorns are yet another variation. Some species have nasty long thorns which led to proposals to use MESQUITE as a natural barbed wire fence around military installations. The thorns have even caused viscious infections (3). However, there are also species which produce no thorns at all.

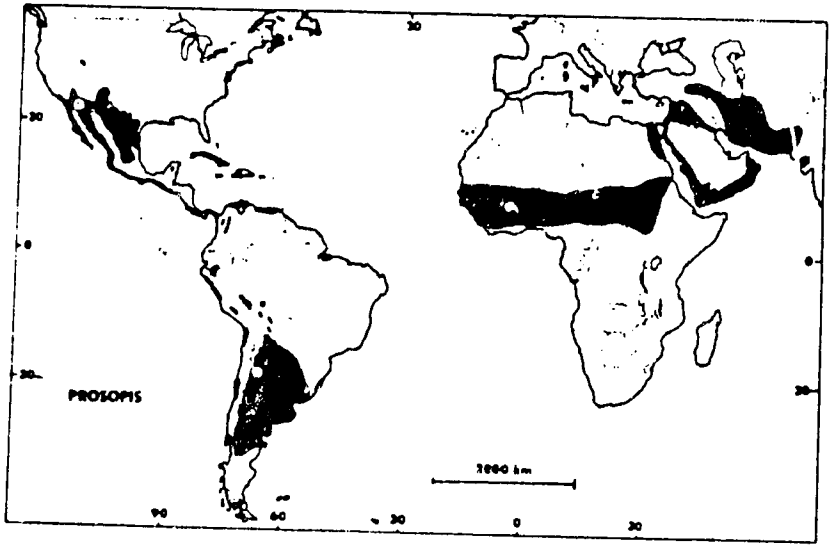
On top of all this variability, Prosopis crossbreads among species, and it is therefore often almost impossible to determine with which specie one is dealing.

1.1.2. Adaptation to environmental conditions

MESQUITE covers 35 million hectares in the United States alone, and is found all around the world in arid and semi-arid zones (Figure 1).

Harsh conditions like extreme temperature, drought, poor soil quality and wind in arid and semi-arid zones pose severe constraints on the growth of a plant. To overcome these problems, MESQUITE possesses special features in the morphology and physiology of its roots, conducting system and leaves.

Figure 1: Worldwide distribution of Prosopis species (14)



The potential water reservoir available to MESQUITE is large compared to other desert shrubs. The trees develop two different rooting system. Tab roots which use ground water (if there is any) have been reported to reach 80 m deep (4). There is also a lateral rooting system, which can extend to 20 m from the tree (5).

Some species can even absorb moisture (dew) through their leaves and translocate it to the roots (6). On the other hand the water losses are minimized by the ability of Prosopis spp. to fold their leaflets together at midday (7).

Some Prosopis species have been found to perform crassulacean acid metabolism (CAM), where the plant closes its stomata during the day to prevent moisture loss and fixes nitrogen at night (60). In addition, Prosopis is capable to absorb water held with high matrix forces and to carry on photosynthesis at xylem water potentials of less than -40 bars (8). The reported figures for water use efficiency differ from 250 water/kg dry matter (9) to 19 700 kg water/kg dry matter (10). The range points out the enormous genetic potential that exists in MESQUITE.

MESQUITE also has the ability to tolerate highly saline conditions. Certain species can grow through a salt crust of several feet (11), and others tolerate a pH value of 9.5-10.0 and a soluble salt content of 0.54-1.0 % which is even better than Acacia arabica (12).

It has been shown that Prosopis spp. are capable to fix nitrogen and are therefore able to grow even in nitrogen-free soil (13).

Not surprisingly, MESQUITE prefers hot temperatures. Optimum shoot growth occurs at 29°C (15), whereas most species do not survive frost at -5.6°C (13).

1.1.3. Pods

As much as the appearance of the tree from different species varies, as astounding is the diversity in size and shape of the pods.

To demonstrate the range of the differences, four species shall be looked at more closely (Figure 2):

P.velutina: The pods are about 10-15 cm long, slightly bent and of a light brown to yellow colour.

P.chilensis: Pods are up to 20 cm long, quite fleshy and light to dark brown. They resemble the pods of the carob tree.

P.tamarugo : Length of the pods about 3-5 cm, slightly brown color.

P.pubescens: Twisted pods, about 5 cm long pod. Their common name "screwbean" is descriptive of the bean, which is screw shaped.

Inspite of these obvious differences, all the pods have certain identical characteristics as well. They are indehiscent and have a similar botanical structure (pericarp/seed; see chapter 2.2.)

1.1.4. Fruit growth and dispersal

MESQUITE trees usually start to carry pods at the age of three to five years and reach a maximal production from year eight to fifteen (16).

Figures 3-6 show the pod-development from flower to the ripe pod of Prosopis velutina. The pictures were taken in the Imperial Valley in Southern California.

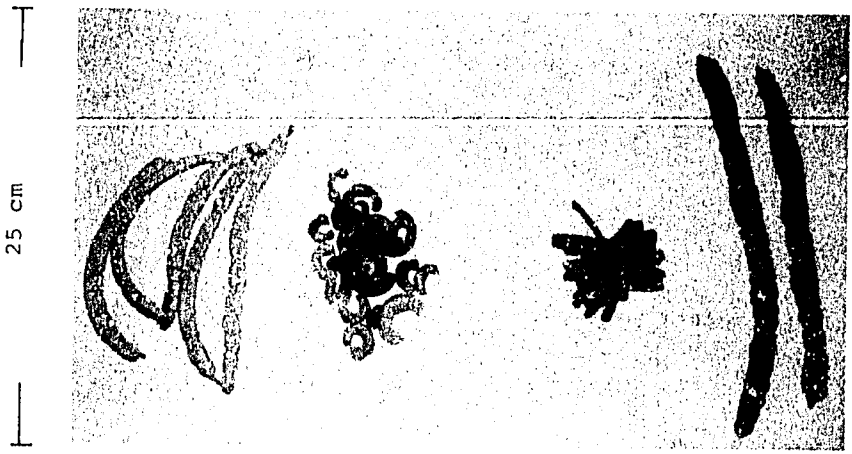
Like all members of the Leguminosae, species of MESQUITE produce their seeds in pods, though unlike many other legumes, the MESQUITE pods do not split open at maturity (indehiscent).

In nature the seeds would never be able to germinate lying on the dry ground. The reproduction cycle requires either mechanical scarification or the involvement of animals. The pods are avidly eaten by coyotes, rabbits, sheep and other mammals, which seem to like it because of its sweetness. Examination of scats of wild animals and feces of domesticated cows and goats reveal that up to 91 % of the seeds pass through the digestive tract of these animals unharmed (20).

This system serves multiple functions in that the seeds are dispersed away from the parent tree (which avoids competition of new plants for the limited water in arid regions); the digestive fluid kills the internal seed parasites and partially hydrolyses the seed coat. Excreted with the moist and mineral rich manure, the seeds are then in a ideal fertilizer. Under these conditions, seeds can then germinate after only six hours at 34 C (17,18).

It could be shown (19), that this natural system provides a much higher germination rate than any other mechanical or chemical treatment of the seeds.

Figure 2: Pods of different MESQUITE species



Figures 3-6: The development of MESQUITE pods from the flower to the ripe pods

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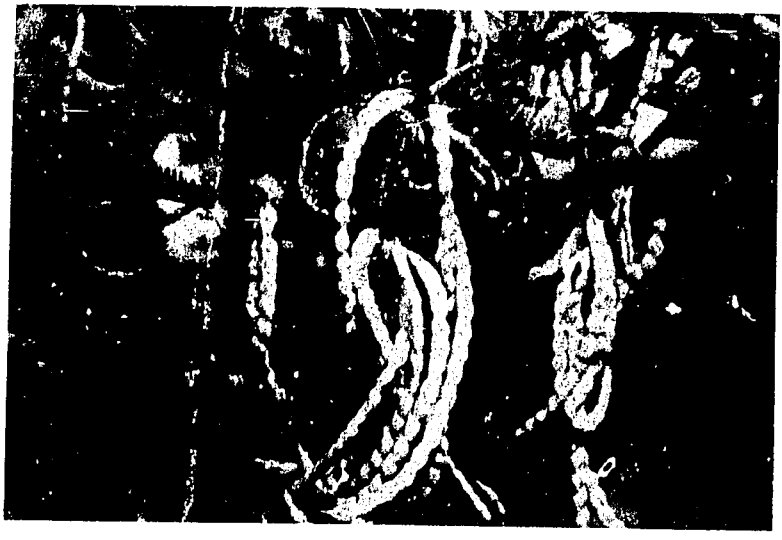


1.2. MESQUITE in the ecosystem

1.2.1. From weed to blessing

The image of MESQUITE varies widely: from a profit robbing nuisance to a valuable asset to mankind, depending upon who is asked, and where it grows.

In the United States, especially in Texas, where MESQUITE grows on an estimated 22.7 million hectares (20), most ranchers desire to eliminate it from their rangeland because it competes strongly with desirable forage. Nevertheless the attempts to get rid of MESQUITE have not been very successful. All methods i.e. fire, herbicides orbulldozing destroy most of the desired vegetation as well, and since MESQUITE seems to be one of the toughest of all plants, it is the first that reoccurs. As a result, the surface coverage of MESQUITE increased dramatically in the last two centuries (21).

In other countries of the world, MESQUITE was and still is, a highly welcome plant. Therefore, plantations have been established (Saudi-Arabia,Chile) for the following different reasons:

- Trees stabilize sand dunes, stop desertification and provide shade
- The pods are used as feed for animals and the wood can be utilized by people in such regions as lumber

A typical example of the bias effects of MESQUITE has been reported from India. A row of MESQUITE had been planted along a jowar plantation. It was observed, that the growth of the field crop was reduced along the MESQUITE belt, but its function as a shelter belt against wind and sand increased the crop on the whole orchard by a factor of 1.5 to 2 . Thus MESQUITE is now recommended as shelter belt on farms (22).

Figure 7 illustrates the general role of MESQUITE in the ecosystem, which is one that would fit almost exactly the requirements of a plant to be used in a concept of "Three dimensional forestry" (23). The following chapters explain certain aspects in more details.

1.2.2. Feed for animals

Many properties of Prosopis fruits and characteristics of their production make them an important resource for numerous animals. The pods being predictable, abundant, nontoxic, and highly nutritious, naturally attract numerous herbivores, many of which destroy the seeds, but the only invertebrates known to use the pods as a food source are insects.

Insects that feed on Prosopis can be divided into two groups, those that feed from the outside and those that feed inside the fruits (24). Mozena obtusa (the hemipteran leaf footed bug) is one of the most abundant external fruit feeders in North America (25). Its damage to the honey MESQUITE in Texas was estimated at 50% of the potential fruit production (26).

Long-horn beetles of the genus Lophopoeum are known to develop inside the pods in Argentina and to consume all of the seeds within the pods while developing. The same damage to MESQUITE pods is done by members of the bruchid family, which are by far the most numerous and best known insects that use Prosopis pods as a food resource (27).

Many wild and domesticated mammals, birds and reptiles are also known to feed on MESQUITE leaves and pods. The following list is not ment to be complete:

Desert cavy, leaf eared mice, hare, jackrabbit, coyote, deer, armadillo, fox, goat, sheep, cow

For many of these animals, MESQUITE pods can be a big part of their diet. It has been reported that jackrabbits can get more than 50% of their calories from them (28).

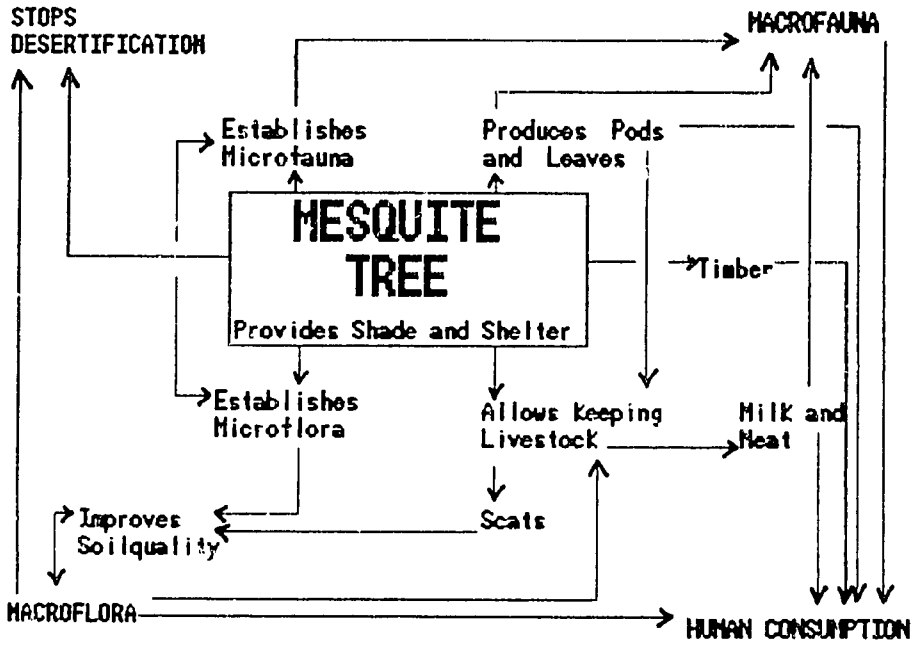
The elimination of MESQUITE can even be responsible for the abundance of animals in certain aeras, as it was observed for scaled squails in New Mexico (29).

Today, many farmers in Central and South America as well as in the Far East use MESQUITE pods in feed mixtures for their livestock. Results of feeding studies showed that up to 20% of the feed can be substituted economically with MESQUITE pods with no deleterious effect on growth of calves (30).

Even in Hawaii, the pods from Prosopis pallida (Kiawe) were of great value prior to the development of inexpensive bulk bin containers for trans-pacific shipment of feedstuff. The pods were often the only available feed during the dry season for dairy cows, cattle horses, donkeys, pigs and chicken (31).

The MESQUITE tree itself is perhaps even more important than the pods. Through its shade and shelter which it provides for animals in the desert and arid zones, the tree is a basic condition to actually establish some livestock.

Figure 7: The role of MESQUITE in the ecosystem



1.2.3. The role of MESQUITE in ancient and modern cultures

A great deal of information is available about the use of MESQUITE by ancient cultures in North and Central America.

The Sonoran Desert which stretches from Southern Arizona to North Western Mexico might be one of the location where MESQUITE played an extremely important role. MESQUITE may have been the second most important staple food to Indians like the Hohokam, who occupied Southern Arizona from about 300 B.C. to 1450 A.C.(32), the Pimas (33), the Mescalero-Apaches and the Seris.

The Seris had names for eight stages of growth of the fruit, from the youngest to the fallen, rotting pod. In the second youngest stage the pods were tied into small bundles and cooked with meat. Mature but still green pods were mashed in a bedrock mortar and cooked in clay pots (34). The most commonly utilized form of the fruit was the dry fallen pods, which have the highest carbohydrate content.

A single man could gather about 80 kilo of pods in a day. Most often the pods were first toasted, by lighting a fire on cleared ground, removing the charcoal and putting the pods on the hot ground. At the same time the pods were sprinkled with sand that had been heated by fires. The women then pounded the pods in mortars with pestels (often made from MESQUITE wood). After the pods were mashed, the flour which is actually only the exo- and mesocarp of the pods, was separated from the unbroken endocarp, which still contained the seeds. The Seris placed the flour in a large basket, mixed it with water, kneated the dough and formed round, 5 to 10 cm thick cakes. They then dried the cakes immediately in the sun, so that they could be stored for weeks (35).

Some tribes pounded the endocarp hulls until the seeds got free. The seeds were then separated and pounded to a fine flour to which water was added and the mixture drunk. Sometimes the different flour/water mixes were allowed to ferment for several days before they were consumed (36).

Father Barzana reported about the use of P. algaroba by South-American Indians (37) :".... they also prepared a very strong alcoholic beverage from the pods and there were never as many querrels and casualties as during the MESQUITE harvesting season."

MESQUITE had also been extensively used for a wide range of medicinal purposes (38). The gum exudate helped curing eyeinfections and sc throat (39). A tea prepared from young MESQUITE roots ser gainst diarrhea (40), whereas a liquid prepared from the ba as used as a laxative (41).

Moreover, the MESQUITE wood served as fuel, as raw material for many "household" gadgets and building material and the Hohokam people of Snaketown cremated their dead on MESQUITE wood pyres (42).

From all this examples it becomes clear, that MESQUITE was not at all a weed for ancient cultures but a necessity for their daily live.

Currently, MESQUITE is of no more positive economical value or cultural importance in the United States. Todays people that inhabit the growing region of MESQUITE have no need for local food production (USA only) or produce cash-crops that require a tremendous input of irrigation and fertilizer (Imperial Valley, California).

There are attempts to use MESQUITE wood as lumber since the wood is of enormous hardness and can be compared to ironwood or white oak. Very appealing furniture and tile floors were manufactered in small quantities (43).

Trees are also chopped for fuel and some charcoal production.

All the current attempts in using MESQUITE are geared towards a utilization of the wood of existing trees which would be chopped anyhow, whereas the utilization of pods as an annual crop has hardly seriously been looked at.

Peter Felker, a researcher and outspoken advocate for MESQUITE, suggests to establish MESQUITE for biomass production, but the current "surplus" of traditional fuels does not favour such attempts. In the future the story might be different again.

In Mexico, MESQUITE charcoal is produced in considerable quantities. This charcoal is mainly exported to the United States where it is used in first class restaurants for barbecue. The charcoal is about three times more expensive than regular type but has a gourmet image due to its characteristics, like hot temperature and special flavor (44).

Pods can also be purchased from dealers in Mexico who buy them from people that collect the pods for a small income. The pods are used in feedstuff mixtures. It is said that some people or even tribes still prepare some food from the pods. This is certainly the case for a region in India, where the custom of eating P.cineraria pods seems to be the major factor in the prevention of protein malnutrition. These people chew the ripe pods and discard the seed (45). By this way of eating the pods, the high protein content of the seeds is waisted.

In South America (especially in Argentina and Chile) the wood is also used as fuel and for tilefloors, and a sirup is produced from the pods as beverage. In Hawaii pods and leaves are harvested from P.pallida for livestock.

Today, MESQUITE is worldwide a under-utilized plant because of its "weed"image, the lack of processing techniques and application of the pods.

1.3. Objectives of this work

It has been outlined in the preceeding chapters that a considerable amount of MESQUITE is growing wild in the United States and other countries around the world. The pods of these trees are hardly used as feedstuff and practically not at all for human consumption.

A look at the growing regions of MESQUITE reveals the following situation:

- Most of these regions do not permit an economically justifiable cultivation with a traditional crop due to their geographical isolation and lack of water.
- Many of these countries (with the exception of the United States) can not produce sufficient amounts of food for their rapidly growing population and have to import big amounts of cereals and legume flour.
- Most of these regions lack infrastructural developement.
- On millions of hectares in these countries, no plants are grown, even though MESQUITE would withstand the harsh conditions.

The single most important reason why MESQUITE pods are currently not being used for human consumption is that no modern technology has been developed to process the pods to a usable raw material.

The problem starts with the morphologically very complex structure of the pods with soft and extreme hard layers as described in Chapter 1.1.4.

By just running the pods through a hammermill a product of unspecific morphological and functional characteristics is obtained, which is only usable as feedstuff for ruminants.

The requirements for a raw material that serves as a basis for more or less sophisticated foodproducts are more specific:
The product has to have a uniform mesh size, texture, color and odor. It has to have a known composition with desirable functional characteristics, such as:

A cereal flour (starch/gluten: structure giving)
A soy concentrate (protein: emulsifier, foam)
Guar gum (Galactomannan: thickening and stabilizing agent)

These requirements were already valid for the Indians. They had a basic but efficent technology to separate the exo- and mesocarp from the seeds (Chapter 1.2.3.). Their ideas and methods were the starting point for the process that will be described here. Some suggestions about milling MESQUITE-pods have been published in 1969 (46) and 1979 (47), but were directed towards obtaining seeds for reforestation purposes. Therefore only very small quantities were processed.

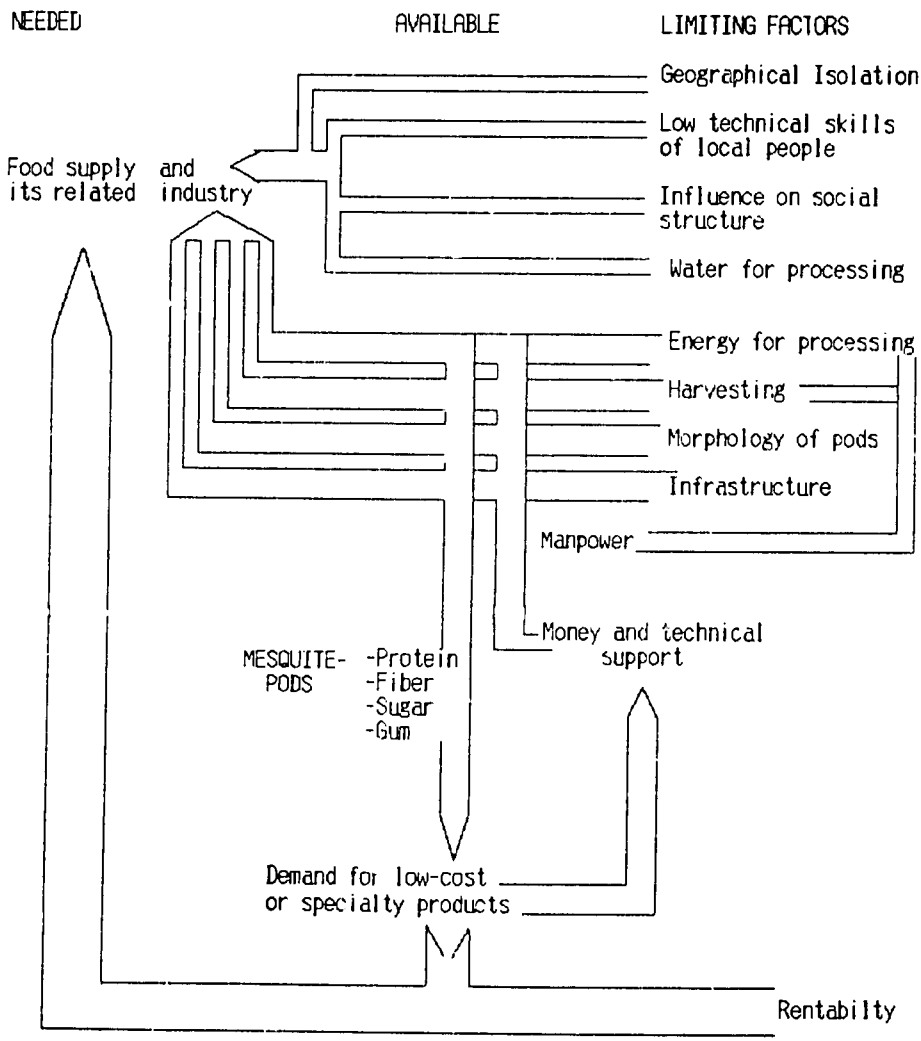
Several authors studied the composition of the pods or some of its morhphological fractions (48;49;50;51;52;53;54;55;107) but its applications in food products have never seriously been investigated, even though no toxic components have been found (56), except of very small amount of cyanide in some species (106).

It is the purpose of this study to fill these gaps. Figure 8 illustrates the problems and possibilities that surround the potential utilization of MESQUITE pods as a food source, and serves as the framework and self-imposed task sheet for this work.

The verbal interpretation of Figure 8 leads to the following formulation:

> IT IS THE OBJECTIVE TO OUTLINE HOW MESQUITE PODS CAN BE HARVESTED, MILLED AND INCORPORATED INTO FOODSTUFF.
>
> THE PROJECT HAS TO RESPECT THE SPECIAL CLIMATIC, GEOGRAPHICAL AND SOCIAL CIRCUMSTANCES OF THE ARID AND SEMI-ARID GROWING AREAS, AND HAS TO BE ECONOMICALLY FEASIBLE.

Figure 8: Problems and possibilities surrounding the utilization of MESQUITE pods



2. EXPERIMENTAL PART AND RESULTS

2.1. Methods and materials

2.1.1. General analytical methods

The following list covers only standard chemical methods that are frequently used for routine analyses. Methods that are specific for certain experiments are mentioned in the according chapters:

Sucrose:
AOAC Methods, 13th Ed. 1980, Method # 31.027-31.028

Glucose:
AOAC Methods, 13th Ed. 1980, Method # 31.032

Protein (N):
AOAC Methods, 13th Ed. 1980, Method # 7.021-7.024

Moisture:
AOAC Methods, 13th Ed. 1980, Method # 14.002-14.003

Crude Fiber:
AOAC Methods, 13th Ed. 1980, Method # 7.061-7.065
Other Fibers:
Forage Fiber, Agric.Handbook #379; Agric.Res.Service
USDA 1970

Fat:
AOAC Methods, 13th Ed. 1980, Method # 7.055-7.056

Ash:
AOAC Methods, 13th Ed. 1980, Method # 7.009

Metals:
AOAC Methods, 13th Ed. 1980, Method # 3.006-3.058

Carbon / Hydrogen:
AOAC Methods, 13th Ed. 1980, Method # 47.009-47.012

Phosporus:
Biochem.J. ; 34B; 858 (1940)

Sulfur:
J.Food Sci. 44 ,p.1772, (1979)

2.1.2. Specification of pods

As described in Chapter 1.1.1., there are 44 known species of MESQUITE which produce pods with considerable morphological variations.

For practical reasons the following studies have been restricted to one type of MESQUITE, unless otherwise mentioned. This one type is not necessarely one species, but rather pods that are morphologically similar. They are basically P.velutina, P.glandulosa and its hybrids. This type of pods represents the overwhelming amount of MESQUITE found in the United States and Central America. The pods that have been used for this work have been collected by the author in the Imperial Valley in Southern California and in the Yuma area in South-Western Arizona. The pods were gathered in July and August 1982 and 1983 under approximately 20 different wild growing trees with racks (Figure 9), stored in guny-bags and brought to the laboratory in Albany,CA where they were kept in freezers at minus 20°C until used for the experiments. Some tests have been performed with pods from Chile (referred to as such in the text).

Figure 9: Pod collecting in Southern California

2.2. Pod structure and terminology

The overall goal of processing the pods has been outlined in Chapter 1.3.2.:

To produce morphologicaly and functionaly homogenous fractions.

A milling and separation process would evidentially have to be based on the general physiological structures of the pod. It is therefore necessary to describe the pod from this point of view:

The pod basically consists of the PERICARP which contains the SEEDS (Figure 10).

The PERICARP itself has three different layers:

-The EXO-CARP, or outer layer is approx. 1 mm thin, relatively soft and of a yellow color.
-The MESO-CARP, lying just beneath the exocarp is about 2-4 mm thick and rather soft.
-The ENDO-CARP (which is often thought to be the seed by people who see a pod for the first time) is a very hard and fibrous layer, enclosing the seed. This hull can hardly be opened by hand.

The small SEEDS inside the endocarp hull again are extremely hard and are composed of:

-The brown, very thin SEED COAT.
-The ENDOSPERM which lies directly beneath the seedcoat
-The COTYLEDON and a tiny GERM.

Table 1 gives the terminolgy of the four fractions according to their origin. These names have been created to simplify the description and will be used from here on through the whole study where applicable.

Figure 10: Pod structure

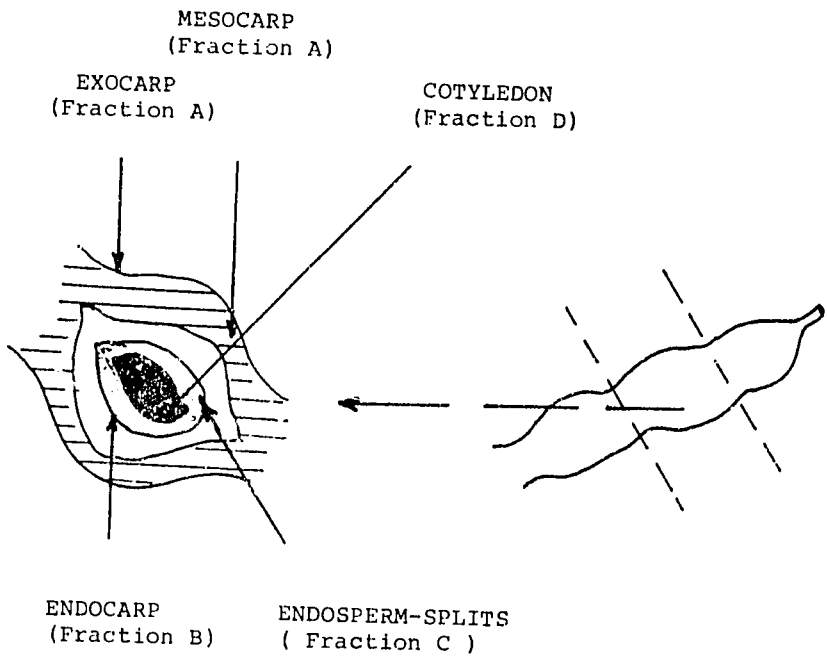


Table 1: Terminology of fractions

Botanical origin		TERM USED IN THIS WORK
Pericarp:		
EXO- and MESOCARP	(outer pericarp)	FRACTION A
ENDOCARP	(inner pericarp)	FRACTION B
Seed:		
ENDOSPERM with adhering SEED COAT	(seed splits)	FRACTION C
COTYLEDON with GERM		FRACTION D

2.3. Milling and separation process

In order to develop a milling and separation process the whole array of different type of mills had to be tested for MESQUITE pods, but only the combination of machinery which will be described, finally provided satisfying results.

It became clear during the evaluation procedure, that there is a need for unbroken seeds for reforestation purposes and the process therefore would not only have to produce raw material for further applications, but would also have to deliver unbroken seeds as an intermediate product. Also the unbroken seeds would be much easier to separate from the remaining pericarp material.

In order to be able to determine the effect and efficency of different mills and separators that were to be used, some helpful standard numbers of the pods had to be determined. For this purpose, the pods were dried for 10 hours at 50°C, run through a laboratory disc-mill without breaking any seeds; still unopened endocarp hulls were openend with pliers. Fractions A, B and unbroken seeds were then manually carefully separated.

This preliminary investigation revealed the average size of product fractions as shown in Table 2. Table 3 shows standard figures of MESQUITE pods that had to be determined in order to evaluate and to control the milling process. Numbers in parentheses are the extremes that were found in this study.

Table 2: Percentages of pod fractions

Whole pod		100.00 %	
Fraction A (Exo-mesocarp)	:	53.0 %	(49.0 -57.0%)
Fraction B (Endocarp)	:	22.0 %	(19.0 -24.0%)
Seeds	:	25.0 %	(18.0 -27.0%)

Table 3: Standard figures for process control (averages)

Weight of 100 pods	:	300.0 g	(155.0 -480.0g)
Number of pods / kg pods	:	333	(645 -210)
Seeds per pod	:	12	(7 - 15)
Weight of 100 seeds or	:	4.0 g	(3.5 - 4.3)
Number of seeds/kg seeds	:	25000	(23200 -28300)

2.3.1. Process description

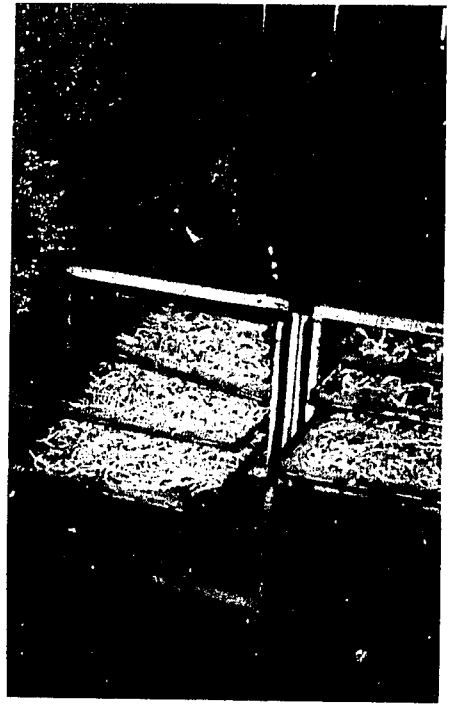
2.3.1.1. Drying

The MESQUITE pods reach a minimal moisture content by the time they mature and fall to the ground. Once they drop, they equilibrate with ambient moisture conditions, usually remaining quite dry in the desert unless rained upon. When transported to the more humid San Francisco Bay Area, they rapidly absorb ambient moisture. Therefore, the pods were either stored frozen or in a low humididty room. Special dry storage conditions were required for broken or milled pods because the mesocarp is very hygroscopic and would rapidly absorb moisture.

The natural moisture of the ripe pods, which has been determined to vary from 8 to 14%, make it impossible to run the pods through any milling process at all; the machinery cloggs up almost immediately. It is therefore mandatory to dry the pods prior to any further processing.

Drying curves were determined with approximately 5 kg pods of three different varieties, which were laid as a 3 cm high layer on trays, and dried in a tunneldrier(Taylor) at 70°C with an air velocity of 250 m/min (Figure 11)

Figure 11: Drying of pods in a tunnel-drier



The pods were weighed several times during the drying process and after 21 hours the remaining moisture was determined. The actual moisture at all intermediate drying times was then calculated.

The drying curves of the pods are shown in Figures 12 and 13.

Temperatures above 75°C have resulted in partial burning or at least browning of the pods. Bellow 65°C the drying times are increasing rapidly.

Figure 12: Drying curve of Prosopis velutina (70°C)

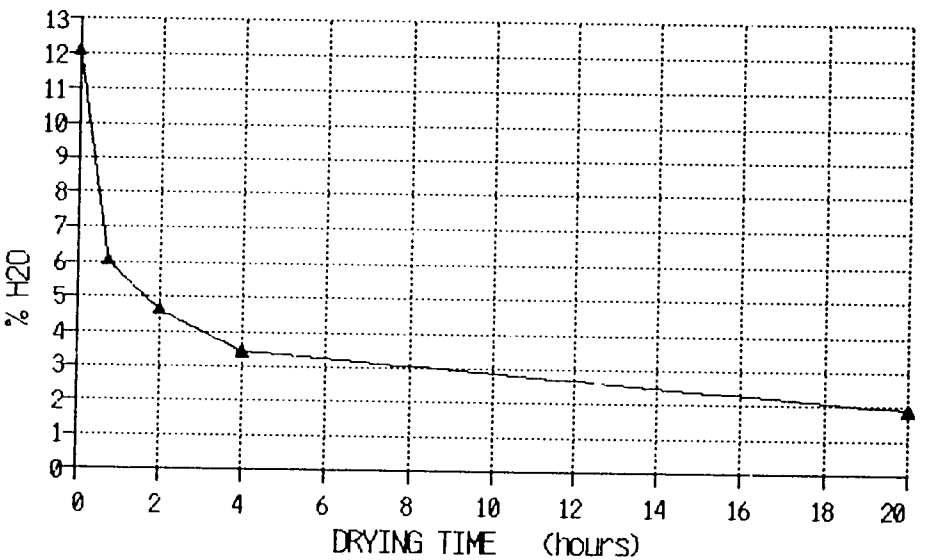
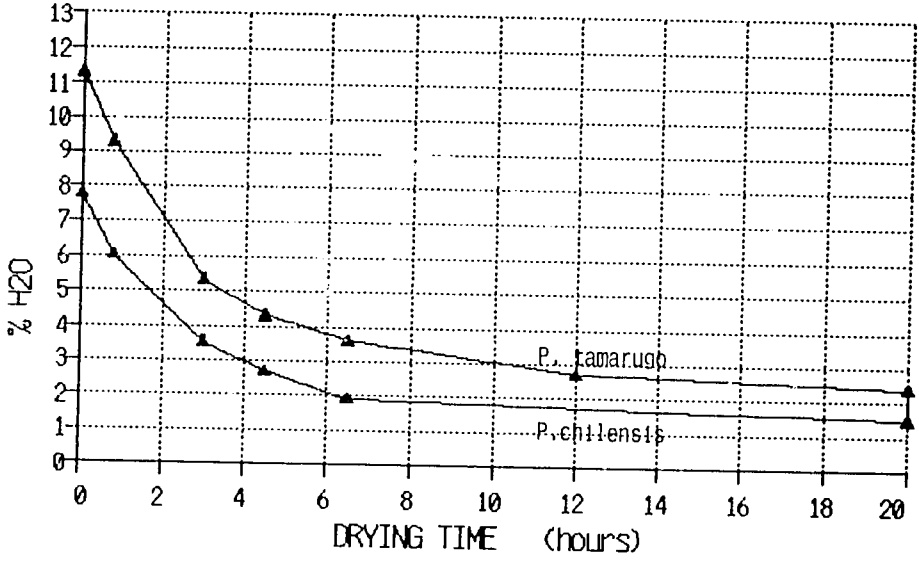


Figure 13: Drying curve of P.chilensis and P. tamarugo (70°C)

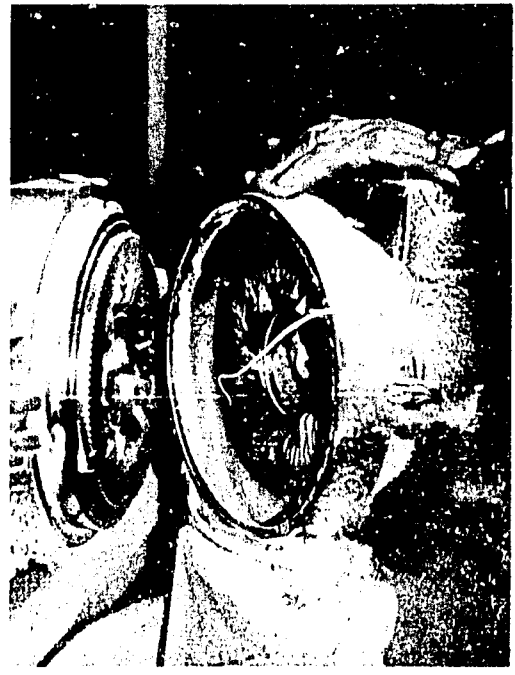


2.3.1.2. Breaking

In order to ensure a proper feed of pods to the subsequent milling operation (2.3.1.3.), the pods have to be broken into smaller pieces, about 3-4 cm long. These pieces are straight, whereas whole pods are slightly bowed. It is important, that this first breaking does not release seeds since they would otherwise be broken in the next step. Also no fine material should be produced in this step, since the dust formed disturbs feeding to the mill. All these conditions can generally be fullfilled with a slow turning disintegrator.
(Rietz Disintegrator; speed 500 rpm; Figure 14).

Figure 14: Breaking

Figure 15: Milling



2.3.1.3. Milling

This is with no doubt the most critical step of the milling and separation process of the pods. Many attempts with a large variety of mills produced unspecific mixtures of different pod-fractions (Table 4).

Table 4: Milling characteristics of two unsuccessful mills

Equipment	Conditions	Result
Corrugated roller-mill	variable speeds and gaps	75% of endocarp hulls not opened; release of broken seeds
Hammermill	500-2500 rpm	Seeds are broken into small pieces

It became obvious, that only a disc-mill could eventually do the expected job. Horizontal discmills, highspeed discmills and squaretoothed discs were however not suitable. Eventually a vertical dicsmill with corrugated discs at relatively low speed proved successful in producing a maximal amount of released but unbroken seeds as well as a proper separation of endocarphulls from mesocarp (Figure 15).

Besides speed and the right type of disc it is even more critical to find the proper gap between the discs. It has to be just a little smaller than the endocarp hulls, but slightly larger than the thickness of the seeds. This gap has to be adjusted depending on the average thickness of the pods before a new different batch is milled. This can be done with a handful of pods and visually checking the output. In the mill, the exo- and mesocarp is cut off the endocarp hulls, which themselves are not pouderized since they are much harder than Fraction A. The hulls are torn apart along the two sides, and the seeds released. The seeds are scarified, but most of them (min. 85%) not broken, since they are smaller than the gap between the discs and the centrifugal force which spins the seeds to the frame is insufficient to break them.

In a first suggestion for a milling process (61), the same machine was used but at a higher speed. Under these conditions the seeds are broken by crashing them to the frame, but the subsequent separation proved to be too unspecific.

Specification, Milling

Equipment : Bauer mill 148 (horizontal disc mill), Size 8
Disc : 8114 Gap-setting: 40 Speed : 3450 rpm

2.3.1.4. Separation A

The milling by means of a horizontal discmill resulted in a mixture of pod fractions (Fraction A and B as well as complete seeds) , which now has to be separated. At this stage this can be done by a unit that allows separation according to mesh size only, with three outlets.

This was carried out by a vibrating screen sifter with two different screens. The milled pods are fed on top of screen 1 which retains Fraction B i.e.the endocarp hulls. The seeds and Fraction A pass this screen. The seeds along with some pericarp fragments are retained on screen 2, whereas Fraction A passes and is collected at the bottom. The steady vibration of the apparatus ensures a proper functioning and automatically ejects the material from the screen which can be collected externally.

It is important that this separation step is performed immediately after the milling, since Fraction A is subject to lumping due to its hygroscopicity. If this happens, separation is not possible anymore. Working in dry environment (dry room) eliminates these restrictions. Fraction A also has to be stored properly after separation, whereas Fraction B and the seeds pose no such problems.

The quantitative flow corresponds to the actual distribution of the fractions of the processed pod if the milling has been carried out properly.

Visual checking of the fractions for unopened endocarp hulls or excessive broken seed material in Fraction A would at this stage inform of necessary adjustment (gap, speed) at the milling level. For analytical purposes, Fraction B could be rerun through the mill if too many hulls were still unopened.

This processing step releases the two pure Fractions A and B which need no further separation except a size reduction for their specific application. The seeds along with pericarp fragments go to the next separation step (Separation B).

Specification, Separation A

Equipement : Sweco, Screen-separator
Screen 1 : 4.8 mm round holes
Screen 2 : 1.0 mm square holes
Pods with extreme seed size might require other sieves,which are easily exchangable in this unit.

2.3.1.5. Seed cleaning

The seeds along with some pericarp fragments are retained by sieve #2 in the preceeding step. The pericarp fragments account for 20-50 % of this fraction, depending on a proper adjustment of the mill (see chapter 2.3.1.3.). The retained material consists of endocarp fragments and exocarp pieces that come from the tips of the pods. This material has to be regarded as "dirt" and must be separated from the seeds.

The seeds are smaller and heavier than the pericarp fragments. Therefore, a cyclone (Mc Gill, Houston TX, Laboratory aspirator 66-17721) with adjustable airspeed effectively separates the two fractions. The clean seeds pass the vertical tube and can be collected; the pericarp fragments are carried away in the airstream and can be discharged or added to Fraction B, since a visual check makes clear, that most of this material is part of endocarp hulls. To prove this observation, an analysis of the pericarp fragments was performed: Fat and protein of the pure fraction as well as of the pericarp fragments were determined (Table 5).

Table 5: Composition of pericarp fragments versus clean fractions

Fat/ Protein	Fraction A (pure)	Fraction B (pure)	**Pericarp fragments**
Protein (N x 6.25)	8.9	6.3	6.9
Fat	2.7	.2	1.7

The calculated composition of the pericarp fragments reveals that one can expect it to be 70-75 % Fraction B and 20-25 % Fraction A.

2.3.1.6. Seed splitting

The cleaned seeds represent an end product if used for reforestation, or can be further processed by splitting into endosperm and cotyledon if their utilization for food-purposes is anticipated.

Two pieces of equipment have proven to be succesful for seed splitting. Both will be described here and basically perform the same function: The seeds are fed to a cyclone mill (Udy-cyclone mill with steel impeller and rough abrasive frame 2000 rpm; Figure 16) or to a graintester (Strong-scott 17810; Figure 17) in which they are thrown to the frame of the unit. The speed and force of the crash causes the seeds to break into three parts; two endosperm splits (=seed coat with endosperm, Fraction C) and the cotyledon with the tiny germ (Fraction D).

If the process works properly with the graintester, it is the one to choose because of its simplicity. The seeds are run in the unit for about 30 seconds (the endpoint can be determined accustically). This unit does not allow adjustments (rotor,frame or speed) and therefore some seeds just break without being splitted, and come out as small pieces or even a fine powder. Table 6 gives the result of a poor splitting experiment with a large percentage of fine material.

Table 6: Example of poor seed splitting

Seed input	:	120.0 g	100.0 %
Unbroken seeds	:	3.4	2.8 %
Splits (C)	:	48.0 g	40.0 %
Cotyledon (D)	:	26.6 g	22.0 %
Fine material	:	48.0 g	40.0 %

As will be shown, the seeds consist of approx. 55 % of Fraction C and 45 % of Fraction D. Table 6 therefore indicates that the fine material contains a substantial amount of Fraction D. This was confirmed by a comparison of the protein content of the fine material with Fraction D:

Fine material = 36.4% Protein
Fraction D = 54.0% Protein
Fraction C = 4.0% Protein

Fraction D accordingly accounted for 70 % of the fine material.

If the unspecifically broken seeds or the fine material are in excess of 25% of the input, it is recomended to use a cyclone mill instead of the graintester. The cyclone mill allows changing of the rotor size, form, material), the frame (coarse or fine surface), speed and air flow. In addition, the top of the unit is made from clear plexiglas which allows to observe exactly what happens with the help of a stroboscope.

The seeds are run through the unit for 90 seconds, then the small sieve in front of the outlet is removed to allow the splitted seeds to fall in the collector. The disadvantage of this unit is that it requires more attention and fine tuning from the operator.

An average of 85 % of the seeds can be recovered as splitted seeds with 15% of the input being collected as fine material which consists of 70% Fraction D and 30% Fraction C (see above).

2.3.1.7. Separation B

The purpose of this step is to separate the endosperm splits (Fraction C) from the cotyledon (Fraction D). The process is the same whether the graintester or the Udy-cyclone-mill is used in the preceeding step.

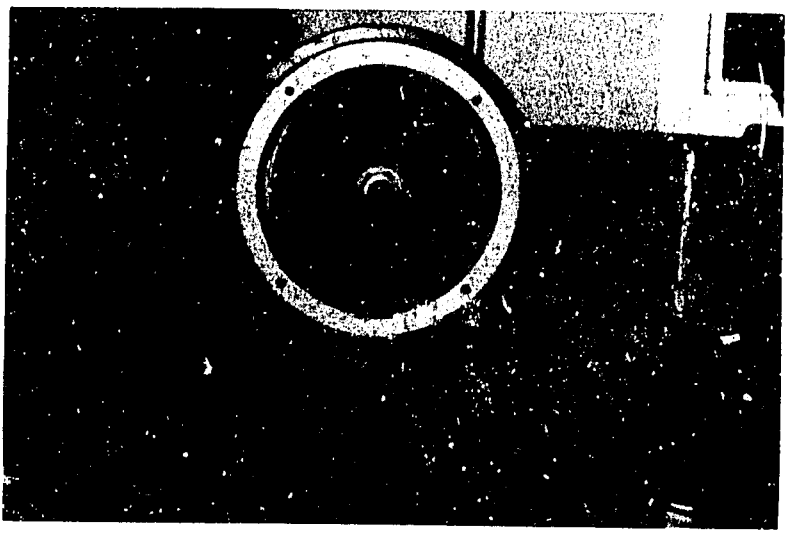
The inevitable fine material that forms during splitting of the seeds is first of all removed by running the material through a 10 mesh sieve. Fractions C and D can then be separated by air classification. Theoretically any air classifier such as the cyclon that is used in separation A (2.3.1.4.) could be used, but a unit that allows good finetuning is prefered, since the size/weight differences of the two fractions are not as pronounced as in separation A.

A simple clear plexiglass tube with the necessary collecting devices and an adjustable airflow performs a completely satisfying seperation. Fraction C is collected at the top and Fraction D stays at the bottom of the tube.

The average distribution of the two fractions is 55 % Fraction C (endosperm splits) and 45 % Fraction D (cotyledon).

Figure 16: Seed splitting with a cyclone-mill

Figure 17: Seed splitting with a graintester



2.3.1.8. Fine-milling

Each fraction that is obtained by the described process has its relatively uniform mesh-size at this stage, and needs only to be reduced in size depending on what further application is intended.

Fraction A: The flour has already a partical size of <1mm, which corresponds to <20 mesh. All proposed applications except sucrose-extraction (2.5.2.1.) require a size reduction to at least <60 mesh. This can be achieved by milling the flour with a Wiley-mill, using a 60 mesh oulet-screen. Bigger quantities were produced with a disc-mill (Alpina, Augsburg 160 Z).

Size reduction of the other fractions will be discussed along with their specific application (2.5.2.), since no standard procedures are applicable.

2.3.2. Flow sheet and process yield

Figure 18 shows the flow sheet for the complete milling and separation process, whereas Figure 19 illustrates the yield of each fraction obtained through this process.

Figure 18: Flow sheet for the milling and separation process

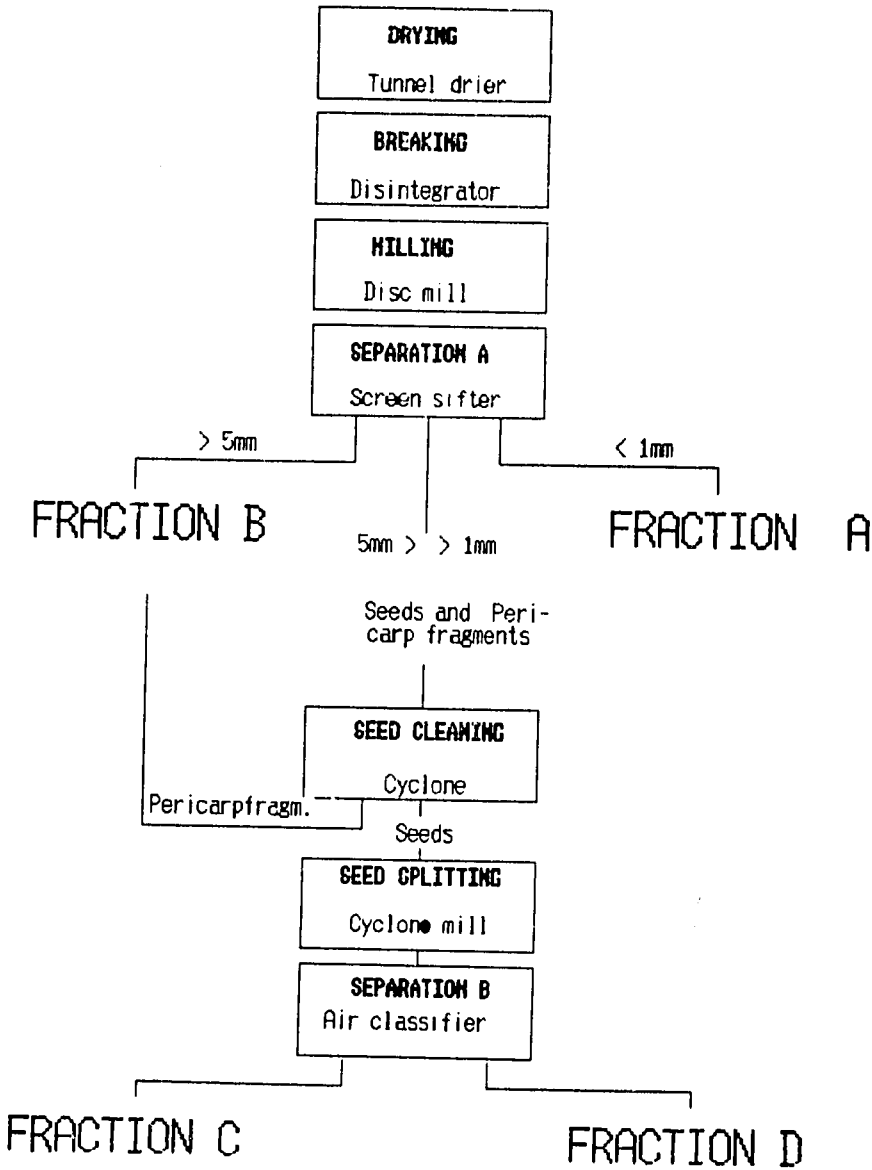
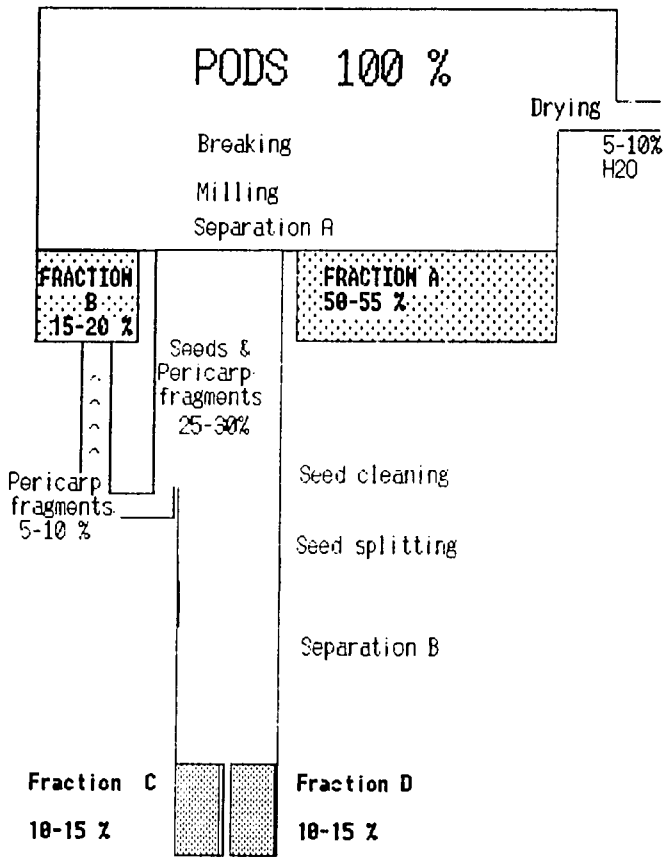


Figure 19: Process yield of the milling and separation process



2.4. Chemical composition of the pods

2.4.1. Detailed analysis of the fractions

Work by Becker (49), Figuereido (50) and Del Valle (58) concentrated on the chemical composition of either the whole pod or differentiated only between seeds and pericarp. The following chapters study the fractions as obtained by the described milling and separation process with regard to their possible application.

The results present a representative sample of all pods which were used and analyzed uring the time of this study. They are based on a rounded average of samples of 25 different trees (P.velutina type), as well as extremes.

It was not attempted to investigate the minor compounds, but each chapter will mention other interesting substances found by other researchers (if applicable).

2.4.1.1. Fraction A

Tables 7-11 show the overall chemical composition of Fraction A (exo-and mesocarp) as well as the analysis of individual components (all results on a moisture-free basis).

Table 7: Chemical composition of Fraction A

Compound	Average %	Extremes %
Total sugars	48.0	25 ; 58
Protein (N x 6,25)	9.5	6 ; 11
Fat	2.0	0.8 ; 4
Crude Fiber	16.0	10 ; 23
Ash	4.5	3.7 ; 4.9

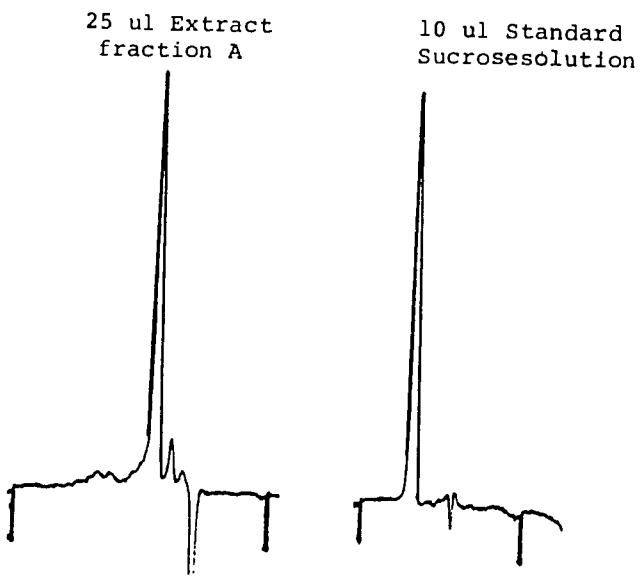
It is not surprising that almost all the sweetness of the pod is caused by the very high sugar content of Fraction A. Nevertheless, its percentage (close to half of the drymatter) is unique for a leguminous plant, only carob pods being comparable.

Sugars:

A considerable sweetness is the dominant organoleptic impression when tasting the flour of Fraction A. The question was, whether sucrose would be the only compound, or whether other sugars would also be detectable in large quantities. Samples that were analyzed by HPLC for sucrose/ glucose/ fructose resulted in a respective content of 92 % / 3 % / 5 % (Figure 20). Therefore, the ratio of sucrose versus reducing sugars is approximately 9:1 .

Figure 20: HPLC-analysis of a water extract of Fraction A

Solvent : Aldonitrilacetat:H2O = 80:20
Flow : 2.0ml /min
Column : Water Associate Carbohydrate Column
Printer : Atten. 8x; 10 mv AUFS
Refractiveindex : 8x
Reference : Conrad (101)



Sugar components found by other researchers:
Malhotra (55) reports ellagic acid 4-0-rutinoside, to be present in pods of P. juliflora.
Becker (49) found small amounts of raffinose and inositol in the pericarp of P.velutina.
Shalaby (59) reports traces of rhamnose, galactose and glucuronic acid in the pericarp of P.stephaniana.

Protein:

The protein content of Fraction A is relatively high (close to 10%). In an attempt to determine its quality, the amino acid composition was investigated (Table 8).

Table 8: Amino acid composition of Fraction A

Analyzed with a Durram amino acid analyzer, Model D-500 (110)

Amino acid	Grams per 100g of Fraction A	mg per gram nitrogen		Provisional score (FAO) mg/g N (102)
ASPARTIC ACID	2.026	866		
THREONINE	0.461	197		250
SERINE	0.553	236		
GLUTAMIC ACID	1.784	762		
PROLINE	1.126	481		
GLYCINE	0.615	263		
ALANINE	0.561	240		
CYSTEINE	0.193	83		
VALINE	0.699	299		310
METHIONINE	0.125	54	(MET+CYS)	220
ISOLEUCINE	0.387	165		250
LEUCINE	0.933	399		440
TYROSINE	0.377	161		
PHENYLALANINE	0.385	165	(PHE+TYR)	380
HYSTIDINE	0.317	135		
LYSINE	0.506	216		340
ARGININE	0.975	533		

Fatty acids:

The small amount of fat (<3%) would definitely not justify to use this fraction as a source for oil. For reasons of completeness however, the fat which had been extracted with hexan from Fraction A had been analyzed by GLC for its fatty acid composition (Table 9).

Some technologically important characteristics are discussed in chapter 2.5.2.1.

Table 9: Fatty acid composition of Fraction A

Conditions:
Carriergas : N_2 , pressure 4 bar, flow 30ml/min
Detector : FID, H_2 1.86 bar, Air 1.8 bar
Oven temp. : 175°C isotherm Attenuation : 5

Fatty acid	Retention time	Area	Percentage
Myristic acid	1.47	1.1362	1.1
Palmitic acid	2.55	14.2899	13.7
Stearic acid	4.52	4.8313	4.6
Oleic acid	5.24	25.5500	24.5
Linoleic acid	6.65	48.6912	46.7
Linolenic acid	8.94	4.8374	4.6

Fat components found by other researchers:
Figuereido (50) found beta-sitosterin in the ether extract of the pericarp of P.juliflora.

Fiber:

Several different types of fibers of Fraction A were determined, in order to receive a most complete overview over this compound (Table 10).

Table 10: Types of fiber of Fraction A

Type of fiber		% of Fraction A
a) Dietary fiber		35.3
b) Crude fiber		16.0
c) Neutral detergent fiber		23.1
	Standard deviation	0.[illegible]
d) Acid detergent fiber		24.7
	Standard deviation	1.0
e) Lignin		5.7
	Standard deviation	0.8
f) Cellulose		14.6
	Standard deviation	1.0

a-b, respecively c-f, were determined on different batches

2.4.1.2. Fraction B

The endocarp hulls (Fraction B), which make up an average of 20-25 % of the pod, appear to be the least interesting part of the MESQUITE-pod. They are extremely hard and fibrous. Nevertheless, they deserve a closer look at their chemical constituents (Table 11)

In an attempt to obtain a better quality of Fraction B, the endocarphulls were milled in a pin-mill and separated into two fractions with a cut at 40 mesh. This separates quantitatively 1:1. Differences in their composition are listed in Tables 12 and 13.

Table 11: Chemical composition of Fraction B (on moisture-free basis)

Compound	Average % of Fraction B	Extremes % of Fraction B	Fraction B >40mesh	Fraction B <40mesh
Total sugars	6.0	3; 11	-	-
Protein (N x 6,25)	6.5	4; 9	4.3	15.5
Fat	1.3	0.8; 1.8	-	-
Crude Fiber	45.0	39; 55	51.5	25.3
Ash	3.5	3.3; 3.9	3.0	3.5

Sugars:

The sugars found in Fraction B are most likely to be residues of Fraction A, since its percentage varies quiet widely.

Samples that were analyzed for sucrose and reducing sugars respectively, showed 97.5% sucrose versus 2.5% reducing sugars.

Protein:

The protein content of Fraction B averages around 6 % and is therefore considerably lower than in Fraction A . Its amino acid composition is shown in Table 12 (the analytical conditions are the same as shown in Table 8)

Table 12: Amino acid composition of Fraction B

Amino acid	Grams per 100g of Fraction A	mg per gram nitrogen	Provisional score (FAO) mg/g N	(102)
ASPARTIC ACID	1.897	666		
THREONINE	0.541	190		250
SERINE	0.808	284		
GLUTAMIC ACID	2.929	829		
PROLINE	0.997	350		
GLYCINE	0.856	301		
ALANINE	0.710	249		
CYSTEINE	0.259	91		
VALINE	0.769	270		310
METHIONINE	0.054	19	MET+CYS	220
ISOLEUCINE	0.590	207		250
LEUCINE	1.186	416		440
TYROSINE	0.497	175		
PHENYLALANINE	0.664	233	PHE+TYR	380
HYSTIDINE	0.465	163		
LYSINE	0.812	285		340
ARGININE	1.516	533		

It is apparent, that the amino acid composition of Fraction B is very similar to the one of Fraction A, or even slightly more valuable, except for aspartic acid, proline and especially methionine, for which the percentage in Fraction B is significantely below Fraction A and only about 15% of the FAO-score.

Fiber:

For the analysis of the fiber content of Fraction B (Table 13), the same methods were used as for Fraction A. It is evident that this fraction has a very high fiber content.

Table 13: Types of fiber of Fraction B

Fiber	% of Fraction B	Fraction B >40mesh	Fraction B <40mesh
a) Dietary fiber	61.6	-	-
b) Crude fiber	45.0	51.5	25.3
c) Neutral detergent fiber	69.0	85.0	52.9
Standard deviation	3.5	2.3	4.8
d) Acid detergent fiber	53.7	69.5	37.8
Standard deviation	2.8	2.4	3.2
e) Lignin	9.8	11.3	8.2
Standard deviation	0.8	0.6	1.1
f) Cellulose	41.0	54.8	27.2
Standard deviation	2.2	1.6	2.7

a-b, respectively c-f, were determined on different batches

2.4.1.3. Fraction C

Fraction C in its form after the milling and separation process consists of two different morphological parts, namely the seed coat and the endosperm; the combination is called **endosperm** split. The seed coat is a very thin, brown and fibrous layer, which adheres to the transparent endosperm.

A complete separation of the seed coat from the endosperm can only be achieved manually. The endosperm split has to be soaked in water and can then be peeled off carefully.

Analysis of these two parts reveals differences in their composition. These results as well as the composition of the complete Fraction C is shown in Table 14.

Table 14: Composition of Fraction C

Compound	Fraction C %	Seed coat %	Endosperm %
H2O	6.0	-	-
Protein (Nx6.25)	4.0	6.2	3.1
Crude Fiber	7.6	18.1	0.6
Fat	0.0	0.0	0.0
Gum content (by diff.)	82.5	75.7	96.3

The most interesting constituent of Fraction C as far as its commercial utilization is concerned, is the carbohydrate fraction of the endosperm.

GLC-analysis reals that it consists predominantly of a galactomannan a polysaccharide similiar to locust bean and guar gum. Galactomannans form highly viscous solutions at low concentrations. This interesting characteristic is well known. Galactomannans are therefore used extensively for thickening purposes (61;62;63;64).

The carbohydrate of MESQUITE Fraction C contains also traces of other sugars. Table 15 shows their quantitativ distribution.

Table 15: GLC-analysis of the hydrolysate of MESQUITE endosperm

Monosaccharide	Retention time	Concentration (%)
Rhamnose	99	0.225
Fucose	123	0.100
Arabinose	139	4.182
Xylose	156	1.957
Xylit	177	0.222
Mannose	221	**56.470**
Glucose	248	0.596
Galactose	**269**	**36.240**

According to Table 15, the mannose : galactose ratio is 1:1.6, which is similar to guar gum. This ratio is important for some of the functional properties of the galactomannan (Chapter 2.5.2.3.).

It is known from other galalctomannans that this ratio can vary widely among different species, place of origin or even seasonly (61). As an example, for Prosopis juliflora, a mannose : galactose ratio of 1:4.2 has been reported (108). Another variable is the actual amount of galactomannan in Fraction C. This will be discussed in Chapter 2.4.2.

In chapter 2.5.2.3., methods are described how the purity of Fraction C can be increased. Purity means a higher percentage of endosperm or a reduction of the seed coat.

2.4.1.4. Fraction D

The cotyledons and the tiny germ make up Fraction D, which is yellow and of a relatively soft structure.

The germ itself is so small that it is almost impossible to visually or physically separate it from the cotyledons. The whole Fraction consist basically of protein and fat, as shown in Table 16.

Table 16: Chemical composition of Fraction D

Compound	Average %	Extremes %
Moisture	4.5	2.0 ; 6.0
Protein (N x 6,25)	61.0	56.0 ; 63.0
Fat	8.0	5.0 ; 11.0
Crude Fiber	4.0	3.0 ; 6.0
Ash	4.7	4.1 ; 5.1

Protein:

The amino acid composition of Fraction D is shown in Table 17.

Table 17: Amino acid composition of Fraction D

Amino acid	Grams per 100g of Fraction D	mg per gram nitrogen	Provisional score (FAO) mg/g N (102)
ASPARTIC ACID	4.583	505	
THREONINE	1.321	146	250
SERINE	2.291	253	
GLUTAMIC ACID	11.214	1.236	
PROLINE	4.093	445	
GLYCINE	2.508	276	
ALANINE	2.290	252	
CYSTEINE	0.961	106	
VALINE	2.198	242	310
METHIONINE	0.550	61	MET+CYS 220
ISOLEUCINE	1.777	196	250
LEUCINE	4.148	457	440
TYROSINE	1.500	165	
PHENYLALANINE	2.134	235	PHE+TYR 380
HYSTIDINE	1.696	187	
LYSINE	2.292	253	340
ARGININE	7.552	832	

Components in the seeds reported by other researchers:
Beri et al. (65) reports 3.92 % starch in the defatted seeds of Prosopis cineraria.
Bhardwaj et al. (52 and 53) found some polyphenolics in the seeds of Prosopis spicigera: gallic acid, patuletin, luteolin, patulitrin, rutin, prosogerin E and D.
Pant et al. (54) reports two polystyrenes in the seeds of Prosopis juliflora.
Chellamuthu et al. (67) reports a percentage of 17.25 ! fat in Prosopis juliflora seeds with a saponification value of 179.1 mg, iodine number of 69.75 and acid value of 8.55 .
Figueiredo (50) checked seeds of Prosopis juliflora for free amino acids and found arginin, glutamic acid,leucin and alanin. He found two major proteins with molecular weights of 77 000 and 96 500.

2.4.2. Chemical variation in the main constituents of different pods

It is known, that pods from the same species but different trees vary widely in their apparent sweetness. This had been observed by simply chewing the pods. It therefore seemed to be interesting to determine, whether the compositional differences are limited only to the sucrose content or if they are found in other dominant constituents as well. For that purpose, pods from 16 different trees were collected at random, milled and separated as described in Chapter 2.3.. The fractions obtained were then analyzed chemically (Table 18).

Table 18: Compositional variation, Fraction A

Pod #	Total Sugars Sucrose +Glucose	Protein Nx 6.25	Fat	Crude Fiber
FN 1	45.6	10.4	2.2	12.6
FN 2	54.2	9.9	1.6	11.6
FN 5	43.2	8.4	1.7	14.2
FN 12m	43.4	9.1	1.8	19.3
FN 15	50.2	7.7	2.8	14.6
FN 15/30	47.0	8.9	2.25	13.2
FN 16	39.9	7.4	1.3	14.9
FN 17	41.9	10.2	1.7	16.5
FN 23	52.3	5.7	1.6	13.0
12 A	48.2	9.1	1.6	12.9
12 B	46.2	8.9	2.7	10.1
12/8	50.0	7.1	2.1	14.3
3/38	49.6	7.7	1.3	13.6
18/19m	56.4	7.8	1.4	11.1
X	39.0	8.7	2.9	16.3
X 2	46.8	9.0	1.7	17.0
Average	47.1	8.6	1.92	14.1
Standard-deviation	4.9 =10.4%	1.5 =17.4%	0.5 =26.0%	2.4 =17.0%

The analysis shows that the composition does not only vary in the total sugar content, but even more significantly in the other constituents of Fraction A.
Nevertheless, the sugars are the absolute dominant ingredients of this fraction, accounting for almost half of it.

Fraction B consists mainly of crude fiber. The other components however vary more significantly (Table 19).

Table 19: Compositional variation, Fraction B

Pod #	Total Sugars Sucrose + Glucose	Protein N* 6.25	Fat	Crude Fiber
FN 1	9.4	5.0	1.4	46.2
FN 2	10.6	6.9	1.0	45.6
FN 5	4.4	4.3	1.3	54.8
FN 12m	4.3	9.1	1.7	40.4
FN 15	6.5	5.7	1.4	41.6
FN 15/30	8.8	6.5	1.8	41.4
FN 16	5.7	5.9	1.2	45.7
FN 17	7.6	6.8	1.1	48.8
FN 23	5.3	4.6	0.8	51.7
12 A	7.3	5.7	1.2	41.1
12 B	5.7	6.3	1.1	46.6
12/8	5.9	4.9	1.0	47.1
3/38	11.0	7.5	1.1	39.4
18/19m	5.8	6.9	0.9	46.2
X	7.0	5.8	1.2	44.0
X 2	4.2	6.1	1.7	39.0
Average	6.8	6.2	1.3	45.0
Standard-deviation	2.2 =32.4%	1.2 =19.4%	0.45 =34.6%	4.5 =10.0%

As already mentioned in Chapter 2.4.1.3, the interesting question regarding the compositional variation of Fraction C is its ratio of galactose : mannose. Table 20 shows the results.

Table 20: Compositional variation, Fraction C

Pod#	Mannose:Galactose	Pod#	Mannose: Galactose
FN 2	1.14	FN 23	1.22
FN 5	1.22	12 A	1.40
FN 12m	1.99	12 B	1.43
FN 15	1.26	12/8	1.24
FN 15/30	1.14	3/3°	1.31
FN 16	1.38	18/19m	1.36
FN 17	1.37	X	1.04
X-2	1.52		
Average			**1.314**
Standard-deviation			**0.228**

It can bee seen that the galactomannan composition of all samples is within a relatively narrow range, even though the deviation within each sample was above satisfaction, probably due to impurities. The result satisfies insofar as the variation is to small to cause measurable functional differences.

The ratio of Fraction C to Fraction D of a seed is also of importance. A small seed with a high percentage of Fraction C could eventually give a higher yield of galactomannan than a large seed which consists primarily of Fraction D.

The ratio was determined by splitting the seeds with the graintester (see chapter 2.3.1.6.), sieving out the fine material that is being produced, and weighing the two fractions. The protein content of the fine material was analyzed and compared to the protein content of the pure Fraction C and D respectivly. This allowed to determine the percentage of each Fraction lost in this fine material, and led to the correction factor in determing the ratio of Fraction C to D (Table 21).

Example for the determination of correction factor:

Composition of fine material= 75% Fraction D + 25% Fraction C
% fine material = 40%

Fraction C = 2.95g
Fraction D = 2.61g Fine material = 3.71g

Effective C = 2.95g + 0.25 x 3.71g = 3.88g
Effective D = 2.61g + 0.75 x 3.71g = 5.39g

Uncorrected ratio of C:D = 2.95 . 2.61 = 1.13
Corrected ratio of C:D = 3.88 . 5.39 = 0.72
Correction factor = 0.62

The results of this study with the correction factor are shown in Table 21

Table 21: Compositional variation, Ratio of Fration C:D

Pod #	C:D	Pod#	C:D
FN 1	0.71	FN 23	1.10
FN 2	1.12	12 A	0.50
FN 5	0.71	12 B	0.69
FN 12m	0.56	12-8	0.69
FN 15	0.71	3-38	0.74
FN 15/30	0.60	18/19m	0.80
FN 16	0.66		0.74
FN 17	1.00	2	0.60
Average	**0.75**		
Standard-deviation	**0.18**		

The average ratio of Fraction C:D translates into a morphological seed composition of 43% endosperm splits and 57% cotyledons.

In contrast to Fractions A and B (Tables 18,19), Fraction D does not show a significant variations in the amounts of its main constituents. Protein, which accounts for more than half of this fractions, is found in very similiar percentages in all pods analyzed, whereas the fat content deviates to a somewhat greater extend (Table 22).

Table 22: Compositional variation, Fraction D

Pod #	Protein (N * 6.25)	Fat
FN 1	56.1	9.6
FN 2	52.0	9.4
FN 5	60.4	7.6
FN 12m	56.3	8.0
FN 15	56.9	7.5
FN 15/30	56.2	9.0
FN 16	57.7	7.7
FN 17	57.1	7.2
FN 23	59.2	7.5
12 A	56.3	6.2
12 B	55.6	8.0
12/8	55.6	9.3
3/38	59.1	7.0
18/19m	60.7	7.3
X	57.9	7.4
X 2	56.6	6.9
Average	**57.1**	**7.85**
Standard-deviation	**2.1 =3.7 %**	**1.0 =12.7 %**

2.5. Uses and applications of pod fractions

2.5.1. Objectives

The overall objective concerning the use of the MESQUITE-pods is to find the optimal application for each fraction in or as a food product.

"Optimal" is defined as the application which takes maximal advantage of the functional characteristics, leaves a minimal amount of unusable residue and provides the highest economical value.

The following applications fulfill these criterias to varying degrees. Such applications are nevertheless described with regard to the use of MESQUITE in lesser developed countries, where the most important criteria is to produce foodstuff for survival.

Some products might also be unfamiliar to the reader since they are specific to certain areas where MESQUITE grows or had traditionally been consumed. All applications are based on the fractions as received by the milling and separation processes described in Chapter 2.3. .

2.5.2. Applications of the various fractions

2.5.2.1. Fraction A

Fraction A is quantitatively the most important fraction, since it represents almost 60% of the whole pod. The chemical analysises in Chapter 2.4.2.1. revealed, that sucrose is the major compound of the flour (45%), followed by fiber and protein. Therefore, the use of Fraction A as a raw material for sucrose extraction is the first and most obvious application.

The use of Fraction A in composite-flours for cereal-based products will also be described. However, its major disadvantage, i.e. the complete lack of starch or a structure-bulding protein, such as gluten, will be shown to restrict this type of application to either low percentage of incorporation of Fraction A, or to products where structure is not the dominant characteristic.

2.5.2.1.1. Sucrose extraction

In many areas where MESQUITE grows wild, such as the Imperial-valley in Southern California or Hawaai, sugarcane or sugarbeets are grown and processed nearby.

MESQUITE compares favorable to the two traditional sucrose-sources on "as is" sucrose-percentage (sugarbeet 10-15%; sugarcane 14-26%; MESQUITE 30-50%).

The following list provides some thoughts why or why not, MESQUITE could be an interesting alternative to the traditional sugar crops.

Advantages:

-Sugarbeet processing starts in october, so MESQUITE would fit in off season of sugar production.
-Sucrose plants show currently low profitability, partly because of the short season.
-Sucrose is the main compound of MESQUITE Fraction A.
-Infrastructure already available.

Disadvantages:

-High soluble protein and mineral content of MESQUITE Fraction A interferes with the crystallisation and purification of sucrose.
-Existing surplus of sucrose in many countries except Mexico which has to import 300 000 tons of sugar in 1984 (103).
-Extremely high energy and water input.

Conclusions:

MESQUITE Fraction A should be processed using the already existing machinery and process steps of a conventional sugar-plant. No major changes should be required, the product should not compete head-on with regular sugar, but be sold as a "special" MESQUITE sugar.

Another possibility would be to stop the process before crystallization, or to invert some of the sucrose in order to produce a liquid sweetener or syrup, such as a maple syrup.

Therefore, the following experiments were based on the known methods of sucrose extraction as known from sugar beet processing, without attempting to produce a high purity sucrose identical to a conventional sugar.

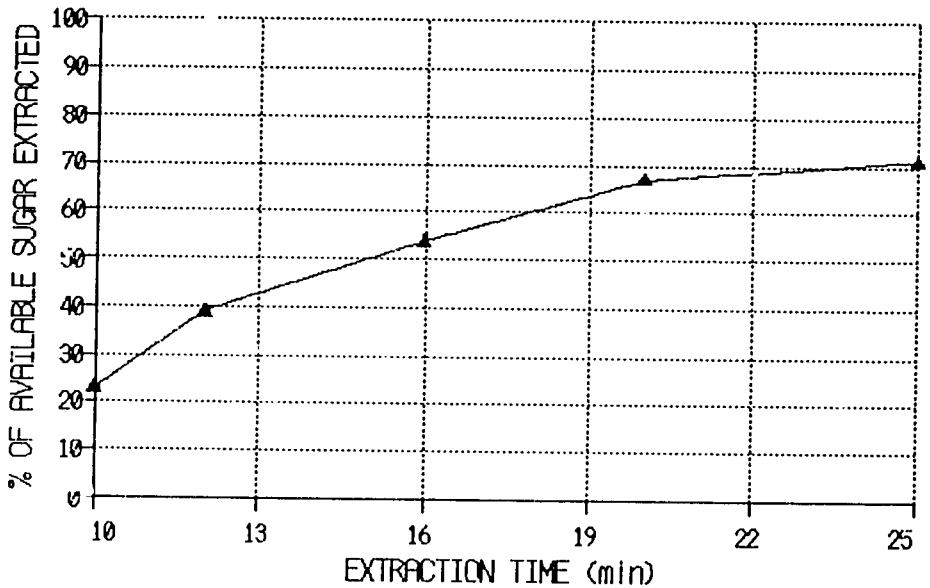
a) Preparation of small batches of sucrose syrup for analytical purposes

- Give 20g MESQUITE-Fraction A to 200ml H_2O
- Heat solution to 80°C for up to 20 min
- Filter solution through cheesecloth
- Run filtrate through roundfilter
- Heat filtrate to 80°C, add 2% CaO then keep at the temperature for 20-25 min
- Cool filtrate to 25°C
- Centrifuge for 20 min at 12 000 rpm
- Decant supernatant , set aside the sediment for analysis
- Inject CO_2 to supernatant for 5 minutes
- Second centrifugation for 20 minutes at 12 000 rpm
- Add 2 % activated charcoal and stir solution for 5 minutes
- Centrifugation for 20 min at 12 000 rpm
- Decant supernatant and concentrate in evaporator to 12.5 % sucrose (refractive index= 1.3515)
- Analyze supernatant by HPLC to determine sugar purity (see Chapter 2.4.2.)

Samples were kept at 80°C for different lenght of times in order to determine the necessary extraction time (Figure 21). Heating for 20 minutes at 80°C proved to be sufficient to extract around 70% of the theoretically available sugar.

Protein (N x 6.25)in the extract was also determined; the ratio of sucrose:protein in the extract varied from 7.2 after 10 minutes extraction, to 8.2 after 20 minutes extraction.

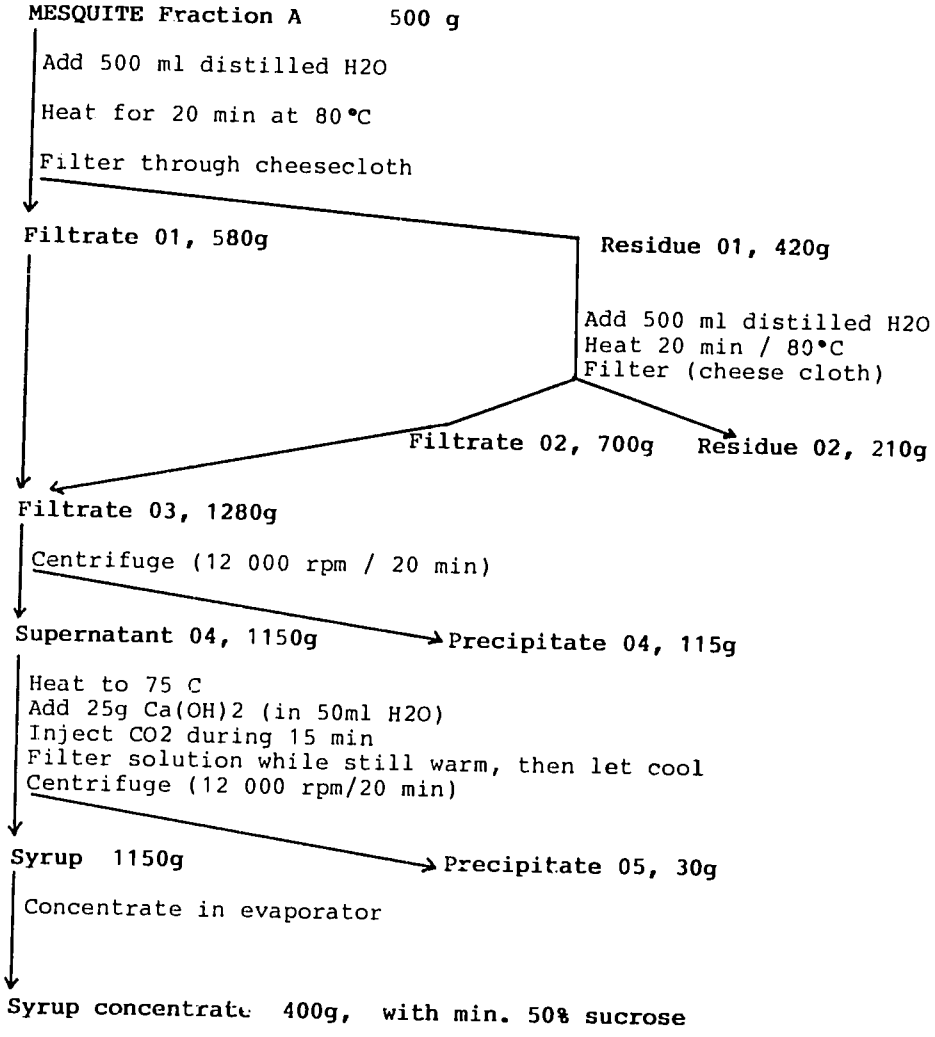
Figure 21: Extraction curve for sucrose from Fraction A at 80°C



b) Procedure to obtain pilot plant scale batches of sucrose syrup

The procedure follows basically the same system as described for small batches, but more data could be collected on a larger scale. The method is based on the industrial procedure for sugar beet processing (68), except for the first few steps that are not necessary for MESQUITE and for the final crystallization. Attention was given to minimize the amount of water and energy to be used (Figure 22).

Figure 22: Sucrose extraction process for MESQUITE Fraction A



The intermediate and end products of the process described in Figure 22 were analyzed in order to determine the accuracy and efficency of the system. The raw material that was used had relatively low percentage of sucrose of 42%.

Table 23 shows the results. The values also correspond to the preceeding page. Figures 23-25 show the extraction at different stages as well as intermediate products of the extraction process.

Table 23: Chemical analysis of intermediate and end products of the sucrose-extraction from MESQUITE Fraction A

Product	g (*)	Sucrose % of product	Sucrose % yield	Protein % of product	Protein %
MESQUITE Fraction A	500	42		10	
1.Extraction					
Filtrate 01	580	21	58	4.2	49
Residue 01	420	21	42	6.1	51
2.Extraction (of residue 01)					
Filtrate 02	700	7.4	25	1.5	21
Residue 02	210	12.2	12	6.9	29
Filtrate 03 (=F 01+02)	1280	13.6	83	2.7	70
1.Centrifugation (of filtrate 03)					
Supernatent 04	1150	13.5	74	1.8	32
Precipitate 04	115	12.1	6.5	12.0	28
2.Centrifugation (of supernatent 04)					
SYRUP	1145	13.1	71	1.2	28
Precipitate 05	30	13.0	2	7.0	4

(*) added water included

It is certainly no surprise, that the pilot plant scale process does not achieve the same extraction rate as the one in the laboratory experiment. Nevertheless, 70% of all available sucrose can be found in the end product after a two step extraction and multiple purification procedures, which effectively separate most of the protein, but also reduce the yield of sucrose slightly. The figures could certainly be improved by enforced stirring of the flour in the solution, or by an increase in the amount of extraction liquid, which in turn would increase costs significantly.

Table 24 illustrates the output of usuable product. The table also shows the mineral content of the syrup, which serves as a quality standard in the sugar industry.

Table 24: Input / output of sucrose extraction

	Sucrose g	Protein g	Crude fiber,g	Zn	Mg	Fe	Cu	Ca	Na
				ppm				g/100g	
Input:									
500g MESQUITE									
Fraction A	210	50	90						
Output:									
400 ml MESQUITE									
Syrup	150	**14**	0	17	4	20	2	**0.4**	**0.1**
160g usuable									
Residue	26	14	85						

The numbers do not necessarily add up to 100% due to material losses and percentages of compounds which are precipitated through centrifugation, and do not present reusable material.

The syrup represents a good tasting end product, which can be compared to a maple syrup even though its aroma is more pronounced. It could be used as a raw material for softdrinks such as rootbeer, pancake syrup or as a general purpose liquid sweetener.

Crystallization is possible, however in this study could not be carried out due to unavailability of equipement.

The residue represents a fibrous by-product with hardly any value except for feeding purposes.

Fermentation:

The syrup might also serve as a raw material for alcoholic beverages after fermentation. A small experiment has been performed to investigate this possibility:

- 1 g Saccharomyces cerevisiae was given to 200 ml MESQUITE syrup with 14.2 °Brix (pH value 5.3) and fermented at 25°C. After 48 hours no more CO_2-production could be observed and the pH value had reached 6.5 .

- The solution was centrifuged during 20 min at 10 000 rpm, the supernatant still measured 6.5°Brix.

- Evaporation under vacuum resulted in 50 ml destillate with 9.1 % alcohol (v/v) or 7.3 % (w/v) (was determined with an ebulliometer; boiling point : 92.9°C).

- An additional 1g of yeast was added and the fermentation continued for 24 hours. 2.2 % alcohol (v/v) could again be recovered. Therefore, with an input of 28.4 g sucrose, which would theoretically result in 14.2 g alcohol, and an actual yield of 6.95 g, the efficency of the fermentation was 49%.

The low yield is probabely due to sub-optimal fermentation condititions.

The obtained destillat had a very pleasant taste.

For the production of alcohol,it might bemore reasonable to ferment the completeFraction A, rather than to extract the sugars, since the residue of the extraction does not represent a valuable material.

Some research has been published on the successful fermentation of whole MESQUITE pods to alcohol for energy production (69). This however represent a completely different approach in the utilization of MESQUITE pods. Nevertheless, it might be an interesting possibility in a mixed-use concept.

Figure 23: Sucrose extraction: first stage

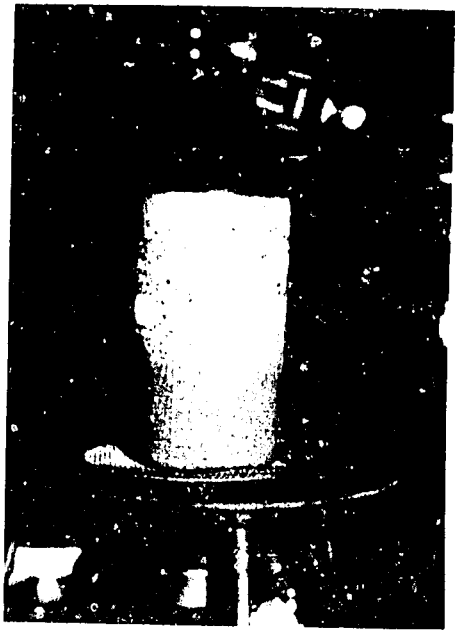


Figure 24: Sucrose extraction: CO_2-injektion

2.5.2.1.2. Composite flours

The use of legumes in composite flours is not new. Soy flour, pea flour and other similar raw materials have been suggested as a partial substitute for cereal flours. Some mixtures are currently used, whereas others have never found wide acceptance.

In order to justify the use of MESQUITE Fraction A in products such as bread, its baking qualities would have to bring some advantages over a product without MESQUITE or at least provide a special taste. In lesser developed countries (LDC) with under-supply of food, the situation is different. It would already be promising to find ways to incorporate MESQUITE at levels where the taste of a product would be acceptable. Incorporation in existing products would not require major changes at production level. A nutritional improvment of already existing products through addition of MESQUITE would definitely be helpfull in establishing its use.

Therefore, the application of MESQUITE Fraction A in composite flours has to be concentrated on the following possibilties, where each end product has to fulfill different criterias:

US market:

-Use in regular American leavened bread.
-Use in other cereal-based products such as drum dried flakes, crackers, biscuits and deep-fried snacks.

LDC market:

-Use in unleavened breads, which are produced in most lesser developed countries (chapati).
-Use in other cereal-based and widely used products such as corn tortillas.

This chapter discusses the possibilities and limits of the use of MESQUITE Fraction A, with emphasis on the feasability rather than on recipe optimization.

2.5.2.1.2.1. Leavened Bread

The procedure to investigate a possible incorporation of MESQUITE Fraction A in regular leavened bread was as follows:

Breads were prepared according to standard recipes with different percentages of MESQUITE Fraction A. An internal panel tasted the products and determined the level at which the incorporation of Mesquite Fraction A was detectable, and the level at which the bread is judged negatively due to its taste.

Judged for taste only (not for volume nor color) an addition above 10% MESQUITE Fraction A could be detected, but was still acceptable.

However, at concentrations above 25% the taste of the bread became increasingly adstringent and was no longer acceptable. Therefore, the dough and baking characteristics of breads were investigated with additions of 10% to 25% MESQUITE Fraction A (some results also refer to breads with higher percentages)

The major variable in the recipes besides the flour itself, is sucrose, since MESQUITE Fraction A already consist of roughly 40% sucrose. Therefore, with the CONTROL containing 4 parts sucrose (based on 100 parts flour), a bread with 12 parts MESQUITE Fraction A requires no additional sucrose. At all other levels, the recipes were adjusted accordingly.

The percentage of water is also depending on the amount of MESQUITE Fraction A, since the water holding capacity of MESQUITE Fraction A is very low. In order to obtain a dough similar to one without MESQUITE, added water has to be reduced by 0.5% for each percent of MESQUITE (example: 10% MESQUITE - 95% H2O). Breads were also prepared using MESQUITE syrup (see Chapter 2.5.2.1.1.) instead of the complete MESQUITE Fraction A, and using no additional sucrose.

Composition of leavend bread with MESQUITE Fraction A:

100 parts	Flour (100%- 75% whole wheat Peavey; 0% - 25% MESQUITE Fraction A)
3 parts	Shortening (Crisco)
2 parts	NaCl
4 parts	Sucrose (- correction)
3 parts	Yeast
59 parts	H2O (- correction)

Procedure:
- -Add ingredients to water
- -Mix for 5 minutes in laboratory-mixer
- -Fermentation: 105 minutes at 29°C / 90% rh
- -1st punch, fold dough
- -Fermentation 20 minutes
- -2nd punch, roll dough and make 2 loafes
- -Fermentation 55 minutes
- -Baking 25 minutes / 220°C

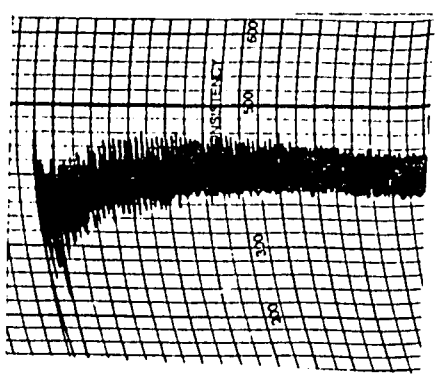
The following results show data collected from doughs with different percentages of MESQUITE Fraction A.

Dough developement (Figure 25): Due to the lack of starch and gluten in MESQUITE Fraction A, the dough development suffers with increasing percentage of MESQUITE. The dough development takes a relatively long time and the strength is reduced, but it does not come to a radical breakdown.

The addition of 1% guar gum (or eventually MESQUITE gum) distinctly improves the dough characteristics. The dough improvement by the gum is also visible in the mixer. Dough without gum is very difficult to handle in comparison to one with 1% gum. Figure 25 shows the farinograms of doughs with 50% MESQUITE Fraction A with and without guar-gum. Locust bean gum and methyl cellulose do not lead to the same improvement.

Figure 25: Farinogram of a dough with 50% MESQUITE Fraction A

a) without gum



b) with 1% guar gum

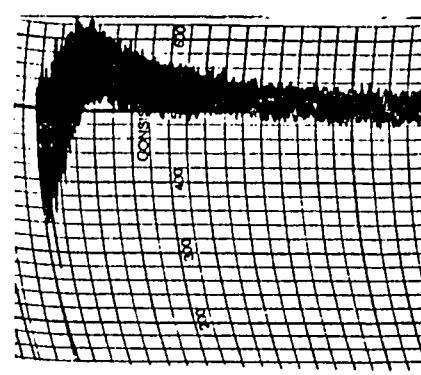


Table 25 shows additional dough and baking characteristics of breads with MESQUITE compared with the CONTROL sample. Tabulated are proof height of the loaves after fermentation, loaf volume, loaf weight and crumb firmness.

Breads were also prepared using MESQUITE Fraction B, the fibrous endocarphulls milled to a 40mesh size (see Chapter 2.5.2.2.), and MESQUITE syrup (2.5.2.1.1.) instead of Fraction A. The recipe and preparation was the same as described for Fraction A.

Table 25: Characteristics of breads with MESQUITE

Bread	Proof height (in 1/16 inch)	Loaf volume cm3 *	Loaf weight grams	Crumb ** firmness
CONTROL	15	680	123.5	335
10% MESQUITE-Fraction A	**21.5**	**675**	**123.5**	**370**
10% MESQUITE-syrup	**15**	**640**	**123.3**	**410**
25% MESQUITE-Fraction B	20.5	500	126	483

* determined with rapseeds
**determined with Bloom gelometer

The bread containing 10% MESQUITE Fraction A developed the biggest proof height but resultet in an almost identical loaf volume and weight after baking. The crumb firmness after 24 hours however was slightly increased. Nevertheless, at this level of substitution with MESQUITE Fraction A, a good tasting bread can be produced with no major negative baking properties.

Incorporation of 10% MESQUITE syrup turned out to be not quite as successful. Loaf volume was almost 10% reduced, along with an increased crumb firmness. The taste was satisfactory.

A bread containing 25% MESQUITE Fraction B showed a clearly reduced loaf volume and increased crumb firmness. The bread was much darker than the CONTROL and the fiber was responsible for a sandy texture. However, it has to be taken in consideration that the comparision should be made with a bread much higher in fiber than CONTROL.

The actual appearance of the breads is shown in Figure 26.

2.5.2.1.2.2. Chapatis and crackers

The incorporation of MESQUITE Fraction A in leavened bread proved to be possible, but did not provide any special advantages which would justify its use in regular bread, except in cases of undersupply of traditional flours.

Because of the limitations in leavened breads,it appeared to be more promising to investigate the possiblilty of using MESQUITE Fraction A in unleavened cereal products such as crackers or chapatis, which is the daily bread in most tropical countries. Volume and short time freshness are less crucial criterias for these products, and the taste expectations are not as specific. This widens the posible applications of MESQUITE Fraction A.

At the same time, the production of a cracker which could be marketed as a "MESQUITE cracker", would not have to try to copy an existing product. The requirement for a cracker are such attributes as crunchy, not subject to breaking in the package and resistance to oxidation. Also, the taste should not be to articulated.

The experiment conducted to study the use of MESQUITE Fraction A allowed basically the same procedure as for bread:

A standard recipe and procedure for crackers (or chapatis) was adapted to incorporate MESQUITE Fraction A at different percentages.

The dough composition is the same for both products, and was found to be optimal as follows:

Composition of doughs for chapatis and crackers:

100 g	Wheat
100 g	MESQUITE Fraction A
112 ml	Water
9 g	Shortening
2 g	Guar gum

Procedure:
- -Dissolve guar gum in water
- -Mix the flours and the shortening
- -Add mix to water
- -Mix in a pin-mixer for 5 minutes and for an additional 10 minutes in a fork-mixer

Crackers:

Roll dough in 3 mm thick sheet; cut dough in pieces (6x3 cm). At this stage three different methods are possible, where each produces a different type of cracker:

1) Bake for 15 minutes at 180°C .
2) Bake for 30 seconds on each side on gridle
3) Deep fry in vegetable oil, 20 seconds each side at 200°C.

Chapatis:

They can even be produced using only the composite flour and water (this is the way they are actually made in most lesser developed countries). The addition of shortening and gum however provides a smoother texture which is similar to chapatis sold as specialities in Californian Supermarkets.

The dough is rolled in 3-5 mm thick sheets and cut to round pieces of 20 cm diameter (40g), which are baked on a gridle for 1 minute on each side.

Results:

Crackers:

Method 1) and 2) produce a visually similar product (Figure 27). The texture is indeed very crunchy. Baking on the gridle however is the better procedure since the slight off-flavor, which is detectable in the oven-baked cracker, is completly eliminated.

Mehod 3) provides even crunchier products similar to a "fortune-cookie" or chips. No off-flavor was registered. This product is not very stable due to the high oil content.
Guar-gum (for dough structure and flavor masking , and shortening for texure), are extremly important additives in all described recipes. Addition of salt as it is usually done in crackers, does lead to an undesirable taste combination.

Chapatis:

An absolutely satisfying product is obtained. No disadvantages over the MESQUITE free product or off-flavors were detected.

Figure 26: Breads with MESQUITE Fraction A (product in the center is the CONTROL sample)

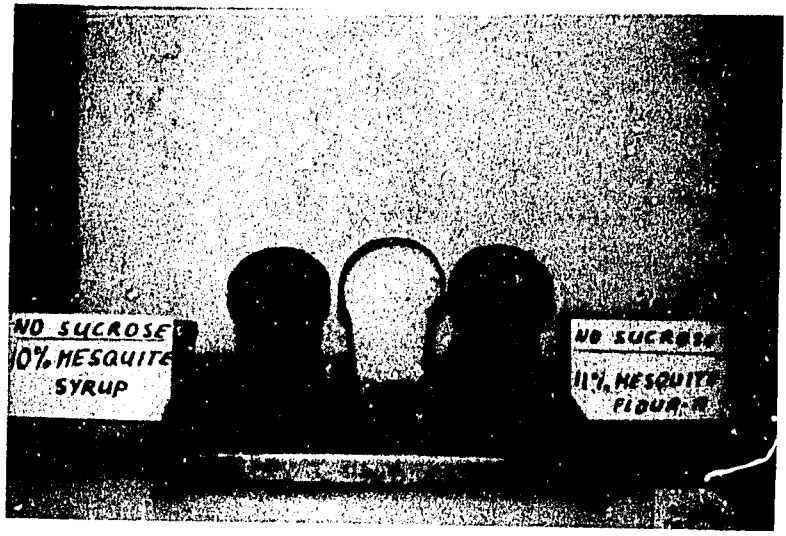
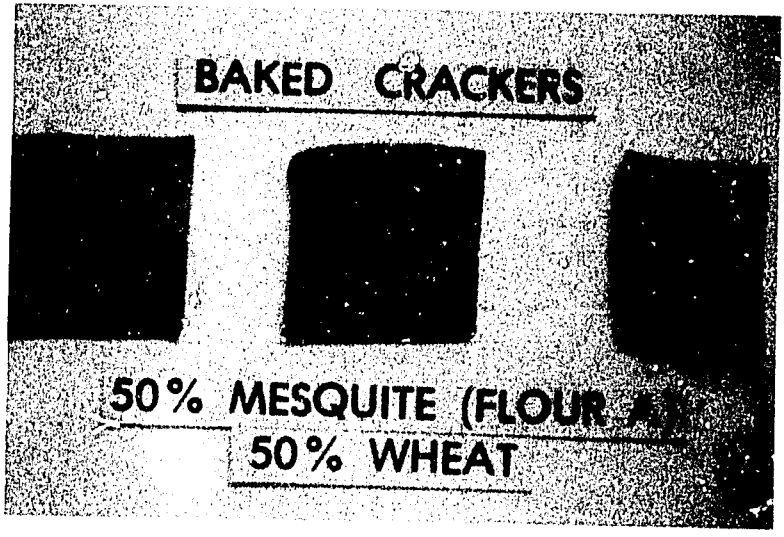


Figure 27: Crackers with MESQUITE Fraction A



Amino acid composition of a composite flour cracker:

Table 26 shows the amino acid composition of crackers, based on 50% wheat / 50% MESQUITE Fraction A.

For comparison the amino acid composition of a pure, untreated MESQUITE Fraction A is listed as well. All numbers are expressed as gram per 100 gram of sample.

Table 26: Amino acid composition of crackers with 50% MESQUITE Fraction A

Amino acid	50% Wheat+ 50% MESQUITE (g/100 g sample)	MESQUITE Fraction A (g/100 g sample)
ASPARTIC ACID	1.147	2.026
THREONINE	0.403	0.461
SERINE	0.650	0.553
GLUTAMIC ACID	3.827	1.784
PROLINE	1.501	1.126
GLYCINE	0.581	0.615
ALANINE	0.482	0.561
CYSTEINE	0.261	0.193
VALINE	0.655	0.699
METHIONINE	0.226	0.125
ISOLEUCINE	0.485	0.387
LEUCINE	0.995	0.933
TYROSINE	0.442	0.377
PHENYLALANINE	0.620	0.385
HYSTIDINE	0.345	0.317
LYSINE	0.398	0.506
ARGININE	0.764	0.975

Comparison with the amino acid composition of a standard wheat shows, that a 50/50 product has a better balance than either of the two flours alone. This comes as no surprise since it has been known from studies with other composite flours, that leguminous flour balances cereal flours in their overall amino acid composition. Chapter 2.5.2.1.2.2. supports these results by feeding studies with a MESQUITE Fraction A / wheat product.

2.5.2.1.2.3. Flakes

Drum dried flakes based on cereal or composite flours are widely used in the U.S. and also exported to lesser developed countries.

The technology is quite simple and the end products relatively stable and offer broad applications.

The intentions of the following experiments were:

-To find the limits of incorporation of MESQUITE Fraction A in an acceptable product.
-To compare the nutritional value of MESQUITE Fraction A / wheat product versus a wheat only product.
-To develop a product with a long shelf-life.

In a first attempt, flakes were produced with MESQUITE Fraction A and other flours but no other ingredients. The amount of MESQUITE Fraction A was varied, but not the drying parameters. The composite flour was either complemented with whole wheat flour (Peavy), Cassava or in one case MESQUITE Fraction D (MESQUITE cotyledon, see chapter 2.4.2.4.). The flakes were used for feeding studies to determine their nutritional qualities. They were also subjected to standard quality measurements.

In a second experiment, the quality of flakes with a given percentage of MESQUITE was optimized by addition of some ingredients and optimization of the operating variables.

Flakes with different levels of MESQUITE Fraction A:

Procedure:

-Mill MESQUITE Fraction A through a Wiley-mill using a 1 mm screen.
-Prepare composite flours with MESQUITE Fraction A incorporated at levels from 0-100% .
-Add the flour to water (20°C) and mix in a laboratory mixer at medium speed for 5 minutes.
-Feed slurry on a double drum drier; gap 0.75mm ; speed 0.8 rpm
-Allow flakes to cool at ambient temperatur, then run through the Wiley-mill with a 5 mm screen and take samples for further investigations.

Characterisation of flakes:

The follwing tests were performed (where applicable):

Sheeting:
Visual description (0= worst; 10= best)

Flake firmness:
Flakes are given in a 300 ml aluminium can (6.5 cm diameter; 9.5 cm long); the can is placed in an Instron apparatus and the 5.5 cm diameter compression-cell is driven four times 1.2 cm deep in sample (speed 12.5cm/min). The resistance is measured with a multiplication factor of 50x; The last drive was the measured value.

Specific volume:
Flakes were filled in a 500ml cylinder and the weight recorded as ml/100 g.

Viscosity:
60 g flakes and 440 ml H2O were given in an Amylograph bowl. Temperature procedure: 10 minutes at 25°C (value A), heated to 85 C and cooled back to 25°C (value B). The difference between A and B is a measure for the degree of cold water swelling and gelatinization during drum drying respectivly. The absolute value is relative to the percentage of starch in the product. (All values in Brabender units = BU)

Chemical analysis:
Composition of the flakes (i.e. carbohydrates, sugar, protein, fat, fiber)

Feeding tests :
Flakes with different levels of MESQUITE were fed to male Sprague-Dawley rats (initial age: 21 days, initial weight: 54g, 5 rats per group) for 28 days. The following data were collected:

- Final body weight;
- Total feed consumption;
- Protein efficency ratio, PER = weight gain / protein intake
- Digestibility of total diet = (feed intake- fecal weight)/ (feed intake x 100)
- Digestibilty of total nitrogen = (N intake- fecal N)/ (N intake x100)

Results

Functional properties (Interpretation of Table 27)

The specific volume (also shown in Figure 29) reaches a maximum when 25% MESQUITE Fraction A is incorporated, higher percentages cause a slight reduction. 100 % MESQUITE Fraction A gives the lowest value which can be increased with the addition of gum. The combination with cassava flour shows similar results as with wheat flour.

The reduction of the starch containing composite flour causes a decrease of the absolute viscosity. The percentage of cold water viscosity is significantly higher with MESQUITE. The incorporation of MESQUITE Fraction A evidentially reduces the need for extensive pre-gelatinization. A surprising exception occurs when MESQUITE Fraction D is incorporated: the percentage of cold water viscosity is even below the value of a 100% wheat flake. It suggests that MESQUITE Fraction D retards the gelatinization during drum drying.

The resistance of the flakes against breaking (strength) shows values that correspond with their specific volume: Higher specific volume (or lower density), causes reduced flake firmness.

The water activity value is slightly reduced with increased percentage of MESQUITE Fraction A, but the moisture content of the flakes is also lower with higher percentages of MESQUITE. The fact that the moisture content is lower with MESQUITE, suggests a reduced water holding capacity which has been observed in other experiments as well.

The most critical factor in the production of drum-dried flakes with MESQUITE is their sheeting-performance. Under the described production parameters, a mixture of 50% wheat / 50% MESQUITE Fraction A produced an excellent film (Figure 28). It was practically impossible to obtain an acceptable film with 100% MESQUITE only. Addition of guar gum improved the sheeting dramatically. Adjustement of process parameter would certainly allow to improve the sheeting characteristics of the other mixtures as well; the here described results have only comparative character.

In summary: It could be seen that the quantitative incorporation of MESQUITE Fraction A as well as Fraction D in composite flours is almost unlimited from the technological point of view.

The taste of all samples was very pleasant. The increase of MESQUITE Fraction A leads to a stronger flavor, but no after-taste or off-flavor could be detected.

Figure 28: Production of drum dried flakes with 50% MESQUITE Fraction A and 50% wheat

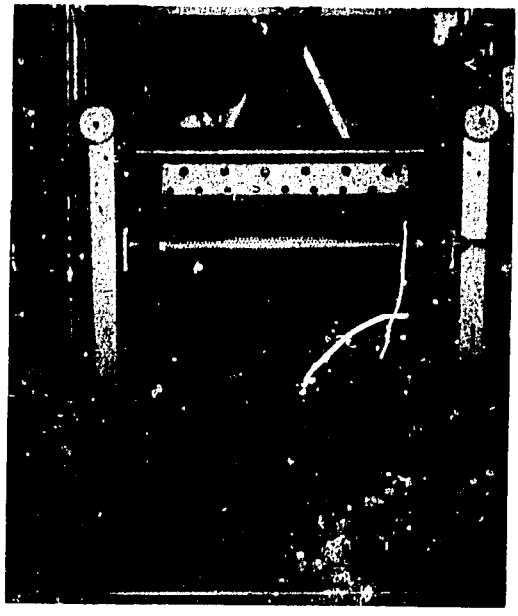


Figure 29: Specific volume of different drum dried flakes (numbers see Table 27)

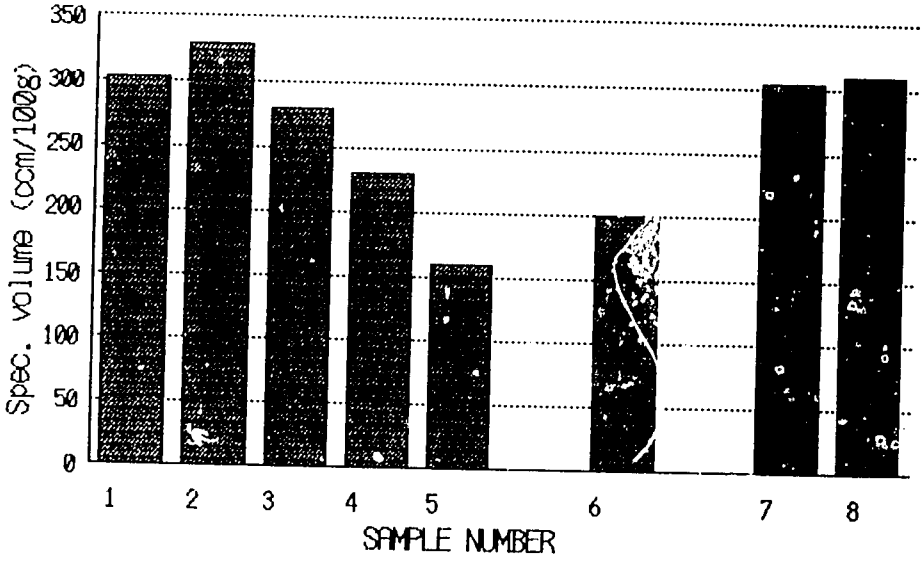


Table 27: Drum dried flakes: Functional properties (methods see page 75)

Composition	Specific volume (ccm/100g)	Viscosity A/B (BU)	Ax100:B	Flake-firmness	a_w	Sheeting quality	Sample# in Fig.29
100% Wheat	303	1360/3200	42.5%	43	0.5	2	1
75% Wheat 25% MESQUITE A	330	1200/1560	77.0%	30	0.48	5	2
50% Wheat 50% MESQUITE A	280	380/ 520	73.1%	62	0.45	10	3
25% Wheat 75% MESQUITE A	230	65/ 85	76.5%	67	0.38	5	4
100% MESQUITE A	160	unmeasurable				0	5
100% MESQUITE A (+1.5% Guar)	200	unmeasurable		69	0.42	7	6
40% Wheat 20% Cassava 20% MESQUITE A 20% MESQUITE D	304	430/1080	39.8%	20	0.55	5	7
75% Cassava 25% MESQUITE A	310	2000/2700	74.1%	18	0.62	5	8

Flour:H2O = 40:60, Gap: 0.75 mm, Speed: 0.8 rpm Productionrate: 10-12kg/h

Chemical Analysis (Interpretation of Table 28)

As can be expected, the chemical composition of the flakes represents basically the arithmetic sum of the combination of the composite flour.

The protein content of the flakes is reduced with increased percentage of MESQUITE Fraction A, since MESQUITE has a lower protein content to start with. This however is partially compensated by its improved amino acid balance (Table 26). The flakes with 20% MESQUITE Fraction D have over 20% more protein and a improved amino acid balance than the product made out of wheat only. Flakes with cassava contain very little protein, since cassava itself is almost protein free. Addition of MESQUITE Fraction A or D would therefore be a positive improvement for the cassava flour.

The percentage of fat is almost on the same level in all the flakes.

As could be expected, the most significant changes in the chemical composition of the investigated flakes are found in their fiber content and the amount of sugars; both ingredients are found at much higher levels with increased MESQUITE incorporation.

Feeding studies (Interpretation of Table 29)

Three types of flakes were used for feeding studies, along with a control sample containing casein:

1) 100% Wheat
2) 50% Wheat / 50% MESQUITE Fraction A
3) 40% Wheat / 20% Cassava / 20% MESQUITE A / 20% MESQUITE D

The results showed, that the products 1) and 2) were overall identical. No statistically signifcant differences were measurable, except for digestability of 2), which is lower for the whole diet as well as for nitrogen. Since this did not cause a lower PER, the protein-quality of the flakes containing 50% MESQUITE Fraction A must be better, due to an improved amino acid balance.

Flakes 3) showed better values than the two other flakes in all measured value. The PER as an example, is 50% higher. Since the digestibility is even lower than 1) and 2), the protein quality must again be significantly better. The improvement is definitly caused by the high-protein MESQUITE Fraction D.

This study also proves that MESQUITE shows no toxicity over the investigated period.

Table 28: Drum dried flakes: Chemical analysis

Composition	H2O %	Protein(1) %	Fat %	Fiber(2) %	Sugar(3) %	Carboh.(4) %
100% Wheat	7.8	13.9	0.9	0.3	3.3	73.4
75% Wheat 25% MESQUITE A	5.5	12.7	1.1	3.0	14.5	76.7
50% Wheat 50% MESQUITE A	3.3	12.1	1.0	5.4	23.4	79.6
25% Wheat 75% MESQUITE A	2.1	10.6	1.1	9.7	35.2	82.2
100% MESQUITE A	5.0	9.8	1.6	9.9	41.1	79.6
40% Wheat 20% Cassava 20% MESQUITE A 20% MESQUITE D	7.4	16.1	2.0	4.3	13.3	70.5
75% Cassava 25% MESQUITE A	10.0	3.2	1.0	3.7	11.5	81.8

(1) N * 6.25 (2) Crude fiber (3) Sucrose and glucose (4) By difference

Table 29: Drum dried flakes: Feeding studies

Composition of feed	Final body weight,g	Total feed consumpt.,g	PER actual	PER adjusted	% digestibility diet	% digestibility nitrogen
Casein CONTROL	174 +-7	349 +-20	3.43 +-.06	2.5	93.3	92.3
100% Wheat	79 +-3(a)	215 +-10(b)	1.13 +-.04(c)	0.82	91.4	87.8
50% Wheat 50% MESQUITE A	74 +-4(a)	186 +-14(b)	1.06 +-.05(c)	0.77	84.7	75.2
40% Wheat 20% Cassava 20% MESQUITE A 20% MESQUITE D	100 +-2	278 +-5	1.64 +-.04	1.2	83.9	71.4

Mean +- S.E. Duncan's Multiple Range Test: Means with a commom letter are not significantly different for p ².05

Optimization of flakes with a given percentage of MESQUITE Fraction A

After it could be shown that drum dried flakes can be produced at any level of MESQUITE incorporation, an attempt was made to optimize the flake quality at a given MESQUITE percentage by changing process parameters, or addition of specific ingredients.

The choosen product was based on 70% wheat and 30% MESQUITE Fraction A. A slurry with no addites served as CONTROL.

Experiments discussed in the preceeding chapter and performed with raw materials other than MESQUITE (72;73;74;75) suggested the use of guar gum (known to reduce cooking time (76)) and shortening for the functional improvement of the flakes.

Sucrose and NaCl are added for organoleptical reasons. In addition, the slurry would be pregelatinized.

The goal of the optimization was to obtain flakes with excellent sheeting characteristics, maximal strenght against breaking, and crispness.

The "ideal" flake at a given amount of MESQUITE percentage was therefore obtained as follows:

Composition:

65	parts	unbleached Wheat flour
35	parts	MESQUITE Fraction A
100	parts	flour
+ 8	"	Sucrose
+ 5	"	Shortening (veget.)
+ 2	"	NaCl
+ 1	"	Guar gum
+200	parts	water

Procedure:

- Prepare dry mix; dissolve guar in water
- Add dry mix to water; mix for 5 minutes in lab mixer.
- Pregelatinize slurry by heating for 4 minutes at 85 °C in steamkettle.
- Feed slurry on drum drier; Drum gap = 0.16 mm
  Time on drum= 1'55" (=0.52 rpm);
  Temperature on drum surface = 145°C (71)
- Let flakes cool at room temperatur for 15 minutes; standardize flake size by running through Wyley-mill with 5 mm screen.

The characteristics of this "ideal" flake are described as follows:

Chemical composition:	80%	total carbohydrates;
	20%	sucrose;
	12.5%	protein;
	2%	fat;
	3.5%	crude fiber;
	3.5%	ash;
	2%	moisture
Specific volume :	300 ccm/100 g	
Breaking :	<3% (*)	

(*) Standard procedure as described on page 75, but sifting through 10 mesh= % breakage

Oxidation stability of drum dried flakes

Samples of the flakes were studied for their stability against oxidation or rancidity, in order to get some ideas about their shelf life. A sample of plain MESQUITE Fraction A which had been stored for 6 month at room temperature(unprotected from light =Ao) was also checked. The amount of oxidation was measured with the GLC as hexanal in the headspace above the flakes, known as the hexanal-value. This has been proven to be a good indicator for rancididty (70;71).

Method: 100 g of flakes were filled in gas tight jars and stored for 16 weeks at 8°C, protected from light. Another batch was stored for the same period of time at room temperature and not protected from light. After termination of the storage time, 5 g sample were given in 250 ml jars, 2 ml standard solution and 100 ml boiling water are added; the jar is immediately closed with a triple layer of aluminum foil; the sample is shaked for 45 seconds and then 1cc headspace-gas is drawn.

Standard 1	: 25 ul isobutyl methylketone, 25 ul heptanone in 1l H2O
Standard 2	: 2-Heptanon
GC column	: J+W fused silica capillary column; OV-351, 0.25IDx15M
Carrier gas	: He, flow rate 6cc/min
Flame	: H2 , 32 psig
Injection temp.	: 260°C splitless injection, 1cc
Oven max. temp.	: 400°C
Columnpressure	: 5 psig (0.33kg/cm2)

The results, shown in Table 30 and Figures 30-31, are quite impressive. The hexanal value decreases parallel to the increased amount of MESQUITE Fraction A. This could be caused by the presence of an anti-oxidative compound in MESQUITE, since untreated MESQUITE Fraction A also shows a very low value. A more likely explanation could a correlation with the moisture content, which is lower with higher percentages of MESQUITE (Table 28). This would also explain the high value of the flakes with MESQUITE Fraction D even though this product is certainly more subject to oxidation due to its high fat content. Storage at higher temperature results in an expected higher oxidation.

Table 30: Oxidation stability of drum dried flakes

Sample	HEXANAL-VALUE stored at 38°C	HEXANAL-VALUE stored at roomtemp.	Sample#
100% Wheat	24.7	21.4	1
75% Wheat 25% MESQUITE Fraction A	-	4.3	2
50% Wheat 50% MESQUITE Fraction A	3.0	3.0	3
100% MESQUITE Fraction A	0.0	2.5	4
40% Wheat; 20% Cassava 20% MESQUITE Fraction A 20% MESQUITE Fraction D	15.3	12.5	5
75% Cassava 25% MESQUITE Fraction A	0.9	1.3	6
MESQUITE Fraction A (Ao)		1.6	7

Sample # refers to Figures 30 and 31

Figure 30: Hexanal value of different flakes , stored at 38°C

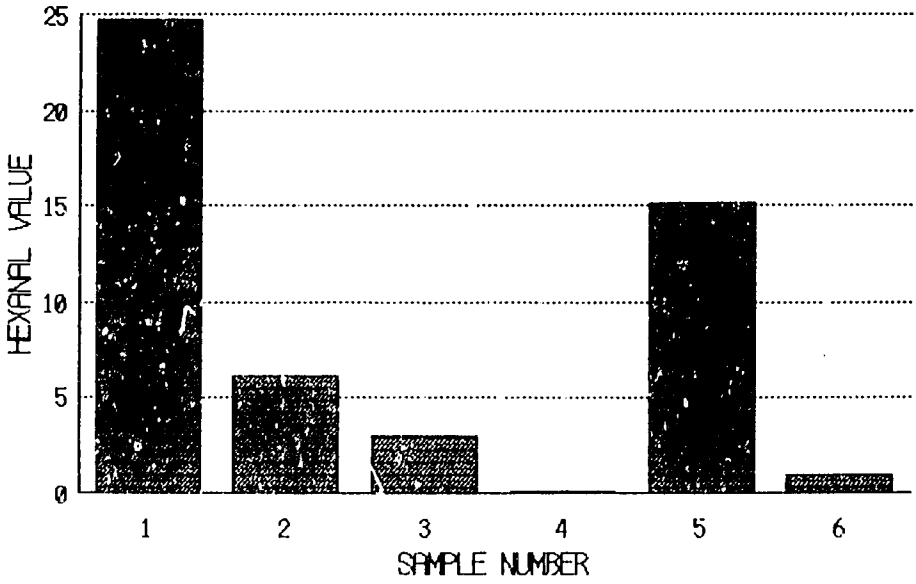
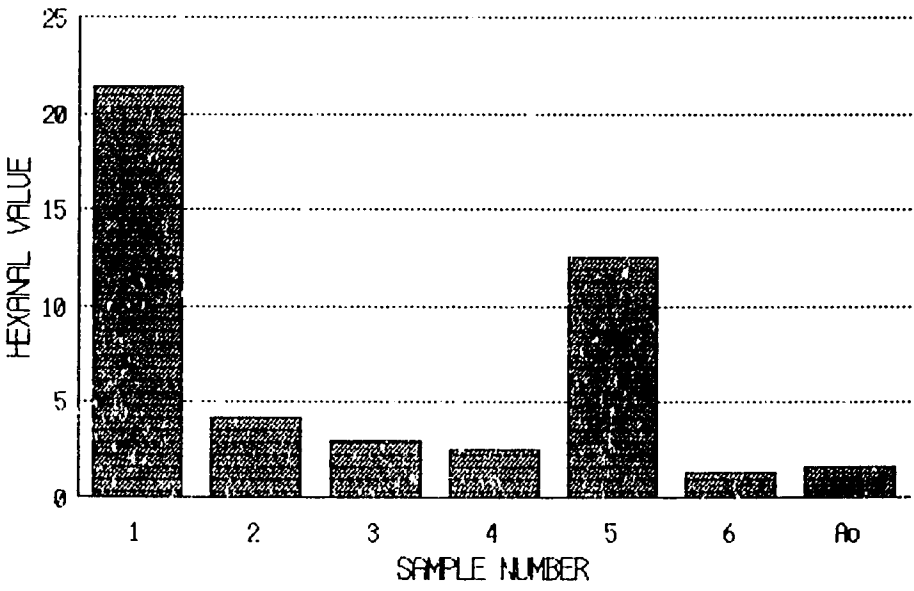


Figure 31: Hexanal value of different flakes, stored at roomtemperature



2.5.2.1.2.4. Corn tortilla chips with MESQUITE Fraction A

Corn is the most important staple food in most lesser developed countries in arid and semi-arid zones. Corn is milled and processed to a product called "Masa", which serves as a rawmaterial for either unleavend flatbreads or deep-fried corn-chips.

The corn chips have also become a best-seller in the snack-food market the United States, mainly in the southern States and California.

Therefore, a corn tortilla chip with MESQUITE FractionA might well be a most promising application for MESQUITE in the U.S. as well as in LDC's. In addition, preliminary tests with wheat/MESQUITE composite-flours showed, that deep-frying destroys the slightly bitter after-taste of some MESQUITE pods most efficently.

There are many different procedures for the production of such corn chips, but this experiment is based on the most commonly used method which allows their production for private consumption as well as in an industrial scale.

Composition:

Standard corn chip: 100 parts processed corn flour (MASA)
2 parts NaCl
100 parts H2O

MESQUITE chip : -Replace percentages of corn with MESQUITE Fraction A.
-Reduce water by 5 parts for each 10 parts of MESQUITE Fraction A.

Procedure:
-Prepare dry mix
-Add warm water (50°C)
-Mix for 5 minutes in lab-mixer
-Roll dough between two pergament-papers into 1.5 mm thick sheets; cut sheets in 2 cm x 5 cm pieces and punch holes in each piece with a fork
-Immerse pieces in 210 °C oil (partially hydrogenated soybean oil, Crisco) and deep-fry for 25 seconds on each side.

Different time/temperature combinations of deep-frying were tested, in the range of 180°C to 220°C for oil temperature and 10 to 35 seconds deep-frying on each side.

A taste panel evaluated the products prepared under different conditions and determined the best combinations of flours and preparation parameters.

It was found, that samples deep-fried below 200°C or/and for less than 20 seconds were chewy (worse with higher MESQUITE percentage); samples deep-fried above 210°C or/and longer than 30 seconds were overcooked (worse with higher MESQUITE percentage). In both cases higher temperature/shorter time were better than lower temperature/long time.

Generally, increased MESQUITE percentages lead to a narrower range and slightly higher temperatur/time combinations for good chips.

Taste panel:

MESQUITE/corn tortilla chips with two different percentages of MESQUITE Fraction A were produced and used for a taste panel investigation. The intention was to determine whether such a chip would be accepted by people who are already consumers of regular corn-chips or whether they would even prefer a MESQUITE/corn tortilla chips over a plain corn tortilla chip. Therefore, the MESQUITE-percentage was kept below the theoretically possible level to make sure that corn was still the main ingredient.

Products: 1) Tortilla-chips made from 100% corn, based on the recipe described on the previous page.
2) 90% corn +10% MESQUITE Fraction A
3) 80% corn +20% MESQUITE Fraction A

Panel : 29 voluntary adults; all were trained and experienced taste panelists;

Test : The panelists did not know what type of product would have to be consumed; tests were performed between 10am and 11:30am;

Questionaire:

Part 1:

---

a) Do you consider yourself a lover of Mexican food ? **Y / N**

b) Do you eat Corn-tortilla Chips ? **Y,More than once a month;**
N,Less than once a month;

c) Please try these samples of Tortilla-chips and give them scores: (1=lowest; 10=highest)

	Sample 1	Sample 2	Sample 3
Color			
Texture			
Odor			
Taste			

Part 2:

(The following question and samples were given to the judges only after having turned in part 1)

---

d) This is a corn-tortilla Chips which contains MESQUITE! Please give scores! (1=lowest; 10=highest)

	Score
Color	
Texture	
Odor	
Taste	

e) What do you like best about the product? .....

f) What don't you like about the product ? .....

g) Do you detect an off-flavor ? **Y / N**
If yes, describe it ! .....

Objectives of each question:

Questions a) and b): To determine whether difference in judgement are based on the basic eating habits of consumer; one **Y** is refered to as "EATER" , two **N** is refered to as "Non EATER" in the resulting charts.
Question c): Actual score of product.

Question d): The product in part 2 was exactly the same as #2 in part 1 for the first 15 judges, and the same as #3 for the other 14 judges (in the resulting charts refered to as REPETITIVE SAMPLE) , but the judges were unaware of this fact. The intention was to determine whether a subjective change in judgement occurs, knowing that the product contains an unfamiliar ingredient. A higher score would favor identification of a MESQUITE chips as such, instead of undeclared incorporation in a corn chips.
Questions e) and f): Additional information for possible improvements of the product.
Questions g) and h): Since off-flavor occurs in some pods, this question served to verify a possible but not dominant off-flavor.

Results:

PART 1

Scores of each criteria (see Figure 32)

The product containing 10% MESQUITE Fraction A obtained the highest score for each criteria, followed by the product with 20% MESQUITE Fraction A (without separating between "EATERS / Non EATERS".

Total score (see Figure 33)

Presents the sum of the scores for all criterias of each product. The ranking is more significant ($p<0.001$).

Total score according to "EATERS/NonEATERS" (see Figure 34)

Shows the results from Figure 32, but according to eating habits of the panelists. It reveals, that people who do not eat regular corn-chips prefer a chips with increased MESQUITE Fraction A.

PART 2

Score of repetitive samples (see Figures 35-37)

Judges prefer the product once they know the ingredient in both percentages and for all criterias. The least obvious change occurs for color, since this characteristic is most unlikely subject to the attitude versus the ingredient.

List of statistical significance:
Numbers "1,2,3" refer to product specfications on page 87; NS = not significant; significance evaluated with standard F-test.

Color	"1;2;3; p<0.005"	"2;2rep; NS "	"3;3rep; NS "
Texture	"1;2;3; p<0.05 "	"2;2rep; NS "	"3;3rep; NS "
Odor	"1;2;3; NS "	"2;2rep; NS "	"3;3rep; NS "
Taste	"1;2;3; NS "	"2;2rep; NS "	"3;3rep; NS "
Sum of score	"1;2;3; p<0.001"	"2;2rep; NS "	"3;3rep;p<0.05 "

Response to single questions:

What do you like best about the product ?

TASTE :32%
COLOR :25%
TEXTURE:25%
ODOR :10%

What don't you like about the product ?

TASTE :14%
COLOR :0
TEXTURE:27%
ODOR :0

Is there a off-flavor ? YES: 27% NO: 70%
If yes, describe it ! sweet 2x; astringent 3x;
single mentionings: chinese food, garlic, oily, nutty burned, cinnamon

Summary:

-Corn tortilla chips which contain up to 20% MESQUITE Fraction A, are judged as being better than pure corn tortilla chips for all organoleptical criterias, with statistical significanc when summarized to a overall score.

-10% MESQUITE Fraction A is prefered over 20% MESQUITE Fraction A by people who regularely consume pure corn chips, whereas people who usually do not eat pure corn chips prefer the highest percentage of MESQUITE incorporation.

-The MESQUITE/corn chips obtains a even higher score for all criterierias when the consumer is aware of the use of MESQUITE Fraction A.

-There is no off-flavor detected in MESQUITE/corn chips, as long as the question is not suggestifely asked . Even then, only a fourth of the judges respond with yes, but give widelly varying descriptions.

Figure 32: Taste panel; scores of each criteria

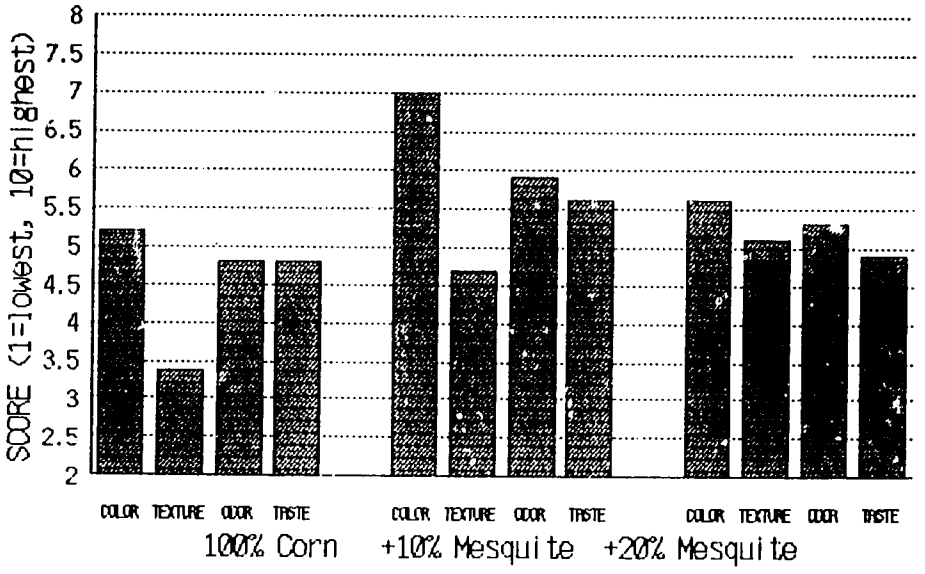


Figure 33: Taste panel; total score

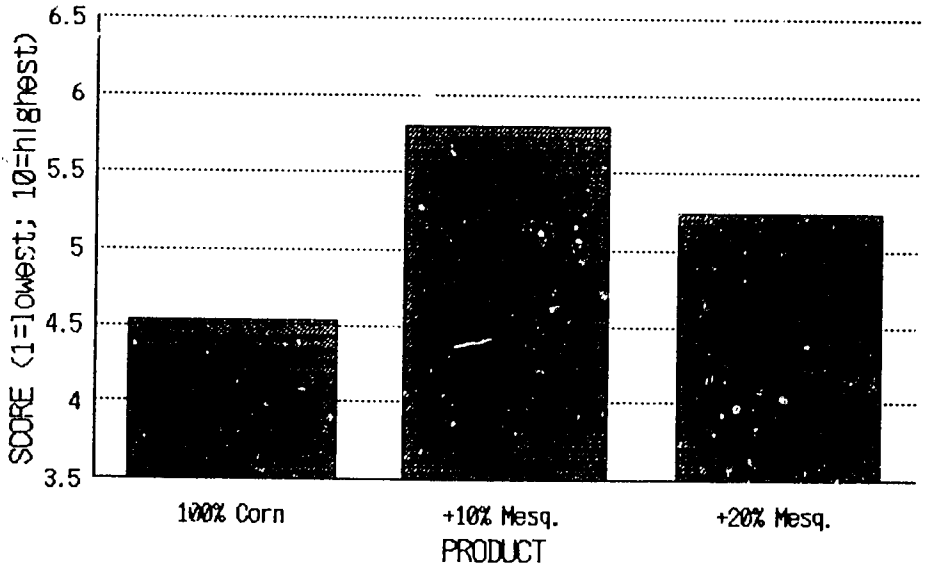


Figure 34: Taste panel; scores according to "EATERS/NON EATERS"

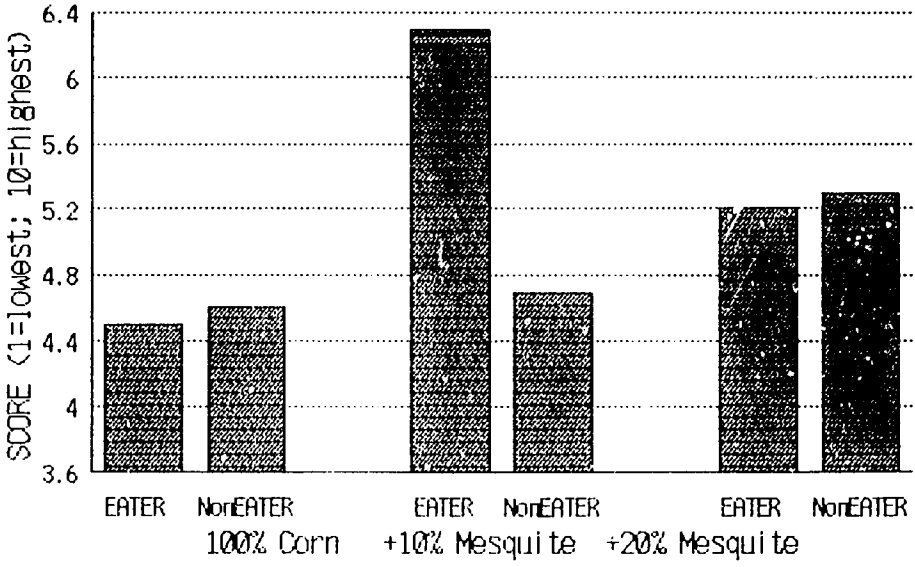


Figure 35: Taste panel; repetitive sample #2 (10% MESQUITE)

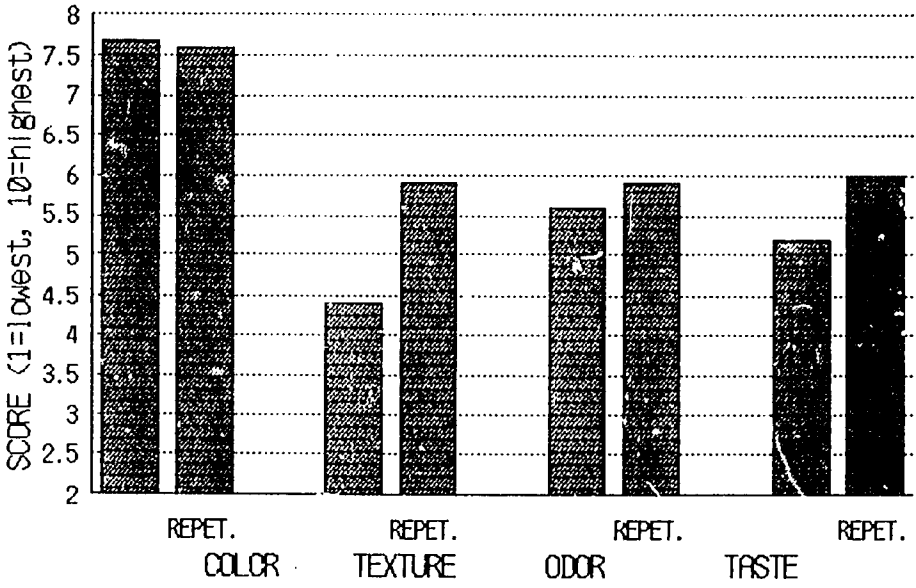


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Figure 36: Taste panel; repetitive sample #3 (20% MESQUITE)

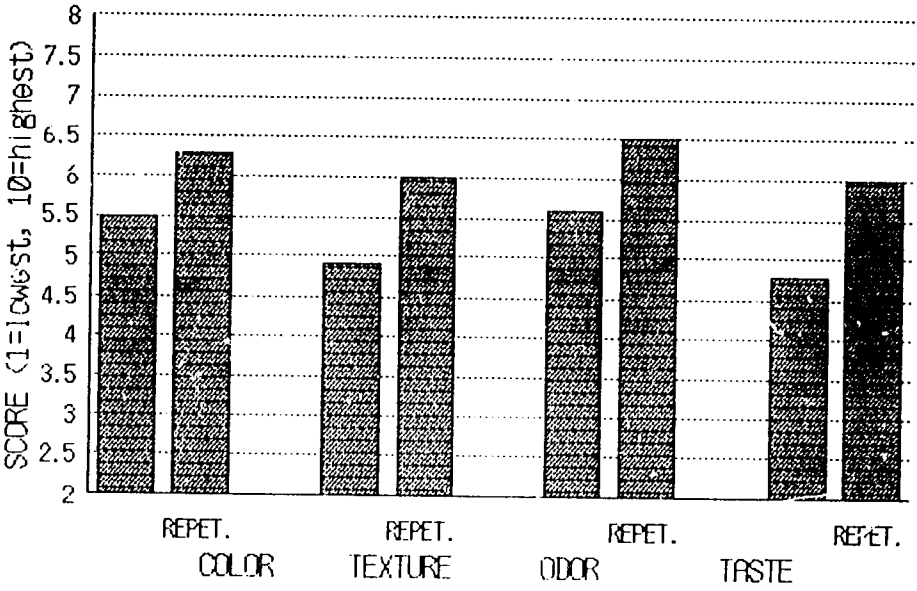
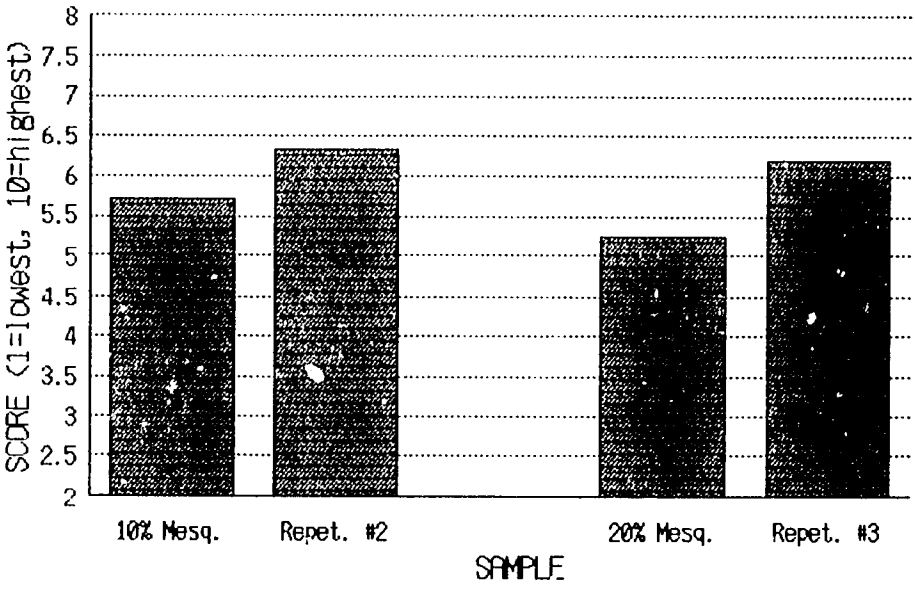


Figure 37: Taste panel; comparison total score with repetitive samples



2.5.2.2. FRACTION B

Fraction B (or endocarp hull) represents quantitativly 20-25% of the whole MESQUITE pod.

The chemical analysis in Chapter 2.4.2.2. has revealed, that this fraction does not offer very interesting prospects as far as its use for human consumption is concerned.

This is due first of all to the very tough and fiberous structure of the endocarp which would require extensive milling and/or some heat treatment in order to be usable as a raw material of any kind .

Secondly, the nutritional value of the whole Fraction B is quite low, since fiber is its main compound (45%; Chapter 2.4.2.2.)

Nevertheless, if food or feedstuff in its ultimate extent shall be produced, it might still be feasible to separate the endocarp into two fractions (B1 >40mesh; B2 <40mesh), since B2 with its better nutritional value and finer texture might be used as a bland "filling" compound in bakery and other products. Its characteristic as an almost flavor- and odorless high fiber flour might justify such a separation.

A swiss chocolate company replaced defatted soyprotein with flour from MESQUITE Fraction B and found percentages up to 3% in the chocolate-mass acceptable. However, one has to be aware, that such an application would put MESQUITE Fraction B into a very competitive, low price market.

Therefore, with one of the basic goals of this work in mind, an economically realistic utilization of MESQUITE pods, alternatives which go beyond food- and feedstuff application had to be considered for Fraction B.

The simplest but nevertheless not useless application could be to plow the endocarp hulls back into the soil before a planting season, as it is most often done with residual crop materials (78). This organic material is an important soil conditioner because it improves the air- and water holding capacity of the soil and reduces wind and water erosion, which is a most urgent problem in MESQUITE-growing areas.

Another alternative would be to sell Fraction B for combustion to individuals, since such regions often obtain more than 40% of their energy needs through biomass (in comparison: worldwide only 14%) (78). However, since the milling and separation process of MESQUITE pods requires energy input itself, it would appear as a logical conclusion to utilize Fraction B as a energy resource in the processing of the pods.

Therefore, the characteristics of Fraction B for energy purposes and the options for its thermal conversion had to be studied at this stage.

A list of energy requirements during the milling and separation process revealed, that hot air, electricity and steam would be necessary along the line (Chapter 3.3.).

Several possible ways of energy-production from biomass have been studied in the last ten years, such as fluid bed combustion (79) or fermentation to ethanol (80;81). Most of these options require an extensive know-how and sophisticated process-control. Direct combustion on the other hand is the simplest and cheapest thermal conversion to produce hot air, which in the case of MESQUITE processing is needed for drying of the pods.

MESQUITE Fraction B as the raw material for combustion has to be compared with the most commenly used biomass source, firewood and crop residues (sugar-cane bagasse (83) or wheat straw). The product which has been chosen to serve for comparison is sawdust, whose characteristics have been studied extensivly by severeal authors (84).

Combustion-characteristics of MESQUITE Fraction B:

The most crucial factor determining the value of biomass for combustion is its moisture-content since drying as the first stage of burning is a highly endothermic reaction. Fraction B has a moisture content (after the milling and separation process) of only 4-6%. This is a value which is far better than most comparable products (Table 31).

Another important factor is the density of a product that should serve for combustion, since volume is quite a costfactor in the handling of such materials. MESQUITE Fraction B has a density of 0.4g/cm³. This is value comparable to sawdust. The density could be increased by a densification process (84), but would hardly pay off since the material does not have to be stored or transported in the proposed system. Another way of densification can be achieved by chopping the endocarp hulls with a pin-mill into two Fractions (B1> 40 mesh; B2 <40 mesh), which primarely serves other purposes (separation into two nutritionaly different fractions; see above).The characteristics of Fraction B for combustion purposes are therefore being studied in two physical stages:

a) As obtained during the milling and separation process (opened endocarp hulls, but not futher reduced in size)
b) Further reduction in size and separation into the above described two fractions (40>mesh; 40<mesh)

Burning value:

The burning value stands for the actual energy which is being released by a given material through combustion and is therefore the most important number besides burning residues. The figures shown in Table 31 (Method ASTM d3286).

Table 31: Burning value of MESQUITE Fraction B

Material	Burning value (as is) BTU/kg	Burning value (dry weight) BTU/kg	KJ/kg
Fraction B, complete	15277	16082	16999
Fraction B1, >40 mesh	15675	16500	17441
Fraction B2, <40 mesh	16101	16949	17916
For comparison:			
Sawdust (80)	16414	18238	19300
Sugarcane bagasse	8300	16600	17563
Rice straw	10480	13100	13860
Average of cereal crop residues (81)	13090	15400	16300

Chemical composition; residues

The chemical quality of a raw material for combustion is not only of importance regarding pollution but also because the efficency and the operating-costs are affected by residues.

Nitrogen and sulfur are two of the compounds which are responsible for possible pollution which is generated upon combustion. Sulfur, phosphorus and ash are to be as low as possible since they also negatively affect the thermal conversion process.

In addition, the distribution of C,H, and O is of importance for the energy efficiency of the process (81).

The figures evaluated for MESQUITE Fraction B are listed in Table 32.

Table 32: Chemical composition of MESQUITE Fraction B for combustion purposes

Material	%C	%H	%O	% S	% P	% Ash
Fraction B, complete	44	6.5	44	none	0.13	3.25
Fraction B1, >40mesh	44	6.3	46	none	0.05	3.0
Fraction B2, <40mesh	45	6.6	42	none	0.23	3.5
For comparison:						
Dry sawdust (80)	50	6.4	42	0.06	-	0.86

Additional chemical information of importance for the combustion process is available in Chapter 2.4.2.2.

In conclusion it can be said, that MESQUITE Fraction B, whether used on a "as is" basis or densified, provides a very good source for direct combustion or other thermal conversion processes. The quality matches dried sawdust easily and is superior to most all other crop residues.

For an application of this information see Chapter 3.3.3.

2.5.2.3. FRACTION C

2.5.2.3.1. Gum preparation

Fraction C represents the two endosperm splits of the seeds, which are obtained by the milling and separation process.

It has been found, that these splits consist of approximately 40% seed coat and 60% endosperm. The seed coats have no functional or nutritional value, whereas the endosperm (containing the galactomannan) could be of considerable economical value. However, the separation of the endosperm from the seed coat is the main obstacle for a utilization of the galactomannan. For analytical purposes this can be done by soaking the endosperm splits in water, pealing off the seed coat and drying the endosperm under vacuum. The endosperm splits contain accordingly 65% pure galactomannan on the average, with a range of 55-75%. For all subsequent studies, 65% gum in Fraction C is regarded as 100% yield of gum.

Since all impurities in the galactomannan such as remaining seed coat material negatively affect its functional properties as a thickening agent and subsequentally its economical value, several methods were evaluated to separate seed coat from the endosperm:

a) Wet process: The splits are allowed to soak in water for various times at different temperatures, the endosperm can then be separated from the seed coat in a juice mixer.

b) Dry milling: The splits are dehulled in a Udy-cyclon mill with a rubber rotor and an abrassive surface.

c) Combination of a) and b): The splits are first dehulled, ground into a fine powder, which is then soaked in water, to disolve the gum, separated by centrifugation and the supernatent gum freeze-dried.

d) Enzymes : The splits are soaked in solutions of pectinase or/and cellulase to hydrolize the seed coat.

e) Liquid Nitrogen :The splits are soaked in H_2O for one hour and then frozen in liquid N_2, to break the endosperm off the seed coat (86).

Of all the described methods only a) and b) were promising enough for further investigation, whereas the other procedures failed completely or resulted in a degradation of the gum.

Method a) and b) were therefore improved with the following results.

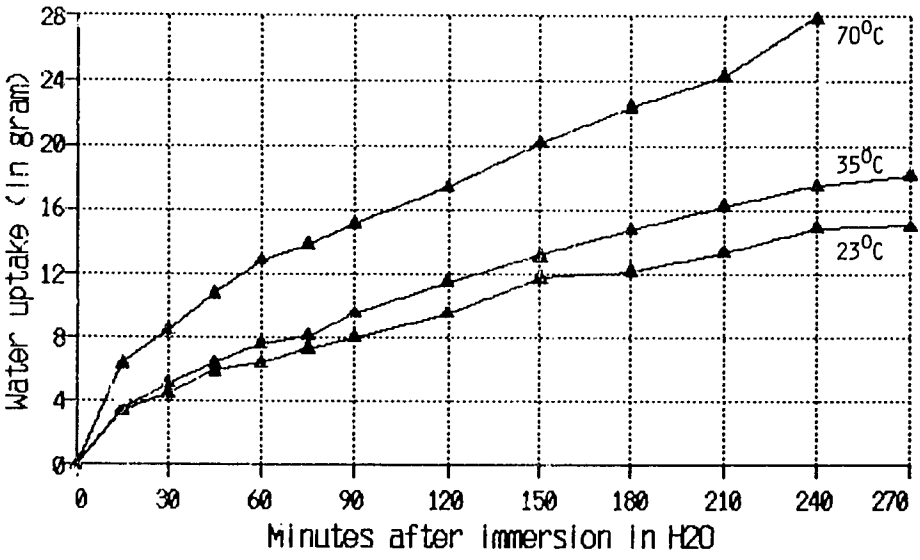
A) Wet process :

When endosperm splits are soaked in water, the galactomannan swells up considerably. The seed coat itself absorbs little water only and the endosperm can be pealed off the seed coat quiet easily. The optimal swelling of the gum was measured as follows:

- 2g of Fraction C are given in flat weighing boats (8 cm wide; 2 cm deep) with twenty 1 mm wide holes in the bottom.
- Three such dishes are placed into beakers, which are filled with distilled H2O at different temperatures (23 °C; 35°C; 70 °C), so that the weighing boats are completely filled with water.
- The samples are stired for 20 seconds every 3 minutes and are weigned every 15 minutes (after the water is dripped off and the weighing boats are dried with absorbing paper to eliminate surface water.
- The weight difference of the samples is equivalent to the absorbed water.

Figure 38 shows the results . It can be seen, that higher water temperatures increase the speed of absorption, and that a immersion time of 240 minutes is aedequate for all temperatures.

Figure 38: Water uptake of Fraction C at different temperatures



The weight of the sample soaked at 70°C increased its weight dramatically after 200 minutes. The sample swells up so much, that surface water can not be removed anymore.

Once that 240 minutes were proven to be sufficient to allow maximal water absorbtion (and subsequentially easiest removal of the endosperm from the seed coat) a second experiment with the same setup was performed to determine the yield of galactomannan:

- The endosperm splits are allowed to absorb water for 240 minutes, as described for "water uptake".
- The splits are removed from the weighing boats, and the remaining water in the beakers is freeze-dried to determine lost galactomannan (L).
- The splits are given in a Omni-mixer, where the endosperm can be removed from the seed coat.
- The mixture is filtered (FILTRATE= G1); the preceding step is repeated with the material retained by the filter and some added water, and this mixture again filtered (FILTRATE= G 2)
- Both filtrats are separately freeze-dried and weighed.
- The seed coats retained by the filter are dried and weighed as well.

Table 33 shows that a soaking temperatur of 70°C provides the highest yield of pure gum and requires only one mixing step. Thanks to the low viscosity at this temperatur, handling is also simplified.

Analysis of the such prepared gum showed for all temperatures the following impurities: protein < 4 % crude fiber < 1 %

Nevertheless, this procedure involves many steps and requires considerable amounts of water and would therefore be a very expensive method, justified only if the resulting gum would have outstanding functional properties.

Table 33: Yield of galactomannan obtained by a wet process at different soaking temperatures

Quantities in g		Soaking temperature 23°C	35°C	70°C
Gum lost in bath	(L)	0.05	0.1	0.14
Gum yield in 1. mix	(G1)	0.61	0.51	1.05
Gum yield in 2. mix	(G2)	0.45	0.5	0.18
Gum recovered	(L + G1 + G2)	1.11	1.11	1.37
Seed coat		0.36	0.48	0.33
Total material recovered		1.47 73 %	1.59 79 %	1.70 85 %
ACTUAL GALACTOMANNAN YEALD:				
G 1 + G 2 - L		1.06	1.01	1.23
IN % OF INPUT		78 %	75 %	91 %

Sample size: 2 g Fraction C containing 1.3 g galactomannan

B) Dry milling:

As an alternative to the wet process, dry milling was studied to produce a relatively pure galactomannan.

-The endosperm splits are first of all run through a UDY-cyclone mill (equiped with a rubber rotor and an abrassive surface, at 2200 rpm for 30 seconds). This produces some fine material (F), which originates primarely from the seed coat, as well as partially dehulled splits (D). These two fractions can easily be separated in a air-classifier.

-The splits (D) are again run through the same mill but this time with a stainless rotor at 3000 rpm for 20 seconds, which results in a fine ground gum powder, that can be classified into the sizes G2 <140 mesh and G3 >140mesh.

Table 34 shows the composition of the produced gum and its residual fraction:

Table 34: Analysis of endosperm split fractions obtained by dry milling

Fraction in %	Quantity	H20	Crude fiber	Protein
Input:				
Splits,untreated	100	7.0	6.1	4.3
Output:				
Splits, dehulled (D)	90	5.0	5.3	3.5
Hullmaterial (F)	10	5.0	10.6	13.7
(D) milled				
G2 <140 mesh	45	5.0	5.3	3.2
G3 >140 mesh	45	5.0	5.5	3.8

The fractions F, G2 and G3 were further analyzed in order to evaluate the sucess of the purification of the gum fraction (G) and accordingingly the purity of the galactomannan (Table 35).

Table 35: Ultimate analysis of endosperm split fractions after purification through dry milling

FRACTION in %	Protein	Crude fiber	Ash	Insoluble*	Galacto-mannan
G2 <140 mesh	3.2	5.3	1.15	30.0	64.0
G3 >140 mesh	3.8	5.5	1.2	45.0	43.0

*Insoluble/ soluble determined by centrifugation of a 5% solution at 12'000 rpm and freeze drying of the supernatant and drying the insoluble material respectively.

SUMMARY:

The wet and dry process resulted in the following three different grades of gums, with which the viscosity studies in Chapter 2.5.2.3.2. were performed.

GRADE 1 : Prepared by wet process Galactomannan-conc. 85-95 %
GRADE 2 : Drymilled, <140 mesh Galactomannan-conc. 55-65 %
GRADE 3 : Drymilled, >140 mesh Galactomannan-conc. 40-55 %

Trace elements and minerals as indicators for gum purity

The two grades of gum obtained by dry milling as well as the remaining hull material (page 102) were analyzed for minerals and trace elements.

It has been found, that some minerals and trace elements are primarily found in either one of the two grades or the hull material. This suggests that these elements are primarily associated with either the galactomannan or the seed coat. The quantity of these compounds is much easier to determine than the amount of galactomannan. Therefore minerals and / or trace elements could serve well as indicators for gum purity. Results of this investigation are shown in Table 36 and Figure 39.

Table 36: Distribution of trace elements and minerals in Fraction C (in ppm)

Element	G2 <140 mesh	G3 >140 mesh	Hull material
Iron	21.4	55.5	314.7
Manganese	11.4	12.9	25.4
Zinc	32.7	57.8	147.0
Copper	17.8	107.8	181.2
Nickel	23.2	63.3	3.0
Cobalt	1.7	7.2	11.4
Calcium	2210	2310	3530
Magnesium	531	567	1310
Potassium	3125	2745	5510
Sodium	200	860	1390

The result shows, that all elements except nickel decrease with higher gum content. In order to support these figures, minerals and trace elements of a pure MESQUITE galactomannan and of a sample of pure seed coats were determined as well. The result (Table 37; Figures 39-41) indicate, that the corelation is true for the following elements only:

Manganese, calcium, magnesium

All the other elements occur in some cases linear as far as the three products in Table 36, but the comparison with pure seed coat or gum does not held up a theory of a corelation with gum purity.

Table 37: Elements corelating with gum purity in Fraction C

FRACTION	% Galactomannan	Manganese ppm	Magnesium ppm	Calcium ppm
Pure seed coat	0-5	26.5	1310	6057
Hull material (F)	2-8	25.4	1276	3530
G3 >140m	45	12.9	567	2310
G2 <140m	60	11.4	531	2210
Pure gum	90	6.0	457	1607

Figure 39: Corelation between MAGNESIUM and galactomannan content

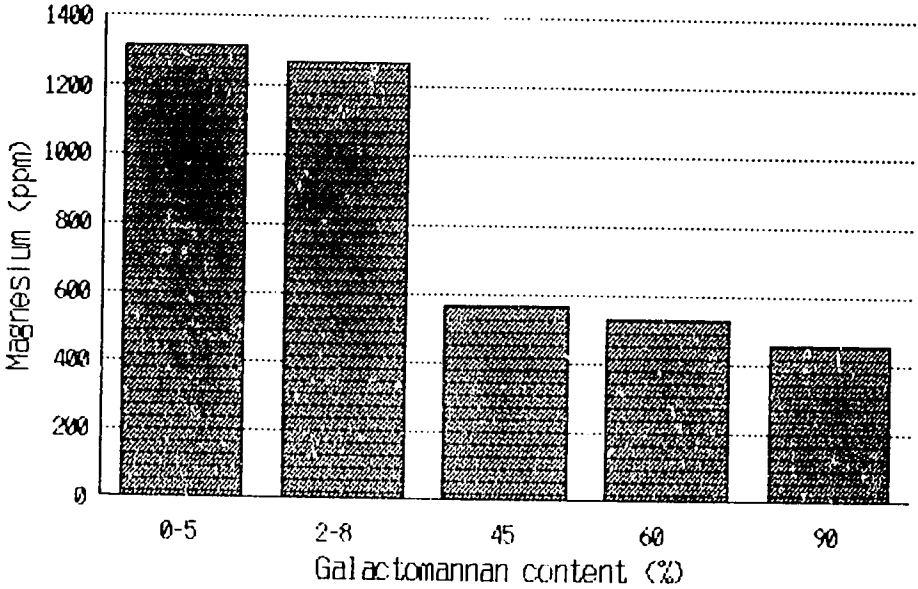


Figure 40: Corelation between MANGANESE and galactomannan content

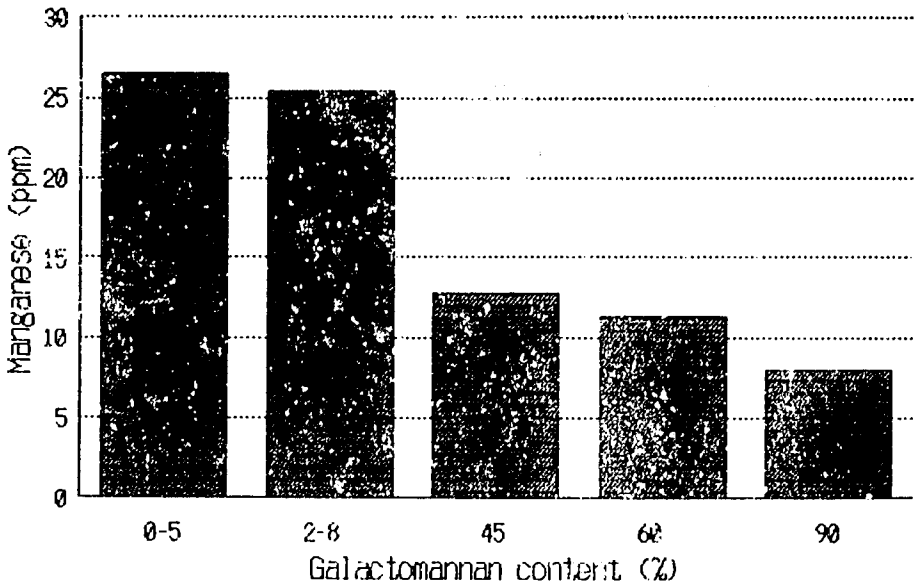
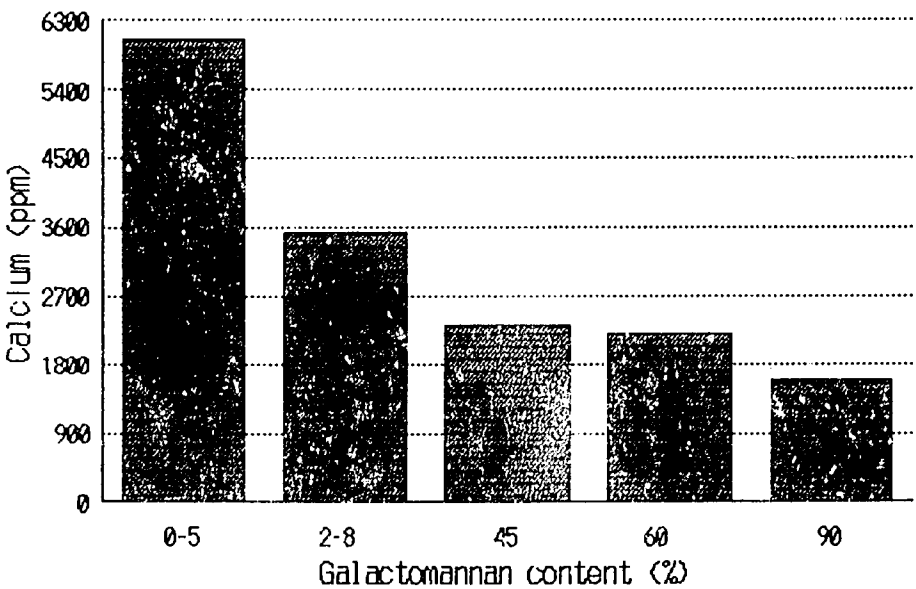


Figure 41: Correlation between CALCIUM and galactomannan content



2.5.2.3.2. Viscosity studies on the galactomannan

Galactomannan gums are used in industries such as oil-well drilling, pharmaceuticals, food and pet-food (61;86). The gum that is chosen for a given application depends on two crucial criterias: Functional characteristics and price

This chapter deals with the functional characteristics, whereas cost and price of the MESQUITE galactomannan will be discussed in Chapter 3.4.

The functional properties of a gum, which consist only of galactomannan are mainly determined by its mannose:galactose-ratio and are quiet predictable once this ratio is known. When used together with another hydrokolloid such as xanthan, the molecular structure plays an important role as well (87).

The mannose:galactose-ratio of the MESQUITE galactomannan in Fraction C has been found to be around 1.6 : 1 (see 2.4.2.3.), which is quite close to guar gum or leucaena gum (88). This would therefore justify comparison of one or both of the gums with MESQUITE. The determination of the molecular structure would definitly go beyond the scope of this work, but the similarities (discussed in the following) of the functional properties between guar- and MESQUITE gum would suggest similarities in their molecular stucture as well.

The viscosity studies were performed with GRADE 2 MESQUITE galactomannan (prepared through drymilling; G2<140mesh).

Preliminary tests showed, that the viscosity of a 1%-solution of GRADE 1 (1.1g/100 ml= 1g pure galactomannan) did not differ from a 1%-solution GRADE 2 (1.65g/100 ml= 1g pure galactomannan). The concentration is always given as absolute galactomannan concentration, by using 1.65 as multiplier to determine the amount of dry matter in solution.
(Example: The viscosity of a 0.5% gum solution is based on 1.65 x 0.5 g = 0,825 g Grade 2)

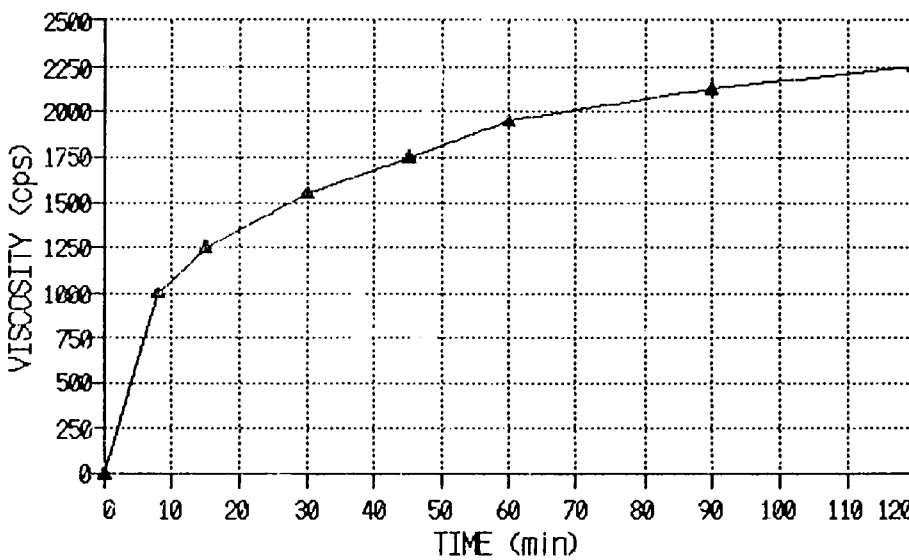
The solutions were prepared by adding 5ml methanol/ g gum to a given amount of dry MESQUITE gum and pouring this dispersion in distilled H2O at 25°C. The samples were mixed for 2 min at speed 8 with a Polytron high-speed mixer. The viscosity was then determined using a Brookfield viscometer (model RTV).

Increase in coldwater-viscosity versus time

For the use in products which do not undergo a heating process, coldwater-solubility and subsequent coldwater-viscosity are of importance. The behavior of MESQUITE galactomannan is shown in Figure 42.

Figure 42: Increase in coldwater-viscosity versus time

Brookfield viscometer (20 rpm; Spindle #3; 25°C)
Concentration: 1%



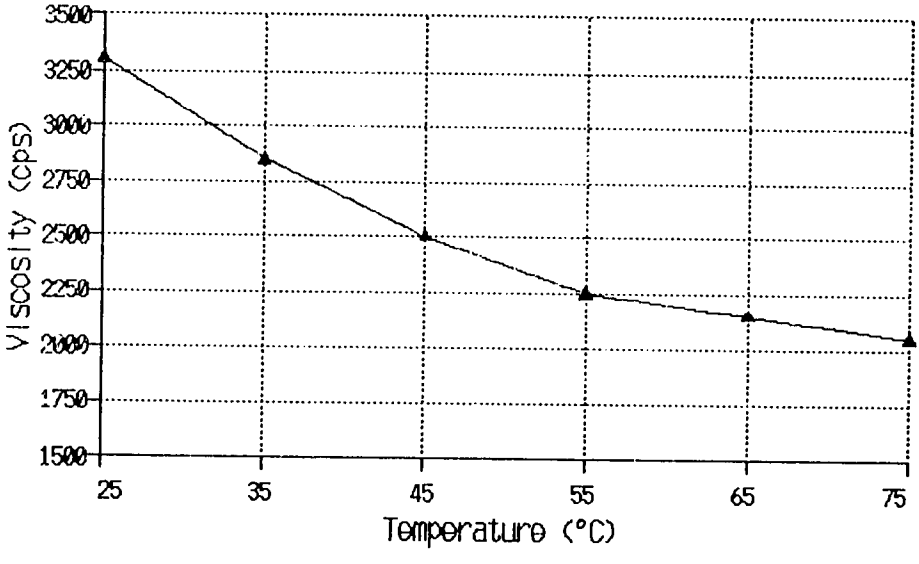
Viscosity at different temperatures

Heating a MESQUITE gum solution reduces the viscosity and increases again upon cooling to a maximum value which is about 30% higher than at the same temperature when the solution has not been preheated. MESQUITE gum is therefore not completly coldwater soluble.

The temperature stability can be determined by reheating a solution and checking the viscosity along the temperature increase (Figure 43).

Figure 43: Temperature stability of solubilized MESQUITE gum

Brookfield viscometer (20 rpm; Spindle #3)
Concentration: 1%

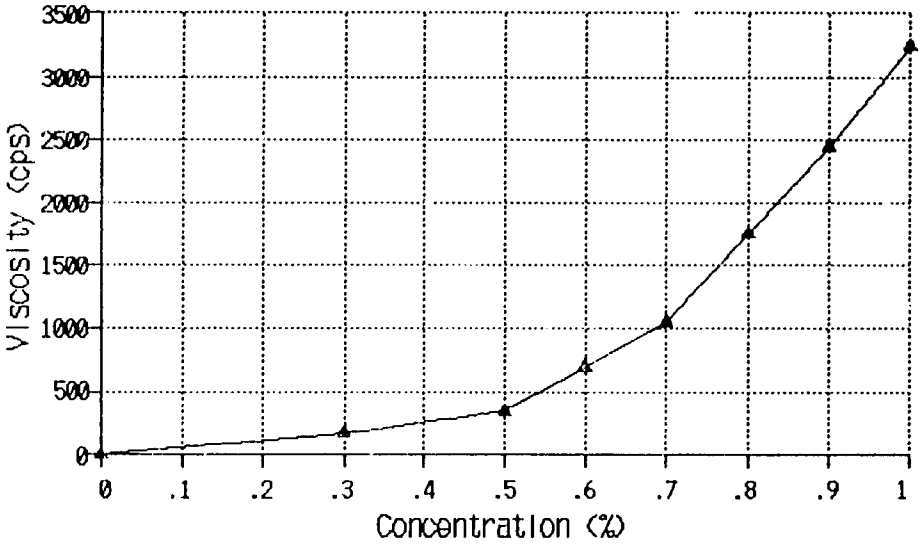


Viscosity at different concentrations

Galactomannan gums are commenly used in foods in concentrations of around 1%. Figure 44 shows the viscosity of the MESQUITE galactomannan in concentrations from 0.1-1.0%. It can be seen, that the viscosity increases exponentially.

Figure 44: Viscosity of solubilized MESQUITE gum at different concentrations

Brookfield viscometer (20 rpm; Spindle #3; 25°C)



2.5.2.3.3. Interaction of MESQUITE galactomannan with xanthan gum

The synergistic reaction of xanthan with galactomannan gums and other hydrocolloids is widely used in the food and petfood industry. This interaction has been called a "useful incompatibility" (89). The mechanism has been extensively studied in the last few years and it is believed to be caused by some kind of physical association of the molecules of the two gums (90). A drastic viscosity increase is observed by combinations of the two hydrocolloids with lower percentages of total gum. The combination with xanthan gum results in a more temperature stable end product. It is therefore important for the market value of a galactomannan that it shows this interaction with an other hydrocolloid.

Optimal ratio of MESQUITE gum to xanthan

The maximum interaction occurs at different ratios of galactomannan to xanthan, depending on the source and structure of the galactomannan. Table 38 shows the viscosity of different ratios of MESQUITE/xanthan at 1% total concentration. Samples were prepared by dry-blending the two gums, wetting with 0.5ml ethanol and heating to 75°C. The viscosity was measured during heating and again at 25°C.

Table 38: Viscosity at different MESQUITE:xanthan-ratios (in cps; total concentration 1%)

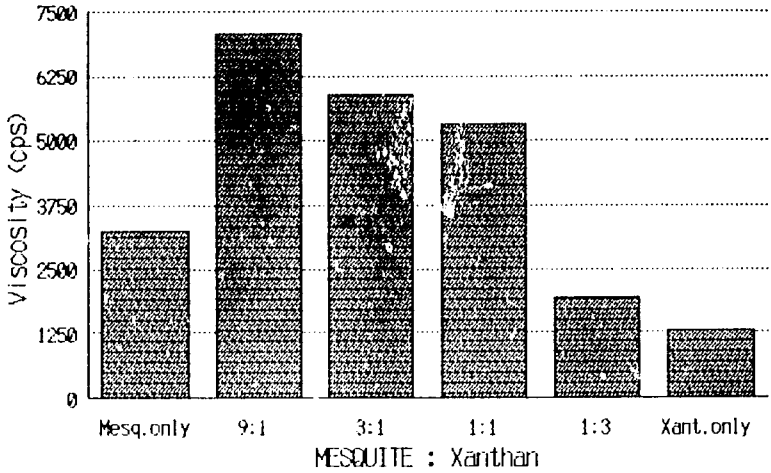
Brookfield Viscometer; Spindle #3, 20 rpm)

Temperature	MESQUITE : Xanthan 9:1	3:1	1:1	1:3
25°C (unheated)	750	800	1100	1450
75°C	2500	2300	1900	1500
60°C	3300	3100	2700	1700
50°C	3750	3350	3100	1750
40°C	4300	4000	3400	1800
35°C	5500	4500	3600	1850
30°C	6050	4800	4300	1900
28°C	6500	5450	4600	1950
25°C	7050	5900	5700	1950

The highest viscosity can be achieved by adding 10% xanthan gum to the MESQUITE galactomannan; it reaches a value more than twice as high of the MESQUITE-only sample. Intensity of the interaction diminishes with higher percentages of xanthan.

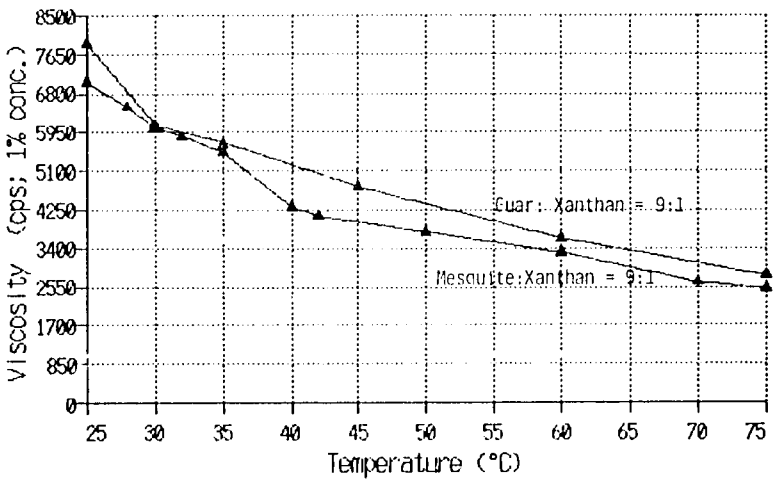
The viscosity of different hydrocolloid mixtures at 25°C (after heating) as well as the comparable viscosities of the single gums are illustrated in Figure 45.

Figure 45: Viscosity of MESQUITE/xanthan combinations (at 25°C)



The temperature stability of the best combination (9:1) is shown in Figure 46: The strength of the interaction is reduced with increased temperature.

Figur 46: Temperature stability of MESQUITE/xanthan (9:1)



2.5.2.4. Fraction D

Fraction D is made up of the cotyledons and the germ of the MESQUITE seed and represents 12-15% of the whole, dried pod (Chapter 2.2.). Its main constituents are protein (61 %) and fat (8 %).

Many protein products from leguminous seeds as well as from other sources, are used in the food industry for two different reasons :

-fortification and balancing of the amino acid composition
-functional properties (e.g. foaming; stabilizer)

The amino acid composition of Fraction D as shown in Chapter 2.4.2.4., reveals that the protein of this fraction is typical for a leguminous seed, which would basically qualify it for fortification purposes.

The significantly improved protein efficency ratio (PER) of flakes containing 20% Fraction D (Chapter 2.5.2.1.2.2.),would be an other argument for the utilization of the MESQUITE Fraction D for such purposes. However, this protein has no clear nutritional advantages over any other leguminous seed protein such as soy or peas protein. It is therefore questionable wether Fraction D could compete as a protein for fortification purposes since the obtainable quantity is far beyond the quantity of already widely used proteins. The only exception is certainly the utilization of Fraction D in the local market on LDC's, where hardly any other protein material can be obtained.

Therefore, the following experiments concentrate on the study of the functional properties of Fraction D, which would give the MESQUITE protein the necessary competitive edge along with the resulting wider price autonomie, provided that it showed some unique characteristics.

The most desirable functional properties of a protein in the food industry are emulsification, fat and water absorption, texture modification, color control and whipping properties (91;92;93;94;95).

Preparation of a protein concentrate from MESQUITE Fraction D

-Mill Fraction D in a Willey-mill through the 30 mesh screen
-Extract fat with hexan during six hours
-Filter extract through Millipore 0.5µ filter
-Evaporate hexane
-Dry protein-residue in vacuum oven at 40°C during one hour
-Reduce size of protein concentrate in a ball mill to <60mesh

Yield: 100g Fraction D results in 91 g protein concentrate and 9 g oil.

Protein content of concentrate: 63.1% (N x 6.25)

All the following experiments were done with this protein concentrate.

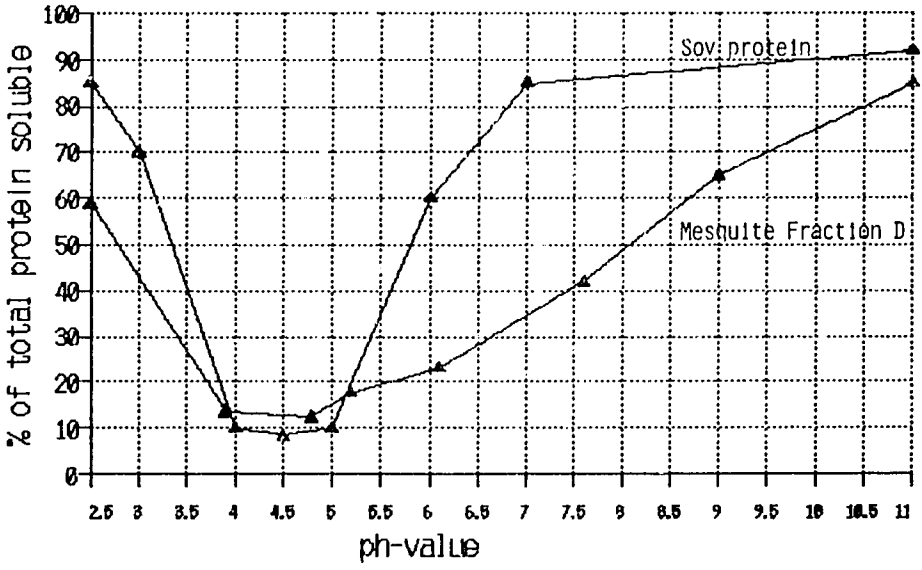
Protein solubility (93;96)

-0.3g of Fraction D protein concentrate are given to 30 ml tap water in centrifuge tubes
-pH-value is adjusted to different levels with HCl or NaOH
-The samples are stirred with magnetic stirrers for 60 min.
-Centrifugation of samples at 5000 rpm for 40 min. at 25°C
-The supernatant is decanted and analyzed for nitrogen
-The precipitate is dried in a vacuum-oven for 12 hours at 60°C and weighed

The percentage of soluble protein was determined as % soluble nitrogen of total nitrogen.

The results are shown in Figure 47, along with the protein solubilty of soy protein for comparison. It can be seen, that the protein concentrate of MESQUITE Fraction D has a rather low solubility. Almost complete precipitation occurs between pH-value 4 and 5.

Figure 47: Protein solubilty of MESQUITE Fraction D



Heat denaturation

Solutions were prepared containing 1% Fraction D protein and were heated to 55°C and 70°C respectively. After centrifugation the supernatents were analyzed for nitrogen. As a reference, two samples were not heated.

The differences in percentages of soluble protein (N x 6.25) were found to be insignificant:

Unheated= 15.7%; 55°C= 17.0%; 70°C= 17.6%

Whipping properties: Foam expansion, foam stabilty (93;97;98)

Foam expansion and foam stabilty of MESQUITE Fraction D protein concentrate was studied as a single ingredient as well as compared and combined with skim milk.

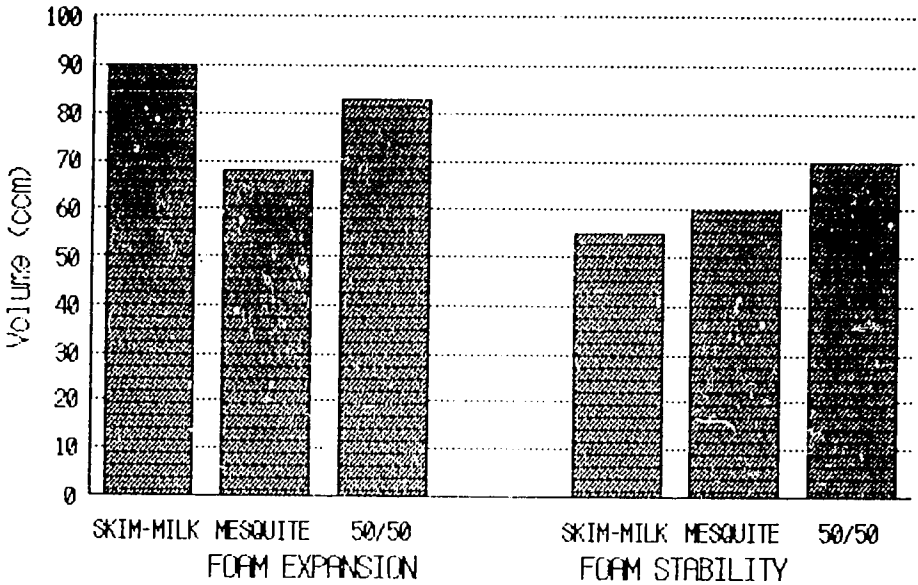
Samples:

A: Skim milk only (Carnation nonfat, instant dry milk)
B: MESQUITE Fraction D protein concentrate
C: 50% skim milk + 50% MESQUITE Fraction D protein concentrate

Procedure:
- Dissolve samples in water to give a 4% protein concentration by mixing with a Polytron at speed 7 for 5 min.
- Shake samples horizontaly for exactly 60 sec.
- Measure volume = FOAM EXPANSION
- Allow samples to stand and measure volume again after 60 min. = FOAM STABILITY
- Repeat 5 times

The results (Figure 48) show that the MESQUITE product has good foam expansion and an even better foam stabilty. Combination with skim milk seem to cause a synergistic reaction that causes a better foam stability than either product alone.

Figure 48: Foam expansion and -stability of MESQUITE Fraction D



Emulsifying properties (91;93;98;104;105)

The **emulsion-capacity** measures the ability of a product to emulsify a solution of water and oil as percentage of the whole solution.

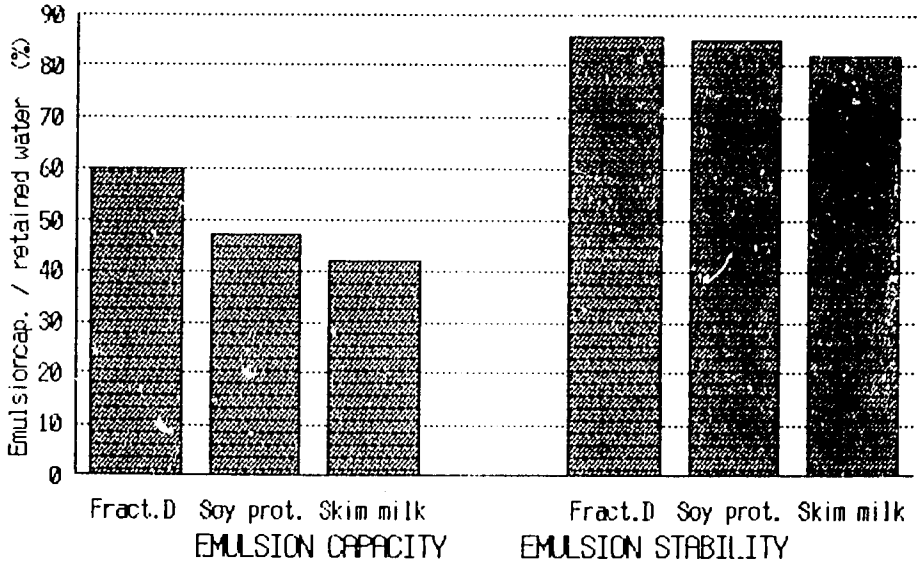
In the following experiment MESQUITE Fraction D protein-concentrate is being compared to a soy-bean concentrate (Archer Daniels, Bakers Nutrisoy with 52% Protein) and to skim milk.

Procedure:
- Add protein concentrate to distilled water to produce a 4% total protein concentration
- Add vegetable oil, equal to the amount of water
- Give oil-soluble stain to the emulsion, mix with a Polytron high-speed mixer at speed 7 for 1 min
- Divide the sample in glass centrifugal tubes (25 ml each) and centrifuge 10 min at 3500 rpm.
- Read "height of emulsisfied layer x100 : height of whole layer" (in the center of tube) = **Emulsion-capacity**

The **emulsion-stability** is determined by measuring the amount of water released from the emulsion following centrifugation using the samples of above experiment . The value is expressed as: Total ml water in emulsion - water released x100 : total water in emulsion = **Emulsion-stability**

The results (Figure 49) indicate that the MESQUITE products compares favourably with the control products in both experiments

Figure 49: Emulsion capacity and -stability of MESQUITE Fraction D



Emulsion viscosity

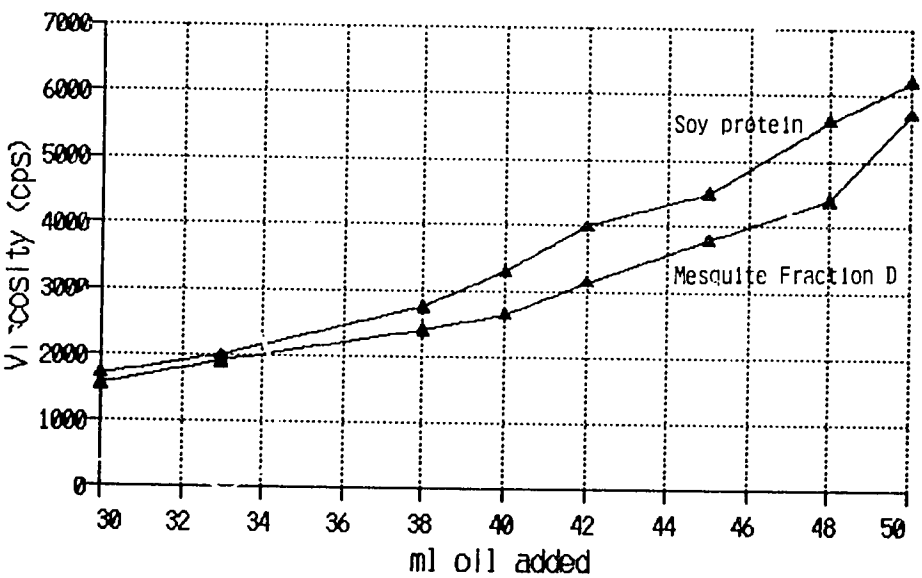
The viscosity of an emulsion prepared with Fraction D (or soy bean flour for comparison) was determined at a protein concentration of 5% in water.

Procedure:

- Dissolve protein concentrate in tab water to give a 5% protein concentration
- Slowly add hydrogenated soybean oil while the solution is permanently mixed with a magnetic stirrer
- Before each viscosity measurement (with Brookfield viscometer; spindle #3 at 20rpm) the solution has to be mixed with the Polytron mixer at speed 6 for 1min.

The results are shown in Figure 50 and reveal very little difference between soy and MESQUITE Fraction D.

Figure 50: Emulsion viscosity of MESQUITE Fraction D and soybean flour (5% protein)



2.5.2.5. Storage and shelf-life of MESQUITE pods

When storage and shelf-life are to be discussed, one has to distinguish between unprocessed whole pods on one side and the single fractions on the other side.

The whole pods survive long periods of exposure to the elements when they fall from the tree. They are nevertheless subject to infestation by a serie of insects, which usually starts already on the tree, and to rain which however occurs very rarely during MESQUITE season in arid zones.

As long as the MESQUITE pods are being processed close to the growing-areas and therefore remain in the same climatic region, storage of unprocessed pods poses no problems (again with the exception of insect damage and rain).

The situation is different as soon as either the pods are relocated into areas with different climats (humidity), or the pods are processed into their fractions.

Humidity then becomes the major storage and shelf-life problem. This was evident during the time of this work. The whole pods were collected in the Southern Californian Desert but processed and stored in the relatively humid San Francisco Bay Area.

It is well known that almost all chemical, enzymatic and microbiologial reactions that negatively affect food products occur more intensly at high relative humidity or moisture contents (99).

Along with the absolutely mandatory moisture level neccesary for milling the pods (see Chapter 2.3.), it is highly advisable to dry the pods immediately before or after relocating the pods to humid areas, and to keep them stored in dry places. Insect damage however occurs even when the pods are dried and an additional fumigation (e.g. Phosphin) is therefore neccessary. Freezing is only recommended when pods are stored in their original state for analytical purposes and to avoid insect damage and mold without fumigation.

The same problems are valid and even more important when the pods are milled and fractioned. Fraction A, due to its high sucrose content, is most sensitive to high relative humidity. Improper storage leads immediately to the formation of clumps and at higher humidities even to mold growth.

Fraction B is subject to similar effects but is less problematic as the fraction is not milled into a powder.

To obtain more information about storage condtitions, the sorption isotherms of Fraction A and B were determined, and shown in Figure 51.

Regarding oxidation it was found, that Fraction A flour is almost not subject to oxidation or development of rancididity. The hexanal value (70;71; also Chapter 2.5.2.1.2.3.) has been determined on two samples:

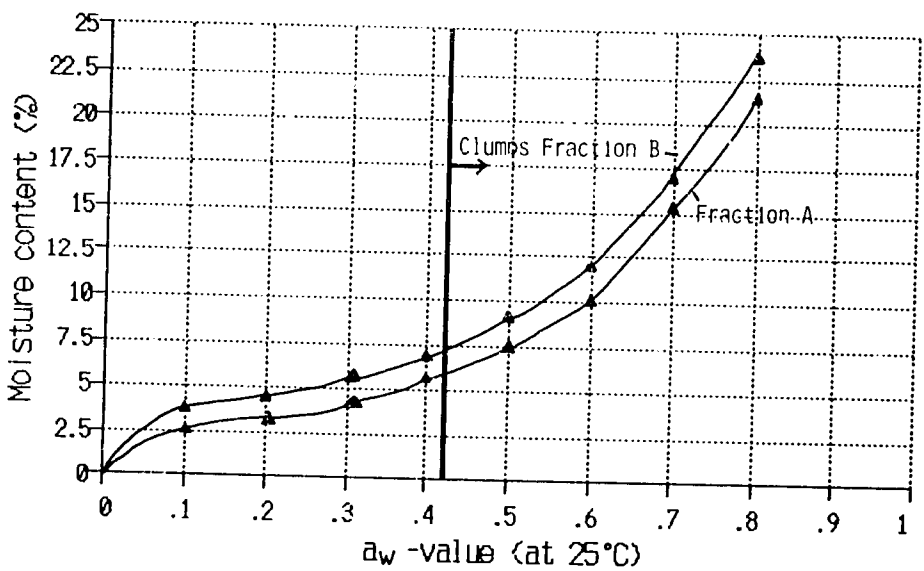
A1 = stored in glass jar at roomtemperatur for 8 month
A2 = stored in glass jar,dark at 38°C for 4 month

The hexanal value was found to be 1.6 for A1 and 9.2 for A2.

Fraction C has an almost unlimited shelf-life. No loss in viscosity could be found during a storage period of two years.

Fraction D shows surprisingly good stabiltiy even against oxidation which one might expect to be critical due to the relatively high oil content. No organoleptical changes could be detected during storage in glassjars for 6 month. This is however understandable considering the rather low iodine number of the oil, 95.6 (50).

Figure 51: Sorption isotherms of MESQUITE Fraction A and B at 25°C



3. PROPOSAL FOR A MESQUITE PROCESSING PLANT

3.1. Objectives

The preceding chapters answered the question whether and how MESQUITE pods can be processed into one or more raw materials for the food industry and studied possible applications of the different fractions. Therefore, the technological and chemical problems have in prirciple been solved.

This chapter goes one step further: It presents a **project for a small MESQUITE processing plant with a capacity of 1000 kg pods per hour.** The objective is to provide the potential enterpreneur with detailed information on the plant lay-out and the type of machinery to be purchased (*).

In addition, the chapter presents information concerning the necessary financial investment and approximate operating costs of such a plant. The figures consider only the processing aspects including pod purchase, but no distribution, management or other non-technical areas. This is a model only, based on certain assumptions that might vary considerably depending on factors such as location or size of the processing facility.

3.2. Process description

The processing capacity of the proposed plant is assumed to be 1000 kg of pods per hour. It is basically a scaled up version of the process described in chapter 2.3.1. and in several cases the same but machinery of a larger scale is used. This chapter contains a great deal of technical information which was developed in voluntary cooperation with Buehler-Miag (Minneapolis, Minn.) (*). For better understanding, the following process description should be read along with the plant lay-out (Figure 52).

The equipment specifications are listed in chapter 3.4., and are not necessary for the understanding of the process, but for readers seriously interested in such a plant. The logical conclusion , a budget and the economics, are discussed in the last two paragraphs of chapter 3 .

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* It is a policy of the U.S.D.A. to state, that mentioning of a manufacturer is not an endorsement and that other brands might also be used.

Section 0: Product delivery

The pods are delivered in trucks to the plant and contain the original moisture content of about 6% with a pod density of 140 kg/ m3. The pods are discharged in a product bin located outside the actual building. They are stored until conveyed by a cleated belt conveyer to the drier.

Section 1: Drying

The drying tunnel which will also be located outside the building, holds two containers, each with a holding-capacity of maximal 1300 kg pods. With a drying time of 2 hours at 55 °C, and one container changed every hour, this results in a sufficent product flow to the next section. The containers, designed with a sliding bottom, are rolled above the horizontal part of the belt conveyor and discharge the pods on it.

Section 2: Milling

The pods are conveyed to a crusher that reduces the pods to a length of about 3 cm, and pass through a suction conveying line to the stone mill. The mill is equipped with corrugated discs by which the seeds are released from the pericarp along with the two other pericarp-fractions.

Section 3: Separation, seed cleaning and seed splitting

An other suction conveying line transports the outlet from the stone mill to the grain separator, where the seeds are separated from Fraction A and B by means of aspiration and a cyclone. Fraction A and B (along with pericarp fragments separated from the seeds in the cyclone) are sucked to the intermediate storage bins, whereas the seeds pass to the strato-huller.

The seeds are splitted into Fraction C and D in the strato-huller and are separated in a second compartment of the grain separator. The two seed fractions C and D are then transported to intermediate storage bins as well.

Section 4: Fine-milling

The four fractions of the MESQUITE pod are now stored in their respective bins from where they can be milled individually in the grinder to a desired mesh size, or in case of Fraction B directly conveyed to the bagging section. The flour from the grinder passes a screener from where material in the desired mesh size goes to the product storage bin, whereas material above the correct size returns to the grinder.

Section 5: Material storage and packaging

The milled fractions are temporarly stored in finished product bins, until they are bagged in the packaging section.

Options:

-If the pods are not be delivered free from stones or heavy mudballs, a destoner would be necessary in Section 2

-Depending on the delivery system of the finished products, the capacity of section 5 might have to be changed significantly.

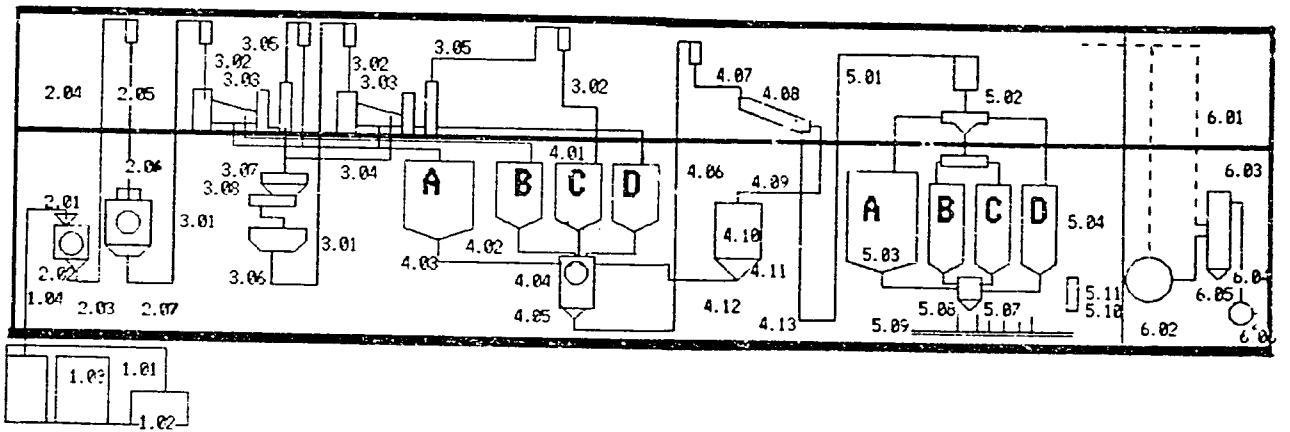
3.3. Plant-layout and equipment list

Table 39 lists all the equipment which is shown in the plant lay-out (Figure 52) and serves as a legend. The quantity of each equipment relates to the processing capacity of 1000 kg/h.

Table 39: Equipment list for a MESQUITE-processing plant

Item	Quant.	Equipment	Item	Quant.	Equipment
1.01	1	Drying Tunnel	1.02	lot	Heating Equipment
1.03	2	Containers for 1.01	1.04	1	Belt Conveyor
1.05	1	Belt Conveyor			
2.01	1	Inlet Hopper	2.02	1	Single Roll Crusher
2.03	1	Outlet Hopper for 2.02	2.04	1	Conveying Line
2.05	lot	Spouting	2.06	1	Stone Mill
2.07	1	Outlet Hopper			
3.01	2	Suction Conveying Line	3.02	lot	Spouting
3.03	1	Grain Separator	3.04	lot	Spouting
3.05	2	Aspiration for 3.03	3.06	1	Strato Huller
3.07	1	Hopper	3.08	1	Screw Conveyor
4.01	4	Hopper	4.02	4	Screw Conveyors
4.03	lot	Spouting	4.04	1	Grinder
4.05	1	Outlet Hopper	4.06	1	Conveying Line
4.07	lot	Spouting	4.08	1	Screener
4.09	lot	Spouting	4.10	[illegible]	Hopper
4.11	1	Srew Conveyor	4.12	lot	Spouting
4.13	lot	Spouting			
5.01	1	Suction Conveying Line	5.02	lot	Material Distributer
5.03	1	Finished Product Bin	5.04	3	Finished Product Bin
5.05	4	Screw Conveyors	5.06	lot	Spouting
5.07	1	Inlet Hopper	5.08	1	Autom. Net Weigher
5.09	1	Belt Conveyor	5.10	1	Bag Closer
5.11	1	Reel-Type Suspension			
6.01	lot	Ductwork	6.02	1	High Pressure Fan
6.03	1	Filter	6.04	1	Hopper
6.05	1	Airlock Package	6.06	1	Exhaust Fan

Figure 52: Plant lay-out for a MESQUITE processing plant with a capacity of 1000 kg / hour



3.4. Equipment and engineering specifications

3.4.1. Milling and separation

SECTION 0: PRODUCT DELIVERY
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0.1 Storage-bin

Capacity: 64 000 kg; 4.75 m dia, 6.4 m high. Allows product storage for about one week

SECTION 1: DRYING
==========

1.01 Drying tunnel

Approximatly 3 m wide, 2.4 m high, and 4 m long ; located outside the actual plant. Brick construction, with doors on both ends for quick loading and unloading the raw material. Holding capacity 19 m3 of beans (=2700 kg).

1.02 Heating and air circulating equipment

Containing the necessary electrical heating coils, fans for air circulation and exhaust for the drying tunnel.

1.03 Containers for drying oven

Approximatly 1.2 m wide, 2.1 m high and 3.6 m long. Each of the two containers holds maximal 1250 kg. Containers equipped with three 15 cm dia. steel V-grooved casters and six 20 cm dia. plain casters. Including 20 m (2x10 m) track bolted in two rows inside the drying tunnel for guiding the the containers. With sliding bottom for dried beans.

1.04 Belt Conveyor

A) For discharging the containers.

Conveying Capacity:	0.11 m3/min.
Arrangement:	7.8 m horizontal with 30° inclined by a discharge height of 2.1 m
Conveying Belt:	60 cm wide with 10 cm cleat heigth
Overall Width:	75 cm

Complete with motor, drive, supporting legs. Including 10.8 m track, bolted to the floor on one side of the horizontal belt for guiding the containers.

B) For loading the containers.

Conveying Capacity:	0.34 m3/min
Arrangement:	3 m horizontal with 30° inclined by a discharge height of 2.7 m

Same secifications as Item #1.04. Including 10.8 m track, bolted on the floor under the discharge of the belt for guiding the containers.

SECTION 2: MILLING

2.01 Inlet Hopper

Bolted to the inlet of the single roll crusher.
10 Ga. HRS construction.

2.02 Single Roll Crusher, Model MBP

In all metal construc tion with spiked discs on the cast iron crushing roll. Including automatic safety release, V-belt drive, and 5 HP motor. Without concrete support.

2.03 Outlet Hopper for Crusher

10 Ga. HRS construction with flange to match the crusher, and an outlet stub to match spouting to the destoner.

2.04 Suction Conveying Line

Including the necessary pick-up shoe, straight tubing, elbows, couplings, sightglasses, cyclone, air regulator and airlock. Mounted on an airlock bench, including motor and gear reducer.

2.05 Spouting from Cyclone to Stone Mill

Including the necessary straight spouting, elbows, transitions, sightglasses and couplings.

2.06 Stone Mill, Model, MJSG-67C

Cast iron construction with 2 metal grinding discs, including product inlet spout with vibratory feeder, feeder control unit, and inlet magnet, Model MMUA-20. Complete with V-belt drive, guard and 20 HP motor. Without concrete support.

2.07 Outlet Hopper for Stone Mill

10 Ga. HRS constrction, with flange to match the stone mill, and an outlet stub to match the pick-up shoe.

OPTION:

Dry Destoner, Model MTSB-50

Frame and support in steel, housing in polyester, with safety windows, built-in distributing frame, hardened stell wire deck. Including a booster fan with drive and 3 HP motor.

SECTION 3: SEPARATION, SEED CLEANING AND SEED SPLITTING

3.01 Suction Conveying Line

Same specifications as Item #2.04

3.02 Spouting from Cyclone to Separator and Bins

Same specifications as Item #2.04

3.03 Grain Separator, Model MTMA-15100 DS

Double sieve compartments with two separating stages. All steel construction with two sieve layers, rubber ball cleaners, two aspiration channels on the product outlets, including V-belt drive, and 1.5 HP motor on the separator and a 0.16 HP motor on the aspiraton channels.

3.04 Spouting for MTMA-15100 DS

Same specification as for item 2.05

3.05 Aspiration Airduct and Cyclone

For the MTMA-15100DS Separator, including the necessary machine transitions, elbows and ducting.

3.06 Strato-Huller, Type DMHB-51

All metal construction with inlet glass, conocal hopper, support legs. With 10HP motor for the rotating disc and moveable baffle ring.

3.07 Hopper

Same specifications as Item 4.10

3.08 Screw Conveyor

Same specifications as Item 4.11

SECTION 4: FINE-MILLING

4.01 Hopper

Capacity: 2 m3 each
10 Ga.HRS construction with one level indicator, and outlet flange to match the srew conveyor.

4.02 Screw Conveyor

15 cm dia. x 1.2 m long. Complete with variable frequency drives.

4.03 Spouting

From the screw conveyors to the pulverizer. Same specifications as Item 2.05.

4.04 Grinder, Model Sturtevant #00 Swing Sledge Mill

Including cast iron frame with manganese steel liners, complete with dive and motor. Excluding any concrete foundation.

4.05 Outlet Hopper for Grinder

10 Ga. HRS construction, with flange to match the grinder, and an outlet stub to match the pick-up shoe.

4.06 Suction Conveying Line

Same specification as Item 2.04

4.07 Spouting to Rotex Screener

Same specifications as Item 2.05

4.08 Rotex Screener, Model 201

Single screen machine in all metal construction, complete with aluminum top cover and sieve frames, and stainless steel bottom, ground smooth but not polished. Including V-belt drive, motor bracket, 1.5 HP motor and three spare screens.

4.09 Spouting

From outlet screener to hopper above screw conveyor.
Same specifications as Item 2.05.

4.10 Hopper

Capacity: 1 m3
In 10 Ga. HRS construction, with one high level indicator, and outlet flange to match the screw conveyor.

4.11 Screw Conveyor

0.15 m dia x 1.2 m long, complete with drive and motor.

4.12 Spouting

Same specifications as Item 2.05.
Including one manually operated diverter valve.

4.13 Spouting

From Rotex screener to pick-up shoe.
Same specifications as Item 2.05.

SECTION 5: MATERIAL STORAGE AND PACKAGING

5.01 Suction Conveying Line

Text as per Item 2.04

5.02 Material Distribution Components

Including one 3-way flow diverter and one 2-way flow diverter, both 0.1m O.D., pneumatically operated. Including the necessary spouting, elbows, and clamps to spout to the finished product bins.

5.03 Finished Product Bins

Capacity: 3 m3
In 10 Ga. HRS construction, including one high level indicator one low level indicator, one bin vibrator, and outlet flange to match the screw feeder.

5.04 Finished Product Bin

Capacity: 2 m3 each
Text same as Item 2.05.

5.05 Screw Conveyors

0.15 m dia. x 1.2 m long, complete with variable frequency drives.

5.06 Spouting

From screw conveyor to inlet hopper of weigher.
Same specifications as Item 2.05

5.07 Inlet Hopper

Located above the weigher, 10 Ga. HRS construction.

5.08 Edtbauer-Duplex Automatic Net Weigher, Model 4E

5.09 Belt Conveyor

2.55m long, located under the weigher.

5.10 Fishbein Portable Bag Closer, Model "E+"

5.11 Reel-Type Suspension, Model 1550

SECTION 6: ASPIRATION SYSTEM

6.01 General Exhaust Ducting

Ducting from the equipment to the dust filter, from the cyclones to the high pressure fan to the filter, and from the filter to the exhaust fan. Including machine transitions, straight ducting, elbows, flanges and gaskets.

6.02 High Pressure Fan, Aerovent Model 475-150 Series 14

For a capacity of 35 m3 per minute. Complete with direct drive arrangment #4, vibration isolators, flanged outlet, access door, inlet damper and 10HP, 3600 RPM motor.

6.03 Dust Filter, Model RPDC-81/8

Filter area 90 m2. Air to cloth ratio of 7.1:1. Complete with 12 Ga. reinforced air plenum, housing ,compressed air header assemly, solid state timer, inspection port, access door internal grid, and flange to match the outlet hopper.

6.04 Outlet Hopper for Dust Filter

12 Ga. HRS construction, with dirty air inlet in the housing with an internal baffle for bag protection. Including support legs, and outlet flange to match the airlock.

6.05 Airlock package, Model MPSX-27

Cast iron construction, with mild steel fabricated rotor, sidemount motor base, and 3/4 HP right angle gearmotor.

6.06 General Exhaust Fan, Aerovent Model MH-800 BW

For a capacity of 650 m3/min. Complete with V-belt drive, guard, langed outlet, access door, base with vibration isolators and a 25 HP, 1800 RPM motor

SECTION 7: INSTALLATION MATERIAL AND STRUCTURAL SUPPORT

7.01 Installation Material

7.02 Structural Support

Approximatly 8 m long x 8 m wide and 4 m high to be used as a mezzanine floor, consisting of steel construction with hand rails, floor grating, and structural stairway.

SECTION 8: ELECTRICAL EQUIPMENT, PANEL, MOTOR CONTROL CENTER

Consisting of a NEMA-12 control panel with motor running lights, hand/off/auto selector switches, motor starters, alarm System, necessary interlocking, transformer (control circuit IMNCC), and all field connections to terminal strip on the sub-panel.

SECTION 9: CRATING, FREIGHT & INSTALLATION OF EQUIPMENT

9.01 Installation of Electrical Equipment and Wiring

9.02 Installation of Mechanical Equipment

9.03 Crating and Freight Charges

SECTION 10: COMBUSTION SYSTEM FOR FRACTION B

Ni-Burner Incinerator to produce hot air to be used as alternative in Item 1.01 to dry MESQUITE pods.
Complete with all controls.

SECTION 11: ELECTRICAL ENERGY SOURCE

200 HP Diesel Generator to deliver electricity to all motors.

SECTION 12: VARIAS

12.01 Engineering and Start-up Services

12.02 Operating Supplies (Spare parts,Lubricants)

12.03 Pressurized Air Connecting Pipes and Fittings

12.04 Concrete Support for Heavy Motors and Machines

SECTION 13: BUILDINGS

Site preparation, buildings, manlifts, sanitary installation, water piping, boiler, air conditioning, offices including furnitures, laboratory including equipment and chemicals.

3.4.2. Energy requirements and supply

Several motors along the processing line require various amount of electricity. Their specific requirements are listed in Table 40.

Since a MESQUITE processing plant would be set up in rather undeveloped areas, possibly with now electrical hook-up, it might be necessary to produce the electricity through a diesel-generator.

Such a diesel-generator should be able to run approx. 10 hours a day, and be set up that it requires the least possible maintenance. The motors in the processing line could be switched on in serie. For that purpose an Ingeneering-company (Stamm, Aarbon-CH) recommends a 190 Hp generator. Such a generator (US$ 25000.-, including all controls) has under given conditions a life expectancy of 6000 hours and requires a revision every 100-300 hours. It requires approx. 35l diesel fuel oil / hour.

A substantial amount of hot air necessary for drying the pods could be obtained through combustion of Fraction B in a Ni-Burner Incinerator (more information available through W.K. Nider, Allied Engineering & Production Corp. 4221 Blanding Ave., Alameda CA 94501 USA). Such a unit could burn 200 kg Fraction B per hour which would release approximatly 560 000 kcal per hour.

Table 40: Energy requirements for a MESQUITE processing plant

Item	Quantity		Hp-requirements
Belt Conveyor	3	1 Hp each	= 3 Hp
Screw Conveyor	10	1 Hp each	= 10 Hp
Single Roll Crusher	1	5 Hp	= 5 Hp
Stone Mill	1	20 Hp	= 20 Hp
Destoner	1	3 Hp	= 3 Hp
Grain Separator	1	2 Hp	= 2 Hp
Strato Huller	1	10 Hp	= 10 Hp
Grinder	1	10 Hp	= 10 Hp
Screener	1	2 Hp	= 2 Hp
Bag Closer	1	1 Hp	= 1 Hp
High pressure Fan	3	10 Hp each	= 30 Hp
Airlock Package	1	1 Hp	= 1 Hp
Exhaust Fan	1	25 Hp	= 25 Hp
Total known electricity requirement			122 Hp
Necessary spare capacity			approx. 50-70 Hp
TOTAL RECOMMENDED POWERSUPPLY			150-190 Hp

3.5. Budget

3.5.1. Investment for the set-up of a MESQUITE processing plant with a capacity of 1000 kg/hour

The cost estimates for a MESQUITE processing plant are based on the equipment specified in Chapter 3.4. The figures are based on information obtained by Buehler-Miag as far as sections 1-9 and 12 are concerned, whereas prices of section 10 were estimated by Allied Engineering. Sections 11 and 13 are based on either average prices for similar equipment or comparable plants. Especially the figures in Section 13 are to be taken as very variable, since location (e.g. Mexico or USA) could cause substantial differences.

The prices in Table 41 were quoted in November 1983 and are understood to be F.O.B. jobsite, California. All prices are for budget estimate purposes only.

Land purchase is included in the budget estimate as a pro memoriam expense only. Land in arid zones is of practicaly no cash-value and accounts for an absolute minor expense only.

Table 41: Budget estimates

Land purchase		US$	1000.00
Section 0	Product delivery	US$	9000.00
Section 1	Drying	US$	61000.00
Section 2	Milling	US$	25500.00
Section 3	Separation,Seed cleaning ...	US$	57500.00
Section 4	Fine milling	US$	57000.00
Section 5	Material storage & packaging	US$	54000.00
Section 6	Aspiration system	US$	38000.00
Section 7	Structural support	US$	29500.00
Section 8	Electrical equipment	US$	41500.00
Section 9			
9.01/9.02	Installation of equipment	US$	222000.00
9.03	Crating & freight charges	US$	17500.00
Section 10	Combustion system	US$	45000.00
Section 11	Electrical energy source	US$	25000.00
Section 12			
12.01	Engineering and start-up services	US$	50000.00
12.02	Operating supplies	US$	45000.00
12.03/12.04	Pipes /Concrete support	US$	3800.00
Section 13	Buildings (700m3 * US$ 150.-)	US$	105000.00
TOTAL INITAL INVESTMENT FOR PLANT SET-UP:		US$	887300.00

This budget estimate does NOT include:
-any warehousing or insurance cost after equipment has been delivered,
-any heavy sundry erection tools such as cranes, etc.
-any truck for moving the containers,
-workshop machinery, tools,
-laboratory equipment, chemicals,etc.
-office furniture and equipment,
-any federal, state, local or other taxes,
-any safety features features unless specified,
-in other words, any items or materials not specifically mentioned herein

3.6. Economics

A) Production costs based on plant location in Mexico

For this model the plant would be set up in:
Matehuala, Mexico, State of San Luis Potosi

This location has been chosen because MESQUITE grows extensively in this area. The pods have traditionally been collected by rural inhabitants for whom this income was of social economic importance. They have either sold the pods to ranchers and feed dealers or used it themselves as a cheap substitution up to 50% in feed formulas. This situation is described in a report by the Instituto Mexicano de Resoursos Naturales Renovables (100) and presents probably the only information about semi-commercial MESQUITE gathering. However, the figures have to be taken cautiously,since this report has been written in 1970 and very few newer information is currently available.

The City of Matehuala is the principal center for storage of MESQUITE pods and it was confirmed that in 1965 some 8000 tons were gathered there, along with 4000 tons in the rest of the state. The average price was 350 Pesos or 28 US$ per ton (1965: 12.5 Pesos = 1US$).

According to personal correspondance, MESQUITE pods could be bought in Mexico in 1980 from commercial dealers for 87 US$ per ton.

It is therefore assumed for this model, that up to 10 000 tons per season of MESQUITE pods could be purchased at a price of 90 US$ in the area of Matehuala.

The operating costs are based on a normal product supply and processing situation over an entire season. A season would cover a processing period of three month with six working days (8 hours/day) per week. This results in 576 processing hours or 576 tons of processed MESQUITE pods per season.

1. Capital cost:

The total investment cost (Table 41) is capitalized with 10% and the annual depreciation of the plant set at 10 %.

Investment capitalized	US$	90000.-/year
Depriciation	US$	90000.-/year

2. Rawmaterial:

Undried clean pods, delivered to the plant	US$	90.-/ton

3. Personnel

8 untrained farmworkers (per worker)	US$	250.-/month
1 Plant mechanic	US$	1000.-/month
1 Supervisor/ Administrator	US$	2500.-/month

4. Energy

Diesel 280 l/ day (1l= US$ 0.15 ;1984)	US$	42.-/day

5. Maintenance

2% of initial investment annualy	US$	18000.00/year

All items are calculated per season and per ton in Table 42a.

Table 42a: Production costs per season or per ton of MESQUITE pods, based on 576 tons per season

Item	US$ per season	US$ per ton
Capital	90000.00	156.25
Depriciation	90000.00	156.25
Raw material	51840.00	90.00
Personnel	16500.00	29.10
Energy	3024.00	5.25
Maintenance	18000.00	31.25
TOTAL	269364.00	467.64
	US$ 0.47 / kg	

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If the season could be extended to an all year operation, the price per ton would decrease significantly; the only change in the plant set-up would be to use bigger storage bins along with fumigation of the pods. This would cause an increase in the budget at Section O by approx. US$ 10000.00 . Also the annual depriciation should be increased to 15%, and the maintenance would be 4% annually of the initial investment.

On the other hand, the processing-capacity would increase to about 2300 tons per year. Such an operation would result in the following cost structure (Table 42b):

Table 42b: Production costs per year and per ton of MESQUITE pods, based on all year operation (2300 tons / year)

Item	US$ per year	US$ per ton
Capital	90000.00	39.10
Depriciation	135000.00	58.70
Raw material	207000.00	90.00
Personnel	45000.00	19.53
Energy	12100.00	5.25
Maintenance	36000.00	15.65
TOTAL	525100.00	228.30
	US$	0.23/kg

The above calculated operating-costs do not include:
-Insurances
-Taxes
-Chemicals
-In other words any items not specifically mentioned herein.

B) Production costs based on plant location in the USA

If a MESQUITE processing plant would be set up in the USA, the situation would be somewhat different:

Currently MESQUITE pods can not be purchased on the market, since its utilization as feed has either not yet been recognized, or the cost would be prohibitive compared to other often subsidized feed.

The situation could certainly change immediately if a market would be created by the demand of a potential processor.

As another possibilty, it has been suggested by Felker (80) to cultivate MESQUITE for ethanol production. Such a utilization, even though very promissing, has not yet been established since an oil-shortage does not seem likely at the moment. Nevertheless, Felker showed, that MESQUITE could be produced in orchards for US$ 46.00 per ton (with insecticide application) or for US$ 25.00 per ton only, if insect resistent varieties could be used.

A processing plant in the USA would basically require the same budget for an initial set-up, whereas the production costs would be higher (Table 43).

The major changes in production costs would be caused by higher salary for the personnel:

Untrained farmworkers	US$ 720.00 / month / person
Plant mechanic	US$ 1500.00 / month
Supervisor	US$ 2500.00 / month

Fuel cost would be US$ 0.25 /l

As a major disadvantage,it would seem unlikely to be able to run the plant all year from the beginning, since the pod-production would not be sufficent for at least the first five years until the trees would produce enough pods. An ideal situation would to set up a MESQUITE processing plant within an other food/feed-plant. Infrastructure and personnel could be used from the existing plant. This would even be a opportunity for industries such as sugarbeet processors to run their plant during off-season of their product.

Table 43: Production cost per ton of MESQUITE pods, based on a seasonal operation (576 tons) ; location USA

Item	US$ per season	US$ per ton
Capital	90000.00	156.25
Depriciation	90000.00	156.25
Raw material	26496.00	46.00
Personnel	29280.00	50.83
Energy	5040.00	8.75
Maintenance	18000.00	31.25
TOTAL	258816.00	449.33
	US$	0.45/kg

Actual cost of final product

It is assumed that Fraction B would be burned for energy purpose. Therefore, the price per kilo processed MESQUITE (Tables 40-43) needs to be divided by the yield of the three remaining fractions, where a loss of 5% of the input is also included. The costs would increase to the figures shown in Table 44 (the value of Fraction B is in the reduction of energy costs).

Table 44: Comparison of the production costs of each Fraction of processed MESQUITE in US$,including a loss of 5% of the input

A) Seasonal operation; location Mexico

Production costs: 47.00 US$ per 100kg

True output:	Fraction A	50kg= 31.50	100kg= 63.00
	Fraction C	12kg= 7.56	100kg= 63.00
	Fraction D	12kg= 7.56	100kg= 63.00
	Fraction B	no value	no value
Total		74kg= 47.00	**100kg= 63.00**

B) Year-round operation; location Mexico

Production costs: 23.00 US$ per 100kg

True output:	Fraction A	50kg= 15.55	100kg= 31.10
	Fraction C	12kg= 3.75	100kg= 31.10
	Fraction D	12kg= 3.75	100kg= 31.10
	Fraction B	no value	no value
Total		74kg= 23.00	**100kg= 31.10**

The costs for location in the USA (US$ 45.00) results in practically the same figure as for seasonal operation in Mexico.

4. CONCLUSIONS

The goal of this work has been to **develop a processing system for MESQUITE pods, in order to achieve maximal utilization of the pod as a raw material for the food industry, and to evaluate the characteristics of the pod material.**

Already a first superficial study of the pod structure revealed, that the pods would have to be fractionated according to their morphological structure. Otherwise it would not be possible to obtain homogenous raw materials.

The milling and separation process developed in this study,resulted in **four fractions** which turned out to be not only morphologically different, but also show chemically and functionally different properties.

The process uses mostly existing machinery (crusher, stone mill and several different classifiers)and represents a relatively easy processing system.

Comparison of the proximate analysis of more than a dozen pods from different trees revealed that their composition varies less than their visual differences might suggest. However, it would be possible to select or breed pods that are high in a desired compound (cross-breeding would limit the success).

The four fractions offer completely different applications:

The major part of the pod, **Fraction A (55% of the pod)**, represents a legume-flour with a unusually high sucrose content of up to 60 %. Its uses range from a raw material for sucrose extraction, composite flour in baked cereal products to drum dried flakes and tortilla chips.

Even though the flour itself is of no extraordinary nutritional value, feeding studies revealed that a combination with cereal based products leads to a desirable improvement of the amino acid composition of such products. The incorporation of MESQUITE Fraction A causes no significant reduction of the PER, even at a reduced digestibilty.

Taste panels with a snack product (corn tortilla chips with MESQUITE Fraction A) revealed preference of the product over a corn-only standard in all criterias, i.e. taste, color, structure and odor.

Nevertheless, applications or incorporations of Fraction A are limited by its specific flavor and the lack of a structure-maintaining compound.

Use of Fraction A as raw material for sucrose-extraction showed no problems, but would currently not be the most profitable utilization.

Fraction B (20% of the pod) must be regarded as the least valuable part of the pod. The fibrous endocarp hulls do not appear to be a promising raw material for the food-industry, except as a possible source for fiber in dietary products. Nevertheless, it represents a very good material for combustion with a burning value of 17000 KJ/kg (comparable to sawdust) and low percentage of remaining minerals. Taking advantage of the publicity of MESQUITE wood for barbecue in the US (44) and the success of fire-logs for private housholds, it might be very interesting to utilize Fraction B in such logs. The Fraction could also serve as an energy source to provide a substantial amount of the necessary hot air through combustion, to dry MESQUITE pods before the milling and separation process.

The endosperm splits of the seed, designated as **Fration C (15% of the whole pod)**, contain about 65% galactomannan with a composition that is almost identical to guar gum (mannose:galactose= 1.6:1) , a widely used hydrocolloid in the food- and other industries. Therefore, it was no surprise to find that the viscosity, temperature stability and characteristics in the interaction of MESQUITE gum solutions with xanthan were all practically identical to guar. A paper reporting a mannose:galactose-ration of 4.2:1 in a South American Prosopis juliflora (which would be very similar to locust been gum) offers even greater possibilities (108).

However, it was not possible to find ways to obtain a high purity gum by a method that would allow projection to a profitable larger scale process, due to the extremely though adhesion of the seed coat to the endosperm. In that connection, it could be shown that certain minerals (magnesium, manganese and malcium) are associated with the endosperm and are useful in the determination of the gum purity.

The relatively low grade gum obtained in this work would limit applications of the MESQUITE galactomannan to products where a colorless grade is not required.

The cotyledons, **Fraction D (15% of the pod)**, represent a protein concentrate with nutritional qualities similar to soybean protein. It is limited in sulfur amino acids. Its functional properties qualify it as alternative to proteins such as soy or skim milk,especially for solutions where improved foam stabilty and emulsion capacity are desired.

Based on the wide array of possible application of the different fractions, a project has been defined for a small MESQUITE processing plant with a capacity of 1000 kg pods per hour. Again, existing equipment that could be purchased from different manufacturers can be used.

A budget estimate showed that approximately US$ 900000.00 would be required to set up the whole plant. The estimated production cost,including the capitalization of the investment, would result in product prices ranging from US$ 0.30 - US$ 0.65 per kilo processed MESQUITE, depending on location of the plant and whether processing would be seasonal or all year round .

A comparison of the prices for each fraction with its most likely competitor on the market is shown in Table 45.

The possible margin (including transport, storage, profit, calculation errors) is also listed. The margin range is calculated as:

Minimum margin= "low price competitor" minus
"production cost high for MESQUITE"

Maximum margin= "high price competitor" minus
"production cost low for MESQUITE"

A minus (-) sign before the figure in the "minimum /maximum margin" column of Table 45indicates, that the MESQUITE product would have to be sold at a loss, whereas a plus (+) sign means that a profit could be made.

Table 45: Prices for MESQUITE products compared with products similar in application range

Product	Price per kg in US$ at production cost low	high
Fraction A	**0.31**	**0.62**
Whole wheat flour	0.50	0.70
Minimum / maximum margin	-0.12 to	+ 0.39
Carob powder	0.20	0.30
Minimum / maximum margin	-0.11 to	- 0.32
Corn	0.30	0.35
Minimum / maximum margin	-0.32 to	+ 0.04
Refined sugar	0.40	0.50
Minimum / maximum margin	-0.22 to	+ 0.19
Fraction C	**0.31**	**0.62**
Guar gum minimal foodgrade/petfoodgrade	0.70	1.40
Minimum / maximum margin	+0.08 to	+ 1.09
Fraction D	**0.31**	**0.62**
Soy Protein concentrate (60%)	1.00	1.20
Minimum / maximum margin	+0.38 to	+ 0.89
Skim milk	1.40	1.60
Minimum / maximum margin	+1.29 to	+ 0.78

Prices of competing products are current 1984 world market prices.

The overall comparison of the prices of the different fractions with possible competing products reveals, that MESQUITE Fraction A would hardly be profitable or allow only a rather small margin.

Fraction C and D however offer a very good profit so that this two fractions could even pay for eventual losses on Fraction A.

It would certainly be very shortsighted to measure the success of the utilization of MESQUITE-pods in its potential return of investment only.

All other positive effect of a cultivation of MESQUITE trees have also to be taken into account (Figure 7, Chapter 1.2.2.), even though their cash value is difficult to determine:
-Keeping back desertification trough the function of soil stabilizing and wind-braking;
-Proving shade to raise animals;
-Employment in rural areas;
-Local production of food, which is often not possible in such regions;

Considering all these aspects, it becomes clear that MESQUITE offers the unique chance to achieve all the above mentioned goals along with the establishment of a crop that can be profitable even without subsidizing through governments.

In addition, MESQUITE could become a very important food crop in the fight against hunger in countries in arid and semi arid zones.

5. SUMMARY

MESQUITE is a leguminous plant that grows wild in arid and semi arid areas around the world. Depending on the specie, it occurs as a shrub or tree and requires no fertilizer or watering.

MESQUITE produces indehiscent pods with a most complicated morphology. They were used by ancient cultures as a staple food, whereas in current times only consumation as a syrup in Southamerica is reported. A commercial utilization of MESQUITE has never been studied seriously. This is first of all due to the lack of a processing technique and the image of MESQUITE as a weed.

This work covers the following aspects of a commercial utilization of the pods:

1) A milling and separation process that results in four fractions with the potential for different applications. The fractions are:
   Fraction A: A flour with up to 60% sucrose
   Fraction B: A high fiber residual fraction
   Fraction C: A galactomannan gum
   Fraction D: A high protein flour

2) The possible applications of the fraction as a raw material for the food industry (baking; snackfood; sweetener; gum; protein concentrate) including taste panels and feeding studies.

3) A comparison of the composition of different pods

4) A project for a small MESQUITE processing plant with a plant lay-out, detailed listing of the necessary equipment, budget and calculation of the production costs.

The results show that MESQUITE pods offer an interesting crop for industrialized countries whith wide application in the food industry, as well as a potential food crop in lesser developed countries that are short on basic foodstuff.

The study could eventually serve as a manual how to set up a MESQUITE processing plant and how to utilize the products. At the same time it represents as an investigation on the composition and possible utilization of a desert plant in its ecological context.

5. Zusammenfassung

Aufarbeitung, Einsatzmoeglichkeiten und Wirtschaftlichkeit von MESQUITE Schoten als Rohmaterial fuer die Lebensmittel-Industrie

MESQUITE (sprich: MESCIIT) ist ein Leguminosen-Gewaechs, welches in Trockengebieten auf der ganzen Welt zu finden ist. Allein in den USA belegt MESQUITE rund 35 Millionen Hektaren. Je nach Species ist die Erscheinungsform von MESQUITE ein Strauch oder ein Baum von bis zu 8 Metern Hoehe.

MESQUITE produziert Schoten mit einer sehr komplizierten Morphology. Obwohl die Schoten in frueheren Zeiten als Grundnahrungsmittel genutzt wurden, ist heutzutage nur noch die Verwendung der Schote in Suedamerika, als Rohmaterial fuer einen Syrup bekannt. Bis anhin hat es sowohl an einer Technologie zur Aufarbeitung der Schoten als auch am Wissen ueber funktionelle Eigenschaften der Inhaltsstoffe gefehlt. So war man bisher allgemein der Ansicht, dass es sich bei MESQUITE nur um ein nutzloses Unkraut handle.

Die vorliegende Arbeit befasst sich mit den folgenden Aspekten einer kommerziellen Nutzung der Schoten:

1) Beschreibung eines Verarbeitungs-Prozess, welcher in vier Fraktions-Produkten resultiert, die unterschiedliche Einsatzmoeglichkeiten offerieren. Die Fraktionen sind:
   Fraktion A: Ein Mehl mit einem Saccharosegehalt von 60%
   Fraktion B: Eine Fraktion mit sehr hohem Rohfasergehalt
   Fraktion C: Ein Galactomannan-Gummi
   Fraktion D: Ein Proteinkonzentrat

2) Einsatzmoeglichkeiten der Fraktionen als Rohmaterial in der Lebensmittelindustrie (Backwaren, Snacks, Verdickungsmittel, Proteinkonzentrate), einschliesslich Degustationsstudien und Fuetterungsversuchen mit den entsprechenden Produkten.

3) Vergleich der Zusammensetztung verschiedener Schoten.

4) Projekt fuer einen kleinen kommerziellen Verarbeitungsbetrieb mit einer Verarbeitungskapazitaet von 1000 kg pro Stunde, einschliesslich Plaenen, Auflistung der notwendigen Maschinen, Budgets sowie Berechnung der Produktionskosten.

Die Ergebnisse zeigen, dass MESQUITE eine hoechst interessante Nutzpflanze darstellt und dass die Schoten breitgefaecherte Einsatzmoeglichkeiten in der Lebensmittelindustrie offerieren.

Kosten-vergleiche erlauben die Schlussfolgerung, dass der Anbau und die Aufarbeitung von MESQUITE profitabel sein kann.

Ebenso koennte MESQUITE eine wichtige Rolle im oekologischen System von Trockengebieten spielen und eine wichtige Nahrungsgrundlage in Hungergebieten darstellen.

Die vorliegende Arbeit ist so gestaltet, dass sie als Grundlage dienen koennte, wie ein MESQUITE Verarbeitungs-betrieb aufgebaut, und die Fraktionen verwertet werden koennten. Gleichzeitig kann die Arbeit als eine Studie ueber die Zusammensetzung und Verwertungs-moeglichkeiten einer Wustenpflanze gelesen werden.

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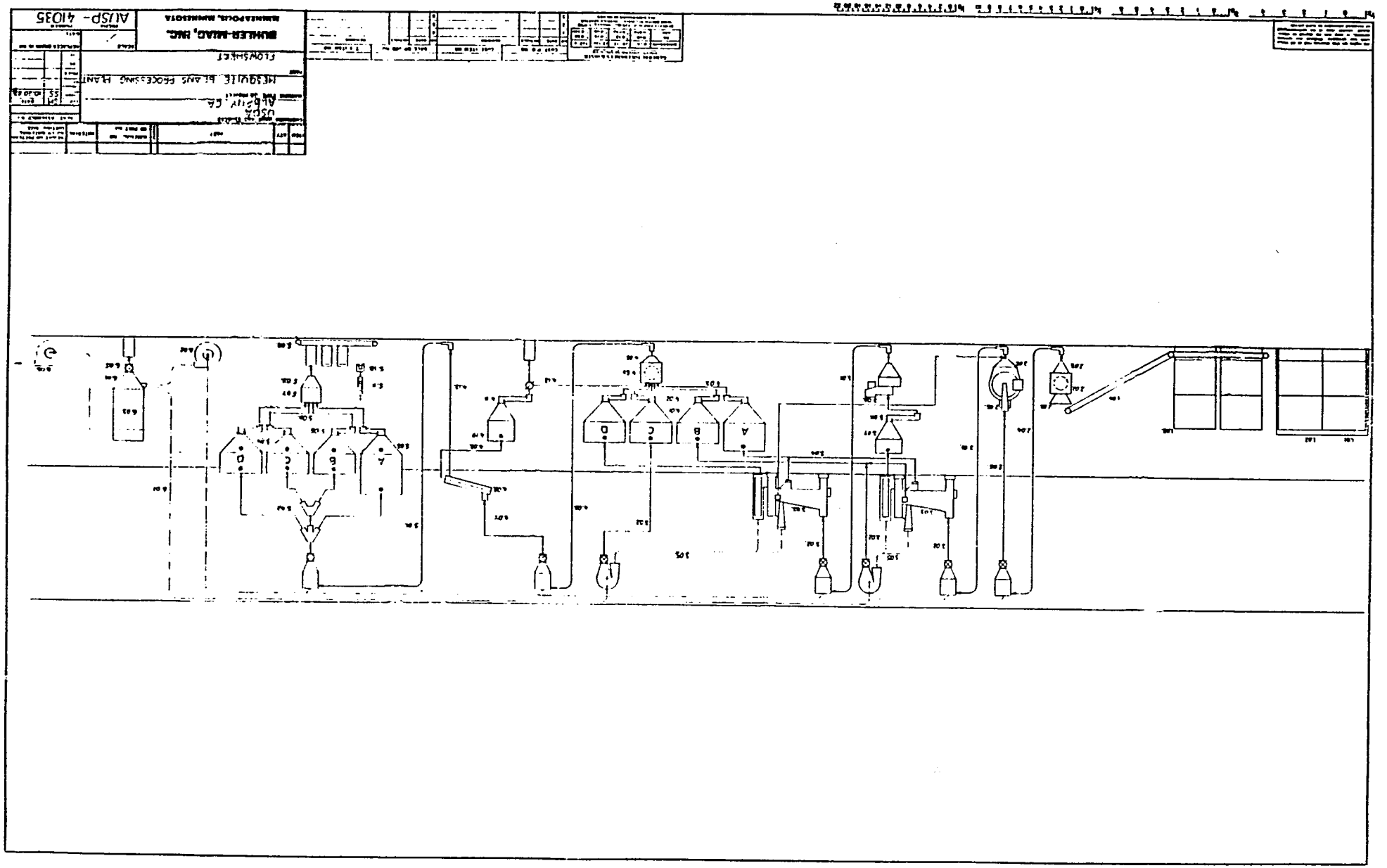
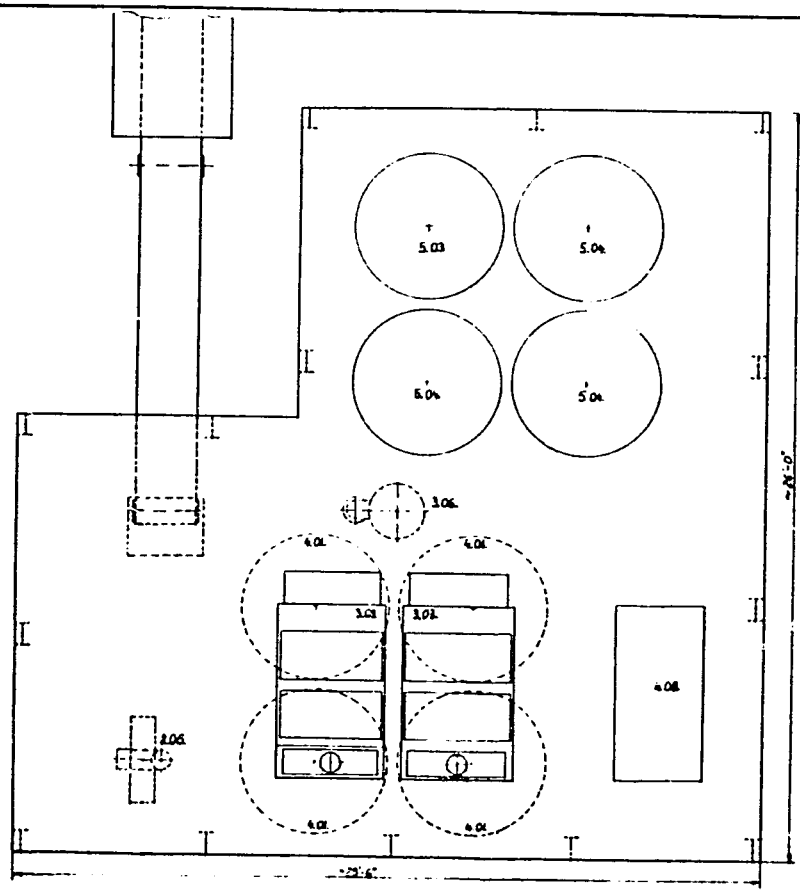
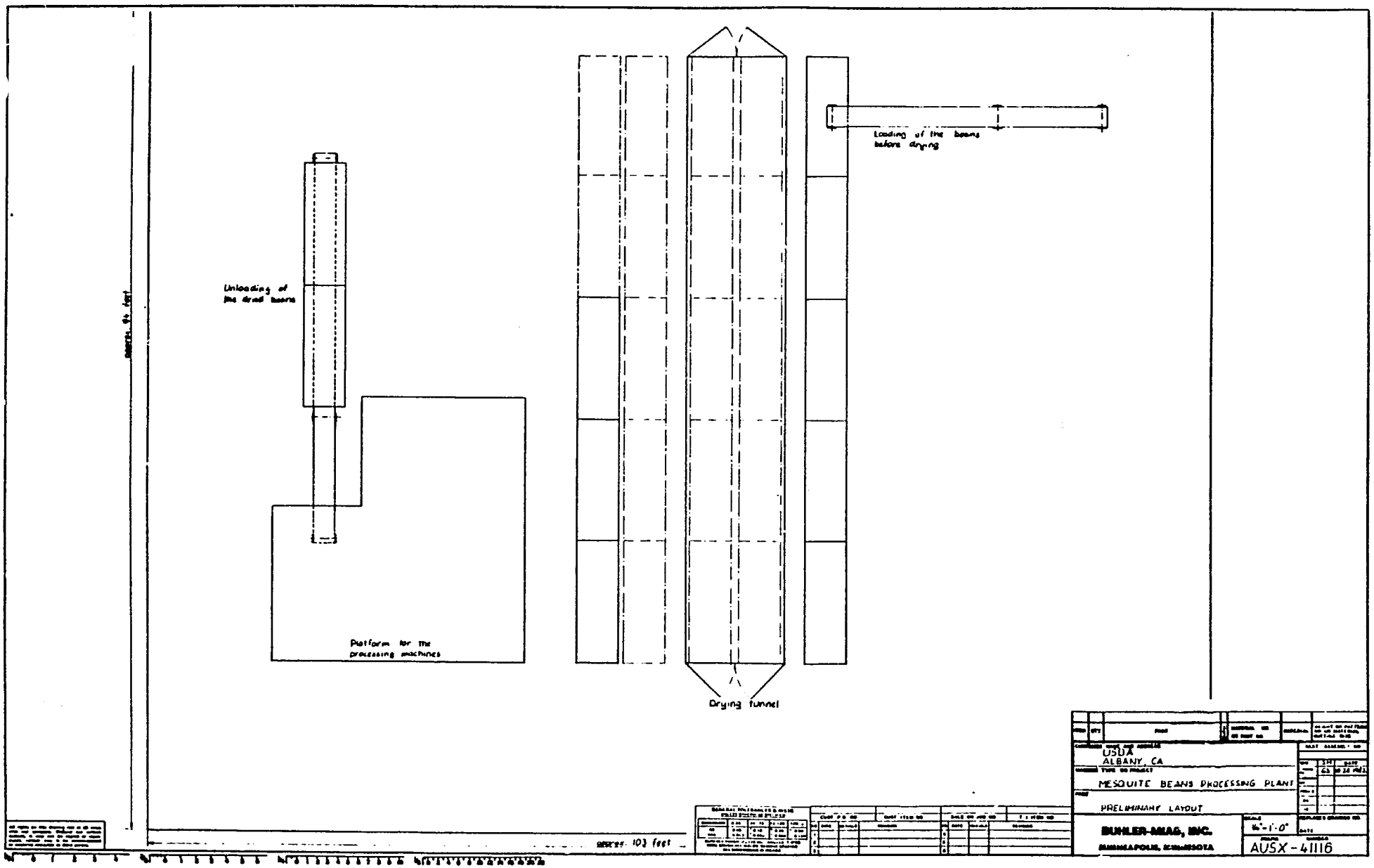
1976	Matura Typus C
1977-1981	Studium an der Eidgenoessischen Technischen Hochschule in Zuerich, Abteilung fuer Landwirtschaft, Fachrichtung Lebensmittel-Technologie Praktika in verschiedenen Betrieben der Lebensmittel-Industrie
1981	Diplom als Lebensmittel-Ingenieur (dipl.Lm.-Ing. ETH)
1981-1984	Wissenschaftlicher Mitarbeiter am Western Regional Research Center des U.S.D.A. in Berkeley,CA (USA) als Doktorand der ETH Zuerich

BUEHLER Blueprint for mesquite pod processing plant





USDA
ALBANY, CA
MESQUITE BEANS PROCESSING PLANT
PRELIMINARY FLOOR LAYOUT
BUHLER-MIAG, INC.
MINNEAPOLIS, MINNESOTA
1/4" = 1'-0"
AUSX-41114


Unloading of the dried beans
Platform for the processing machines
Drying tunnel
Loading of the beans before drying
USDA
ALBANY, CA
MESQUITE BEANS PROCESSING PLANT
PRELIMINARY LAYOUT
BUHLER-MAG, INC.
MINNEAPOLIS, MINNESOTA
AUSX-41116

Semiarid Legume Crops as Protein Resources

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ABSTRACT

Worldwide population pressures and accompanying increased demands on water supplies and tillable land has forced a reevaluation of traditional agricultural techniques and crops. Under-used semiarid lands are becoming candidates for crop production that uses stress-tolerant plants. Desert legume trees and shrubs, e.g., species of *Prosopis*, *Leucaena*, *Acacia*, *Geoffroea* and *Olneya*, fix nitrogen and could be sources of seed protein, forage or biomass. Seeds from desert legume perennials have a high potential as protein producers.

INTRODUCTION

The United States is currently facing the problem of overproduction of food, its main export commodity, and efforts to enhance agricultural production by cultivation of desert lands might appear illogical. However, long-term national objectives and international considerations combine to dictate that a high priority, intensive research effort be directed toward the goals of water and soil conservation as exemplified by minimum irrigation farming and development of crops and technologies to farm our arid and semiarid lands.

Today, ca. 1/3 of the earth's land mass is desert, compared with ca. 12% in 1882. Worldwide, 20% of the land is generally considered arid and 13% semiarid (Table 1) (1,2) when arid zones or dry lands are defined by relating available precipitation to potential evapotransporation (3,4,5). These desert lands represent a diversity of soils and climates and are a home for a variety of cultures (6).

Ca. 8% of US land is arid and 22% semiarid. Three percent of North American land is arid and 11% semiarid. The Americas (North, Central and South) have ca. 14% of the world population, but 16% dry land. Of these countries, Mexico probably has the worst problem with 46% of its land dry and a population of ca. 70 million. Central America is generally tropical, but South America also has large desert areas.

Africa is 69% arid or semiarid. Egypt is essentially all desert, except for land along the Nile. Algeria, Tunisia, Niger and Ethiopia also have a severe lack of agricultural land.

To make a bad situation worse, deserts are expanding. In the Sudan, the desert is advancing at a rate of 5 km per year, in the Sahel 100,000 ha per year are lost, worldwide.

5 million hectares per year (or 0.35% of the world's arable lands) are estimated to have become desert because of man's mismanagement (6). Between 100,000-250,000 people are believed to have died of starvation in the Sahelian region alone between 1960 and 1974, and the toll would have been higher if $200 million had not been spent on emergency relief during that period.

The Middle East is 68% arid and 16% semiarid, and supports 3% of the world's population on land ranging from the hyperarid Sahara Desert regions to the semiarid areas in Turkey.

Asia has less dryland, but is burdened by 56% of the world's population, mainly in China, India and Pakistan.

Most countries with large amounts of drylands are food importers. The US is an exception in that it exports ca. 40% of the food it produces, but productivity of key crops is beginning to peak or flatten out. Export demand is expected to continue, especially because food production must double in the next 40 years to meet population projections.

We should, therefore, be interested in developing these dryland reserves, both domestic and international. One of the best ways to start is by finding plants native to the desert areas that might have commercial potential.

DRYLAND AGRICULTURE

Agricultural practices appropriate for fertile land often bring disaster when applied to marginal land. Plowing the natural grasslands of the Great Plains of the United States during the 1930's and the "virgin lands" of south-central Russia in the 1950's, when combined with natural droughts, produced conditions virtually guaranteeing severe wind erosion. The resulting serious soil losses were controllable only by reestablishing the grass cover (7).

Even today, land-use patterns developed in the sixteenth century, and culturally perpetuated by peasants living close to the absolute margin of survival, have severely degraded plant resources in many countries, from the upland semiarid areas of Chile (8) to the Sahel area bordering the Sahara Desert (9) and the Rajasthan Desert of India (10).

For example, the Indian desert, by far the most populous of the world's deserts, has a population of 48 persons per sq km (0.19/acre or 124/sq mi) and receives 100-500 mm annual rainfall. Demand for local trees and shrubs as fuel increased from 1.64 million t in 1951 to over 3 million t in 1971 as the result of a population increase from 9.4-15.5 million during the same period. Based on this, the native plant population is expected to last for only another 6 decades (10). In addition to using the plants for fuel, the inhabitants eat the pods and seeds, further handicapping natural regeneration.

Cultural and religious factors are also important. Years ago, to protect grasslands and forests, Rajput princes decreed that all desert villages would set aside an "oran" (protected forest) and a "gochar" (grazing land). Serious punishments were prescribed for using an ax in the oran and only deadwood could be collected for fuel. In certain orthodox Indian areas, the orans are still honored and the forests are surviving whereas adjacent areas have been stripped. To protect hill flora, half the hill was also dedicated to the deity "Jogmaya." Today, the well-forested Jogmaya side can be found with the other half absolutely barren and denuded (11). Without these practices, the area would undoubtedly be in much worse condition.

A 40-fold increase in nitrate losses occurs in soils denuded of forest vegetation (12). Potassium losses are 15-fold greater, calcium and magnesium are 4-fold and sodium is 2-fold greater than from unstripped soil. To erode 8 inches of untilled topsoil in midwest America is estimated to take 2234 yr. When subjected to noncontour tillage, the same 8 in. of soil would be lost in only 37 years (13), with similar losses expected for African lands (14). Because of similar ongoing erosion processes, desert lands are characteristically low in organic matter (0.5-0.8%) and fertility, and usually lack moisture storage capacity (15).

Desert lands also can have extreme temperatures, ranging from below freezing to over 50 C. High temperatures, combined with commonly occurring winds and low humidities, often are severely dehydrating. Some plant species have evolved a crassulacean acid metabolism (CAM) that enables stomata to close during the heat of the day and reduce water transpiration losses.

The solar intensity of the desert can be a mixed blessing. It enables high photosynthesis rates and multiple crops, but can combine with other environmental factors to induce plant stress. It can also reduce human activity unless tolerances are developed.

Water quantity and quality are usually the limiting factors in most arid zones. Precipitation can range from no rainfall for 7 years in the Atacama Desert of Chile to over 400 mm annually in some semiarid zones.

For agricultural purposes, water quality is determined by salt content. In general, water with less than 600 mg/L total dissolved solids may be used to irrigate almost any crop. Water with 1,000-1,500 mg salt/L is widely used on all but the most salt sensitive crops if leaching and drainage are adequate. If frequently irrigated, water with 1,000-2,000 mg salt/L can be used for crops of moderate tolerance. Water

TABLE I

Percentage of Drylands in Selected Countries and Their Populations[a]

Country	Arid (%)	Semiarid (%)	World Population–1981 (%)
The Americas	4.2	12	13.9
United States	8	22	5.1
Bolivia	10	15	0.13
Chile	27	7	0.25
Mexico	26	20	1.6
Peru	1	6	0.40
Africa	49	20	8.6
Algeria	85	10	0.43
Egypt	100	0	0.95
Ethiopia	20	50	0.71
Kenya	20	55	0.38
Niger	70	30	0.12
South Africa	35	25	0.67
Tunisia	75	15	0.14
Middle East	68	16	3.0
Iran	7.2	32	0.87
Iraq	74	15	0.30
Jordan	93	6	0.07
Saudi Arabia	98	2	0.21
Turkey	0	18	0.[illegible]7
Yemen (N&S)	81	14	0.17
Asia	12	14	58.2
China	13	10	22.3
India	4	17	15.5
Soviet Union	9	11	5.9
Australia	49	16	0.32
Europe	0.1	2	15.5
World	20	13	

[a]Based on total world land mass of 52,006,000 square miles, which does not include Antarctica (9.6% of total land mass).

with 3,000-5,000 mg salt/L will produce high yields only from highly tolerant crops. The most common salt tolerant crops can withstand about 12,000 mg salt/L, although eelgrass (*Zostera* spp) produces an edible grain and large amounts of biomass in full sea water (16). (Seawater has a total salt content of ca. 35,000 mg/L.) The relative concentrations of sodium to calcium and magnesium, and the anion concentration (chloride or sulfate) may also be important. Additional factors are plant age, soil type and irrigation methods (17).

The accumulation of salts in the soil is one of the problems accompanying irrigation of agricultural land. In many desert areas, evaporation exceeds precipitation by up to 1500 mm (60 in.) per year and is the major factor responsible for the salt buildup in the soil (18). A second problem occurs when good water percolates through saline soils as irrigation runoff. This runoff water is often high in leached salt (up to 3,000 ppm solids) and must be collected and removed to prevent soil salinization and contamination of low salt groundwater supplies (18).

The amount of saline soil in arid and semiarid areas worldwide was estimated in 1977 by Ponnamperuma (19) at 381 million ha, although estimates vary and some of this land may not be suitable for agriculture for reasons other than salinity. Others (20) estimate that 1/3 of the world's irrigated land (47 million ha) is affected by salt. Soil salinization can be a direct cause of creating deserts and contributes to the decreasing productivity of farmland worldwide. Salinity is the most important problem in irrigation agriculture and combating it is among the most costly problems facing the farmer (18).

Productivity decreases of existing farmland associated with salinity can be combated by introducing salt tolerant lines of conventional crops or the introduction of other salt tolerant plants with an equivalent, or better, economic value.

LEGUME TREE SEEDS AS NEW CROPS

Desert legume trees are particularly well suited to meet the stringent requirements of dryland agriculture. In a recent review (21), they were described as the ideal crop for reducing capital and energy expenditures in these special environments. These woody dicotyledonous trees or shrubs from the family Leguminosae (order Rosales) comprise most of the subfamily Mimosoideae and some of the subfamily Caesalpinoideae. Most species examined nodulate and fix nitrogen (22) with reported rates between 200 and 580 kg N/ha/yr (23,24). The soil under leguminous trees has been shown to have levels of nitrogen and organic matter several times higher than surrounding soils (25-28) or soils under nonleguminous trees (27). Legume trees require minimal tillage and their subsurface roots retard erosion (21).

Seed compositions of some commonly used dryland legume trees are shown in Table II. Seed protein content ranges from 17% in a *Gleditsia* species to 37% in *Leucaena lanceolate*, with most being 20-30%. The amino acid chemical score of 38 for Desert Ironwood seed protein is less than the score of 47 for dry beans. The scores of 77 and 66 for *Prosopis* seed protein are higher than that found in soybeans (29), which is shown for comparison. Fat content in the seeds ranged from ca. 2% in several species, as high as 40% in Chanar, which will be described later.

Yields from dryland or minimum irrigation cultivation practices are highly variable, so the calculated values used in the tables are, in many cases, arbitrary (Table II). The correlation between protein content of legume tree seeds and yield is not known. A negative relationship has been shown between protein and methionine content of field beans, and raising soil phosphorus may increase protein content (30), but little is known of the effects on the nutritional value of these proteins.

TABLE II

Dryland Legume Tree Seeds

Plant name			Composition (%)		FAO protein chemical score	Yield, kg/ha	
Common	Botanical	Ref.	Fat	Protein		Lipid	Protein
Mesquite	*Prosopis glandulosa*	34	1.6	22	–	40	550
	P. velutina	34	5.7	29	30	142	725
Algarrobo	*P. chilensis*	a	9.2	31	77		
Tamarugo	*P. tamarugo*	a	3.6	27	47	–	675
Screwbeans	*P. pubescens*	a	–	36	66	–	792
Leucaena	*Leucaena leucocephala*	16	10	28			
	L. lanceolate	16	7	37			
Acacia	*Acacia moniliformis*	20	–	(55)[b]			
	A. auriculaeformis	20	–	(38)[b]			
	A. spp		–	21			
Honey locust	*Gleditsia triacanthos*	a	1.9	17			
African locust	*Parkia clappertoniana*	20	–	(16)[b]			
	P. roxburghii	20	–	(41)[b]			
Djenkol	*Pithecellobium lobatum*	20	–	(16)[b]			
	P. sonorae	20	–	(44)[b]			
Dhaincha	*Sesbania* spp	16	2.9	31			
Carob	*Ceratonia siliqua*	49	2.8	20			
Ironwood	*Olneya tesota*	52	35	31(26)	27	577	511
Chanar	*Geoffroea decorticans*	51	49	29	66		
Palo verde	*Cercidium microphyllum*	a	8.3	25	–	33	100
Blue p.v.	*C. floridum*	a	7.2	26			
Mexican p.v.	*Parkinsonia aculeata*	16	3.8	21			
Beans	*Phaseolus vulgaris*, US, 1981		1.6	22	47	25	348
Soybeans	*Glycine max*, World, 1979		18	34	62	805	934
	US, 1979					955	1804

[a]Becker, Sayre, and Saunders, unpublished observations.

[b]Composition of trichloroacetic acid precipitable fractions from seed embryos (20)

PROSOPIS

Forty-four *Prosopis* species are known, occurring in North and South America, Africa and eastern Asia (31). Examples of useful species have been found that fix nitrogen, are frost hardy, tolerate extreme heat and survive in some of the hottest and dryest of the earth's deserts (31). One of the highest CO^2-fixation rates known for trees (30 mg $CO^2/dm_2/hr$) was observed on a *Prosopis* species in Death Valley, California (32). *Prosopis* trees are thought to have CAM, enabling them to close their stomata during the day and fix CO_2 at night.

Prosopis trees produce indehiscent pods that are palatable to humans and animals (31). Pods of many species, e.g., *Prosopis glandulosa*, *P. velutina* and *P. chilensis*, are rich in sugar, containing 13-41% total sugar in the pericarp, of which over 90% is sucrose (33) (Table III). Most of the pod protein occurs in the seed, which is 15-25% of the pod. The cotyledon, where the seed protein is concentrated, constitutes 7.9-14% of seed weight, the remainder being seed coat and endosperm mucilage material (33,34). Amino acid analysis of protein from these seed samples in each case demonstrated that the sulfur amino acids methionine and cysteine were limiting when compared with the FAO standard. The protein content of the trichloroacetate (TCA) precipitable fraction of seed embryos ranges from 56-60% in *Prosopis* species and 16-58% in other tree legume seeds (21) (Table II).

The protein efficiency ratio (PER) was determined to be 0.71 and 0.61 for uncooked and cooked *P. velutina* pods, 0.69 and 0.63 for the uncooked and cooked seeds and 0.32 for the pericarp, similar to other common legumes. *P. pubescens* pods had a PER of −0.32, which was depressed to −1.35 by autoclaving, indicating it is not a desirable feed. For both species, lowering of the PER after cooking was probably caused by increased solubilization and accompanying increased water absorption and bulking effects of the seed gum when heated. A similar effect was observed when *P. velutina* pods were fed to poultry; the metabolizable energy dropped from 1.65 to 0.70 after heating (35).

Pods from mesquite trees have traditionally been used by desert dwelling cultures worldwide for animal feed, and in processed form for food products. Established food technology principles have been recently applied to pod processing in attempts to create modern nutritious products from what until now has been an underused food source (36).

The pods were dry milled and separated into 4 fractions: exo-mesocarp (58%), endocarp (26%), seed coat plus gum (6%) and seed cotyledon (5%). The exo-mesocarp fraction was rich in sugar and contained most of the typical mesquite taste components; it may be useful as a fermentation substrate or as a flavor and sweetening ingredient in food products. The endocarp fraction was high in fiber content. The seed coat and mucilage fraction contained large amounts of a galactomannan gum, with properties similar and in some applications superior to guar gum. The seed cotyledon fraction was richest in protein and contained most of the seed lipids. This fraction had a characteristic legume nutlike flavor and aroma, and can probably be used in typical legume applications.

Prosopis pods and seeds are known to contain varying quantities of antinutrients, e.g., tannins and related phenolics, trypsin inhibitors and cyanogenic compounds (33). Kinds and amounts of these compounds may vary with species, accession and perhaps agronomic factors, but so far have not been found to present unsurmountable difficulties.

In South America, the predominant *Prosopis* species are tamarugo (*P. tamarugo*) and algarrobo (*P. chilensis*). Tamarugo is being used in an attempt to reclaim parts of the Chilean Atacama desert. Most areas there are generally denuded of all plant life except for shrubs that are low in palatability to goats or useless as firewood. The botanical desolation increases in direct proportion to nearness to villages (8). In a recent forestation project involving 10,875 ha (37), tamarugo seedlings were planted in 40-50 cm deep holes cut in the salt crust and irrigated until the roots reached groundwater, which is often only 2-10 m below the soil surface. The mature trees were pruned to permit livestock access and the agro-forest maintained as a fodder source for goats, sheep and some cattle.

Groundwater under the forested areas is less salty than under adjacent barren areas. The forest is thought to lower

TABLE III

Proximate Composition of *Prosopis* Fruit[a]

Acession Number	Species	Part analyzed	H_2O (%)	Protein (%) N × 6.25	Fiber (%)	Ash (%)	Sugar (%)
		Trees grown on experimental plots					
F0001	*P. glandulosa*	Whole pod	2.2	14	20	3.4	34
F0020	*P. velutina*	Whole pod	1.6	11	30	4.4	13
F0025	*P. velutina*	Whole pod	2.1	14	19	3.1	28
F0032	*P. velutina*	Whole pod	2.6	17	24	4.4	19
		Mature wild or ornamental trees					
B0060	*P. velutina*	Whole pod	4.3	12	31	4.1	19
B0201	*P. velutina*	Whole pod	4.2	12	23	3.4	28
B0078	*P. velutina*	Whole pod	2.2	12	23	4.8	22
B0078	*P. velutina*	Pericarp	6.0	7	23	5.5	32
B0078	*P. velutina*	Seeds	2.4	29	7	3.8	4
B0024	*P. glandulosa*	Whole pod	7.5	11	22	3.3	26
B0024	*P. glandulosa*	Pericarp	8.5	7	27	3.4	32
B0024	*P. glandulosa*	Seeds	7.1	31	7	3.4	4
F0377	*P. glandulosa*	Pericarp	8.1	8	30	–	13
F0372	*P. glandulosa*	Pericarp	8.3	5	23	–	41
B0219	*P. pubescens*	Whole pod	5.9	11	17	3.8	25
B0219	*P. pubescens*	Seeds	7.4	26	–	–	–

[a]From reference 36.

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the groundwater level, thus reducing surface evaporation and its salt-concentrating effects. The forested salt flats and soils have a lower mean annual evaporation rate (309 m^3/ha) than the unforested areas (1590 m^3/ha). Under conditions of high humidity, tamarugo reportedly absorbs water through its foliar system, deposits it in the microrhizosphere and reabsorbs it as water (37).

In the extreme western parts of the Indian desert (200 mm annual rainfall), village fuel is supplied by miscellaneous shrubs, including Khejri (*Prosopis cineraria*), which has a density of only 1-5 trees/ha (10). For religious reasons, the Khejri trees are not usually cut down, but are only lopped during midwinter to provide branches for fuel and air-dried leaves for livestock feed. These trees are thought to be slow growing, or more likely stunted by the yearly lopping, so that 100-year-old trees are only 8-10 m high. The usual meager seed production is often consumed by the population.

In the US, mesquite (*P. velutina*, *P. glandulosa*) is found in ca. 90 million acres of the Southwest (50 million of which are in Texas). Here, it is generally considered an invasive pest that captures moisture that might otherwise sustain grasses. Mesquite is not currently used in the US; however, it is a strong candidate for biomass culture. *Prosopis* forests have been proposed as a fuel source, enabling the production of a million BTU's of energy at a fuel cost of $1.50, compared with $3 for natural gas and $6 for crude oil (38).

LEUCAENA

Leucaena is the common name given to *Leucaena leucocephala*, but it as well as other varieties may have local names, e.g., ipil-ipil, lamtoro, yaje, kao kaole or tan-tan. Fifty-one species of leucaena have been reported, but only ca. 10 of these are valid, the remaining being synonyms resulting from a confused taxonomy. The most commonly exploited species is *Leucaena leucocephala*, although other species may have value throughout the tropics (39).

Leucaena is commonly grown in the tropics or subtropics to provide windbreaks, firebreaks, shade, ornamentation and as a food and forage crop, but it is not grown in the US. It grows best in areas of high rainfall (600-1700 mm annually), but also grows well even in areas with long, severe dry seasons. It survives in its native Mexico habitats in Yucatan and Guerrero (west-central Mexico, where no rain may fall for 8½ months a year), and in cooler parts of the Sonoran desert, and is the dominant vegetation on Honolulu's Diamond Head, where only 250 mm (10 in.) of rain falls annually. The varieties range from short bushy types of 5 m height (Hawaiian), tall plants to 15 m (Peruvian), to treelike plants with heights to 20 m (Salvadoran) (40).

Leucaena's drought tolerance, hardiness and nitrogen-fixing ability combine to make it a promising candidate for increasing milk and meat supplies throughout the dry tropics. The large quantities of foliage it produces are highly palatable, digestible and nutritious to beef and dairy cattle, water buffalo, sheep and goats. The seeds have been used as a source of galactomannan gum and as pig and chicken feed (41,42).

Leucaena leaves and seeds contain from 2-6% of the amino acid minosine, with up to 10% in the growing points (40). When ingested by nonruminants (monogastric animals), especially horses, it may cause depilation, growth reduction and general ill health. In poultry, it may cause a reduction of egg production. When more than half of the diet is leucaena and the diet is continued for more than 6 months, cattle may experience general ill health with loss of tail and rump hairs, excessive salivation and poor growth. These effects are probably caused by malfunctioning thyroids (goiters) because of rumen bacterial transformation of mimosine to 3,4-dihydroxypyridine (DHP), an acknowledged goitrogen. Goiter in cattle can be detected at early stages and the effects reversed by removal from leucaena pastures. Mimosine has no known effects on the meat or milk of ruminants that can be detrimental to man (40), although leucaena-fed dairy cattle produce off-flavored milk (removable by pasteurization), poultry shows reduced egg production and pigs experience fetal resorption, reduced birth weights and teratogeny (41,42).

ACACIA

Acacia species are another underexploited dryland leguminous tree (43-45). Their main value is as a forage plant in areas with a prolonged dry season, although the wood and pods have uses similar to other legume trees. Acacia species possess the attributes common to many of the other leguminous trees previously described: they fix nitrogen, are drought and heat hardy, the foliage is a valuable fodder for all types of livestock and the trees produce palatible pods (135 kg pods/tree in the Sudan). The trees are usually found in riparian communities, although many are the dominant species in more arid areas. In many instances, acacia trees stand isolated in otherwise treeless arid environments or are the last surviving woody plant to form stands on sandy soil adjoining the desert.

Acacias also have many of the worse characteristics of legume trees; they often are thorny and invasive because they propagate from suckers and the seeds are spread by animals. They often form impenetrable thickets and pioneer the invasion of grasslands by brush and other forms of thickets. Eradication of some species can be extremely difficult, so introduction should be carefully considered (44).

CAROB

Carob (*Ceratonia* spp. subfamily Caesalpiniodeae) is one of the oldest known cultivated plants. Noted for its drought resistance, it has contributed for centuries to the economy of the Mediterranian basin and may well be suitable for cultivation in the dry subtropics elsewhere. The pharaohs fed their cattle on it, the seeds and sweet pulp are supposedly the locust and wild honey eaten by John the Baptist in the wilderness (hence the name St. John's Bread) and Wellington used it to sustain his horses during the campaign against Napoleon in Portugal and Spain. The tree is used for fodder and for its wood, but the main product is the carob pod (46), which contains more sugar than sugar beet or sugar cane. The pod is often used as a chocolate substitute and the seeds roasted and substituted for coffee. The seeds contain about 21% protein but are usually only about 10% of the pods. The ground whole pod is about 7% protein, 30% sugar, 9% fiber, and 1-2% fat with a comparatively low energy value of 180 calories/100 gm (46).

CHANAR

Chanar (*Geoffroea decorticans*, subfamily Papilonoldeae) grows in the South American deserts of Chile and Argentina as shrubs or trees 5-7 m high (47). The tree fixes nitrogen and tolerates saline water (2,000 mg/L). It produces plum-sized fruit used locally as a beverage and for fermentation. The fruit pericarp contains 48% sugar, most of which is sucrose. The fruit seed, which is only ca. 5% of the fruit, is 29% protein and nearly 49% fat. The limiting amino acids in the seed protein are lysine and the sulfur amino acids. The seed protein has a FAO chemical score of 65, which is

in the range of groundnuts, 65; millet, 63; polished rice, 67. The oil is rich in oleic and linoleic unsaturated fatty acids and smells and tastes like peanut oil.

Whole chanar fruit has a negative PER (−3.97), indicating the presence of an antinutrient, probably hemagglutinin, although small amounts of cyanogenic compounds were found and the high fiber content may also contribute.

If species could be found with a higher seed-to-pod ratio to enhance exploitation of the fat and protein, and the plant's invasiveness could be controlled, chanar might have potential as a new crop (47).

DESERT IRONWOOD

Many plants throughout the world with very hard, dense wood are called ironwood. In North America, the name Desert Ironwood has been given to *Olneya tesota*, a leguminous tree common to the Sonoran and Coloradan deserts. Desert Ironwood trees are often found in dispersed stands with *Prosopis*, *Cercidium* and *Atriplex* species, although it will tolerate more arid conditions than *Prosopis* species. *Olneya* trees annually produce single-seeded pods that, on maturing, fall to the ground and split open to release the seed, which is eagerly eaten by local inhabitants (desert-dwelling Indians and wild animals). These seeds are 17-21% protein, 33-30% lipid and have a pleasant nutty taste after cooking. Unfortunately, the seeds contain as much as 5% canavanine (a structural analog of arginine), which is a potent antinutrient and could hinder protein exploitation. The lipid is rich in palmitic, stearic, oleic and linoleic acid and tastes much like peanut oil. Workers have collected 8 kg seeds from 1 tree. If trees were planted on 7 × 7 m plots and similar yields were obtained, a yield of 571 kg/ha lipid and 424 kg/ha protein could be expected without fertilizing and with minimum tillage (48).

OTHER TREE LEGUMES

A number of other tropical legumes are sufficiently drought tolerant to be considered for semiarid dryland agriculture (44). Honeylocust (*Gleditsia* species) produces pods with up to 40% sugar in reported yields of 230 kg pods/tree/yr after the 4th or 5th yr, but little is known of its performance under stress conditions. Little is known of African Locust (*Parkia* spp) and the Djenkol bean (*Pithecillobium* spp) and their drought hardiness, but they may also merit further research. *Sesbania* species are tropical leguminous trees common in Asia, India and Australia and should be tested in dryland areas (43).

Palo Verde (*Cercidium* and *Parkinsonium* species) are also found in the desert and have historically been used as food and feed by desert dwellers. Some of these beans are quite tasty, especially when harvested green and blanched. Their occurrence in some of the more inhospitable areas of the desert and their significant seed protein content suggests that they may be exploitable as arid land protein resources (21).

ANNUAL LEGUMES

Desert annual legumes have a potential for development as a protein resource that is equal to or greater than legume trees. Annual legumes are easy to plant, they usually produce a crop in a short time, need little fertilization because they fix nitrogen and may be drought hardy and disease and insect resistant. The beans are usually high in protein, with amounts generally equal to or greater than the protein found in common commercial beans. Typical of most legume seeds, the protein is low in the sulfur amino acids and would be expected to contain heat-labile antinutrients (trypsin inhibitors and hemagglutinins). The beans listed in Table IV all have a history of being consumed by local inhabitants and all are normally prepared for consumption in much the same way, usually by boiling.

TEPARY BEANS

Tepary beans (*Phaseolus acutifolius*) are ideally suited for the desert, as documented in a recent review (49). They require more moisture to germinate and flower than other desert ephemerals, but beyond that they grow and produce fruit rapidly (60-90 days) with little water, sometimes permitting 2 crops. They thrive in arid and semiarid desert regions, withstanding heat and low humidity, to produce edible dry beans in climates often too arid for even the hardiest pinto bean.

Native to North America, wild species have been found from Guatemala to central Arizona and from sea level to a 1650 m summit and on an extremely arid, volcanic scoria slope. The most useful variety, the broad-leaved *P. latifolius*, is commonly found climbing into the overstory in shady shrub thickets on floodplain alluvia. The narrow-leaved variety, *P. tenuifolius*, prefers grassy slopes or woodland openings and vines on the ground or twines on grasses or forbs.

Wild teparies reportedly produce 20 kg/ha seed under natural conditions. Domestic white teparies produced 2,020 kg/ha in irrigated fields in the Sonoran desert and 4,633 kg/ha seed with minimal irrigation from areas near Fresno, California, where the climate is less extreme. They equal or surpass the average Arizona bean yield of 560 kg/ha in wet years and produce some beans in dry years when other crops completely fail. The pods explosively dehisce when dry so harvesting is usually during the morning, before the dew is dried.

Teparies may also have potential as a forage crop. They are better at evading drought (because of their short life cycle) and tolerating drought than *Phaseolus vulgaris* species.

The protein content of tepary seed ranges from 22-25% (a high of 39%) with the sulfur amino acids as a limiting factor. Fat ranges from ca. 1-2% and large quantities of carbohydrate (65%) are present (49).

Around the turn of the century, agronomists in the arid southwestern US were promoting teparies for dryland

TABLE IV

Dryland Pulses

Plant name		Percentage		Yield, kg/ha	
Common	Botanical	Fat	Protein	Fat	Protein
Tepary	*Phaseolus acutifolius*	1.5	24	24	400
Bambara groundnut	*Voandzeia subterranea*	9	20	202	450
Lablab	*Lablab purpureus*	1.4	25	56	1000
Marama	*Tylosema esculentum*	36	34	–	–
Guar	*Cyamopsis tetragonoloba*	4	32	40	320

farming, and by 1915 a tepary boom had begun. Tepary cultivation on marginally productive land in Arizona, New Mexico and California was initiated, and by 1918 expanded onto 41,000 ha. In the marketplace, they were cheaper than other dry beans. They were also smaller and less attractive than the navy or pinto bean, had a stronger flavor and were reportedly more flatulent. They could not gain acceptance in restaurants and soon the bottom fell out of the market. Gasoline-powered pumps were introduced and groundwater irrigation became popular at the same time. Dryland farms were irrigated and converted to many of the cash crops seen today: alfalfa, vegetables, small grains and fruits. Indians began working for wages and abandoned their traditional agricultural fields and their barter and gift economy was replaced by a cash economy. Soon, only the unemployed Indians farmed teparies. Agricultural techniques of the era made tepary fields susceptible to severe wind erosion, and the 1930's dust bowl made farmers wary. Today teparies are grown only by a few farmers for marketing on trading posts and reservations, usually bringing prices better than pinto beans because of their scarcity.

BAMBARA NUT

The National Academy of Sciences has suggested several African legume annuals that may be useful in desert areas (44). The bambara groundnut (*Vigna subterranea*, subfamily Papilionoidea) is little known in areas outside its native Africa. Named for the Bambara district near Tombouctou (Timbuktu) in the southern edge of the Sahara Desert, the plant grows from Senegal to Kenya and from the Sahara to South Africa and is one of Africa's most popular pulses. It tolerates harsh conditions and variable rainfall better than peanuts, corn or sorghum and, as a *Rhizobium* symbiont, does well in poor soils.

It grows much like the peanut; the plant being either erect or prostrate with pods on or just beneath the soil surface. The pods contain 1-2 round seeds (ca. 1.5 cm diameter), which are very hard when mature or dried. The seeds are usually harvested while soft and sweet, mature seeds being too hard to be eaten unless roasted or boiled. Bambara groundnut seeds contain 14-24% protein, 6-7% fat (not a good oilseed) and ca. 60% starch, making them useful as a nutritious flour for baking. The protein reportedly is richer in the sulfur amino acids than other grain legumes. They do not seem to be grown in the US.

LABLAB BEANS

Lablab beans (*Lablab purpureus*) are generally thought of as a tropical plant; however, they reportedly will tolerate semiarid climates with annual rainfall of 200-400 mm. The plant is used as forage and hay for cattle, sheep, goats and pigs; the leaves and flowers can be cooked and eaten as a vegetable; the sprouts are tasty; the pods are used as a table vegetable and the dried seed have the usual legume seed uses (cooked or processed for tofu or tempeh). The seeds contain ca. 25% protein, 2-3% fat and considerable starch (44) but reportedly hydrate poorly and contain significant amounts of heat-labile trypsin inhibitor. The plant has a long taproot, which contributes to the drought hardiness of established plants.

MARAMA BEAN

Another underdeveloped leguminous African plant is the Marama bean (*Tylosema esculentum*, subfamily Caesalpinioideae) (44). It grows uncultivated in the Kalahari and neighboring sandy areas of southern Africa and is a dietary staple in many of the native cultures. The low-lying vines produce pods containing 1-6 seeds, which are normally roasted before eating and taste much like roasted cashew nuts; Africans also boil them whole or grind them as a flour. The plant also produces an underground tuber which is also edible.

Not much is known about yield as the plant has not been cultivated. Analysis of the dry seed indicates ca. 30% protein and 36-43% oil (soybean has 34% protein and 18% oil). Marama protein is reportedly high in lysine (5%) and limiting in methionine (0.7%).

GUAR

Guar is one crop that has been successfully introduced in many arid areas in the US and is beginning to establish a place for itself in the market (50). Introduced from India in 1903, Guar (*Cyamopis tetragonoloba*) was recognized as a source of an industrial gum, animal feed and for its protein. World production is now concentrated in India, Pakistan and on the plains of Texas and southwestern Oklahoma. In the US, 12,000-80,000 ha have been planted (20,000 ha in 1978-1979), yielding 437-896 kg/ha seed. Even so, almost 43,000 mt were imported in 1977, the price often being inversely tied to production conditions on the Indian subcontinent.

The seed contains 50% endosperm and yields 40% gum. The protein content of guar seed ranges from 27-37% with ca. 4% fat also present. The seed protein is low in methionine, traces of hydrocyanic acid were present in mature seed and trypsin inhibitor but no hemagglutinin activity has been observed.

RESEARCH NEEDED

The plants described here are obviously only a sampling of potentially useful new protein sources. As more interest is focused on these topics, other useful plants will undoubtedly be identified and additional mechanisms for their exploitation developed.

Some of these plants are already items of international commerce. Leucaena fodder is a well-developed industry in the tropics. Carob is established in the Mediterranean area and guar in parts of Asia and North America. Lablab beans are grown as a tropical crop.

In the US, of the plants mentioned, only guar has become commercially competitive as a semiarid crop. Other plants, e.g., jojoba, are being actively marketed and appear to have a commercial future.

As mentioned, Tepary beans tried and failed to become an established crop. Circumstances have changed since then, so they may now be another good candidate for exploitation. The other plants have an even longer and more difficult path to acceptance in the US market.

Most current work has been focused on identifying and growing new stress-tolerant plants. Future research should also include a critical evaluation of the potential commercial usefulness of the plants. Many of the plants being investigated are wild species whose quality could perhaps be significantly improved by breeding, but these breeding studies should be aimed at a compromise of best stress tolerance and best product characteristics. Even though grown on previously unproductive land, the products will still have to compete in the marketplace with established crops of known characteristics.

If a specific stress-tolerant crop does not have a single commercial characteristic of sufficient high quality to make the crop economically competitive, multiple products should be considered. For example, mesquite trees could be used for forage, biomass and erosion control while being

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grown with little water or fertilizer. The pods could be collected and milled into fractions rich in protein, sugar and galactomannan gum. None of these attributes may economically justify growing the trees by itself, but collectively they may make a new crop attractive. The same argument could be applied to the other plants being considered. Unfortunately, plants that are thought to be stress tolerant may not prove to be so. Also, the plant may tolerate the stresses but at the expense of yield or product quality. If one argues that a low yield in a hostile environment is better than nothing, then the range of accepted conditions must be defined, and such a range would probably differ for each plant and in each agronomic situation.

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Farming the Desert--Prosopis Species (Mesquite) Pods As A Food Crop

Those faced with the problem of raising food on land with low fertility or limited water supplies should consider desert legume trees as a multi-use crop. There are many useful legume trees, but Prosopis species (commonly called mesquite in North America and algarrobo in South America) seem to offer characteristics ideally suited for extreme environments. Typically, Prosopis species will grow in some of the hottest, driest, and most barren places on earth. In many countries, the tree is already commonly used as fuel wood and fodder, and as an agent to control desertification. New research has focused on the pods as a food or feed resource.

Some Prosopis trees are prolific pod producers (10,000 kg/ha). These pods may contain as much as 40 percent sugar (measured by weight). The sugar is localized in the pod pericarp and is almost exclusively sucrose. About 15-25 percent of the pod is comprised of seed, where most of the 11-17 percent pod protein is stored. About 5 percent of the pod weight is a galactomannan gum which occurs exclusively as a seed mucilage.

The pod can be readily milled into four discrete fractions: (1) a sugar-rich exo-mesocarp fraction; (2) an endocarp hull fiber-rich fraction; (3) a protein-rich seed cotyledon fraction; and (4) a seed coat-seed gum fraction.

The sugar-rich fraction is the sweetest and contains most of the other taste components as well. As such, it may be a useful ingredient in baking. It can also be used as a sweetening and flavoring ingredient in other food products, as a source of sucrose, and in the production of ethanol by fermentation. The fiber-rich fraction, on the other hand, contains little sugar or protein and appears to have limited food use.

The seed cotyledon is usually 56-60 percent protein with small amounts of fat, trace amounts of starch, and less than 5 percent free sugars (alpha-galactosides, sucrose, and monosaccharides). The sulfur amino acids of the cotyledon protein are invariably nutritionally limiting. The protein produces a flavor and aroma both nut-like and legume-like. Thus, the pod may have uses in baked products, as a foaming agent, and as an ingredient in pet foods.

Large quantities of gum can be separated from the gum-seed coat fraction. This gum is a high molecular weight galactomannan and compares favorably with guar gum. The galactose: mannose ratio of Prosopis gum is 1:1.6; guar has a ratio of 1:2. Prosopis gum has a slightly higher viscosity than guar gum, has similar temperature/viscosity characteristics, and forms superior xanthan gels. Thus, Prosopis gum has the potential for use as a guar replacement in many feed or food applications.

These four fractions have unique individual uses that combine to offer a variety of new alternatives for exploitation. For additional information on this research, write: Robert Becker, Daniel Myer, or Robin M. Saunders, Department of Agriculture, 800 Buchanan Street, Berkeley, CA, 94710, U.S.A.

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FROM AROUND THE WORLD.....

Postharvest Documentation Service

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SEED STRUCTURE AND COMPOSITION OF POTENTIAL NEW CROPS

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Abstract

Prosopis, Olneya, and Amaranthus have potential economic value as food or feed crops for arid/semi-arid regions. Mature seeds of these genera were examined using scanning electron and fluorescence microscopy to define anatomy and localize storage structures in cells. Protein bodies, some containing phytin inclusions, were localized in the embryos of five Prosopis species. Prosopis chilensis was the only one of the five Prosopis examined which contained starch. In all Prosopis, endosperm was attached to the inner layer of the seed coat, was thickest in the center of the seed, and gradually decreased in thickness toward the periphery. Olneya tesota contained numerous protein and lipid storage bodies throughout the cotyledons. The cotyledons also contained small starch granules. The thin leguminous seed coat had a small quantity of endosperm attached to the inner surface. Amaranthus cruentus and A. edulis contained abundant starch located in the perisperm, a storage structure encircled by the embryo. Protein bodies, some with phytin inclusions, were located in the A. cruentus embryo. These results provide information for development of processing methods of these seeds for use in foods.

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Introduction

Several arid or semiarid plants are candidates for development as resources for food or feed particularly for cultivation and utilization in Third World countries. Agricultural practices in these countries are often primitive in terms of irrigation and farming equipment, therefore, plants requiring minimum tillage and irrigation are of primary importance.

Prosopis species are tree legumes native to the Southwestern deserts of the United States, Mexico, and South America. Prosopis has been utilized in the past by Native North Americans as a source of food, fuel, shelter, weapons, and tools (Felger 1977). The seed is high in protein and contains a galactomannan gum and may, therefore, be of economic value as a food or feed (Felker 1979; Becker and Grosjean 1980; Becker 1982).

Olneya tesota, also a leguminous tree native to the Southwestern deserts of the United States, has been used as a food (Becker 1983). Abundant oil and high protein content in the seed and the ability of the tree to grow under extreme high temperatures make O. tesota a particularly valuable crop for desert regions.

Amaranthus, as an alternate food crop, has been of renewed interest for several years. Studies have included feeding and incorporation into foods (Betschart et al 1981), composition (Becker et al 1981), breeding (Hauptli and Jain 1977), and seed morphology (Irving et al 1981). A comprehensive review (Saunders and Becker 1984) and history (Sauer 1950) have also been reported.

This study deals with anatomy, histochemistry, scanning electron microscopy, and composition of Prosopis alba, P. tamarugo, P. chilensis, P. pubescens, P. velutina, Olneya tesota, Amaranthus cruentus and A. edulis seeds.

Materials and Methods

Prosopis alba Grisebach, P. pubescens Bentham, and Olneya tesota Gray (Munz and Keck 1975) pods and seeds were collected in Southern California in July, 1983 and 1984. P. velutina Wooton pods were collected in Tucson, Arizona in 1977. Prosopis tamarugo Philippi and P. chilensis emend. Burkart were supplied by Mr.

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Luis Zelada Gonzales of CORFO, Chile. The pods were harvested in 1982 from trees growing on a plantation in Northern Chile. Prosopis taxa are described in Leakey and Last (1980) and in Simpson (1977).

Amaranthus cruentus seed was harvested in Mexico in 1976 by Rodale Press, Inc., Emmaus, PA.

All seeds and pods were stored below 4°C.

Light Microscopy

Prosopis and Olneya tesota seeds were dissected and cut into approximately $1mm^3$ in fixative. Tissues were fixed in a mixture of 3% glutaraldehyde, 1.5% acrolein, and 1.5% formaldehyde (Mollenhauer and Totten 1971) in 0.05 M NaH_2PO_4/Na_2HPO_4 pH 6.8-7.2 for 3-4 hr at 21°C. Tissues were rinsed in buffer and dehydrated in an ethanol-butanol graded series (Jensen 1962; Irving 1984) and infiltrated and embedded in glycol methacrylate (GMA) (JB-4 medium, Polysciences, Warrington, PA) (Feder and O'Brien 1968).

Amaranthus cruentus seeds were fixed in 6% glutaraldehyde in 0.05 M NaH_2PO_4/Na_2HPO_4 buffer pH 6.8 for 3-4 d at 4°C. Tissues were rinsed briefly in phosphate buffer and dehydrated in methoxyethanol, ethanol, propanol and n-butanol. Samples were then infiltrated and embedded in GMA (Feder and O'Brien 1968; Irving 1983).

Embedded samples were sectioned 2-4 µm thick on a Sorvall MT-2 ultramicrotome with glass knives. Unstained sections were observed using polarizing, Hoffman (differential interference contrast), or fluorescence optics. Fluorescence or brightfield conditions were used to observe stained sections.

Carbohydrates with vicinal hydroxyl groups were visualized by treating GMA sections with periodate-Schiff's (PAS). Sections were treated 15 min in a saturated solution of dinitrophenylhydrazine (Feder and O'Brien 1968) in 15% acetic acid to block fixative-induced aldehydes. Tissue sections were then treated with periodic acid for 15 min and stained in Schiff's reagent for either 2 min (Fulcher and Wong 1980) for fluorescence or 15 min for bright field work. Slides were washed in running tap water for 20 to 30 min following each step. Sections were observed using fluorescence microscopy at 500-550 nm excitation wavelength or using standard brightfield conditions.

Sections were treated with a few drops of iodine potassium iodide (IKI) (Jensen 1962), covered with a cover glass and observed using standard brightfield or Hoffman optics to determine presence of starch.

Cell walls were detected by treating sections 1-2 min in aqueous 0.01% calcofluor or congo red (Yiu et al 1982) and washing briefly under running water. Sections were air-dried and mounted in immersion oil. Calcofluor-stained sections were viewed using fluorescence optics with an excitation wavelength of 330-380 nm. Congo red-stained sections were observed using 500-550 nm excitation wavelength.

Protein was localized by staining sections 1-2 min in 0.01% acid fuchsin in 1% acetic acid (Fulcher and Wong 1980), washing briefly in water and observing at 500-550 nm excitation wavelength in the fluorescence microscope. Other sections were stained for protein with mercuric bromophenol blue (Mazia et al 1953) for 2 hr, washed briefly in water, dried, and mounted in Aquamount (Lerner Laboratories, New Haven, CT). Mercuric bromophenol blue-stained sections were viewed using standard brightfield or Hoffman optics.

Globoid inclusions, which contain phytate and minerals (Ca, P, Mg), were identified by staining sections in aqueous 0.01% acriflavine HCl (Yiu et al 1982; Fulcher and Wong 1982) adjusted to pH 5.0-5.5 with 0.1 M Na_2HPO_4. Sections were viewed and photographed using fluorescence microscopy at 500-550 nm excitation wavelength. Acriflavine HCl was also used to differentiate A. cruentus seed coat layers. Sections were examined at 385-425 nm excitation wavelength.

Lipids were localized in O. tesota fresh hand-sections and GMA sections by staining in 0.01% aqueous nile blue A (Fulcher and Wong 1980). Sections were rinsed, air-dried, and mounted in Aquamount or water. Sections were examined using fluorescence microscopy at 450-490 nm excitation wavelength.

Fluorescence work was recorded on 35 mm Kodak Plus-X pan film using a Nikon Fluophot fluorescence microscope with a 200W mercury bulb and filter combinations as described above. Nile blue A work was recorded on panatomic-X film using a Leitz Orthoplan fluorescence microscope with a 100W Mercury bulb and 450-490 nm excitation wavelength. Brightfield work was recorded on either 4X5 Tri-X or 35mm Kodak panatomic-X film using a Nikon Fluophot microscope and standard brightfield or Hoffman optics.

Amaranthus edulis seeds were fixed in 10% neutral buffered formalin and embedded in paraffin (Jensen 1962). Paraffin blocks were sectioned on an American Optical Model 820 rotary microtome. Deparaffinized sections were stained in Mayer's hematoxylin 20 min, washed in running water 20 min, and counterstained in eosin 2 min (Berlyn and Miksche 1976). Paraffin sections were used to obtain a flat cross section of a large area; glycol methacrylate sections from whole, embedded samples tend to wrinkle.

Scanning Electron Microscopy--SEM

Prosopis cotyledons were sectioned into approximately $1mm^3$ and fixed in 2% glutaraldehyde in 0.05 M NaH_2PO_4/Na_2HPO_4 pH 7.2 at 0-4°C for 18 hr. Samples were rinsed in buffer and post-fixed in 1% OsO_4 in water at 25° C for 2 hr. Amaranthus cruentus seeds were fixed using the above procedure except they were not cut up prior to fixation.

Prosopis seed coat/endosperm samples were cut into $1mm^2$ pieces and fixed in 2.5% glutaraldehyde in 0.1 M NaH_2PO_4/Na_2HPO_4 and 0.2 M NaCl pH 6.9 at 0-4° C for 18 hr. Sodium chloride was added to prevent excessive swelling of the hygroscopic endosperm tissue.

Olneya tesota cotyledons were cut up in fixative and fixed in 3% glutaraldehyde in 0.05 M NaH_2PO_4/Na_2HPO_4 pH 6.8 at 0-4° C for 18 hr. Cotyledon pieces were rinsed twice and post-fixed in buffered 1% OsO_4 at 25° C for 3 hr.

All SEM samples were rinsed in phosphate buffer and dehydrated in an ethanol-graded series.

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Specimens were ethanol-cryofractured (Humphreys et al 1974) and critical point dried in a Polaron E3000 Critical Point Dryer. Tissues were mounted on aluminum specimen stubs with carbon graphite and sputter-coated with gold in an ISI PS-2 Coating Unit. Prosopis and A. cruentus samples were photographed in an ISI Super I scanning electron microscope with a universal stage. Viewing conditions were approximately 20kV and 30° tilt. Olneya tesota samples were photographed in a Philips 505 SEM (15kV, 30° tilt) or an ISI SS40 SEM (10kV, 30° tilt). All images were recorded on Kodak Tri-X pan 4x5 film.

Data in Tables 1 and 2 were obtained by AOAC methods (1975).

Results

Prosopis (Leguminosae-Mimosoideae)

Seed size and shape of the five Prosopis species studied differed, however cotyledon anatomy was similar. Cotyledons of all species had 2-3 rows of palisade parenchyma on the adaxial side beneath the epidermis as previously found in P. velutina (Irving 1984). Prosopis chilensis was the only Prosopis member which contained starch (Fig. 1a), albeit few, very small granules. Presence of starch was determined by IKI, PAS (Fig. 1a), and with polarizing optics. Cotyledon parenchyma cells were filled with protein bodies which were identified histochemically by staining with acid fuchsin or mercuric bromophenol blue (not shown).

Two types of protein bodies were evident; those without inclusions (Fig. 1b) and those with globoid inclusions (Fig. 1b-e) which were detectable in sections stained with acriflavine HCl. Protein bodies containing globoids were localized in the pro-mesophyll cells (Fig. 1d) of cotyledons of all Prosopis studied. A gradation of protein body types was evident within a single cotyledon in most Prosopis taxa. Protein bodies with the most abundant and largest globoids were centrally located in the pro-mesophyll (Fig. 1d); decreasing in size and number in the outer regions. Prosopis pubescens contained globoid inclusions located more extensively throughout all cells in the cotyledons (Fig. 1c). Prosopis chilensis contained few globoids in the subepidermal layers (Fig. 1b). Prosopis velutina, P. tamarugo, and P. alba contained globoids only in the center of the cotyledons.

Abaxial epidermal cells contained non-proteinaceous bodies in all Prosopis studied. Abaxial epidermal cells in P. chilensis and P. pubescens contained deposits considered to be globoids since they stained with acriflavine HCl (Fig. 1b,c); globoids were not found in epidermal cells of the other three Prosopis taxa.

In scanning electron micrographs, globoids appeared as solid structures with smooth surfaces (Fig. 1e) embedded in protein bodies. Protein bodies in cross section were smooth with no apparent structural features. The matrix between protein bodies was mesh-like and irregular with small indentations and large holes.

The seed coat, which provided rigid support and protection for the intact embryo, was similar in all Prosopis studied. A pleurogram, an oval line on the seed coat surface open at the hilar (root) end (Corner 1951; Bragg 1982; Irving 1984), was evident on Prosopis. The internal seed coat structure exhibited a cuticle, palisade sclereids, and osteosclereids on either side of sclerified parenchyma (Fig. 1f). Variation in seed coat structure was found in the thickness of the separate layers particularly the sclerified parenchyma layer. Endosperm was firmly attached to the interior surface of the seed coat (Fig. 1f).

Endosperm was thickest in the center of the seed and gradually decreased in thickness towards peripheral margins. Endosperm cells evidenced thick walls (Fig. 1f) which expanded rapidly upon hydration. It was noted that most of the swelling of the seed in early stages of imbibition occurred in the endosperm. Upon swelling, production of a viscous and sticky gum resulted. The walls, which are believed to be the source of the gum when hydrated, stain intensely with calcofluor (not shown) and congo red (Fig. 1g). During sample preparation of seed coat/endosperm tissues for SEM, NaCl was added to the fixative to reduce the amount of swelling of endosperm. Thus, endosperm tissue in Fig. 1f shows little swelling of cell walls. Sodium chloride was not added to the fixative during preparation of GMA embedded tissues, therefore, swelling and solubilization of cell wall components in the endosperm was apparent (Fig. 1g). An endosperm cell wall component, not solubilized during sample preparation was observed (Fig. 1g).

Olneya tesota (Leguminosae—Papilionioideae)

Olneya tesota seed was dark, reddish brown in color and nearly spherical in shape. The typical leguminous seed coat was a thin structure with endosperm firmly attached to the subepidermal layer. Endosperm was typically one cell thick. Interior to the endosperm were two large, fleshy cotyledons.

Cotyledon tissue blocks were embedded in GMA using standard techniques including dehydration with lipid solvents (ethanol and butanol). However, lipids were preserved in the central portion of the GMA blocks. GMA (Fig. 2a) and hand-cut (not shown) sections compared favorably when stained with nile blue A and viewed at 450-490 nm excitation wavelength. Lipid bodies surrounded much larger protein bodies of varying shapes and sizes; protein bodies were evident following staining with mercuric bromophenol blue (Fig. 2b). Cell walls in GMA sections of the cotyledons stained intensely following treatment with calcofluor (not shown) or congo red (Fig. 2c).

Cotyledon tissues were fixed in glutaraldehyde (GA) and post-fixed in OsO_4 but because of the poor penetration of OsO_4 into tissues during preparation for SEM, lipid was ethanol-extracted out of the central portion of tissue blocks during dehydration. It was therefore possible to compare OsO_4-fixed tissues (GA + OsO_4) (Fig. 2d,e) with those which were not (GA - OsO_4) (Fig. 2f) in the same block. Lipid bodies appeared to fill most of the space between protein bodies (Fig. 2d,e). In some cases, protein

bodies were pulled away from surrounding tissues during specimen preparation leaving large indentations lined with lipid bodies (Fig. 2d,e). Intact protein bodies exhibited small pits in their surfaces (Fig. 2d,e). These pits resulted from lipid bodies which were pulled away from the protein body surface during fracturing. A reticulated appearance of the interior of protein bodies was evident in cross section (Fig. 2e). Protein body inclusions were not evident in GMA sections or in tissues prepared for SEM.

GA - OsO_4 tissue prepared for SEM exhibited a reticulated cytoplasmic matrix with small indentations attributed to the removal of lipid bodies (Fig. 2f). Protein bodies were detectable beneath this mesh. Ovoid-shaped starch granules were evident at the periphery of cotyledon cells (Fig. 2f). Starch granules were not discernible in GA + OsO_4 material but a small number were identifiable in GMA sections which had been stained with IKI (Fig. 2g) and viewed in the light microscope.

Amaranthus cruentus (Amaranthaceae)

Amaranthus cruentus seed is borne in a single-seeded fruit called a utricle (Munz and Keck, 1975) (Fig. 3a). The lenticular seed is approximately 1mm in diameter and has an embryo which completely encircles the perisperm in one plane (Fig. 3a,b). Endosperm comprises a small portion of the mature seed at the tips of cotyledons and radicle (Fig. 3b). Seed coat tissue surrounding the perisperm is firmly attached and appears as a single, crushed layer. Two cell layers are evident in the seed coat surrounding the embryo (Fig. 3c).

Embryo cells were filled with protein bodies as demonstrated by acid fuchsin (Fig. 3d) or mercuric bromophenol blue (not shown) staining of GMA sections. Small protein bodies were localized in endosperm cells (Fig. 3e). Two types of protein body were discerned in both the embryo (Fig. 3d) and endosperm (Fig. 3e); those with globoid inclusions (not shown for endosperm) and those without inclusions. Protein bodies with globoids were much more prevalent in the embryo than in the endosperm. Globoids were identified by staining with acriflavine HCl and viewing at 500-550 nm excitation wavelength in the fluorescence microscope (not shown).

Much of the protein in the perisperm of the A. cruentus seed was localized in a single peripheral cell layer (Fig. 3e,f). Protein bodies were not evident in the perisperm using either light or scanning electron microscopy (Irving et al 1981). Starch granules in the peripheral layer appeared to be about one-third the size of those in the central portion (Fig. 3g), which were 1-3 µm in diameter. Scanning electron micrographs of the perisperm revealed closely packed, polyhedral starch granules (Fig. 3h).

Discussion

Minor differences were detected in seed anatomy of Prosopis. Four Prosopis taxa (P. alba, P. pubescens, P. tamarugo, and P. velutina) lacked starch in the embryo as was reported for P. glandulosa (Allen et al 1982) and P. velutina (Irving 1984). Prosopis chilensis exhibited few small starch granules in the pro-mesophyll of the cotyledons (Fig. 1a). Protein bodies were located throughout the embryo including much of the provascular system in all Prosopis taxa studied and constituted the major portion of protein reserves in the seed.

Prosopis velutina and P. glandulosa contained approximately 32% protein (Table 1). Milling of P. velutina pods by Meyer et al (1982) yielded two seed fractions: endosperm splits (seed coat + endosperm) and cotyledon (embryo). The endosperm splits fraction contained 8% protein while the cotyledon fraction contained 56% protein. This is in agreement with histochemical findings that the major storage organ for protein was the embryo, specifically in the cotyledons in the form of protein bodies.

Two types of protein bodies were identified in Prosopis cotyledons; those without inclusions and those with globoid inclusions. Globoids were located in the pro-mesophyll of all Prosopis and, in most cases, a gradation in size and number was noted as was reported for P. glandulosa (Allen et al 1982). Prosopis pubescens contained globoids in virtually all parenchyma cells although there were few in protein bodies of the palisade parenchyma. Globoids were localized in abaxial epidermal cells of both P. chilensis and P. pubescens.

Globoids are rich in phytin, a cationic salt of myoinositol hexaphosphoric acid and contain

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Figs. 1-3. Symbols: C, cotyledons; CW, cell wall; E, endosperm; G, globoids; L, lipid bodies; Os, osteosclereids; P, perisperm; Pa, palisade; PB, protein body; R, radicle (root); S, starch granules; Sc, seed coat; SP, sclerified parenchyma; U, utricle.

Fig. 1. (facing page) Prosopis. a. P. chilensis glycol methacrylate section stained with periodate-Schiff's to denote carbohydrates using standard brightfield optics. Note starch granules. Bar = 25 µm. b. Abaxial side of cotyledon of P. chilensis at 500-550 nm excitation wavelength stained with acriflavine HCl to localize phytin globoids. Bar = 50 µm. c. P. pubescens cotyledon abaxial side stained with acriflavine HCl and viewed under fluorescence at 500-550 nm excitation. Bar = 50 µm. d. P. chilensis section of the central portion of a cotyledon stained with acriflavine HCl (500-550 nm). Globoids are the small, bright structures; protein bodies are gray. Bar = 15 µm. e. P. velutina scanning electron micrograph of part of a cotyledon cell showing protein bodies, two of which are fractured and contain globoids. Bar = 5 µm. f. P. velutina scanning electron micrograph of a cross-section of a seed coat with a bit of endosperm attached. Bar = 50 µm. g. Fluorescence micrograph of P. tamarugo endosperm stained with congo red and visualized at 500-550 nm excitation. Note the cell wall which has been partially solubilized. The unsolubilized portion is that which stains most intensely next to the cell interior. The faint (darker) part of the cell wall has been partially or completely solubilized. Bar = 100 µm.

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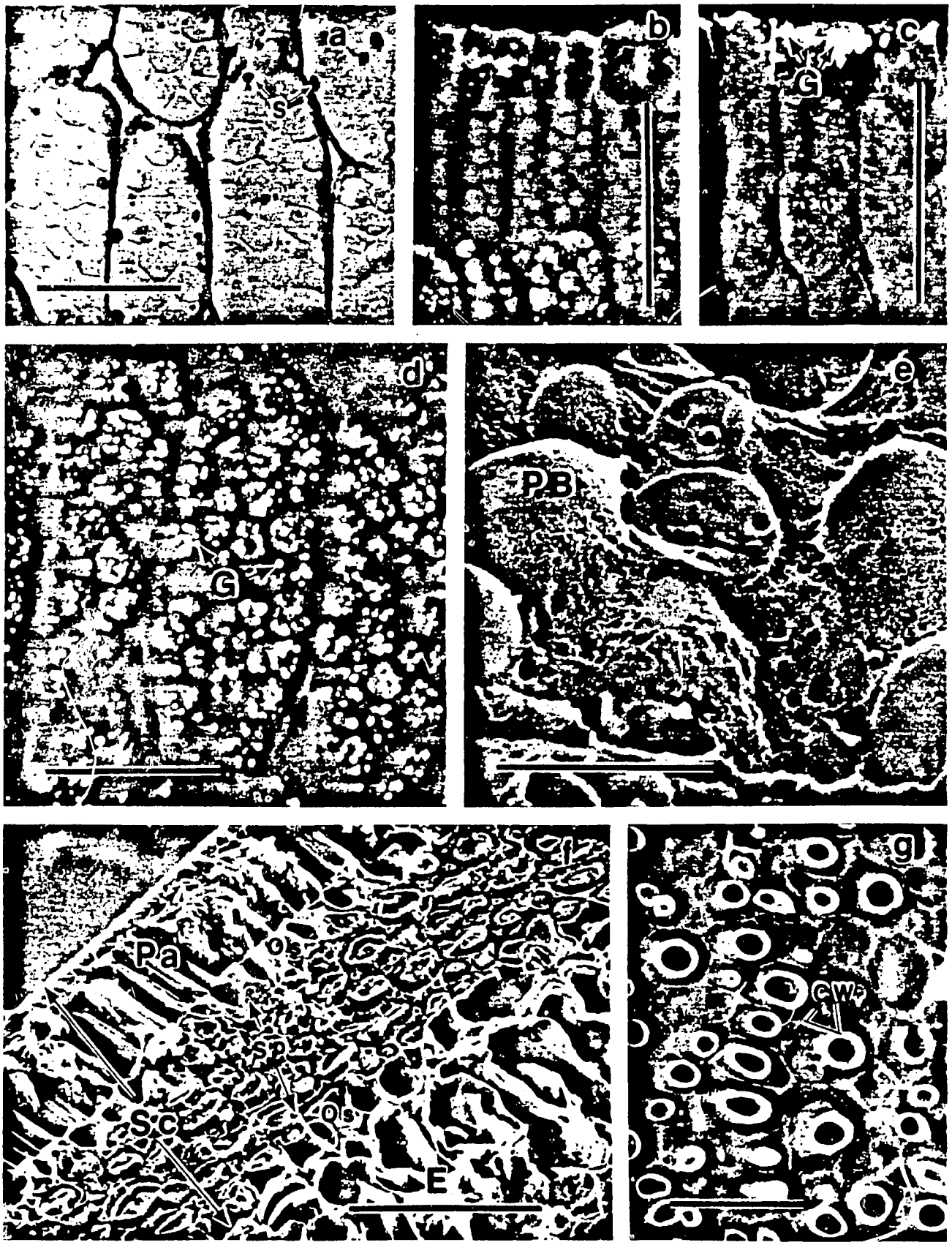
a
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TABLE 1

Proximates and Phytic Acid Content

	%N	Crude Protein†	%Fat	%Fiber	%Ash	Phytic Acid§
P. velutina [a]	5.13	32.06	5.68	7.12	3.83	2.47
P. glandulosa[a]	5.08	31.75	4.32	6.99	3.42	2.90
O. tesota[b]	4.91	30.69*	35.00	4.79	3.50	——
A. cruentus[c]	3.00	18.75	7.71	3.44	2.80	2.20

*When corrected for canavanine, protein ranges 17-21%
†Calculated N x 6.25
§Millimoles per 100 g, calculated from phosphorus determinations.

Data from Becker and Crosjean (1980[a]), Becker et al (1981[c]), and Becker (1983[b])

TABLE 2

Fatty acid composition of Olneya tesota

Fatty acid		% total fatty acid
Myristic	14:0	0.177
Palmitic	16:0	14.87
Stearic	18:0	17.70
Oleic	18:1	41.95
Linoleic	18:2	12.04
Linolenic	18:3	3.54
Arachidic	20:0	0.531
Behenic	22:2	4.43
Unknown	——	0.177
Lignoceric	24:0	4.60

mineral (Ca, P, Mg) storage reserves (Lott and Buttrose 1977; Lott 1980). Phytic acid has been quantified chemically in P. velutina and P. glandulosa (Table 1). Values for other Prosopis taxa have not been determined, however it is expected that phytic acid values for P. pubescens and perhaps P. chilensis will be higher.

The second fraction obtained by milling P. velutina seeds, endosperm splits, contained 60% galactomannan gum, all of which was located in the endosperm. Endosperm accounts for roughly 50-60% by weight of the seed coat-endosperm fraction, indicating that virtually all of the endosperm is composed of galactomannan. Congo red or calcofluor, which stain most cell walls, both had a strong affinity for the endosperm cell walls suggesting the possibility of quantification of galactomannan in sections of Prosopis endosperm. Mucilage from Prosopis endosperm was only partly soluble in cold water and achieved maximum viscosity after solubilization by heating to 90°C and cooling to 25° C (Meyer et al 1982). The seed coat made up the remaining 40-50% of the endosperm splits fraction.

Seed coat structure was similar in all Prosopis studied and was similar to P. glandulosa (Bragg 1982; Meyer et al 1971) and P. pallida (Bragg 1982). Variations in seed coat anatomy between species were determined to be primarily differences in thicknesses of the sclerified parenchyma and palisade layers.

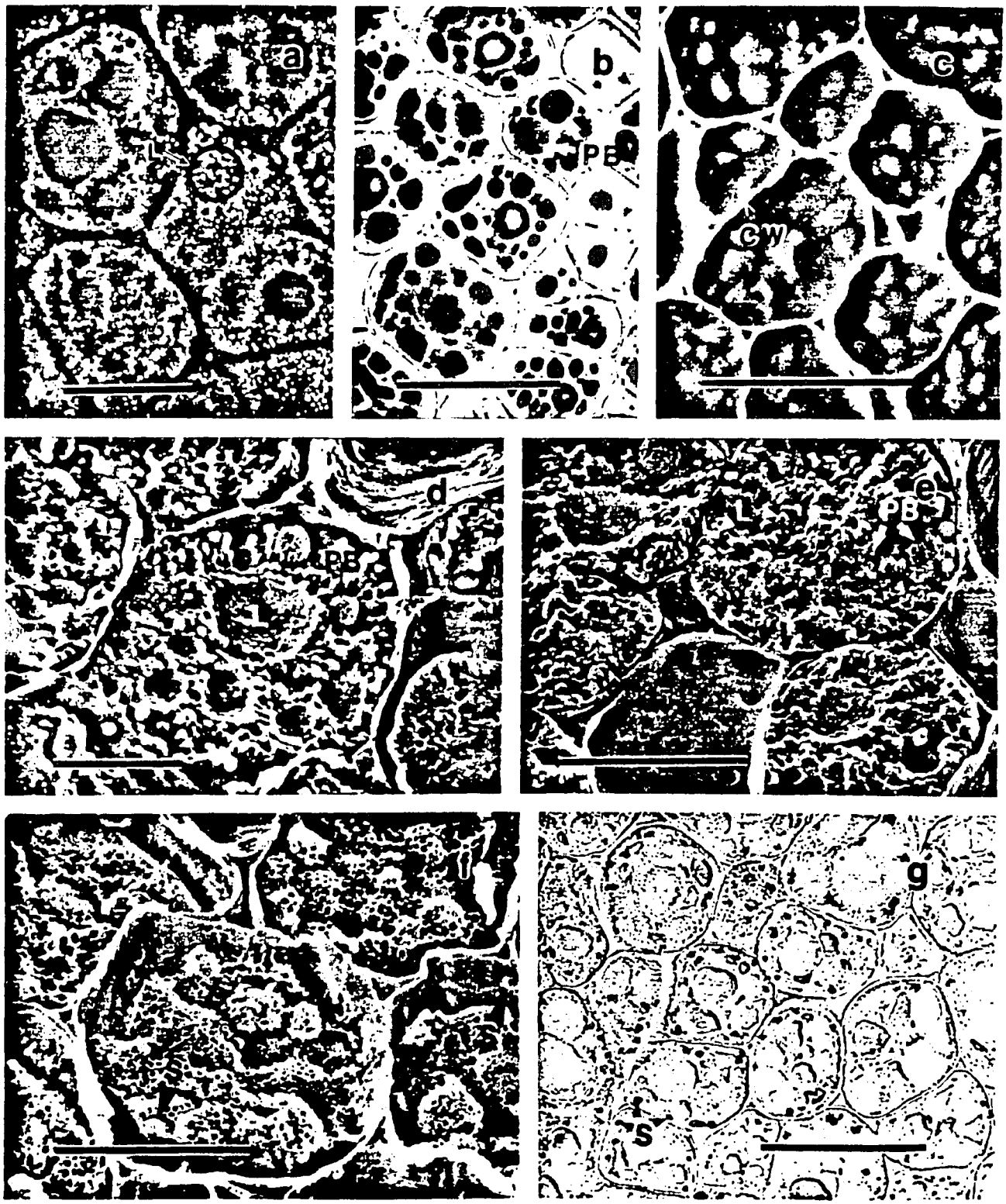
Olneya tesota seed contained 33-39% lipid (Table 1) (Becker 1983), considerably higher than soybean (18%). The fatty acid profile (Table 2) indicated that the oil is rich in oleic, stearic, palmitic, and linoleic acids and compared with peanut oil in flavor (Becker 1983). Lipid reserves were visualized in scanning electron and light micrographs as distinct deposits in the cotyledons. Phytin was not detected in chemical analyses of O. tesota seed (Table 1) nor were phytin globoids evident histochemically in the protein bodies.

Sectioned protein bodies of O. tesota revealed a reticulated, mesh-like structure in scanning electron micrographs. In contrast, protein bodies of P. velutina evidenced a solid structure with or without globoids. The mesh-like appearance of protein body internal structure could be attributed either to extraction during sample preparation or to partial digestion of the body. Protein bodies have been reported to contain hydrolytic enzymes (Yatsu and Jacks 1968) and Rost (1972) noted all stages of protein body digestion in dormant caryopses of Setaria lutescens. Protein bodies were the major storage site in the O. tesota seed for protein.

Protein content of O. tesota seed was found to range 26-32% (Table 1) but a substantial proportion of the protein (35%) was determined to be canavanine, an arginine analog and a potent growth inhibitor in animals. Methionine + cystine are the first limiting amino acids as was found in Prosopis and other legumes. In addition, a number of other amino acids are significantly limiting in the O. tesota seed. Olneya tesota seed cotyledons contained few starch granules as was determined histochemically. These finding agree with Becker (1983) who quantified 1.09% starch in the O. tesota seed.

Three members of the sixty species of the genus Amaranthus have been grown as grain

Fig. 2. Olneya tesota. (facing page) a. Fluorescence view of a section stained with nile blue A to denote lipids visualized using fluorescence at 450-490 nm excitation. Lipids are the small, bright spots. Bar = 25 µm. b. Brightfield microscope section of a mercuric bromophenol blue-stained section showing protein bodies. Bar = 50 µm. c. Congo red-stained section showing cell walls viewed at 500-550 nm excitation. Bar = 50 µm. d. Scanning electron micrograph of cotyledon cells showing lipid bodies, protein bodies and cell walls. Bar = 10 µm. e. Scanning electron micrograph of cotyledon showing the interior of several protein bodies. Bar = 20 µm. f. Ethanol-extracted (GA-OsO_4) scanning electron micrograph showing protein bodies covered by matrix material containing small holes where lipids were before extraction. Notice the few starch granules. Bar = 20 µm. g. Iodine potassium iodide stained section of cotyledon cells viewed with Hoffman optics showing starch granules. Bar = 50 µm.



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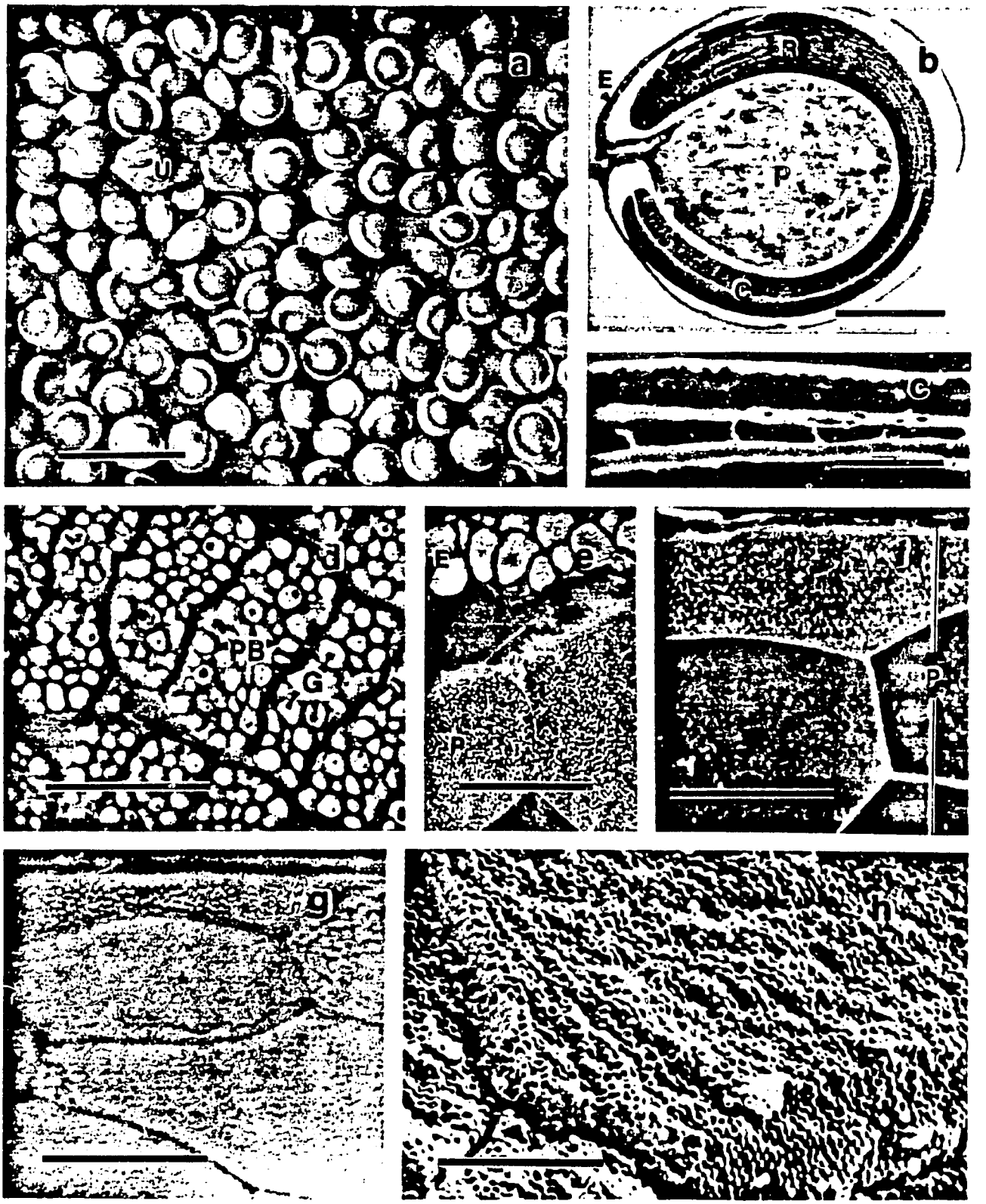

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Fig. 3. (facing page) Amaranthus. a. A. cruentus seeds and fruits photographed through a dissecting microscope. Bar = 2 mm. b. A. edulis cross section of a seed stained with hematoxylin and eosin to show relationships of tissues. Bar = 250 µm. c. A. cruentus seed coat section adjacent to the embryo stained with acriflavine HCl and viewed at 385-425nm excitation. Bar = 25 µm. d. Fluorescence view of the radicle of A. cruentus stained with acid fuchsin (500-550 nm excitation) showing bright protein bodies and dark (unstained) globoid inclusions. Bar = 25 µm. e. A. cruentus section of perisperm and endosperm stained with acid fuchsin and viewed at 500-550 nm excitation. Note the small protein bodies in the endosperm. Protein in the perisperm occurs as brightly stained material between darker (unstained) material which are starch granules. Bar = 50 µm. f. Fluorescence micrograph of the outer peripheral layer of the perisperm (brightest area) at the top of the micrograph of A. cruentus and the layer interior of that stained with acid fuchsin (500-550 nm excitation). Protein is the brightly stained material. Cell walls are also stained. Bar = 25 µm. g. Perisperm outer layers viewed at 500-550 nm excitation. Similar view to 3f but stained with periodate-Schiff's to denote carbohydrates. Notice small starch granules at top of micrograph. Layers below are densely-packed starch granules. Bar = 25 µm. h. Scanning electron micrograph of a few adjoining cells of the perisperm. Notice the small polyhedral starch granules. Bar = 15 µm.

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crops. A. caudatus (which includes A. caudatus cv edulis sometimes known as A. edulis) is grown in the Andean highlands and is toasted, popped, milled into flour, or made into gruel. Amaranthus cruentus, used for grain (light seeds) and as a vegetable or ornamental (dark seeds), is grown in Mexico and Guatemala. Amaranthus hypochrondriacus is the most robust and highest yielding of the grain types of Amaranthus and is cultivated in India and Central America (National Research Council 1984). All have been found to be high in protein which was stored in the A. cruentus seed in two forms; as matrix material in the perisperm or as protein bodies with or without globoids in the embryo and endosperm.

Globoid inclusions containing phytic acid were localized throughout the A. cruentus embryo. Compositional data (Table 1) agree with the presence of phytic acid.

Evaluation of protein quality in Amaranthus indicated that the first limiting amino acid was leucine (Betschart et al 1981; National Research Council 1984) and unlike cereals (wheat, corn, rice) was high in lysine (Downton 1973). Amaranthus seed, therefore, would be a good complement to corn, wheat or rice (National Research Council 1984).

Much of the protein in A. cruentus was located in the embryo and the outer peripheral layer of the perisperm. Milling studies followed by chemical analyses agree with these findings. Protein content of whole A. cruentus seed was determined to be 18.75%. The bran/germ fraction (seed coat + embryo) in milled A. cruentus seed contained 42% protein and the perisperm fraction contained 7.7% protein (Betschart et al 1981). Other nutrients of the seed were also found to be more concentrated in the outer layers. Fat was found to be 7.7% (Table 1) in the whole seed and 19-20% in the bran/germ fraction. Fatty acid composition of the oil was 70% oleic + linoleic, 20% stearic, and 1% linolenic (National Research Council 1984), therefore, the bran/germ fraction has potential value as an oil source. Although the embryo is high in fat, oil droplets were not detectable in the SEM (Irving et al 1981). Fat was determined to be 2.3% in the perisperm fraction (Betschart et al 1981).

The perisperm fraction was composed mostly of starch and had only 7% amylose in A. hypochrondriacus (Becker et al 1981) and amylose was not detected in A. paniculatus (Modi and Kulkarni 1976). Amaranthus leucosperma was also found to have "waxy" (high amylopectin) starch (Wolf et al 1950). Amaranthus seed was found to contain about 62% starch (Becker et al 1981). "Waxy" starch, particularly where the granules are minute as in Amaranthus (1-3 µ m in diam.) could have commercial applications both in food and industrial products.

Reference to a company and/or product named by the Department is only for purposes of information and does not imply approval or recommendation of the product to the exclusion of others which may also by suitable.

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Discussion with Reviewers

L.H. Bragg: Why do some protein bodies within the same cotyledon have inclusions whereas others are without these inclusions? Do you think this absence is a result of chance sectioning or fracturing of the protein body?

Authors: I assume you mean "protein bodies within the same cell"? As I stated in the paper, globoids are more abundant in the promesophyll of the cotyledons of Prosopis. Why this is the case is not certain. Chance sectioning would necessarily eliminate some of the globoids in a protein body in a single section as would the removal of globoids during sectioning due to the hardness of globoids compared to surrounding tissues. In this study, many sections, including serial sections from several seeds were stained and observed, therefore this "chance sectioning" problem was eliminated.

L.H. Bragg: Are the "large holes" in the described mesh-like matrix between the protein bodies which are shown in Figure 1e real or are they artifacts due to preparatory techniques?

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Authors: All fixed samples showed this characteristic. Dry samples observed in the SEM did not exhibit this feature suggesting the characteristic appears as a result of hydration. We used this micrograph primarily to demonstrate fractured protein bodies and the globoid inclusions.

L.H. Bragg: Why do you anticipate that phytic acid values for P. pubescens and P. chilensis will be higher than those of Prosopis velutina and P. glandulosa?

Authors: We expect the values for P. pubescens and P. chilensis to be higher than the others primarily because they appeared to be more abundant and sometimes larger in these species than the other Prosopis taxa. We did not look at P. glandulosa.

J.N.A. Lott: The globoids in the epidermal cells of P. pubescens in figure 1c are very large and numerous compared to those of other seeds. Are all the cotyledon epidermal cells of this species like this?

Authors: Not all epidermal cells contain large globoids as shown here, but globoids are numerous in most epidermal cells especially those on the adaxial side. The large size may have resulted from agglutination of several globoids prior to or during specimen preparation; however, P. pubescens was the only member which exhibited this characteristic. P. chilensis did contain globoids in epidermal cells but these were much smaller and less numerous than P. pubescens.

J.N.A. Lott: Do you have any information on the solubility properties of the storage proteins in the species you studied?

Authors: Sorry, no we do not. Solubility properties of the proteins is one of the questions on the agenda.

K. Saio: You mentioned that the three crops are valuable as resources for foods. Will you please explain the traditional and potential uses of these in modern technologies?

Authors: Many of the traditional uses of these crops are also appropriate for modern technologies. For example, early desert settlers collected and ground Prosopis pods. The pericarp flour was used as a sweetener or as a fermentation substrate and the ground seeds as a protein source. Today, potential uses would also include utilization of the seed mucilage (endosperm) as a guar gum substitute. Olneya seeds have a pleasant bean taste but have not yet been commercially exploited. Amaranthus is a rediscovered cereal grain which is gaining wide acceptance in the U.S. health food industry.

K. Saio: In Fig. 2 variable size of protein bodies are distributed in a cell. I observed in soybean that the size of mature protein bodies becomes rather equal as the seeds reach maturation. Do you know the exact degree of maturation of this seed?

Authors: Since these seeds are collected from trees growing under natural conditions (i.e., not experimental), it is impossible to determine the exact degree of maturation of these seeds. The protein bodies in O. tesota are very different than any I have looked at previously. Staining intensity of protein bodies in sections stained for protein varies a great deal suggesting partial digestion (autolysis) and/or solubility within the protein body. The interior of the protein bodies, exhibited by SEM, is reticulated also suggesting solubility or digestion.

In Arid Lands: Today and Tomorrow. Proc. Int'l. Res. Develop. Conf. October 20-25, 1985. Tucson, AZ. Whitehead, D.W., Hutchenson, C.F., Timmerman, D.N., Barady, R.G. (eds.)

DEVELOPMENT OF *PROSOPIS* SPECIES LEGUMINOUS TREES AS AN AGRICULTURAL CROP

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ABSTRACT

An international effort is being focused on means to exploit *Prosopis* pods as a food/feed resource. Pod processing methods have been developed to produce fractions rich in protein, galactomannan gum, sugar, fiber, or protein-sugar. The sugar rich fraction is useful in bakery goods, may be drum dried, or used as a fermentative substrate for ethanol production. The protein fraction has nutritional qualities and food applications similar to soy protein. The seed mucilage is a galactomannan with properties similar to guar gum. A high protein-high sugar flour can be separated from milled *Prosopis* pods and used in refined food applications. The pods may also be coarsely milled, mixed with other grains, and extruded.

Products prepared containing *Prosopis* fractions as major ingredients are breads, chapatis, chips, crackers, syrups, jellies, beverages, granola bars, emulsifiers, and xanthan-gum mixtures.

All processes and products are being subjected to

chemical, nutritional, and economic analyses to determine their suitability for further development.

INTRODUCTION

There are 44 known species of *Prosopis* leguminous trees, many of which occur in some of the hottest and driest deserts of the Americas, Africa, and Asia (1). Because they are often one of the few edible plants in the environment, *Prosopis* pods are widely consumed by wildlife and have been an important food resource of desert dwelling cultures throughout history (2,3). More recently, the mature pods have been used as livestock and poultry feed in Hawaii and occasionally as food in India and South America (4, P. Felker, personal communication 1982). Traditional food uses have typically involved minimal preparation, usually consisting of grinding the pods to a flour for use in unleavened breads, in gruels, or as a fermentative substrate. The compositional and nutritional attributes of the pods have been documented (5,6).

Since we were aware of these early uses, we became interested in developing applications using techniques of modern food processing appropriate for small and commercial scale industries. We therefore established an international collaborative project between workers in the US, Mexico, and Chile which will be reported upon here.

METHODS

Two different procedures have been developed for processing mesquite pods. In one process, the pods are disk milled, the resulting material sieved into pericarp flour, exocarp flour, and seed, and the seeds separated into gum and protein cotyledon fractions. The second process involves pin milling the whole pods to a flour and sieving out coarse, fibrous material. The pin milled pods were also mixed with soybean or polished oat groats, extrusion cooked, and milled to a fine flour.

Disk Milled Pods

The disk mill process is shown in figure 1. Before milling, the pods are dried in a tunnel dryer at 70 C to less than 4% moisture. Without drying, the pods are too flexible and do not mill well. The dried pods are broken using a Rietz mill into 2-5 cm pieces to facilitate handling, then milled in a Bauer Disk Mill (Model 148, size 8 disc 8114) with the gap distance set to release the seeds from their endocarp hull. The milled flour is passed through a SWECO vibrating screen sieve where the fibrous endocarp seed envelopes are removed and the seeds are separated from the pericarp flour. The seeds are then further milled, either with a Udy cyclone mill or a Strong-Scott grain tester, and the cotyledon protein separated from the seed gum and seed coat by sieving. Endocarp seed gum can be separated from seed coat by hydration, followed by treatment with low heat, abrasive milling, and sieving.

Pin Milled Pods

Whole mesquite pods were pin milled with and without toasting, with one or both mill faces turning, and with one to four passes through the mill. An Alpine pin mill was used in all cases. This mill could be operated with one or both disks rotating to provide increasingly fine flour. Multiple passes of mesquite pods through the pin mill with both disks rotating produced a fine textured flour, 73% of which passed a 100 mesh screen. When the pods were dried before milling, 67% of the flour passed through the 100 mesh screen after just one pass through the pin mill. Since each pass through the mill increased energy and handling costs, and the yield of fine flour was not substantially improved by repeated milling, it was decided that the best combination of product yield and process economics would be to dry the pods, pin mill with only one pass through the mill, and sieve (fig. 2).

In a related process, mesquite pods were pin milled with only one disk rotating and the resulting coarse flour mixed with an equal amount of either cracked soybean, polished oat groats, or a mixture of soybeans and oat groats. The mixtures were cooked in a Brady extruder at 155 C and pin milled under varing conditions. Again, one pass of the mixture through the mill gave almost as much 100 mesh flour as four passes and required less handling and energy. Attempts to cook and extrude coarse mesquite flour by itself were generally unsuccessful.

DISCUSSION

Disk Milled Pods

The compositions of the four fractions produced by disk milling are shown in table 1. Fraction A is pod exo-mesocarp material and contains most of the pod sugar and flavor components. Analysis has shown the sugar component to be over 90% sucrose. Fraction B is comprised of the endocarp seed envelopes, which are primarily fibrous material. Fraction C contains endosperm splits (the seed coat and seed gum material), and fraction D is the seed cotyledon, which is rich in protein and contains most of the seed fats.

Of these four fractions, fraction A is useful in the widest variety of applications (table 2). Its high sugar content makes fraction A an excellent source of mesquite syrup, although the ash and protein content prohibit sucrose crystallization. The sugar can also be fermented to make a pleasant tasting beverage or for ethanol production.

Fraction A is produced as a fine flour. The flour can be used in unleavened breads or wheat breads, where it has no effect on loaf volume when replacing 10% of the wheat flour, although it does provide attractive taste components. The mesquite flour, which lacks gluten and starch, can be mixed up to 50% with wheat flour to make chapatis or be drum dried into flakes. When mixed 30% with corn and deep fried, it makes an excellent tortilla chip which was preferred by a taste panel over a 100% corn chip.

Fraction B, the endocarp seed envelope, is primarily fiber and has little food value. Tests have shown it has excellent heat capacity (16999 KJ/kg) and can be burned to produce energy at a level comparable to sugarcane bagasse (17563 KJ/kg) (7). It has been proposed that this material be used for initial pod drying when processing mesquite (7).

Fraction C, which is present at about 25% of the seed weight, consists of the endosperm gum (60%) and seed coat (40%) (endosperm splits), and may have the greatest economic value of all fractions. The seed gum in this fraction is a galactomannan with a composition similar to guar gum. Mesquite gum forms highly viscous solutions at low concentrations, has viscosity characteristics comparable to guar gum (figure 3), and when mixed with 0.3% xanthan gum has viscosity superior to a comparable guar-xanthan mixture (figure 4). The seed coat in fraction C does not appear to have any nutritional or functional value.

Fraction D, the seed cotyledon, contains typical leguminous protein. Its amino acid profile is deficient in threonine and the sulfur amino acids and has an amino acid score of 55 when compared with the FAO standard (8). It forms an emulsion more stable than a comparable level of soybean protein, has typical bean taste and food applications, and presumably would have an economic value comparable to soybean protein (7).

Based on the above laboratory and pilot plant observations, a large scale mesquite processing faclity has been designed and the necessary financial investment and operating costs computed (7). The plant would have a capacity of 1000 kg/hr with processing costs estimated to be $0.47/kg for a throughput of 576 MT/season, decreasing to $0.23/kg at 2,300 MT/season in Mexico (1984 prices).

This technology, although developed with *Prosopis velutina* and *P. glandulosa* pods, is applicable with only minor modification to other *Prosopis* species such as *P. chilensis* and *P. tamarugo* (Becker, personal observation).

Pin Milled Pods

The composition of the fractions produced by pin milling and sieving are shown in table 3. The fine material (-100 mesh), which is enriched in protein (65.5%) and contains less ADF, cellulose, and lignin, was used as an ingredient in two prototype food products, a candy and a beverage.

Mesquite flour/ground peanut pressed candy was prepared in a small factory in Chihuahua City, Mexico. These candies had a distinctive mesquite taste component and a high protein and high energy content (Table 4). The candies, which sell for 30 pesos (about $0.09 at 1985 prices), have been well received in local test markets (Del Valle, 1985, personal communication).

The beverage base, a mesquite flour/soy flour "horchata" type, was prepared in a factory in Delicias, Mexico. The base can be mixed with either water or milk, and in each case makes an attractive high protein, high energy beverage (Table 5). When mixed with water it contains 40% of the protein of milk, yet is considerably cheaper and more appealing than milk, due to its sweetness and cinnamon flavor. Consumer tests and product economic studies are incomplete, but experienced food manufacturing personnel have indicated the flavor of toasted mesquite pods is a definite asset (Del Valle, personal communication). The contribution of the dietary fiber in mesquite is an additional advantage to both products.

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Table 1. Proximate composition of *Prosopis velutina* pod subfractions after disc milling[a]

Subfraction	% Protein (N x 6.25)	% Fat	% Carbohydrate	% Fiber	% Ash
Fraction A	9.5	2.0	48.0	16.0	4.5
Fraction B	6.5	1.3	6.0	45.0	3.5
Fraction C	4.0	0.0	87.7	8.0	n.a
Fraction D	64.0	8.0	n.a	4.0	4.7

a. From Saunders et al (9).

n.a - not available

Table 2. Uses of fraction A (exocarp) flour in food systems[a]

Tests	Observation/ Conditions	Conclusion
Syrup extraction	High sucrose syrup easily recovered, mesquite taste	Use as sweetener, flavoring agent
Fermentation	Alcohol produced	Liquor or energy
Composite flours		
Leavened bread	Loaf character acceptable up to 10% incorporation	Could displace 10% of flour in specialty breads
Chapatis & crackers	50% fraction A plus wheat flour	Acceptable products, flavor
Flakes	50% fraction A plus wheat flour	Acceptable flakes, flavor
	35% fraction A plus wheat flour	Optimized sheeting, strength, and crispness, good oxidative stability
Tortilla chips	20% fraction A plus corn flour	Taste panels ranked chip superior to 100% corn chip

a. For details see Meyer (7).

Table 3. Proximate composition of whole *Prosopis glandulosa* pods and subfractions prepared by pin milling

Component	% Whole Pods	% Coarse Flour + 100 mesh	% Fine Flour - 100 mesh
Moisture	4.9	1.4	2.1
Protein	11.2	9.1	13.6
Fat	1.7	1.8	2.0
Ash	4.6	3.6	4.6
ADF[1]	28.6	38.8	23.4
Cellulose	20.1	29.4	16.5
Lignin	9.1	9.4	6.9
Yield	---	44.0	56.0
Percent of total protein	---	34.3	65.7
In vitro digestibility			
Dry matter	---	38.4	---
Organic matter	---	36.8	---

1 ADF= Acid detergent fiber

Table 4. Proximate and nutritional composition of mesquite flour-peanut butter candies.

Ingredient	Percent
Mesquite flour	10
Ground peanuts	29
Powdered sucrose	60
Salt	1

	Percent	Grams per serving (a)
Protein	11	3
Fat	16	4
Sucrose	60	15
Other carbohydrates	7	2
Fiber	2	0.5
Calories		108

(a). One serving is one 25 gm bar.

Table 5. Proximate and nutritional composition of mesquite flour-soybean beverages.

Ingredient	Percent
Mesquite flour	12
Full fat soy flour	18
Sucrose	68.65
Salt	1
Cinnamon flavor	0.35

	Percent	Grams per serving (a)
Protein	8.6	3.5
Fat	4.7	1.9
Sucrose	70.9	27.5
Other carbohydrates	8.4	4.3
Fiber	2.0	0.8
Calories		158

(a). One serving is two tablespoons (40 gm) in one glass water (250 ml).

Figure 1. Flowsheet for disc milling and separation of *Prosopis velutina* pods

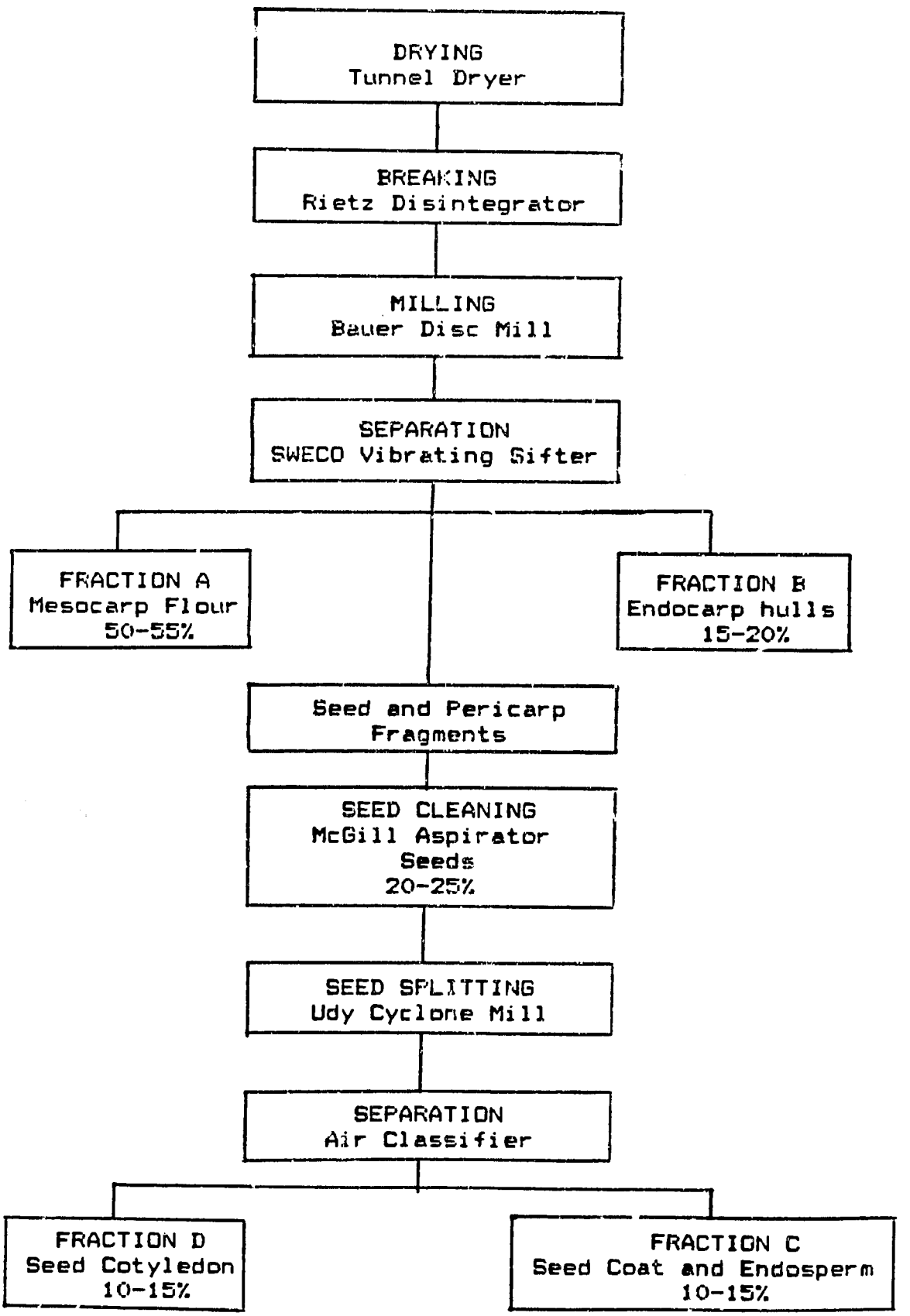


Figure 2. Flowsheet for pin milling and separation of *Prosopis velutina* pods

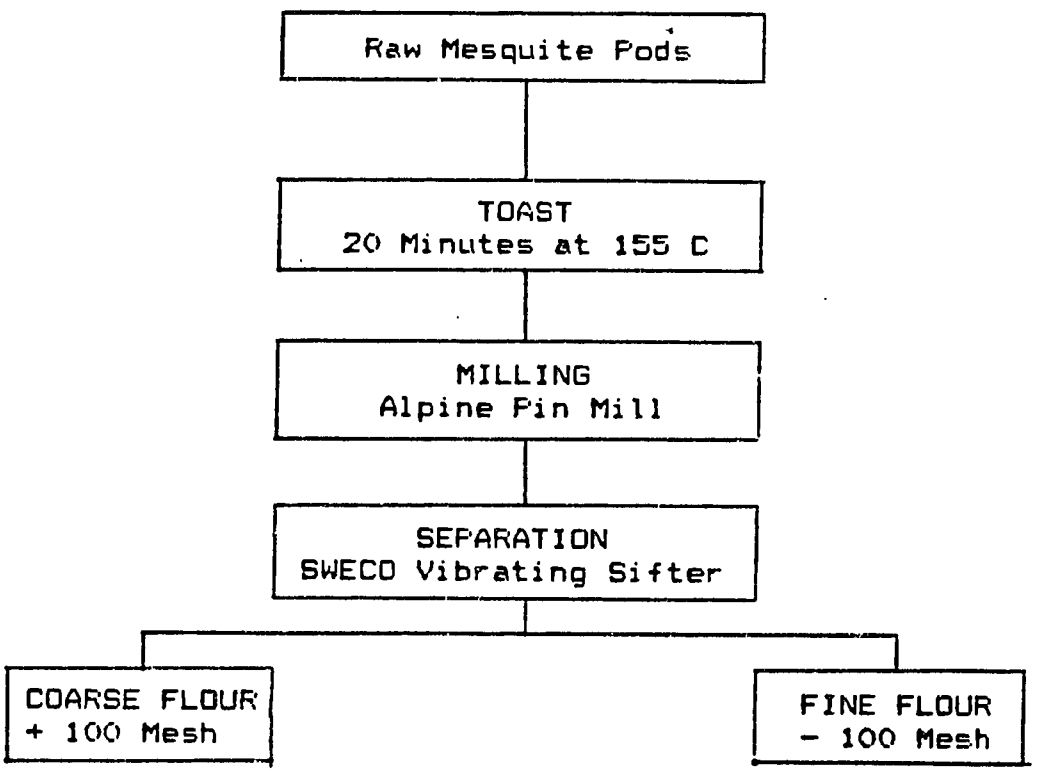
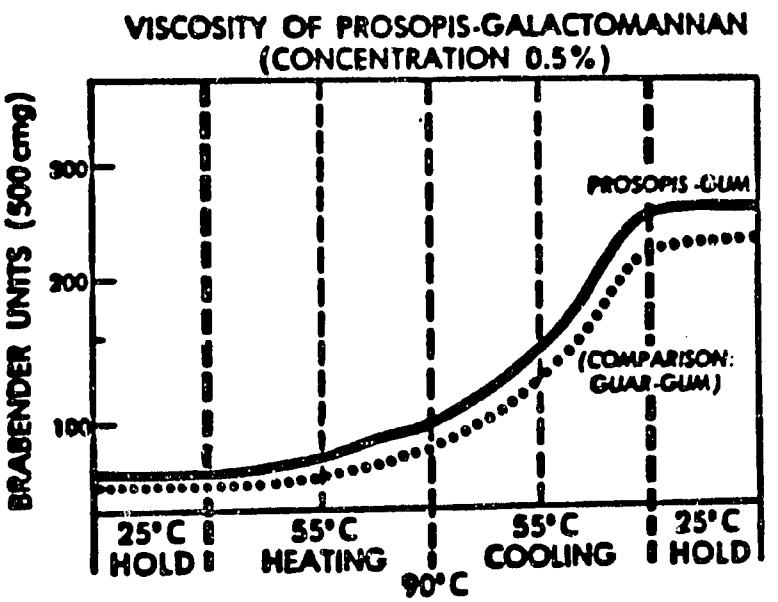
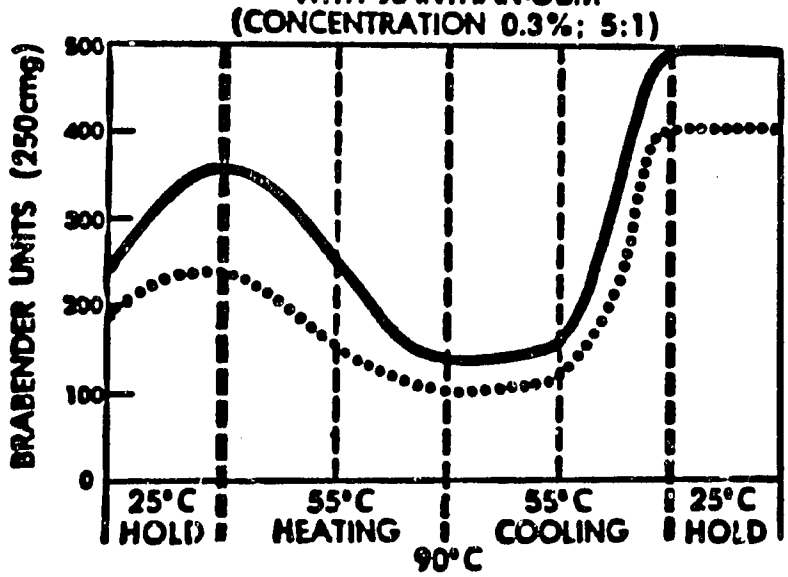


Figure 3. Viscosity of gum from mesquite (*Prosopis velutina*) seed (solid line) compared with guar gum (dotted line) with both at 0.5% concentration.

Figure 4. Effects of heating and cooling on a mesquite (*Prosopis velutina*) seed gum-xanthan mixture (solid line) compared with a guar gum-xanthan mixture (dotted line) with both at 0.3% concentration.


VISCOSITY OF PROSOPIS-GALACTOMANNAN
(CONCENTRATION 0.5%)
BRABENDER UNITS (500 cmg)
300
200
100
PROSOPIS-GUM
(COMPARISON:
GUAR-GUM)
25°C
HOLD
55°C
HEATING
90°C
55°C
COOLING
25°C
HOLD

VISCOSITY OF PROSOPIS-GALACTOMANNAN
WITH XANTHAN-GUM
(CONCENTRATION 0.3%; 5:1)



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Microstructure and Composition of Seeds of Potential New Arid Crops

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Olneya tesota, Prosopis, and Amaranthus have potential economic value as a food or feed crops for arid/semi-arid regions. Mature seeds of these genera were examined using scanning electron and fluorescence microscopy to define anatomy and localize storage structures in cells. O. tesota contained numerous protein and lipid storage bodies throughout the cotyledons. The typical leguminous seed coat was a thin structure which had a small quantity of endosperm attached to the inner surface. Protein bodies, some containing phytin inclusions, were localized in the embryos of four Prosopis species. P. chilensis was the only one of the four Prosopis examined which contained starch. All Prosopis evidenced a pleurogram on the seed coat beneath which much of the endosperm was located. A. cruentus contained abundant starch located in the perisperm, a storage structure encircled by the embryo. Protein bodies, some with phytin inclusions, were located in the A. cruentus embryo. These results have provided valuable information for development of processing methods of these seeds for use in foods.

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Legumes and a Cereal with High Methionine/Cysteine Contents

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The amino acid and chemical composition of seeds from three lesser known legume species and an African cereal with high Met + Cys contents is presented. Mesquite (*Prosopis spp.*): 41% protein, 2.5% Met + Cys. Djenkol bean (*Pithecellobium lobatum*): immature seeds, 32% protein, 2.8% Met + Cys; mature seeds, 16% protein, 3.9% Met + Cys. Tamarind seeds (*Tamarindus indica*): 18% protein, 3.5% Met + Cys. Acha (*Digitaria exilis*): 8% protein, 7.3% Met + Cys. Threonine is the first limiting amino acid for mesquite and tamarind while leucine is for Djenkol bean. The overall chemical scores are as follows: mesquite, 55; Djenkol bean, (immature) 31, (mature) 38; tamarind, 80. Tamarind seed protein has a very favorable amino acid balance and deserves further study. These legumes can not only complement cereals but supplement legumes with lower Met + Cys contents as well. The exceptionally high Met + Cys content of the cereal Acha makes it an excellent complement to legumes.

INTRODUCTION

Legumes, as protein-rich crops, are becoming increasingly important sources of plant proteins for human food and animal feed. In 1972–1974, legumes contributed 7% to the total protein supply worldwide (Hoshiai, 1980). With the ability to fix nitrogen from the atmosphere and a much higher efficiency to produce protein per unit land area than animals, legumes hold a promise of meeting protein needs of an increasing world population. However, legume proteins are of lower quality than animal protein due to the limiting amounts of Met + Cys, poor digestibility, and the presence of antinutritional factors.

The low levels of Met + Cys are usually corrected by supplementation with methionine, as in animal feed, or complementation with cereals, as practiced by various human populations. However, there are good reasons for improving the amino acid balance of legumes without resorting to these practices. Addition of methionine to foodstuffs may result in off-flavors caused by bacterial degradation and release of volatile sulfides (Damico, 1975; Bookwalter et al., 1975). Certain populations consume edible roots such as cassava and other starchy foods such as plantain as their chief carbohydrate sources instead of cereal (Bressani, 1973). Due to the very low protein content and a deficient amino acid profile of these starchy foods, which are not complementary with legumes, such population groups can benefit from legumes with improved amino acid balance.

Our objective in this study was to identify lesser known legumes and other plant seeds with high Met + Cys contents. Traditional plant breeding techniques have so far failed to improve the amino acid balance of legumes and other plant foods. Thus, there is a continuing need to identify legumes with relatively high Met + Cys to provide the genetic base for traditional plant breeding methods or the genes for the rapidly developing tools of genetic engineering. On the molecular level, the genes coding for the (Met + Cys)-rich proteins can be studied with the tools of molecular biology with the aim of enhancing the biosynthesis of such proteins. In our search, we include a cereal of reported high Met + Cys content. We present, in this paper, the amino acid and chemical composition of some lesser known legumes and an African cereal with high Met + Cys.

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MATERIALS AND METHODS

Legumes and Cereal Samples. *Prosopis velutina*, *Prosopis alba*, and *Prosopis pubescens* seeds were collected by one of us from mature trees in the Sonoran Desert of Southern California while *Prosopis chilensis*, *Prosopis tamarugo*, and *Prosopis strombulifera* seeds came from mature trees in the Atacama Desert near Pica, Chile. Sample code numbers indicate the field number of the tree and year of collection. Seeds of tamarind (*Tamarindus indica*) were from the Philippines, seeds of Djenkol bean (*Pithecellobium lobatum*) from Indonesia, and seeds of the African cereal Acha (*Digitaria exilis*) from Senegal. The seed coats of Djenkol bean and tamarind were removed before grinding the cotyledon to 80-mesh size. Seeds of *Prosopis spp.* and Acha were ground whole to 80 mesh in an Udy Mill.

Proximate Analysis. All proximate analyses were carried out according to AOAC methods (AOAC, 1980).

Amino Acid Analysis. Ether-extracted milled samples were heated in 6 N HCl under vacuum for 24 h at 110 °C. After filtering, the HCl was removed by evaporation and the amino acid composition of the acid hydrolysates determined with a Durrum amino acid analyzer, Model D-500, by the modified Spackman et al. (1958) ion-exchange method. Cysteine and methionine were determined separately as cysteic acid and methionine sulfone after per-

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Table I. Chemical Composition of Some Tropical Legume Seeds and *Digitaria exilis*[a]

	moisture, %	protein,[b] %	fat, %	ash, %	carbohydrate, %
Prosopis tamarugo	9.6	44.8	6.5	3.5	45.2
Prosopis chilensis	10.0	39.6	4.7	3.5	52.2
Prosopis velutine					
FN 1-82	10.0	46.1	6.5	3.9	43.5
FN 1-83	9.1	46.9	5.9	3.6	43.6
FN 1-84	9.4	41.4	6.3	3.5	48.8
P. velutina					
FN 12-82	8.0	44.5	4.5	3.8	47.2
FN 12-83	8.4	43.6	5.9	3.8	46.7
FN 12-84	8.7	44.0	5.2	3.8	47.0
P. velutina					
FN 25-84	8.3	44.3	5.6	3.6	46.5
Prosopis alba					
FN 24-83	8.4	41.0	5.1	3.6	50.3
FN 24-84	8.4	45.0	4.1	3.6	47.3
Prosopis pubescens	10.0	26.2	4.1	3.1	66.6
Prosopis strombulifera	8.2	30.0	5.2	3.7	61.1
Pithecellobium lobatum (Djenkol bean)					
immature	63.8	32.2	1.1	3.2	63.5
mature	29.4	15.8	1.4	2.7	81.1
Tamarindus indica (Tamarind)	9.7	17.7	9.6	2.6	70.1
Digitaria exilis (Acha)	10.9	8.2	3.0	1.7	87.1

[a] Average of duplicate analysis; results reported on moisture-free basis. [b] Protein = 6.25 × Kjeldahl nitrogen. [c] Carbohydrate by difference.

formic acid oxidation as in Moore (1963). Results are averages of duplicate determinations except as indicated. On samples where the analysis was repeated, the results varied by no more than 0.1 g/100 g of protein for, at most, three of the amino acids determined.

RESULTS

The chemical composition of the legumes we studied are shown in Table I. The 13 accessions of *Prosopis* had a mean protein content of 41.3 ± 6.0%. Eleven of the samples ranged from 39.6 to 46.8% protein, which is somewhat higher than the values reported by Becker and Grosjean (1980) for *P. velutina* (32.8%) and *Prosopis glandulosa* (34.2%) but near values from del Valle et al. (1983) for *Prosopis juliflora* (37%) and Zalfaghari and Harden (1985) for *P. glandulosa* (39.3%). The two lowest protein values of 26.2 and 30.0% are in *P. strombulifera* and *P. pubescens*, both section Strombocarpae, series Strombocarpae (Burkart, 1976), suggesting the six other species in this series may also have relatively low protein contents.

Much of the carbohydrate content of the seeds has been shown to be mucilage (Becker and Grosjean, 1980). The carbohydrate data in Table I and viscosity measurements of heated seed flour solutions (data not shown) indicate *P. strombulifera* and *P. pubescens* seeds contain more mucilage than seeds from other series.

The fat content ranged from 4.1 to 6.5% and ash from 3.1 to 3.9% in the *Prosopis* species. There was surprisingly little variation in the composition of the seed from a specific tree over the 3-year period studied.

The immature seeds of Djenkol bean have twice the protein content (32%) of the mature seed (16%). However, on a fresh basis, the two types of seeds, both consumed in Indonesia, have the same amount of protein. The protein content of the mature Djenkol bean is similar to that reported by Felker and Bandurski (1977). Tamarind seed, with the hulls excluded, has a protein content of about 18%, very close to a previous analysis (FAO, 1970). Interestingly, tamarind has a relatively high oil content of 10%. We included Acha, a tropical African cereal, in our studies because it has been reported to have a very high Met content (FAO, 1970). Its protein content of 8% is typical of cereals.

The amino acid composition of the legumes is given in Table II, and the calculated chemical score for each of the essential amino acids is presented in Table III. The average Met + Cys content of *Prosopis* is 2.5%, giving it a chemical score of 71% for the sulfur amino acids. This score is very similar to soybean and winged bean and higher than cowpea, chickpea, dry bean, and broad bean, all of which have Met + Cys as the first limiting amino acids. It is worth noting that the Met + Cys content of *Prosopis* is on the high side of the range of values for legumes (Table II) and higher than most legumes. The first limiting amino acid of *Prosopis*, however, is threonine (mean content 2.2%, chemical score 55), giving it an overall chemical score lower than soybean and winged bean and similar to dry bean.

Both samples of Djenkol bean have unusually high Cys content, although the Met content is low, the sum of the two sulfur amino acids gives them a high chemical score (80, 111) for these amino acids. However, Djenkol bean is seriously limiting in the rest of the essential amino acids. Djenkolic acid, a dimer analogue of Cys that is not metabolized like Cys is very high in Djenkol bean (2.2% of the seed) and imparts a strong sulfury odor (Armstrong and Du Vigneaud, 1947; Sastrapradja, 1984). The unusually large amount of Cys probably serves as a pool of Djenkolic acid precursor.

Tamarind seed has a very good balance of essential amino acids. Except for the first limiting amino acid threonine (chemical score 80) and valine (chemical score 98), all the essential amino acids are as high or higher than the FAO reference protein. Its favorable chemical score of 80 is higher than other legumes. The content of sulfur amino acids of 3.5%, equally divided between Met and Cys, is unusually high for legumes while its high lysine content, similar to that of soybean and winged bean, is expected for legumes.

We confirmed that Acha has a high Met content (4.8%) and a very high Met + Cys content of 7.3% (FAO, 1970). Like other cereals, it is complementary to legumes with low Met content.

DISCUSSION

The objective of this study was to identify lesser known legumes and other plant seeds with relatively high Met + Cys contents. Our data on *Prosopis*, Djenkol bean, and tamarind demonstrate the wide range of Met + Cys in legumes. On the basis of their Met + Cys contents, Djenkol bean and tamarind are high in their chemical score (80 and higher). *Prosopis* seeds are in the low 70s, putting them in the same group as soybean and winged bean, which are still higher than other legumes such as cowpea, chickpea, dry bean, and broad bean with chemical scores in the low 60s and below. However, since the first limiting amino acid of *Prosopis* seed is threonine, its overall chemical score of 55 puts it below cowpea and chickpea. Our data demonstrate that sulfur amino acids are not always the first limiting amino acids in legumes. Threonine is first limiting in *Prosopis* and tamarind, which both belong to the subfamily Mimosaceae. Djenkol bean, although high in Cys is seriously limiting in leucine and isoleucine and the rest of the essential amino acids. In the search for high Met + Cys legumes, it is therefore important to analyze the complete amino acid composition to determine imbalances in essential amino acids.

Tamarind seeds deserve further studies because of their very favorable amino acid composition. Unfortunately, tamarind seeds are not eaten in Asia, as far as we know,

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Table II. Amino Acid Composition of Some Tropical Legumes (g/100 g of Protein)[a] and *Digitaria exilis*[c]

	% N recd	Asp	Thr	Ser	Glu	Pro	Gly	Ala	Cys	Val	Met	Ile	Leu	Tyr	Phe	His	Lys	Arg	Met + Cys	Met + Cys/ 100 g of sample[c]
Prosopis tamaruge	79	7.7	2.2	3.9	17.0	4.8	4.9	3.5	1.1	3.7	1.1	2.7	5.5	2.2	3.5	2.4	4.1	11.8	2.2	0.94
Prosopis chilensis	82	8.0	2.5	4.4	17.5	5.1	5.2	3.7	1.1	3.9	1.2	2.9	5.8	2.4	3.7	2.4	4.2	11.8	2.3	0.94
Prosopis velutina																				
FN 1-82[b]	82	7.5	2.2	4.1	18.0	5.4	4.4	3.9	1.6	3.9	1.0	3.0	6.7	2.8	3.6	2.8	3.7	11.8	2.6	1.29
FN 1-83[b]	84	7.8	2.3	4.2	18.4	5.6	4.6	4.2	1.4	4.1	1.0	3.0	6.6	2.5	3.5	2.8	3.8	12.3	2.4	1.14
FN 1-84[b]	80	7.4	2.1	4.1	17.2	5.2	4.6	3.7	1.5	3.7	1.1	2.9	6.3	2.3	3.4	2.7	3.7	11.8	2.6	1.07
Prosopis velutina																				
FN 12-82[b]	82	8.3	2.1	4.0	17.6	5.4	4.7	3.7	1.5	3.8	0.6	2.9	6.3	2.6	3.5	2.7	3.7	11.0	2.1	1.05
FN 12-83[b]	84	8.2	2.2	4.2	18.1	5.7	4.9	3.9	1.7	4.0	1.0	3.1	6.7	2.6	3.5	2.8	4.0	11.9	2.7	1.18
FN 12-84[b]	83	9.1	2.2	4.2	18.0	5.5	5.1	3.8	1.6	3.8	1.0	3.0	6.4	2.5	3.4	2.7	3.8	11.4	2.6	1.12
Prosopis velutina																				
FN 25-84[b]	83	7.8	2.3	4.2	18.2	5.6	4.9	3.9	1.6	4.0	1.1	3.1	6.6	2.6	3.6	2.6	4.0	12.2	2.7	1.20
P. velutina																				
mean	83	8.0	2.2	4.1	17.9	5.5	4.7	3.9	1.6	3.9	1.0	3.0	6.5	2.5	3.5	2.7	3.8	11.8	2.5	1.17
±SD	1	0.6	0.1	0.1	0.4	0.2	0.2	0.2	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.4	0.2	1.23
Prosopis alba																				
FN 24-83[b]	86	7.8	2.4	4.4	18.5	6.0	5.0	4.1	1.8	4.1	1.1	3.3	7.0	2.5	3.6	2.7	4.2	12.2	2.9	0.64
FN 24-84[b]	81	7.6	2.2	4.1	16.7	5.7	4.6	3.8	1.7	3.8	1.1	3.8	6.4	2.4	3.4	2.5	3.8	11.7	2.8	0.59
Prosopis pubescens	78	9.2	2.4	3.6	19.0	5.5	5.1	3.9	1.2	5.1	1.0	3.1	6.1	2.6	4.0	2.7	5.3	12.7	2.2	1.02
Prosopis strombalifera	74	8.6	2.1	3.6	14.5	4.5	4.6	3.6	1.0	3.5	1.0	2.5	5.0	2.1	3.3	2.1	4.1	11.0	2.0	0.67
Pithecellebium lobatum (Djenkol Bean)																				
immature	61	5.9	1.6	3.0	5.0	12.8	1.5	1.7	2.5	1.8	0.3	1.3	2.2	0.9	3.0	4.1	2.5	2.9	2.8	0.58
mature	53	4.6	1.9	2.3	5.5	5.5	2.0	2.7	3.4	2.3	0.5	1.6	2.7	2.1	3.2	3.4	3.2	2.7	3.9	
Tamarindus indica (Tamarind)	88	12.3	3.2	5.6	16.9	4.6	5.3	5.0	1.7	4.9	1.8	5.0	8.5	4.6	5.1	2.3	7.6	7.2	3.5	
Digitaria exilis[c] (achs)	78	7.2	3.9	5.0	18.8	6.4	3.6	8.4	2.5	5.5	4.8	3.8	9.8	3.1	5.2	2.3	3.1	4.7	7.3	0.67
legumes (general)[d]		2.5–5.0							0.2–1.1	3.8–7.8	0.5–1.8	5.1–9.9	3.2–10.9	3.2–10.9	1.0–3.8		5.4–11.4			

[a] Tryptophan was not analyzed in our samples. Protein = 6.25 × Kjeldahl nitrogen. [b] Single determination. [c] Tropical cereal from Senegal. [d] Range of values from Bressani (1973). [e] Dry-weight basis.

Table III. Chemical Scores of Essential Amino Acids of Some Legumes[a]

legume	amino acid							limiting amino acid	
	Thr	Val	Met + Cys	Ile	Leu	Phe + Tyr	Lys	first	second
Prosopis spp.[b]	55	76	71	75	90	105	71	Thr	Met + Cys, Lys
Djenkol bean (*Pithecellebium lobatum*)									
immature	40	36	80	32	31	65	45	Leu	Ile
mature	48	46	111	40	38	88	58	Leu	Ile
Tamarind (*Tamerindus indica*)	80	98	100	125	121	161	138	Thr	Val
soybean[d] (*Glycine max*)	96	97	74	114	110	133	117	Met + Cys	Thr, Val
winged bean[c] (*Psophocarpus tetragonolobus*)	107	99	79	122	128	148	147	Met + Cys	Val
peanut[d] (*Arachis hypogaea*)	65	84	68	84	91	146	65	Lys, Thr	Met + Cys
cowpea[d] (*Vigna spp.*)	90	91	64	96	100	128	126	Met + Cys	Thr, Val
chickpea[d] (*Cicer arietinum*)	94	92	63	111	106	142	126	Met + Cys	Val
dry bean[d] (*Phaseolus vulgaris*)	99	93	54	105	108	127	132	Met + Cys	Val
broad bean[d] (*Vicia faba*)	84	89	44	100	101	124	119	Met + Cys	Thr

[a] Calculated according to the provisional amino acid scoring pattern (FAO/WHO, 1973). The overall chemical score for the legume is the lowest score for any of the essential amino acids. [b] Calculated from the average amino acid values of 13 *Prosopis* accessions listed in Table II. [c] Newell and Hymowitz, 1979. [d] FAO, 1970.

although the pulp, which is sour–sweet, is widely used for snacks. Our analysis is the first complete amino acid data reported and differs from an incomplete analysis reported previously (FAO, 1970). However, more samples need to be analyzed. Its protein content of 18% is in the low range for legumes but still high for plant foods. The protein yield per pod can be high, however, since the seeds are big and make up as much as 50% of the pods. Amino acid analysis of more samples, feeding studies on animals, and analysis for toxic and antinutritional factors are needed for a complete nutritional evaluation of tamarind seeds.

Our amino acid data on a large sample of *Prosopis* species show a relatively high range of Met + Cys, contrary to the very high Met content reported by Pant and Tulsiani (1969) and de Valle et al. (1983). Our analysis of del Valle's samples of *P. juliflora* showed Met + Cys values similar to our present data. Differences in the amino acid content of the *P. velutina* seeds reflect yearly climatic and tree to tree variations. The very high value of 5.6% Met reported by FAO (1970) for *Prosopis africana* remains to be verified, since we have been unable to obtain samples of this species. The interesting food uses of *Prosopis* in Mexico, Central America, and Southwestern U.S. and its high protein content make this legume worth studying further.

Felker and Bandurski (1977) reported a high chemical score for Djenkol bean (*P. lobatum*) and a generally favorable amino acid composition, contrary to our data. It is disappointing that a legume with such a high level of total sulfur amino acids has a poor balance of the other essential amino acids.

The Met content of Acha of 4.8% we are reporting is lower than the value 6.1% reported by FAO (1970). However, this Met level is still higher than any cereal included in the same report. Compared with isolated corn protein fractions of high Met contents, Acha is 30% higher than glutelin (3.7%) but 30% lower than the alcohol-soluble reduced glutelin (6.3%) (Paulis, 1982). We expect that the proteins contributing to the high Met content of Acha would have higher than 4.8% Met. The total sulfur amino acid content of 7.3% is exceptional and makes Acha a very good complement to legumes. Feeding studies are in order to verify this.

The lysine content (3.1%) of Acha is expectedly lower than that of the FAO reference protein. It is similar to wheat, lower than rice, barley, and oats and higher than maize and sorghum (Doll, 1984).

These legumes and cereal we are reporting present some uses. The legumes can be used not only to complement cereals but to supplement other legumes with lower Met + Cys content. Again, Acha should be a very good complement to legumes. Also, they can be used as a genetic base to improve the protein quality of other plant foods through traditional plant breeding or molecular biology techniques, as it is expected that the high Met + Cys contents of these crops are due to (Met + Cys)-rich proteins.

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Registry No. L-Met, 63-68-3; L-Cys, 52-90-4; L-Thr, 72-19-5; L-Leu, 61-90-5.

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Identification of Commercial Milling Techniques to Produce High Sugar, High Fiber, High Protein, and High Galactomannan Gum Fractions from *Prosopis* Pods

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ABSTRACT

Saunders, R.M., Becker, R., Meyer, D., Del Valle, F.R., Marco, E. and Torres, M.E., 1986. Identification of commercial milling techniques to produce high sugar, high fiber, high protein, and high galactomannan gum fractions from *Prosopis* pods. *For. Ecol. Manage.*, 16: 169-180.

Prosopis velutina pods were milled into exo-mesocarp (55%), endocarp (25%), endosperm 'splits' (10%) and cotyledon (10%) fractions. These fractions had as their major components, respectively, sucrose (30-40%), fiber (35-45%), galactomannan (50-70%), and protein (56-63%). Each fraction showed potential for specific end uses in food systems. Similar results were obtained on Chilean species *P. chilensis* and *P. tamarugo*. The processes described have been used as a model for proposing a commercial process for quantities up to 1000 kg h^{-1} of pods. Pin-milling followed by particle size fractionation of raw, toasted, or extruded *P. velutina* pods yielded flours with compositions suitable for baked foods.

INTRODUCTION

Numerous *Prosopis* species are known, occurring in the Americas, Africa and Asia (Simpson, 1977). Species have been documented that fix nitrogen, tolerate extremes of temperature, and survive in the driest of earth's deserts (Simpson, 1977). One of the highest CO_2-fixation rates recorded for trees was on *Prosopis* (Mooney et al., 1977). *Prosopis* pods are consumed widely by wild animals but have found only limited use in domesticated feed situations (Meyer, 1984). For example, jackrabbits reportedly can obtain more than 50% of their calories from *Prosopis* (Vorhies and Taylor, 1933). Talpada et al. (1982) showed

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TABLE 1

Proximate composition of whole *Prosopis* pods[a]

Species	Accession number	H_2O (%)	Protein (N×6.25) (%)	Fiber (%)	Ash (%)	Sugar (%)
Trees grown on experimental plots						
P. glandulosa	F0001	2.2	14	20	3.4	34
P. velutina	F0020	1.6	11	30	4.4	13
P. velutina	F0025	2.1	14	19	3.1	28
P. velutina	F0032	2.6	17	24	4.4	19
Mature wild or ornamental trees						
P. velutina	B0060	4.3	12	31	4.1	19
P. velutina	B0201	4.2	12	23	3.4	28
P. velutina	B0078	2.2	12	23	4.8	22
P. glandulosa	B0024	7.5	11	22	3.3	26
P. pubescens	B0219	5.9	11	17	3.8	25

[a]Samples with accession numbers with F prefix were supplied courtesy of P. Felker, Texas A & I University, Kingsville, TX and correspond to accessions described by Felker et al., 1984.

that up to 20% of a calf ration could be replaced satisfactorily by *P. juliflora* pods, and Eggler (1947) has described their use in Hawaii for feeding of cattle, donkeys, pigs and chickens.

As a food, *Prosopis* pods have been an important resource for Indian cultures during past centuries (Nabhan et al., 1979; Felger, 1977; Felger and Moser, 1971), but only in rare situations in India (Gupta et al., 1974), and Argentina and Chile (Felker, pers. commun., 1982; Meyer, 1984), do pods find food use today.

In any venture to establish *Prosopis* as a viable species, for whatever purpose, economics predicate that maximum utilization of the crop is essential. The species will be domestically cultivated only if the person or persons responsible for cultivation derive a positive economic return. One cannot rely on government subsidies indefinitely. It can be reasonably anticipated that economic return from *Prosopis* species development would be enhanced if the annual pod crop was efficiently utilized. This implies feeding to domesticated livestock, or even better yet, using the pods or a fraction of the pods as a food resource. With this premise in mind, technology has been developed for small and commercial scale industry to convert *Prosopis* pods into fractions with unique compositions and potential food uses.

Numerous publications attest to the favorable nutritive composition of *Prosopis* pods, examples of which are listed in Table 1. Although exhaustive studies have not been carried out, results to date suggest that *Prosopis* pods, in general, do not contain toxic compounds (Del Valle et al., 1983; Meyer, 1984) however

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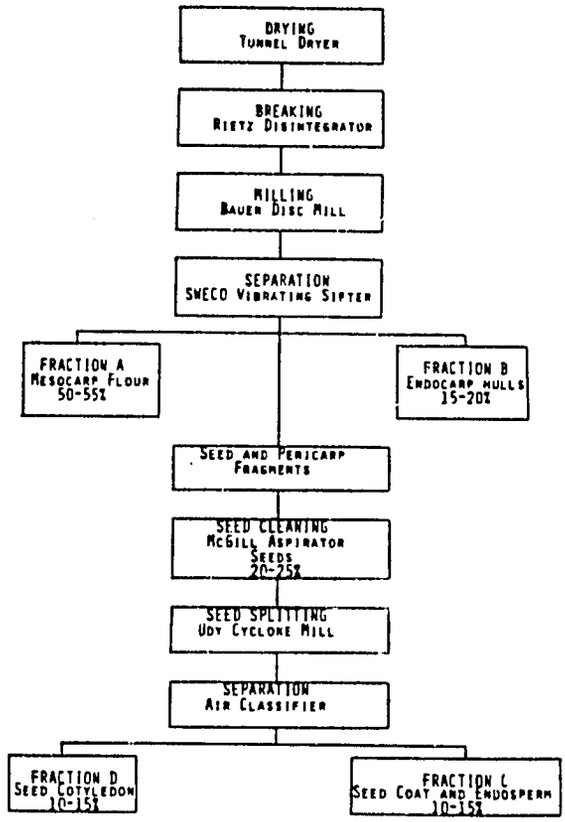

Fig. 1. Flowsheet for milling and separation of *Prosopis* pods.

some species such as *P. kuntzei* may have pods which are too hard for consumption by most animals (P. Felker, pers. commun., 1982).

METHODS

A scheme developed for milling and separation of *Prosopis* pods into subfractions is summarized in Fig. 1. Because of the high sugar content, the pods must be dried to about 5% moisture before milling. The pods are then broken into 2–5 cm pieces using a Rietz Disintegrator, at slow speed to avoid releasing seeds. A Bauer disk mill (Model 148, size 8, disc 8114, gap-setting 40, speed 3450 rpm) proved to be the optimum system for milling the pod pieces into subfractions A plus B plus seeds (Fig. 1). A vibrating screen sifter (Sweco, top screen, 4.8 mm round holes; bottom screen, 1.0 mm square holes) separated the milled mixture. The endocarp hulls (fraction B, Fig. 1) were retained on the top screen, while the seeds, plus fraction A, and some pericarp fragments passed through. The seeds and pericarp fragments were retained by the lower

TABLE 2

Process yield and composition of *Prosopis velutina* pod subfractions after milling

Fraction and process yield	Protein (N×6.25) (%)	Fat (%)	Carbohydrate (%)	Fiber (%)	Ash (%)
A (exo-mesocarp) 50-55%	9.5 (6-11)[a]	2.0 (0.8-4)	48 (25-58)[b]	16 (10-23)	4.5 (3.7-4.9)
B (endocarp) 15-20%	6.5 (4-9)	1.3 (0.8-1.8)	6 (3-11)[b]	45 (39-55)	3.5 (3.3-3.9)
C (endosperm splits) 10-15%	4 (n.a.)	0	87.7 (n.a.)[c]	8 (n.a.)	n.a.
D (cotyledon) 10-15%	64 (59-66)	8 (5-11)	n.a.	4 (3-6)	4.7 (4-5)

[a]Lower/upper range of results.
[b]Mono- and disaccharides.
[c]Galactomannan gum.
n.a.: not available.

screen, whereas fraction A passed through the screen. The seeds were cleaned from pericarp fragments by separation in a cyclone (McGill Laboratory aspirator, 66-17721). Cleaned seeds at this stage have been scarified by the mill, and since this is essential for a high germination rate (>90%), are thus well suited for planting in forestry programs.

Seed splitting was accomplished in a Udy cyclone mill (steel impeller, rough abrasive frame, 2000 rpm), or in a graintester (Strong-Scott, 17810). The milled seeds split into two fractions, the outer seedcoat/endosperm fraction C (endosperm splits) and the inner cotyledon fraction D. The economically important seed mucilage occurs in the endosperm and is later separated from the testa. About 15% of the seed-splitting product is an inseparable fines mixture of fractions C (endosperm splits) and D (cotyledon), which is actually added to fraction B, whereas 85% of the seeds is converted to fractions C and D which are easily separable by air classification.

RESULTS AND DISCUSSION

The process yield, average composition, and range in analysis, where available, of the milling fractions are listed in Table 2. The wide range in composition reflects the extreme diversity in pod morphology encountered with *Prosopis*.

Fraction A

This floury fraction has a particle size of less than 1 mm, and further reduction in particle size can be obtained by milling on conventional mills. The dominant component of this fraction consists of simple sugars, which have

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TABLE 3

Tests, observations and conclusions on use of *Prosopis* exomesocarp (fraction A) in food systems[a]

Tests	Observation/conditions	Conclusion
Sucrose extraction	Sugar syrup easily recovered	Potential use as sweetner
Fermentation	Alcohol produced	Liquor or energy
Composite flours		
Leavened bread	Loaf character acceptance up to 10% incorporation	Could displace 10% of flour in U.S. bread types
Chapatis and crackers	50% Fraction A plus wheat flour	Acceptable products
Flakes	50% Fraction A plus wheat flour	Acceptable flakes
	35% Fraction A plus wheat flour	Optimized sheeting, strength, and crispness Good oxidative stability
Tortilla Chips	20% Fraction A plus corn	Taste panels ranked chip superior to 100% corn chip

[a]Complete details are described by Meyer (1984).

been identified as sucrose (92%), glucose (3%) and fructose (5%) (Meyer, 1984). Elsewhere, Malhotra and Misra (1981) reported an ellagic acid glycoside in *P. juliflora*, Becker and Grosjean (1980) found traces of raffinose and inositol in *P. glandulosa* and *P. velutina*, and Shalaby et al. (1976) reported traces of rhamnose, galactose, and glucuronic acid in *P. stephaniana*.

Thorough tests (Table 3) have been conducted on use of fraction A as a partial substitute for wheat flour in cereal-based products. Because of the absence of gluten and starch, fraction A finds use only where structural integrity of the product is not an essential characteristic. Its distinctive taste makes it an interesting component for use in sweetening and in certain baked products.

Fraction B

Chemical analysis indicates that this material would not find use as human food. It could find use as a low-quality cattle food, or alternatively as a combustion source. Its burning value, on a dry weight basis, was found to be 16,999 kJ kg^{-1} (Meyer, 1984), which compares favorably with an average value of 16,300 kJ kg^{-1} (dry basis) for cereal crop residues, or 13,860 kJ kg^{-1} (dry basis) for sugarcane bagasse. Possibly in a *Prosopis* processing plant, burning this material would provide energy for initial pod drying.

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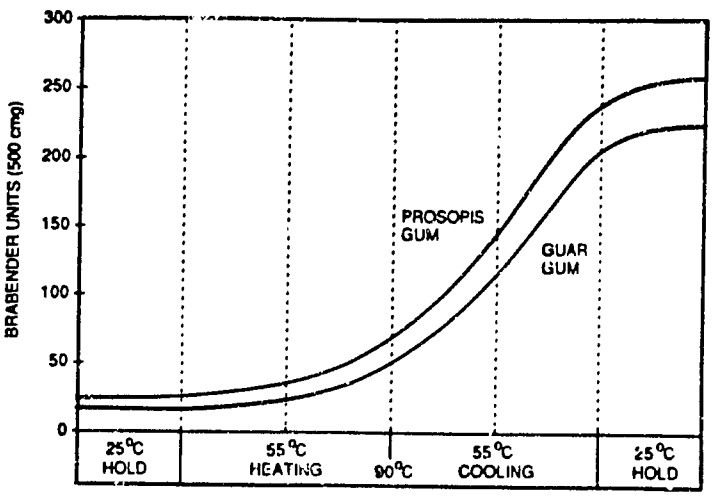

Fig. 2. Viscosity of *Prosopis velutina* galactomannan (0.5%), and comparison with guar gum.

Fraction C

Examination of the endosperm splits revealed approximately 40% seed coat and 60% endosperm. It is unlikely that the seed coats have any functional or nutritional value, but the endosperm, which contains galactomannan gum, could be of considerable economic value. Galactomannan was separable from the splits by an aqueous process, producing gum of 85–95% purity, yield 60%.

In situations where lower purity (40–65%) would be acceptable, dry milling separation can be employed (Meyer, 1984). Galactomannan gums are used in industries as widely diverse as oil-well drilling, pharmaceuticals, food, and pet-food (Whistler and BeMiller, 1959). The gum chosen for a given application depends on two criteria: functional characteristics and price. The functional quality of purified *Prosopis* galactomannan is very close to that of guar galactomannan, the most common of these gums (Fig. 2). In water, the galactomannan causes excellent viscosity increases, and displays thermal stabilities, either alone or in a mixture with xanthan, analogous to those displayed by guar and guar-xanthan (Meyer et al., 1982). These characteristics indicate the economic value, and utility of *Prosopis* gum should be similar to those of guar gum.

Fraction D

This fraction comprises the cotyledons and germ of the *Prosopis* seed. Its main constituents are protein and fat, and, by virtue of the amino acid composition of its protein, it would be expected to find food use where protein content and quality need to be enhanced. Mesquite seed protein has a sulfur amino acid content (Met and Cys) similar to soy protein, but a lower threo-

TABLE 4

Equipment list for a *Prosopis* processing plant

Item[a]	Quantity	Equipment	Item	Quantity	Equipment
1.01	1	Drying tunnel	1.02	lot	Heating equipment
1.03	2	Containers for 1.01	1.04	1	Belt conveyor
1.05	1	Belt conveyor			
2.01	1	Inlet hopper	2.02	1	Single roll crusher
2.03	1	Outlet hopper for 2.02	2.04	1	Conveying line
2.05	lot	Spouting	2.06	1	Stone mill
2.07	1	Outlet hopper			
3.01	2	Suction conveying line	3.02	lot	Spouting
3.03	1	Grain separator	3.04	lot	Spouting
3.05	2	Aspirator for 3.03	3.06	1	Strato huller
3.07	1	Hopper	3.08	1	Screw conveyor
4.01	4	Hopper	4.02	4	Screw conveyors
4.03	lot	Spouting	4.04	1	Grinder
4.05	1	Outlet hopper	4.06	1	Conveying line
4.07	lot	Spouting	4.08	1	Screener
4.09	lot	Spouting	4.10	1	Hopper
4.11	1	Screw conveyor	4.12	lot	Spouting
4.13	lot	Spouting			
5.01	1	Suction conveying line	5.02	lot	Material distributor
5.03	1	Finished product bin	5.04	3	Finished product bin
5.05	4	Screw conveyors	5.06	lot	Spouting
5.07	1	Inlet hopper	5.08	1	Autom. net weigher
5.09	1	Belt conveyor	5.10	1	Bag closer
5.11	1	Reel-type suspension			
6.01	lot	Ductwork	6.02	1	High pressure fan
6.03	1	Filter	6.04	1	Hopper
6.05	1	Airlock package	6.06	1	Exhaust fan

[a]Item numbers refer to Fig. 3.

nine level. After defatting, *Prosopis* fraction D displayed functional characteristics little different from soy protein concentrate (Meyer, 1984). These characteristics included protein solubility, whipping properties, and emulsifying properties. Such properties indicate a value and utility for *Prosopis* fraction D comparable to soy protein concentrate.

Based on the observations above, a design has been developed for a commercial plant capable of processing 1000 kg h^{-1} of pods. The plant requirements and layout are summarized in Table 4 and Fig. 3. An economic analysis of costs associated with such a processing plant, and the production costs that

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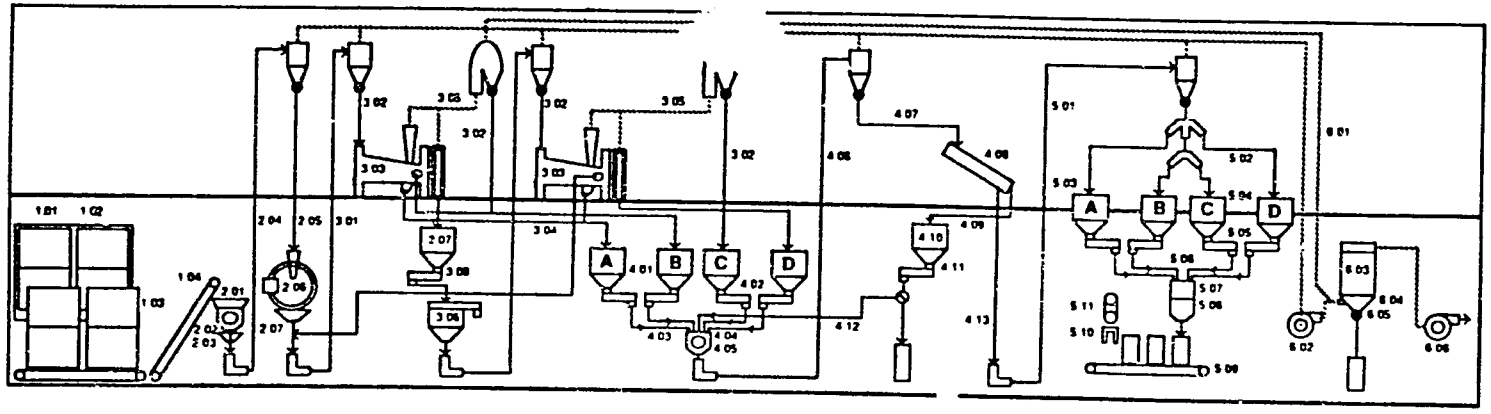

Fig. 3. Lay-out for a *Prosopis* processing plant with a capacity of 1000 kg h^{-1}. Numbers refer to Table 4.

TABLE 5

Yield and protein content of fractions derived by pin-milling and fractionation of *Prosopis velutina* pods

Process	% Yield and (protein content) of fractions		
	45 mesh	100 mesh	> 100 mesh
Raw *Prosopis*			
1 pass	42.9	20.7	36.4 (22.9)
4 passes	45.6	8.6	45.8
Extruded *Prosopis*			
1 pass	36.3	12.0 (7.2)	51.7 (23.5)
4 passes	20.8	6.8	73.2
Toasted *Prosopis*			
1 pass	27.1	7.9	65.0 (17.2)
4 passes	17.8	5.8	76.4

would be anticipated for fractions A, B, C, and D, is available (Meyer, 1984). Processing costs per metric ton of *Prosopis velutina* pods were estimated in 1984 to be 47 ¢ per kg at a throughput of 576 t per season, decreasing to 23 ¢ per kg at a throughput of 2,300 t per season in Mexico.

With only minor modifications, the technology described above for *Prosopis velutina* has been successfully extended to similar processing of *P. chilensis* and *P. tamarugo*. This is of critical importance, since *Prosopis* pods from different species differ considerably in size, shape and chemical composition, which would be expected to radically affect processing performance.

In addition to the process described above, an alternative scheme for conversion of *Prosopis* pods into nutritious subfractions has been developed. Whole *Prosopis velutina* pods were ground in an Alpine pin-mill (1–4 times), either raw, or after being toasted or extruded. The fines (smaller than 100 mesh) fraction increased with the number of passes through the mill. Protein concentration was higher in the fines, while fiber was lower. The composition of the fines fraction is indicative of their use in food systems. Preliminary results are summarized in Tables 5 and 6.

Other modifications of these basic processes are possible. For example, a hammer mill might replace the pin mill if it is thorough enough to break the seeds so they do not pass through the alimentary system without digestion. Also, the digestibility of feed mixtures is often improved by heat treatments, so various methods of toasting or extrusion could be chosen.

CONCLUSIONS

The above data demonstrate the feasibility of processing *Prosopis* pods into economically valuable subfractions. The process scheme that produces four

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TABLE 6

Composition of fines (> 100 mesh) fraction from pin-milling and fractionation of *Prosopis velutina* pods[a]

Process	Moisture (%)	Protein (%)	Fat (%)	Fiber[b] (%)
Raw *Prosopis*	6.8	17.2	5.3	13.2
Extruded *Prosopis*	5.9	24.9	11.4	12.7
Toasted *Prosopis*	5.5	18.1	6.0	20.1

[a]Four passes through mill.
[b]Acid-detergent fiber.

subfractions offers the widest range of products based on technology suitable for small businesses or developing countries. A complete plant layout to process 1000 kg pods per hour has been described for this process. The most economically important product of this fractionation would probably be the seed gum fraction, although all pod fractions would undoubtedly need to contribute to the economic success of the process.

The second process scheme utilizes simplified technology but does not promote isolation of the seed gum. This process would be expected to produce a smaller variety of products at lower costs.

Both processing schemes described here provide a range of products which can be derived from *Prosopis* pods. Alteration of treatment conditions would be expected to provide an even greater range of compositions and potential uses.

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Processing, Composition, Nutritional Evaluation, and Utilization of Mesquite (*Prosopis spp.*) Pods as a Raw Material for the Food Industry[1]

Daniel Meyer, Robert Becker,* M. R. Gumbmann, Pran Vohra, H. Neukom, and Robin M. Saunders

Mesquite pods (*Prosopis spp.*) were milled in a Bauer disc mill and mechanically separated into four fractions. Fraction A, the exo mesocarp powder, contained most of the pod sugar and flavor components. It was useful as a starting material for sugar syrup and as an ingredient in breads, crackers, and chapatis. Fraction B, the endocarp hulls, was comprised mainly of fiber, with little food value. The seed mucilage/seed coat was separated as fraction C. Gum from this fraction has a galactose to mannose ratio and food applications similar to guar gum. The protein-rich seed cotyledon was separated as fraction D and found to have uses typical of bean protein. This protein is nutritionally limiting in tyrosine and methionine/cysteine. The PER of uncooked pods and seeds was found to be 0.71 and 0.69, respectively. Both pods and seeds had reduced PER's and metabolizable energy values from chick feeding studies after cooking, probably due to the seed gum.

INTRODUCTION

There are 44 *Prosopis spp.* of leguminous plants that occur worldwide in arid and semiarid zones. *Prosopis spp.* grow wild, require little water, fix nitrogen, and depending on species and growing conditions occur as trees or shrubs. The plants produce large amounts of indehiscent pods that many former cultures utilized as an important food staple. Pod yields of 10000 kg/ha have been projected from cultivated trees in an established orchard (Felker, 1979). *Prosopis* biology has been reviewed by Simpson (1977) and its ecology by Felker (1979).

Use of *Prosopis* pods as a modern food source has been suggested by several recent chemical and nutritional studies (Becker and Grosjean, 1980; Del Valle et al., 1983; Zolfaghari and Harden, 1985). The whole pod is 11–17% protein and 13–34% sugar, with the protein being concentrated in the seed (26–37% of the seed) and the sugar, which is mainly sucrose, residing in the pod pericarp. The seed also contains a galactomannan gum similar to guar gum. We therefore became interested in methods to isolate these pod components and to determine their nutritional characteristics and possible uses in food products.

EXPERIMENTAL SECTION

Processing and Fractionation. Mature *Prosopis velutina* pods were collected from beneath trees in the Salton Sea area of California, transported to the laboratory, and stored frozen until processed by the scheme shown in Figure 1. Before milling, the pods were air-dried overnight on trays in a Taylor tunnel dryer at 70 °C with an air velocity of 250 m/min. Pod rehydration was rapid, depending on ambient relative humidity, so milling and separations were performed in a dry room (8% RH). The dried pods were then broken into 1–3-cm-long pieces by one pass through a chopper mill such as a Rietz disintegrator operated at 500 rpm.

The broken pods were milled in a Bauer disc mill, size

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[1]A portion of this work was performed as part of the requirement for the Ph.D. degree of D.M.

Table I. Proximate Composition of *P. velutina* Pods and Pod Fractions (%)

sample	typ rec,[a] %	total sugars	protein (N × 6.25)	fat	crude fiber	ash
whole pods	100	22	12	2.5	22	3.5
fraction A	53	48.0	9.5	2.0	16.0	4.5
fraction B	15	6.0	6.5	1.3	45.0	3.5
fraction C	13	87.7	0.0	0.0	8.0	na
seed coat	40[c]	na[b]	0.0	na	na	na
endosperm gum	60[c]	na	0.0	0.0	na	na
fraction D	15	na	61.0	8.0	4.0	4.7

[a]Percent recovery from fraction C. [b]na = not available. [c]Typical recovery.

Table II. Amino Acid Composition of Fractions A, B, and D (mg/g of N)[a]

amino acid	fraction A	fraction B	fraction D	FAD provisional score
aspartic acid	866	666	505	
threonine	197	190	146	250
serine	236	284	253	
glutamic acid	762	1029	1236	
proline	481	350	445	
glycine	263	301	276	
alanine	240	249	252	
cysteine	83	91	106	
valine	299	270	242	310
methionine	54	19	61[b]	220
isoleucine	165	207	196	250
leucine	399	416	437	440
tyrosine	161	175	165	
phenylalanine	165	233	235[c]	380
histidine	135	163	187	
lysine	216	285	253	340
arginine	533	533	832	

[a]Tryptophan not determined. [b]Met + Cys. [c]Phe + Tyr.

Table III. Dietary Fiber Composition of Fractions A and B (%)

fiber	fraction A	fraction B
dietary	35.3	61.6
crude	16.0	45.0
neutral detergent	23.3	69.0
std dev	0.7	3.5
acid detergent	24.7	53.7
std dev	1.0	2.8
lignin	5.7	9.8
std dev	0.8	0.8
cellulose	14.6	41.0
std dev	1.0	2.2

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Table IV. Characteristics of Mesquite Fraction B

material	burning value, BTU/kg as is	burning value, BTU/kg dry-wt basis	% C	% H	% O	% S	% P	% ash
fraction B	15 277	16 082	44	6.5	44	0	0.13	3.3
fraction B1, >40 mesh	15 675	16 500	44	6.3	46	0	0.05	3.0
fraction B2, <40 mesh	16 101	16 949	45	6.6	42	0	0.23	3.5
sawdust	16 414	18 238	50	6.4	42	0.06		0.86
sugar cane bagasse	8 300	16 600						
rice straw	10 480	13 100						
cereal crop residues	13 090	15 400						

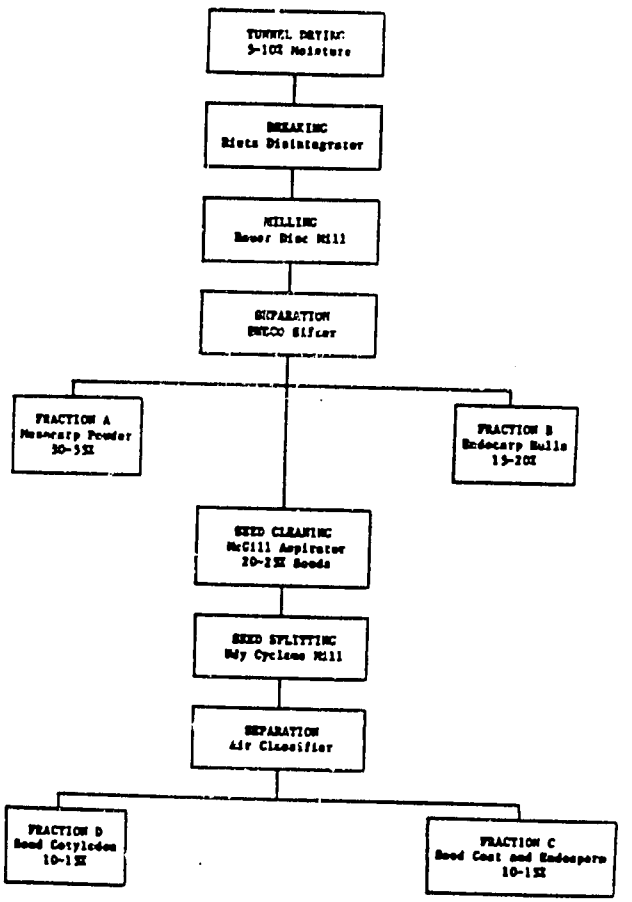

Figure 1. Flowsheet for milling and separation of *Prosopis* pods.

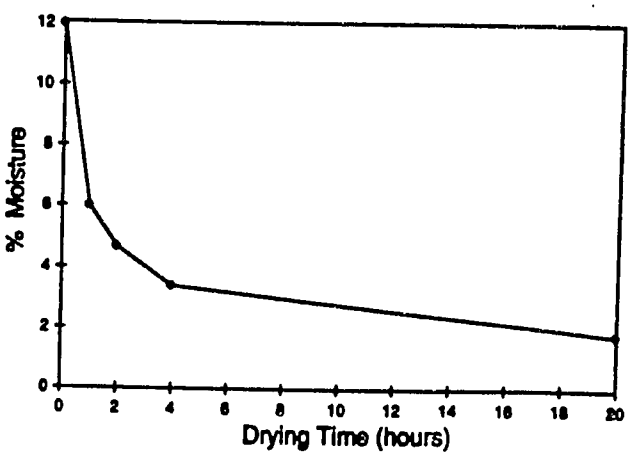

Figure 2. Drying curve of *P. velutina* pods at 70 °C.

8, using #8114 disks and operated at a speed of 3450 rpm. The disk gap was adjusted, depending on the pod size of each lot, so that the endocarp hulls were opened but the seeds were not broken.

The milled pods were immediately fractionated on a continuous Sweco vibrating separator equipped with an upper screen of 4.8-mm-round holes and a lower screen of 1.0-mm-square holes. The endocarp hulls (fraction B) were retained by the upper screen, the seeds along with some pericarp material were retained by the lower screen, and all fine material (fraction A) passed through the screens. Fraction A was used as produced.

The seed pericarp material from the lower screen was further separated with a McGill laboratory aspirator, Model 6C, with adjustable air flows, to produce a seed fraction and a pericarp fraction. The pericarp fragments were combined with the endocarp hulls in fraction B.

Either a Udy cyclone mill or a Strong-Scott grain tester was used to separate the seed into two fractions (the seed cotyledon and the seed endosperm). These devices function by throwing the seeds into the unit's frame, causing them to break into endosperm splits (seed coat with endosperm; fraction C) and cotyledon and germ (fraction D). These fractions were separated by multiple passes through the McGill aspirator or by using an air classifier.

Table V. Carbohydrate Composition of *P. velutina* Endosperm Mucilage, Fraction C (Ratio 1.56 Mann/Gal)

monosaccharide	concn, %	monosaccharide	concn, %
rhamnose	0.23	glucose	0.59
arabinose	4.18	galactose	36.24
xylose	1.96	unknown	0.32
mannose	56.47		

Composition. The chemical compositions of the pods and pod fractions were determined by AOAC (1975) procedures. Sucrose and monosaccharides were determined on a Waters HPLC using a Waters carbohydrate column. The sugars were isocratically eluted with 80:20 acetonitrile–water and quantified with a refractive index detector (Conrad, 1976). Amino acids were determined with a Durum amino acid analyzer as in Spackman et al. (1958), with the sulfur amino acids determined after perchloric oxidation as in Moore (1963). Dietary fiber content was determined as in Saunders et al. (1973). The energy of combustion of fraction B was determined by calorimetry (AOAC, 1975). Mucilage carbohydrate composition was determined after hydrolysis with trifluoroacetic acid by gas chromatography of the trimethylsilyl esters as in Becker and Grosjean (1980). Peak identification and quantification were based on comparison of retention times and peak areas with those of known standards. Fatty acids were determined as their methyl esters with a Hewlett-Packard Model 5830A gas chromatograph using a 0.25 mm × 30 mm glass capillary column operated isothermally at 175 °C, with helium as the carrier gas and fid detection (Becker and Grosjean, 1980).

Nutrition. The protein efficiency ratio (PER) was determined by a 28-day rat feeding study using AOAC (1975) methods with diets containing 10% protein. The samples were ground to 20 mesh, autoclaved for the indicated times at 120 °C, and lyophilized. Pericarp and seed samples were mechanically separated and treated as above. The pericarp sample corresponds to combined fractions A and B; the seed sample was comprised of whole seeds before separation into fractions C and D. *Prosopis pubescens* and *Olneya tesota*, other desert legume trees, were

Table VI. Compositional Variations of Fractions

sample accession no.	% total sugar		% protein			% fat			% crude fiber		ratio[a] Mann:Gal	ratio[b] % C:% D
	A	B	A	B	D	A	B	D	A	B	C	
FN 1	45.6	9.4	10.4	5.0	56.1	2.2	1.4	9.6	12.6	46.2	1.14	0.71
FN 2	54.2	10.6	9.9	6.9	52.0	1.6	1.0	9.4	11.6	45.6	1.22	1.12
FN 5	43.2	4.4	8.4	4.3	60.4	1.7	1.3	7.8	14.2	54.8	1.99	0.71
FN 12	43.4	4.3	9.1	9.1	56.3	1.8	1.7	8.0	19.3	40.4	1.26	0.56
FN 15	50.2	6.5	7.7	5.7	56.9	2.8	1.4	7.5	14.6	41.6	1.14	0.71
FN 15/30	47.0	8.8	8.9	6.5	56.2	2.3	1.8	9.0	13.2	41.4	1.38	0.60
FN 16	39.9	5.7	7.4	5.9	57.7	1.3	1.2	7.7	14.9	45.7	1.37	0.66
FN 17	41.9	7.6	10.2	6.8	57.1	1.7	1.1	7.2	16.5	48.8	1.52	1.00
FN 23	52.3	5.3	5.7	4.6	59.2	1.6	0.8	7.5	13.0	57.7	1.22	1.10
12 A	48.2	7.3	9.1	5.7	56.3	1.6	1.2	6.2	12.9	41.1	1.40	0.50
12 B	46.2	5.7	8.9	6.3	55.6	2.7	1.1	8.0	10.1	46.6	1.43	0.69
12/8	50.0	5.9	7.1	4.9	55.6	2.1	1.0	9.3	14.3	47.1	1.24	0.69
3/38	49.6	11.0	7.7	7.5	59.1	1.3	1.1	7.0	13.6	39.4	1.31	0.74
18/19 M	56.4	5.8	7.8	6.9	60.7	1.4	0.9	7.3	11.1	46.2	1.36	0.80
X	39.0	7.0	8.7	5.8	57.9	2.9	1.2	7.4	16.3	44.0	1.04	0.74
X2	46.8	4.2	9.0	6.1	56.6	1.7	1.7	6.9	17.0	39.0	-	0.60
mean	47.1	6.8	8.50	6.2	57.1	1.9	1.3	7.8	14.1	45.0	1.34	0.75
std dev	4.9	2.1	1.2	1.2	2.1	0.5	0.4	1.0	2.4	4.5	0.22	0.18
%	10.4	31.3	14.1	19.4	3.7	26.0	34.6	12.7	17.0	10.0	16.4	24.0

[a] Weight mannose in gum divided by weight of galactose. [b] Weight percent of fraction C divided by weight percent of fraction D.

Table VII. Fatty Acid Composition of Fraction D

fatty acid	concn, %
myristic acid (C 14:0)	1.1
palmitic acid (C 16:0)	13.7
stearic acid (C 18:0)	4.6
oleic acid (C 18:1)	24.5
linoleic acid (C 18:2)	46.7
linolenic acid (C 18:3)	4.6

Table VIII. Protein Efficiency Ratio (PER) and Digestibility of Pods and Seeds from Desert Plants

sample	adjusted PER[a]	% digestibility[b] diet	% digestibility[b] nitrogen
P. velutina			
pods, uncooked	0.71	66	56
pods, autoclaved			
5 min	0.63	64	57
10 min	0.61	65	55
20 min	0.55	45	44
seeds, uncooked	0.69	86	64
seeds, autoclaved 10 min	0.63	85	58
pericarp, uncooked	0.32	63	49
P. pubescens			
screwbeans			
pods, uncooked	−0.32	44	19
pods, autoclaved 10 min	−1.35	40	4
O. tesota			
desert ironwood			
seeds, uncooked	0.15	89	81
seeds, autoclaved 10 min	0.46	85	74

[a] PER (protein efficiency ratio) = weight gain/protein intake. [b] Digestibility: diet = (feed intake − fecal weight)/feed intake × 100. Nitrogen = (N intake − fecal N)/N intake × 100. Pooled data, from 7th through 14th test days.

Table IX. Metabolizable Energy Values and Body Weights of Chickens Fed Whole Pods

feedstuff	metabolizable energy, kcal/g
P. velutina pods	
uncooked, 20% of diet	1.65
cooked, 20% of diet	0.70
corn	3.40
oats	2.66
alfalfa meal	1.41
wheat bran	1.19

feedstuff	av body wt, g
control	400
P. velutina pods	
uncooked, 20% of diet	360
uncooked, 40% of diet	260
autoclaved, 20% of diet	335
autoclaved, 40% of diet	348

included for comparison. All diets were compared to an ANRC casein diet containing appropriately adjusted amounts of fiber and corrected to a PER of 2.50.

The chick feeding experiments were performed with *P. velutina* pods ground to 20 mesh, autoclaved 10 min at 120 °C, and substituted into chick diets (Vohra et al., 1982). Literature values for other common feedstuffs are shown for comparison (Schaible, 1970). The metabolizable energy (ME) of a feed was calculated as the gross energy of the feed less the amount lost in the excreta.

Products. Mesquite syrup was prepared by suspending 20 g of fraction A in 200 mL of water, heating to 80 °C for 20 min, and filtering through cheesecloth and then through S and S #602 filter paper. The filtrate was heated to 80 °C, calcium oxide added to 2% level, the resultant mixture held at 80 °C for 25 min, cooled to 25 °C, and centrifuged for 20 min at 12000 rpm, and the supernatant decanted.

Table X. Composition of Bread and Crackers Using Mesquite Fractions

Bread

100 parts whole wheat Peavey flour with 0–25% mesquite fraction A
3 parts shortening
2 parts NaCl
4 parts sugar (or mesquite syrup)
3 parts yeast
59 parts water

procedure: add ingredients to water, mix 5 min, ferment 105 min at 20 °C (90% RH); 1st punch, fold dough, ferment 20 min; 2nd punch, roll dough and make two loaves, ferment 55 min; bake 25 min at 220 °C

Chapitas and Crackers

100 g of wheat flour
100 g of mesquite fraction A
112 mL of water
9 g of shortening
2 g of gum

procedure: dissolve gum in water, mix flours and shortening, and add to water; pin-mix 5 min and fork-mix 10 min; roll dough until 3 mm thick, cut shapes as desired; bake 15 min at 180 °C or bake 30 s/side on griddle or deep fry in vegetable oil 20 s each side at 200 °C

Gaseous carbon dioxide was bubbled through the supernatant for 5 min, the solution was centrifuged for 20 min at 12 000 rpm, and the supernatant was made 2% in activated charcoal with stirring for 5 min. After centrifuging, the decanted supernatant was concentrated in a rotary evaporator to 12.5% sucrose (refractive index 1.3515).

Tortilla chips were made from 100 parts of processed corn flour (Masa), 2 parts of salt, and 100 parts of water. Corn flour was replaced with various percentages of mesquite fraction A, while water was reduced by 5 parts for each 10 parts of fraction A. Warm water (50 °C) was added to the dry mix and the dough mixed for 5 min and rolled into 1.5-mm-thick sheets. The sheets of dough were cut into 2 cm × 5 cm pieces and pierced with a fork and the pieces deep fried 25 s on each side in partially hydrogenated soy oil (Crisco) at 210 °C.

Chapatis were prepared with equal amounts of whole wheat flour and fraction A. Water, shortening, and gum were added for smoother texture, and the mixture was baked on a griddle for 1 min on each side.

Drum-dried flakes were prepared with mesquite fraction A, which had been milled to pass a 1-mm screen. The mesquite fraction A was combined with equal amounts of whole wheat flour, mixed 5 min with enough water or dilute mesquite syrup to form a thick slurry, and drum dried. The drum dryer was operated at a drum temperature of 145 °C at 20 psig of stream pressure, gap of 0.016 in., and drum speed of 0.52 rpm. Rancidity of the drum-dried samples was measured as the hexanal value by headspace determination on samples stored in the dark at 38 °C for 16 weeks (Fritsch, 1977).

RESULTS AND DISCUSSION

Drying, Milling, and Separation. The milling and separation process shown in Figure 1 was designed to yield fractions with optimum economic value (mesocarp flour, gum, seed cotyledon) while removing less valuable components (fiber). A critical step in this process is drying the pods. If the pods contain more than about 4% moisture, they become flexible and the pod sugar becomes sticky (hygroscopic), which makes milling impossible with most mills.

The drying curve of typical *P. velutina* pods is shown in Figure 2. Drying temperatures above 75 °C resulted in severe browning of the pods with little improvement in drying time; temperatures below 65 °C required much longer drying times. The dried pods were broken in the Rietz disintegrator to facilitate feeding into the Bauer mill.

Several other types of mills were tested before selection of the Bauer disc mill. A corregated roller mill opened less than half of the endocarp hulls and tended to break the seeds. Hammer mills and pin mills invariably broke most of the seeds into small pieces. These mills may be useful to mill pods into a homogeneous mixture but could probably not be used in applications where whole seeds are desired. The Bauer disc mill has the advantage of producing up to 85% of the seeds intact, allowing easy separation. It also scarifies the seeds, which promotes rehydration and germination, a significant advantage in reforestation applications. Additionally, the intact seeds can be easily milled to produce seed cotyledon and seed mucilage, both economically important fractions.

The milled pods from the disk mill were readily separated by the SWECO vibrating sifter. The screens chosen worked well for *P. velutina* and *Prosopis chilensis* pods, but *Prosopis tamarugo* and *P. pubescens* pods require somewhat smaller screens. During milling the fractions were inspected for unopened endocarp hulls or excessive broken seed material, indicating the need for mill adjustment (disk gap, speed). Fractions A and B were useful as obtained from the separator, but these fractions can be easily milled to smaller particle size in almost any mill for special applications.

The seed fraction from the SWECO vibrating sifter contains from 5 to 20% pericarp fragments, depending on the mill adjustment, which can be separated with almost any air classifier.

After the pericarp material was removed, the seeds were next milled with either the Udy cyclone mill or Strong-Scott grain tester. The Udy mill is more efficient but requires more operator attention and fine tuning than the Strong-Scott mill. Both mills produced some fine material that is primarily cotyledon fragments. Seeds typically consisted of 45% by weight fraction C (seed coat and endosperm) and 55% fraction D (seed cotyledon).

Composition. The proximate composition of the fractions is shown in Table I. The recovery and composition of the mill fractions varied, depending on the quality of the starting material and mill adjustments, but these figures are considered representative. The exo mesocarp powder (fraction A) was the preponderant fraction from the pod and contained most of the pod sugar with lesser amounts of fiber and protein. Analysis by HPLC shows the sugar is 92% sucrose, 3% glucose, and 5% fructose (data not shown). Fraction A is the sweetest fraction (Table I) and also contains most of the flavor components. The protein in fraction A is limiting in the sulfur amino acids methionine and cysteine (Table II). Considerable amounts of dietary fiber are present in fraction A (Table III).

Fraction B is primarily fibrous material (Tables I–IV) with a caloric content near that of sugar cane bagasse. Its protein composition is similar to that in fraction A in that the sulfur amino acids are nutritionally limiting, followed by threonine (Table II).

Fraction C is made up of seed coat and endosperm gum. Before milling, the whole seeds comprise 20–25% of the pod (Figure 1). About 85% of the seeds is recovered in the milling process. When the recovered seeds are milled, 42% is fraction C and 56% fraction D. Fraction C is comprised of about 40% seed coat and 60% gum. The seed gum is a galactomannan gum with an average mannose to galactose ratio of 1.34 ± 0.22 (Tables V and VI; Meyer et al. (1985)).

Fraction D is seed cotyledon and seed germ. It contains large amounts of protein, most of the seed fat, small

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Table XI. Characteristics of *Prosopis* Flours in Cereal Products

product	opt amt of added mesquite flour, %	remarks	effects of inc amts
bread, wheat flour + fraction A	10	sweet, favorable color	over 25% fraction A hay taste, astringent compct loaf, coarse
bread, wheat flour + mesquite syrup	10	satisfactory taste	too dark
bread, wheat flour + fraction B	15	neutral	too coarse, gritty
crackers + fraction A	5	neutral	off-flavor
chapitas + fraction A	50	good taste, good appearance	poor texture
tortillas + fraction A	20	better than pure corn chips	poor texture
drum-dried wheat flour + fraction A	50	better taste and oxidn stability than wheat flour alone	poor sheeting, browning

amounts of fiber, and ash similar to the other fractions. This protein is nutritionally limiting in threonine followed by cysteine and methionine (Table II). Fraction D contains about 4.5% free sugars (data not shown). The fat (8%) is made of linoleic, oleic, and palmitic acids and small amounts of other fatty acids (Table VII).

The milling process (Figure 1) was tested on pod samples from 16 different trees (Table VI). Fraction A was invariably richest in sugars, fraction B richest in fiber, fraction C in gum, and fraction D in protein and oil. The uniform quality of the gum was demonstrated by the generally constant mannose to galactose ratio. Variations in the yield of gum are shown by the ratio of % C:% D. These data demonstrate that the milling and separation process will produce fractions of predictable composition and that gum compositional variations between trees are not extreme.

Nutrition. The whole pods were fed to rats to determine the PER (Table VIII). Uncooked pods had a PER of 0.71, and autoclaving the ground pods for 20 min reduced the PER to 0.55. This reduction in PER is possibly due to increased solubilization and accompanying increased water absorption and bulking effects of the heated seed mucilage and its subsequent interference in digestion. These heated extracts were found to be free of trypsin inhibitor, hemagglutinins, and cyanogenic compounds (data not shown). Similar galactomannan gums are thought to interfere with nitrogen retention in poultry by reducing the food to feces transit time (Vohra et al., 1979).

Related effects were observed in the chick studies, where cooking decreased the ME from 1.65 to 0.70 (Table IX). The uncooked *P. velutina* pod flour ME is less than that of the traditional cereal grains such as corn and oats but more than the ME of high-fiber commodities such as wheat bran. The weight gain of the chicks fed cooked *Prosopis* flour was also reduced, which when considered with the ME and PER data indicates that whole pods should not be cooked before use as a feed. This does not hold for pod fractions free of seed mucilage, which should be cooked.

Uses and Applications of Pod Fractions. The mesocarp flour (Fraction A) is the preponderant fraction from the pods. Chemical analysis revealed that sucrose is the major component, followed by fiber and protein, so use of fraction A as a raw material for sucrose recovery is an obvious application.

Unfortunately, the high soluble protein and mineral contents of mesquite fraction A would interfere with the crystallization and purification of sucrose, so it was decided not to compete directly with refined sugar but to prepare a "special" mesquite sugar or syrup such as a maple syrup.

The syrup preparation procedure described in the Experimental Section was used on 500-g lots of fraction A, with an initial sucrose concentration of 42%, to produce a syrup containing 13% sucrose and 1.2% protein with a 71% yield of extracted sucrose. The syrup contained 17 ppm Zn, 4 ppm Mg, 20 ppm Fe, 2 ppm Cu, 0.4% Ca, and 0.1% Na. Pilot plant lots were concentrated to over 50% sucrose.

The mesquite syrup had an attractive taste, comparable to maple syrup, but a more pronounced aroma. It could likely be used as an ingredient for soft drinks, as a pancake syrup, or as a general-purpose liquid sweetener.

The precipitates and filtrates from syrup production are fibrous byproducts that may be useful for animal feed.

Fraction A, mesquite syrup, and fraction B were also tested as bakery ingredients using the recipes shown in Table X with substitution of various percentages of mesquite fractions for wheat flour or sugar. Characteristics of mesquite breads are shown in Table XI. A taste panel of untrained judges found that substitution of 10% mesquite flour A could be detected but was still acceptable. At concentrations of 25% fraction A and above, the bread tasted astringent and the texture was too coarse. Intermediate levels of fraction A received mixed scores (data not shown).

Incorporation of 10% mesquite syrup reduced bread loaf volume and increased crumb firmness while maintaining a satisfactory taste.

Use of fraction A in crackers was not very successful. Oven baking and griddle baking resulted in products with a similar appearance, but both had an undesirable off-taste. Deep frying gave a crunchier product with no off-flavor, but the crackers were not very stable due to the high oil content. The chapatis had a very acceptable taste, texture, and appearance and were undoubtedly the best products made from the fractions. Amino acid analysis demonstrated that the 50% wheat–50% mesquite fraction A blend had a better balance than either individual product (data not shown).

A variety of cooking conditions for tortillas using fraction A were examined. Samples deep fried below 200 °C for less than 20 s were chewy (worse with higher fraction A concentrations); those deep fried above 210 °C for longer than 30 s were overcooked (worse with higher fraction A concentration). In both cases higher temperature/shorter time gave a better product than lower temperature/longer time.

A taste panel of 29 adults tested two tortilla recipes of 10:90 and 20:80 mesquite fraction A to corn flour (data not shown). Chips containing 20% mesquite fraction A were judged as better than pure corn chips in all organoleptic categories (color, texture, aroma, taste). Judges who regularly consumed corn chips preferred the higher level of mesquite incorporation. Mesquite corn chips scored even higher in all categories when the judges were aware mesquite was in the chips.

Drum-dried flakes based on cereal or composite flours are widely used in the U.S. as food ingredients. Drum-dried flakes can be produced at any level of mesquite fraction A incorporation up to about 50% fraction A:50% wheat flour. A dilute mesquite syrup may replace the water. Samples containing mesquite fractions had 4–62% lower hexanal values than a 100% wheat control. The oxidation stability and overall good taste and appearance of the mesquite containing flakes make them another attractive mesquite based product.

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Breads containing 25% mesquite fraction B (milled endocarp hulls) had reduced loaf volume and increased crumb firmness. The bread was much darker than the control and had a sandy texture due to the high fiber content. Fraction B may have some use as a dietary fiber, but its high BTU value (Table IV) probably gives it more value as a fuel. In the mesquite processing plant designed by Meyer (1984), it is incinerated to supply the hot air required to dry the pods before processing.

The seed gum is the most valuable component in fraction C. Its galactose to mannose ratio and viscosity (data not shown) are close to those of guar gum so it has applications and a commercial value similar to guar, i.e. as a food thickening agent or for use in oil-drilling operations. The seed coat in fraction C could be burned as a heat source.

Fraction D has the typical beaney, nutlike taste of other legumes and would be expected to have similar food and feed uses. The protein has a lower solubility than soy protein, good foam expansion, foam stability, and emulsifying properties (Meyer, 1984).

Registry No. C (14:0), 544-63-8; C (16:0), 57-10-3; C (18:0), 57-11-4; C (18:1), 112-80-1; C (18:2), 60-33-3; C (18:3), 463-40-1; lignin, 9005-53-2; cellulose, 9004-34-6; L-rhamnose, 3615-41-6; arabinose, 147-81-9; D-xylose, 58-86-6; D-mannose, 3458-28-4; D-glucose, 50-99-7; D-galactose, 59-23-4.

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Value of Mesquite Leaves as Forage

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Summary. The nutritive value of six species or cultivars of mesquite (*Prosopis*) was investigated: *alba*, *articulata*, *chilensis*, *nigra*, *velutina* and "Ruby". Chemical analyses indicated that all of these are suitable sources of forage. However, *in vitro* digestibilities are negatively correlated with the content of phenolic compounds. Species (*alba* and *chilensis*) with high concentrations of phenolics are significantly less digestible than other species with lower phenolics content. Toxicity of the phenolic components of *P. chilensis* leaves was observed in feeding studies with weanling mice.

1. Introduction

Mesquite trees and shrubs, various species of Prosopis, are vigorous, drought and heat tolerant plants that are able to survive and even thrive in many arid parts of the world. In some of these regions mesquite leaves and pods are principal sources of forage during dry seasons.[1-3] Species of mesquite that have been reported to be useful sources of forage for cattle, sheep, goats and camels include: Prosopis juliflora in India,[4,5] P. glandulosa in the U.S.A.,[1] P. specigera D. (syn. P. cineraria L.) in India,[5,7] P. tamarugo in Chile,[8] P. chilensis in South America and India[1] and P. pallida in Australia.[1]

Detailed studies have been made of the nutritive value of mesquite seed pods for man and livestock.[3,9,10] Less is known about the value of mesquite leaves. This is a report of a study of the nutritive value of leaves from six species or cultivars of mesquite.

2. Materials and Methods

2.1. Mesquite leaves.

Fresh mesquite leaves were collected from trees planted by P. Felker at the Imperial Valley Conservation Research Center, U.S.D.A., Brawley, California. These leaves were transported on ice for 2 days before being freeze-dried. Leaves from the following Prosopis species were included: alba, articulata, chilensis, nigra, (an accession from Thermal, California, - field code "Ruby") and velutina.

2.2. Analyses.

Proximate analyses were carried out by AOAC methods.[11] Fiber and fiber component analyses were based on the procedures of Goering and Van Soest.[12] Hydrolysis for amino acid analyses was done in vacuo for 22 h at 110°C with 6N HCl.[13] A separate hydrolysis was done, after performic acid oxidation, for

cystine and methionine. Phenolic compounds were determined in 80% methanol extracts of dried leaves using the Folin-Ciocalteu reagent without added cupric ion.[14] This method is not specific for tannins but yields a measure of total phenolic compounds. Results were expressed as tannic acid equivalents.

2.3. Enzymatic digestibility

Simulated digestibility by ruminants was determined by the total solubles after enzyme (TSAE) treatment of Guggolz et al.[15] using Onozuka cellulase SS (Yakult Biochemicals Co., Nishinomiya City, Japan) and the protease Pronase (Cal Biochem., La Jolla, Calif.). An additional digestion of each sample was performed without cellulase, but with buffer and Pronase to determine the amount of material solubilized by non-cellulase components. The difference in dry matter disappearance obtained with and without cellulase (enzyme-digested carbohydrate, EDC) is a measure of the amount of material solubilized by carbohydrate-splitting enzymes.[16]

2.4. Feeding study

Freeze-dried P. chilensis leaves were used either before or after autoclaving (20 min at 115°C with 40% water, then freeze-drying) or extraction with methanol in a Soxhlet extractor. Part of the dried methanol extract (28% of leaf) was partitioned between ether and water in a separatory funnel to yield, when dried, a water dispersible fraction (85% of dry methanol extract) and an ether soluble fraction (15% of dry methanol extract).

Mesquite leaf meals and extracts were fed to weanling mice in two tests for up to 14 days. The composition of the diet was: protein from mesquite and casein as indicated, 8% corn oil, 5% added water, 3% cellulose, 2% complete vitamin mixture,[17] 5% AIN mineral mixture,[18] 20% glucose, and cornstarch to make 100%.

In the first feeding test, diets contained 10% protein from either leaf meal or casein. To the casein diets were added amounts of leaf extracts that had been obtained from the weight of leaf meal used in the leaf meal diets. In a second test, diets contained 10% protein from casein plus either 2.5 or 5.0% protein from leaf meal. The mice were weighed each day since change in body weight is a sensitive criterion for detecting toxicity in short term rodent assays.[19]

3. Results and Discussion

Analyses of mesquite leaves were compared with those of alfalfa (Medicago sativa L.), a principal cultivated forage crop in temperate climates (Table 1). The mesquite leaves, in general, contained less protein and more fiber than alfalfa but, based on these analyses, appear to be suitable sources of forage.

The essential amino acid content of leaves from the six species of mesquite leaves is listed in Table 2. In general, the content of these amino acids is similar to that of alfalfa. Amino acid content of leaf proteins has been reported to be similar regardless of source.[20] With two exceptions, P. alba and P. chilensis, the mesquite leaves contain amounts of lysine and the sulfur-amino acids comparable to those in alfalfa. It is not known whether the lower content of sulfur amino acids in P. alba and P. chilensis is intrinsic or is caused by losses during processing, possibly by the high phenolic content of these two species (see below). There was a small deficiency of isoleucine and valine in the mesquite leaves. The specific amino acid content is not particularly important if the leaves are to be used as browse for ruminant animals but is important if the leaves are to be fed to poultry or swine.

The enzymatic digestibilities and phenolics (as tannic acid equivalents) content of the mesquite leaves are listed in Table 3. Here the mesquite leaves are quite different from alfalfa,- containing 2.5 to 6.5 times as much phenolics as alfalfa. The enzymatic digestibilities are negatively correlated with phenolic content. The digestibility with cellulase plus protease (TSAE) is only 22-26% in the leaves with high phenolics content but is 39-47% in leaves containing less phenolics. Joshi et al.[7] have also reported low *in vitro* dry mater digestibilities of leaves of P. *cinerarea* caused by high tannin contents. Negative values were obtained for digestibility by cellulase alone (EDC) of leaves from the two species with the highest phenolics content. This seems to indicate that some of the added enzyme is bound by phenolic compounds in the sample and increases the weight of the residue after digestion. This was borne out by increased nitrogen contents in the residues in these two cases.

Mice fed diets with high proportions of mesquite leaf did not grow well and feed consumption generally reflected weight gain. In the first feeding test (Table 4), the mice could not survive on diets in which leaf meal was the sole source of protein. The test was therefore terminated after four days. The presence of toxic components, poor palatability and possible poor nutritive value may have contributed to this poor performance. On feeding diets containing casein plus extracts of mesquite leaf, the entire extract and the water soluble fraction were found to be equally toxic and brought about marked weight loss (Table 4). This toxicity is probably due to the high concentration of phenolic compounds which are extracted from the leaf and concentrated in the water soluble fraction. The diet containing the ether soluble fraction was able to support growth almost as well as the casein

control although some growth inhibition due to minor toxicity was evident on day 4.

Weight gains obtained on feeding 10% protein from casein and either 5 or 2.5% protein from leaf meals are shown in Table 5. The dried and autoclaved leaf meals were clearly toxic, causing severe weight loss at the 5% protein level. There was some evidence, at four days with 2.5% leaf protein, that autoclaving had reduced the toxicity slightly. This indicates the possible presence of a heat labile toxin, such as a trypsin inhibitor, in the leaf. The extracted meal was considerably less toxic but still inhibited growth when fed at the 5% protein level. It can be seen in Table 4 that the extracted meal is still not free of phenolic compounds.

4. Conclusions.

Although mesquite leaves are an important source of forage for ruminant animals in some arid parts of the world, their usefulness may be limited by their relatively high content of phenolic compounds and other toxic components. Species with lower contents of phenolics were found to be more digestible by *in vitro* enzymatic studies. *In vivo* studies with weanling mice confirmed the toxicity of leaf extracts with high concentrations of phenolic compounds, but did not give information about digestibility since the mice could not survive on dried mesquite leaf as a sole source of protein. Feeding studies with other and more mature animals might be more helpful.

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Table 1. Comparison of mesquite and alfalfa leaf compositions[a]

Analysis (% dry basis)	*Prosopis* spp. or cv.						Alfalfa
	alba	*articulata*	*chilensis*	*nigra*	(Ruby)	*velutina*	(Lucerne)
N	2.59	3.08	2.93	2.94	3.25	3.23	3.66
Crude protein	16.2	19.3	18.3	18.4	20.3	20.2	22.9
Crude fiber	25.5	25.3	25.1	28.3	20.2	27.0	20.8
Fat	6.8	11.0	6.5	11.8	8.5	10.3	10.0
Ash	6.6	5.6	4.5	4.0	3.4	5.5	3.3
Neutral detergent fiber	39.0	37.2	37.5	43.3	32.6	41.8	33.9
Acid detergent fiber	35.5	28.9	28.8	31.7	27.8	33.1	28.6
Lignin ($KMnO_4$)	7.8	7.6	6.2	4.5	6.1	7.8	7.2
Cellulose	26.6	19.8	22.0	26.2	20.2	24.5	20.0
Hemicellulose[b]	3.5	8.4	8.7	11.6	4.8	8.7	5.3

[a] Mesquite and alfalfa leaves were freeze-dried.

[b] Estimated = neutral detergent fiber-acid detergent fiber.

Table 2. Amino acid content of mesquite leaves

Amino acid (g/16g N)	*Prosopis* spp. or cv.						Alfalfa[a] (Lucerne)
	alba	*articulata*	*chilensis*	*nigra*	(Ruby)	*velutina*	
Arginine	5.04	5.29	4.61	4.55	4.99	4.35	5.04
Histidine	2.04	2.17	1.95	1.95	2.03	1.87	2.31
Isoleucine	3.60	3.97	3.52	3.79	4.06	3.48	5.05
Leucine	6.87	8.01	6.87	6.97	7.79	6.59	7.66
Lysine	5.62	6.07	5.67	5.82	6.00	5.49	6.11
Methionine	0.81	1.82	0.72	1.45	1.72	1.60	1.79
Methionine + cystine	2.20	3.37	1.98	2.89	3.33	3.27	3.06
Phenylalanine	4.94	5.27	4.82	5.05	5.07	4.60	5.24
Threonine	3.57	4.18	3.62	3.65	4.29	3.44	4.66
Valine	4.69	5.28	4.70	4.78	5.36	4.60	6.11

[a] Freeze-dried alfalfa[21]

Table 3. Enzymatic digestibility and phenolic content of mesquite leaves[a]

Prosopis spp. or cv.	TSAE[b]	EDC[c]	Tannic acid equiv.
	%	%	%
chilensis	22.3	-4.2	21.9
alba	25.6	-2.5	17.5
nigra	39.2	3.0	8.2
velutina	43.1	6.1	10.6
articulata	45.8	11.5	12.2
(Ruby)	47.0	6.3	14.0
alfalfa (Lucerne)	58.2	24.2	3.4

[a] Dry basis.

[b] TSAE = total solubles after enzyme (cellulose + protease) treatment.

[c] EDC = enzyme-digested carbohydrate.

Table 4. Weight gain of mice fed mesquite leaf as the sole source of protein or mesquite leaf extracts with casein.

Test material	Weight gain[a] Day 2		Weight gain[a] Day 4		Relative phenolics content of diet
	N	(grams)	N	(grams)	
Leaf meal[b]					
dried	6	-3.5D		--[c]	1.00
autoclaved	6	-2.3C	3	-3.7D[d]	0.91
extracted	6	-2.3C	2	-4.0D[e]	0.17
Methanol extract[f]					
entire extract	6	-1.5B	6	-2.5C	0.60
water soluble fraction	6	-1.7B	6	-2.5C[g]	0.67
ether soluble fraction	6	1.5A	6	2.3B	0.004
Casein control	6	1.7A	6	3.5A	0.00
standard error		± 0.2		± 0.3	

[a] Means with no letter in common are significantly different ($P<0.05$) (Duncan's multiple range test).[22] Initial body weight 11.3 ± 0.1g (S.E.). N = number of mice per group.

[b] Diets contained 10% protein from leaf meal (N X 6.25).

[c] Found 5 dead and 1 moribund on day 3.

[d] Found 1 dead on day 3 and 2 on day 4.

[e] Found 2 dead on day 3 and 2 on day 4.

[f] Diets contained 10% protein from casein (N X 6.25).

[g] Found 1 moribund on day 4.

Table 5. Weight gain of mice fed mesquite leaf meal in diets containing 10% protein from casein.

Test material	Weight gain (grams)[a]			
	Day 4		Day 14	
	5%[b]	2.5%[b]	5%[b]	2.5%[b]
Leaf meal				
dried	-2.8C[c]	0.3B	--[d]	7.3B
autoclaved	-2.3C	2.8A[c]	--[d]	8.6B[c]
extracted	0.8B	3.0A	8.3B	11.3A
Casein control	3.3A		12.7A	
standard error	± 0.3		± 0.5	

[a] Means within a given time with no letter in common are significantly different ($P<0.01$) (Duncan's multiple range test).[22] Initial body weight 10.5 ± 0.2g (S.E.). Number of mice per group was 6 unless otherwise noted.

[b] Diets contained 5% and 2.5% protein from leaf meal (N X 6.25) in addition to 10% protein (N X 6.25) from casein.

[c] Found 1 dead on day 4, n = 5.

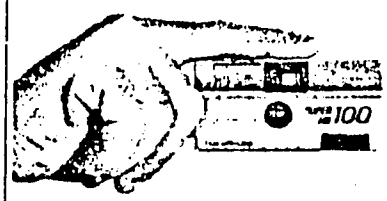
[d] Animals terminated on day 4.

Bob Becker

Developments to Watch

EDITED BY SANA SIWOLOP

IT TAKES PICTURES WITHOUT A CAMERA



Japan's Fuji Photo Film Co. has an answer for all those times when you've thought, "I should have brought my camera." It's a film package that takes pictures all by itself.

What it is, in fact, is a throwaway 110-mm camera in a paperboard box not much bigger than a regular film cartridge. But when it goes on sale in Japan on July 1, Fuji will peddle it as film with a built-in lens and shutter. The price? About $8, or slightly more than twice the cost of a 24-exposure cartridge of 110 film. It's called Fujicolor *Utsurun-desu*. In English: "It takes pictures." When it's done doing so, you return the box intact for processing.

The gadget will not replace a top-of-the-line camera. The plastic lens and shutter are preset for brightly lit outdoor scenes, so photos taken under a heavy overcast probably won't be satisfactory. Still, Fuji expects to sell a million rolls in the first year, largely at resorts, sports events, and street festivals regularly held in big Japanese cities. And it hopes that businesses will buy the product for premiums and that parents will give them to children for school field trips. Despite some English language on the box, Fuji says it has no immediate plans to offer the product in the U.S.

THE OZONE LAYER IS SHRINKING FASTER THAN EXPECTED

When chlorofluorocarbons (CFCs) were banned as aerosol propellants in 1978, scientists believed the depletion of protective ozone from the upper atmosphere would be slowed. The ozone filters out most of the sun's deadly ultraviolet radiation. Even a 1% loss could damage crops and cause 15,000 new cases of skin cancer annually in the U.S.

But new satellite data collected by the National Aeronautics & Space Administration suggest that the ozone layer is shrinking more quickly than estimated. The data show that over the past five years it has declined by approximately 2.5%—an amount scientists predicted would take 40 years. They blame the damage on the continued use of CFCs as refrigerants and industrial solvents and in the making of plastic foam. In 1984 more than 1 billion lb. of CFC—the largest amount since 1977—were emitted worldwide.

The data are already creating a stir in Washington. A Senate environmental subcommittee has scheduled hearings. And the findings may influence the Environmental Protection Agency, which is under court order to decide by next May if further controls are needed.

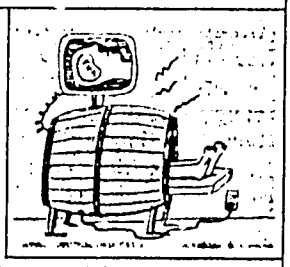
TREATING HIGH BLOOD PRESSURE WITHOUT THE SIDE EFFECTS

More than a quarter of all Americans suffer from some form of hypertension, or high blood pressure. Diuretics and a low-salt diet now fight the fluid retention that characterizes the condition. But they often cause the loss of vital potassium that can result in weakness, respiratory distress, or even stroke if not watched carefully.

In late May a team of researchers testing a substance called "atrial natriuretic peptide" or ANP, announced findings that may lead to a superior antihypertensive medication. ANP, which is produced by the heart, signals body cells to retain or secrete fluid. In early trials, California Biotechnology Inc., of Mountain View, Calif., found that injections of genetically engineered ANP showed potent diuretic powers and lowered blood pressure without sapping a patient's potassium. The substance may also prove useful in treating congestive heart failure, kidney failure, and cirrhosis.

Licensed to Wyeth Laboratories, the product—to be called Auriculin—is now entering widespread human testing. Although several major companies, including Monsanto Co., are studying ANP, CalBio is the first to test it on humans.

MAGNETIC RESONANCE FOR HOSPITALS ON A BUDGET



In the early 1980s magnetic resonance imaging (MRI) was hailed as an important medical breakthrough. Unlike X-rays, MRI let doctors look with unprecedented clarity at the body's internal organs. But MRI systems are still limited to major medical centers and well-funded stand-alone clinics. That's because they cost upward of $1 million and require special structures to contain their powerful magnetic fields.

However, hundreds of smaller community hospitals may be able to acquire MRI technology now that Resonex Inc., of Sunnyvale, Calif., has developed a lower-cost unit. Instead of the huge superconducting magnets now used, the new machine—called the Rx-4000—relies on an electromagnet. The Rx-4000's iron core shields against the strong electromagnetic field generated by the magnet, so the system doesn't have to be sheathed in 100 tons of iron or housed in a remote location. In fact, it's small enough to fit into the same size room—about 900 sq. ft.—that would be needed to hold a large, conventional X-ray machine. The company says reduced installation and operating costs allow the system to turn out images for about $400, half the cost of competing machines.

MESQUITE: THE NEXT HEALTH FOOD?

Habitués of trendy restaurants already are familiar with the pungent taste of mesquite—at many such establishments it is *de rigueur* for grills. But are we ready for mesquite tortilla chips and crackers?

Researchers at the Agriculture Dept. contend that the desert plant's seed pods are rich in protein. Since it grows where food staples such as wheat, corn, or rice can't, scientists are promoting mesquite as a valuable food source that can be grown in areas with poor soil. Taking a cue from desert dwellers who harvest the wild bean pods, they've developed an automated process for producing an inexpensive flour that is as nutritious as wheat. The flour tastes "great—a little sweet and strong," reports Robert Becker, an Agriculture Dept. chemist. In tests, consumers preferred crackers and tortilla chips made from a mixture of mesquite and wheat flour to those made with wheat alone.

PHOTOGRAPH BY WALTER CHRYNOWSKI, ILLUSTRATIONS BY MARC ROSENTHAL

Houston Chronicle
Page4, Section 5
Sunday, June 15, 1986

Sagebrush gains value

WASHINGTON (UPI) -- What cowboy ever imagined sagebrush in the American West was worth anything?

And a cowboy in West Texas would have thought a person suffered from heat stroke in the midday sun if he had told him that a pest, the mesquite tree, could produce a sweet-tasting, high-protein flour to make tortilla chips taste better.

But scientists have found wild plants from the American West have benefits no one would have dreamed.

Settlers and ranchers abused low-lying wild shrubs and viewed them as nuisances to be eliminated whenever possible. They were wrong.

Maligned wild shrubs that cover 400 million acres of the West are an important part of the region's ecosystem.

For the past 11 years, Forest Service researchers have worked to develop superior shrubs to improve range and wildlife habitats and to rehabilitate eroded lands.

The Shrub Sciences Laboratory in Provo, Utah, is the only lab in the world devoted entirely to shrub research.

Geneticists, chemists, physiologists, botanists, wildlife biologists and plant pathologists are contributing to the effort to give abused shrubs the respect they deserve as protectors of soil, wetlands and wildlife in the West.

The lab is gaining support from state, federal and university researchers.

Durant McArthur, the Forest Service project leader assigned to the Utah lab, said public attention first focused on a need to manage shrubs in the 1950s, when urban development destroyed shrublands and forced wildlife that depended on them into populated areas.

"Since then, the important role of wildland shrubs in Western ecosystems has slowly gained recognition," he said.

The mesquite tree has suffered from the same bad reputation as wild shrubs. Found on millions of acres, it forms dense, thorny thickets and crowds out grasses needed to feed cattle. If cut down, it simply grows back.

Mesquite pods have been ground by hand into flour and fermented to produce a beerlike drink or added to cattle feed.

In recent years, mesquite has been in demand as fuel to grill food at trendy American restaurants.

But Agriculture Department researchers on the mesquite tree have also developed a simple, automated procedure to convert dried mesquite pods into flour and gum that can be used as a natural thickening additive in foods.

Robert Becker, a chemist with the Agriculture Department's Western Research Center in Albany, Calif., said mesquite gum is better than guar gum that American food processors import to use as a natural thickener in ice cream, salad dressings, puddings and other foods.

In taste tests, crackers and tortilla chips containing sweet mesquite flour were preferred to those made with conventional flour alone.

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News in agriculture... by Sonja Hillgren, U-P-I farm editor in Washington.

Animal scientists say 19th century range wars were unnecessary... government economists say farm bust came from drop in land income not farming income... and new process converts mesquite tree pods into fo d.

Now... a look at today's top news on the farm front.

Animal scientists studying behavior of cattle and sheep have come to an amazing conclusion that America's 19th century range wars pitting cattle ranchers against sheep farmers were unnecessary.

People... not animals... were adversaries.

Agriculture Department scientists working at Las Cruces, New Mexico, have shown cattle and sheep exist well side by side on the same range. They are developing a thesis that cattle can be useful protectors sheep.

Normally, when sheep and cattle graze together... they ignore one another.

But scientists Clarence Hulet and Dean Anderson have found cattle and sheep behave differently if they are introduced when lambs are very young. Animal bonds become strongest when 45-year-old lambs are penned with yearling heifers for 30 days. After that, they intermingle.

Hulet... an animal physiologist... says lambs form a social bond with cattle and develop an impelling need to be close to them as they move about on the open range. Scientists believe they can take advantage of cattle's butting and kicking of strange dogs and coyotes to protect lambs from predators.

Hulet says the scientists lost nearly half their sheep to coyotes the first year they had them alone on the range. Losses dropped to around five percent with expensive electrical fences and guard dogs. Hulet says he hopes the bond between sheep and cattle can lower losses even more without fences.

The animals coexist well on the same range because cattle eat mainly grasses while sheep prefer broadleafed plants and leaves from some small shrubs.

The ideas are not new. A classic study in the 1950s and 1960s found cattle, sheep, goats and deer exist well together on the same range.

MORE MORE

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Scientists say the mesquite tree... a range pest now used to grill food at trendy restaurants... produces bean pods that can be turned into nutrient-rich foods.

Pods harvested by hand from wild plants are used on a limited basis... to produce a beer-like drink or as an additive to cattle feed. But the Agriculture Department has developed a simple procedure to convert dried mesquite pods into a high-protein flour and a gum that can be used as a natural thickening agent in food.

A scientist says the gum is better than guar gum that American food processors import to use as a natural thickener in foods.

A food-processing plant in Mexico is using the method to produce a sweet, high-energy snack food. In taste tests, crackers and tortillo chips containing mesquite flour were preferred to those made with conventional flour.

The mesquite infests Millions of acres in the American Southwest. Its advantage over other crops is that it flourishes where most other plants fail... it grows fast... and does not NOT need irrigation or fertilizer.

End Farming Today

upi 05-26-86 07:27 ped

■ Researchers at University of Gottingen are developing adhesives based on lignin from sulfite liquor and phenoloxidase produced by white rot fungi. Use of phenoloxidase has advantages of enzyme thermostability up to 70°C and storage at room temperature more than one month without loss of activity. Phenoloxidase can be produced within four days at quantities up to 100 units/mL.

Room-temperature adhesive can be produced by mixing phenoloxidase containing culture fluid with dry lignin. Because binder is very viscous, lignin must be milled before mixing and spraying procedure performed at 50°C. Particle boards joined with lignin-phenoloxidase binder reached 75% of standard versal tensile strength, so researcher is trying ways to increase strength.

Details: Annegret Haars, Institute of Forest Botany, Univ. of Gottingen, Busgenweg 2, D-3400 Gottingen, Fed. Rep. of Germany. Phone: 05 51-39 34 82.

New Products from Mesquite Pods: Mesquite, a shrub native to the southwestern United States and Mexico, may be a source of more than just woody biomass. U.S. Department of Agriculture aims at finding ways to use each component of mesquite pods: mesocarp, endocarp hulls, and seeds. They have already developed two products -- from the mesocarp they've made a sweet flour containing up to 60% sugar that could be used in food or fermented, and from the seed a gum that could compete a d thickener in $135,000/yr guar gum market. Scientists are still looking for ways to use endocarp hull, a fibrous component, and cotyledon, which is limiting in sulfur-containing amino acids as most legumes are.

In Mexico, mesquite pods are already being used in food, so getting approval for use in foods in the United States is not likely to be a problem. Mexican product is mazapan, a peanut-based confection in which ground mesquite pods (with fibers removed) can displace 10% to 15% of the peanut content.

The main problem in growing mesquite commercially in developed countries such as the United States is that labor is expensive. To mechanize process for harvest, farmers would have to prune plants so that machines could pick the pods. However, if good harvesting methods were developed, mesquite cultivation could enable lands too arid for growth of more conventional crops to become productive.

Details: Robert Becker, Research Chemist, U.S. Dept. of Agriculture, Western Regional Research Center, 800 Buchanan St., Albany, CA 94706. Phone: 415-486-3623. Or: Francisco R. Delvalle, Foundacion de Estudios Alimentarios y Nutricionales, A.C., Apartado Postal 1545 Sucursal C., Chihauhau, Chihauhau, Mexico.

SHORT NOTES

Japanese Companies: C. Ito Metals and Materials has completed demonstration plant that can process 3 tons/day of bean curd waste to generate methane. System consists of pulverizer and fermentation tank that uses anaerobic bacteria at high temperature. Details: C. Ito Metals and Materials Co., Ltd., 4, Nihonbashi-Honcho 2-chome, Chuo-ku, Tokyo, Japan. Phone: 03-639-4111. Meidensha Electric Mfg. has developed a system to produce heat and electrical power out of methane gas from fermented pig manure. Company has already supplied the system to eight different clients. Details: Meidensha Electric Mfg., 2-1-17, Osaki, Shinagawaku, Tokyo 141, Japan. Phone: 03-492-1111.

Fiber Yield Enhancement: Israeli researchers have found way to increase plant fiber content by 50% to 100% and alter length and thickness of fibers by addition of three plant hormones. Studies were done using Kenaf, a plant cultivated for fiber used in the paper industry. New process is patented in Israel, the United States, and other countries. Details: Dr. R. Aloni, Tel Aviv Univ., Ramat Aviv, 69 978 Tel Aviv, Israel. Phone: 03-420-111.

Pulping Process Control: Researcher from Yan Research has come up with a theory that describes the kinetics of lignin degradation. Overall approach emphasizes changes in molecular weight distribution as the most important information at all stages of delignification. Work will result in computer software for use in routine process control and in research. Details: Johnson F. Yan, Yan Research, P.O. Box 4115, Federal Way, WA 98063-4115. Phone: 206-952-4460.

adapted to southern parts of California, Arizona, and Texas.
Germplasm Introduction and Evaluation Lab, Beltsville, MD
Robert E. Perdue, Jr., (301) 344-2431

Lowering U.S. need to import rapeseed oil is a possible benefit from two new varieties of crambe. BelAnn and BelEnzian crambe could produce two crops per season on 22,000 acres. The new crop, being further tested in an ARS pilot project in Iowa, could replace imported rapeseed as the source of erucic acid for plastics, nylon, and high-temperature lubricants.
Germplasm Quality and Evaluation Lab, Beltsville, MD
T. Austin Campbell, (301) 344-2720

Fresh fruits and vegetables shipped in a new and improved refrigerated van will stay crisp and fresh longer. Because the van--known as the Advanced Design Perishables Trailer--provides far better air circulation than conventional refrigerated vans, produce should arrive at its destination no more than 4 to 8° warmer than when it left, according to ARS marketing specialists. Its exclusive design features allow better circulation underneath the load and provide more uniform chilling of the sides. The van has been extensively tested using long-distance shipments of lettuce, melons, grapes, oranges, and other fresh fruits and vegetables.
European Marketing Research Center
Rotterdam, The Netherlands
Tom Hinsch, 011-31-10-765-535

Puff-drying of mushrooms could solve two problems of the processed foods industry. Besides saving 40% of the energy required in conventional food-drying systems, this process allows the mushrooms to be stored indefinitely. Extended storage would allow growers to retain part of their crop to extend sales. Uncooked, the mushrooms can be eaten as a tasty, nutritious, low-calorie snack; cooked in boiling water they retain their flavor and texture. Mushrooms processed this way are tasty and inexpensive to produce. Puff-drying is also an alternative to canning, where solids, vitamins, and amino acids are lost, and to freeze-drying which is very expensive.
Eastern Research Center, Philadelphia, PA
John Sullivan/Michael Kozempel, (215) 233-6588

Lawn furniture coverings, tents, tarpaulins, and other outdoor and industrial fabrics can be improved by combining cotton with high-tenacity artificial fibers, such as glass and Kevlar. The blended fabrics are lighter, stronger, more durable to weathering, and more flame-resistant than standard all-cotton fabrics.
Southern Research Center, New Orleans
George F. Ruppenicker, (504) 589-7023

Matching the right weave with the right finish can make for stronger outdoor cotton fabrics, such as tents and awnings. All-cotton fabrics, finished with a flame-retardant treatment, can be made more durable and tear-resistant with advanced "open" weaves--like those found in baskets. Previously, tightly-woven cotton could not stand up to a large amount of chemical finish.
Southern Research Center, New Orleans
Robert J. Harper, Jr., (504) 589-7029

A nutritious, high-energy flour can be made from mesquite bean pods, using a new process developed by ARS scientists. By using standard food-processing techniques, dried pods of mesquite, a prolific range pest, are converted into high-protein, sweet-tasting flour and a gum that can be used as a natural thickening additive. Scientists found mesquite gum to be better than the guar gum U.S. processors import to thicken ice cream, salad dressings, puddings, and other foods. Taste tests proved crackers and tortilla chips made with mesquite flour preferable to those made only with conventional flours. Scientists in Chile and Mexico cooperated in the mesquite pod research, which was partially funded by the Agency for International Development. A firm in Chihuahua, Mexico, is using the process to produce various food items.
Western Research Center, Albany, CA
Robert Becker, (415) 486-3623

Scientific Research News

United States Department of Agriculture
Agricultural Research Service

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Beltsville, MD 20705

Hank Becker
(301) 344-3547

NEW PROCESS CONVERTS MESQUITE PODS INTO NUTRITIOUS FOODS

WASHINGTON--Mesquite trees--a range pest now used to grill steaks at trendy American restaurants--produce bean pods that a new process can turn into nutrient-rich foods.

"Even though mesquite has been used as a food source for hundreds of years, the bean pods are currently harv. ted from wild plants only on a very limited basis," said Dr. Robert Becker, a U.S. Department of Agriculture chemist.

He said that because harvesting is done only by hand, the process would probably be economical only in Mexico, South America and other dry regions where nutritious food sources are needed.

A simple, automated procedure, developed by Becker and colleagues, of USDA's Agricultural Research Service, converts the dried mesquite pods into a high-protein, sweet-tasting flour and a gum that can be used as a natural thickening additive in foods. Standard food-processing equipment can be used.

A food-processing plant in Chihuahua City, Mexico, is now using the method to produce a soft, sweet, high-energy snack food from compressed mesquite flour.

Previously, whole mesquite pods have been ground by hand into flour, fermented to produce a beerlike drink, or added to cattle feed.

Of the more than 40 species of mesquite in the world, most have pods that could be processed into food, Becker said. Depending on the species, pods can range in length from 1-1/2 to 10 inches, while the plants can range in size from shrubs to trees.

In the American southwest, mesquite infests millions of acres. In some places the plant forms dense, thorny thickets and crowds out grasses that are needed to feed cattle. If cut down, the plant simply grows back again.

-more-

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Certain varieties of mesquite could be grown in orchards in other countries that have climate and soil suited to the plant, Becker said.

Mesquite has several advantages over other crops that world food experts have suggested for dry areas: It flourishes in places where most other plants fail, it grows fast, and--once established--it does not need irrigation or fertilizer.

Becker said analyses at the agency's Western Research Center, Albany, Calif., showed that the natural gum in mesquite pods is better than the guar gum U.S. food processors now import to use as a natural thickener in ice cream, salad dressings, puddings and other foods.

In taste tests, crackers and tortilla chips containing some mesquite flour were preferred to those made with conventional flours alone.

Scientists in Chile and Mexico cooperated in the mesquite pod research, which was funded in part by the Agency for International Development.

# # #

CONTACT: Dr. Robert Becker, chemist, Western Research Center, Agricultural Research Service, USDA, Albany, Calif. 94710. Telephone: (415) 486-3623.

(written by Marcia Wood, Albany, Calif.)

NOTE TO EDITOR: Black and white 8 x 10 glossy photos are available on request from Anita Rogers, Photography Planning Unit, Rm. 306, Bldg. 005, BARC-West, Beltsville, Md. 20805. Telephone: (301) 344-3357.
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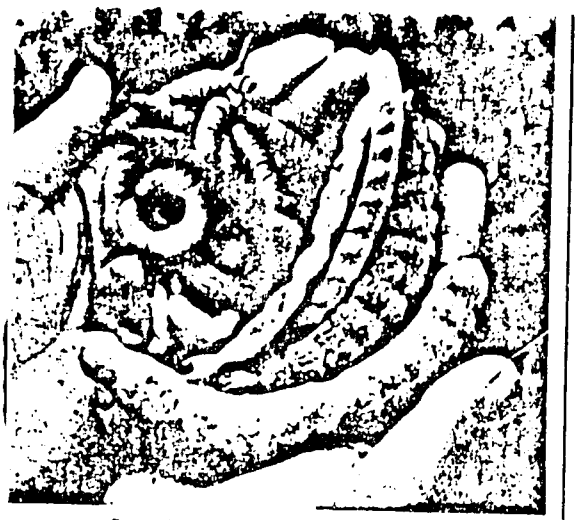

Several varieties of mesquite pods. (0586X604-2)

Mesquite Pods Into Nutritious Foods

Mesquite trees—a range pest sometimes used to charcoal-grill steaks at trendy American restaurants—produce bean pods that a new process can turn into nutrient-rich foods.

"Even though mesquite has been used as a food source for hundreds of years, the bean pods are currently harvested from wild plants only on a very limited basis," says Robert Becker, a USDA Agricultural Research Service chemist at Albany, CA.

A simple, automated procedure, developed by Becker and colleagues, converts the dried mesquite pods into a high-protein, sweet-tasting flour and a gum that can be used as a natural thickening additive in foods. Standard food-processing equipment can be used.

For flour, whole pods are ground with a disk mill, which produces a mixture of seeds and flour. The mixture is then sifted to separate the two components.

It's the seeds that contain the gum—a thin, white film that lines the inside of the hard, brown seed coat. To extract gum, seeds are split and soaked in an alkali solution. The solution, after being neutralized, is sprayed through a fine-mist nozzle into a heated chamber, where it dries as a fine powder of edible gum. This spray-drying is the same process that converts fresh milk into powdered.

Analyses at the ARS Western Research Center, Albany, CA, showed that the natural gum in mesquite pods is better than the guar gum U.S. food processors now import to use as a natural thickener in ice cream, salad dressings, puddings, and other foods.

A food-processing plant in Chihuahua City, Mexico, is now using Becker's method—with minor modifications—to produce a sweet, high-energy snack food from compressed mesquite flour.

Currently, pods are picked by hand, limiting mesquite's use as a crop to countries where labor costs are lower than in the United States.

In the American Southwest, mesquite infests millions of acres. In some places it forms dense, thorny thickets and crowds out grasses that are needed to feed cattle.

Scientists in Chile and Mexico cooperated with Becker in the mesquite pod research, which was funded in part by the U.S. International Development Cooperation Agency.—By **Marcia Wood**, ARS.

Robert Becker is at the USDA-ARS Western Research Center, 800 Buchanan St., Albany, CA 94710. ■

Carbon Dioxide Makes Heat Therapy Work

Scientists can now propagate healthy blueberry and raspberry plants from virus-infected stock by treating it with heat and carbon dioxide.

"We grow plants at 100°F Fahrenheit, which makes them develop faster than the virus can spread," says ARS plant pathologist Richard H. Converse. "Then, we take cuttings of the new growth—less than an inch long—and raise them into full-sized, virus-free plants."

But in this race to outdistance the virus, some plant species are not able to take the heat. Some even die.

"Chemical reactions double for every 14°F rise in temperature," Converse says. "So, if you try to grow a plant at 100°F that was originally growing at 86°F, it will double its respiration rate. The danger is that the plant growing at the higher temperature could soon exhaust its stored food reserves much like a runner who runs too hard and tires."

Adding carbon dioxide increases the rate of photosynthesis in plants, which increases the plant's food reserves.

Converse's findings on blueberries and raspberries are based on earlier research Australian scientists did on grapes.

The Australians had discovered that they could successfully grow plants in growth chambers at continuously high temperatures if the slight amount of carbon dioxide normally present in the air (about 350 ppm) was increased to 1,200 ppm.

"What carbon dioxide does," says Converse, "is to make the heat treatment safe. It allows some plants to grow at temperatures they would otherwise not survive and allows other plants to grow for longer periods at 100°F."

One problem with the process, says Converse, is that the longer plants are exposed to heat the greater the mutation rate. So, resulting clones should be closely examined for trueness to horticultural type.—By **Howard Sherman**, ARS.

Richard H. Converse is at the USDA-ARS Horticultural Crops Research Laboratory, 3420 Southwest Orchard St., Corvallis, OR 97330.

[A technical paper covering this subject, by R.H. Converse and R.A. George, will appear in early 1987 in volume 71 of the journal Plant Disease.] ■

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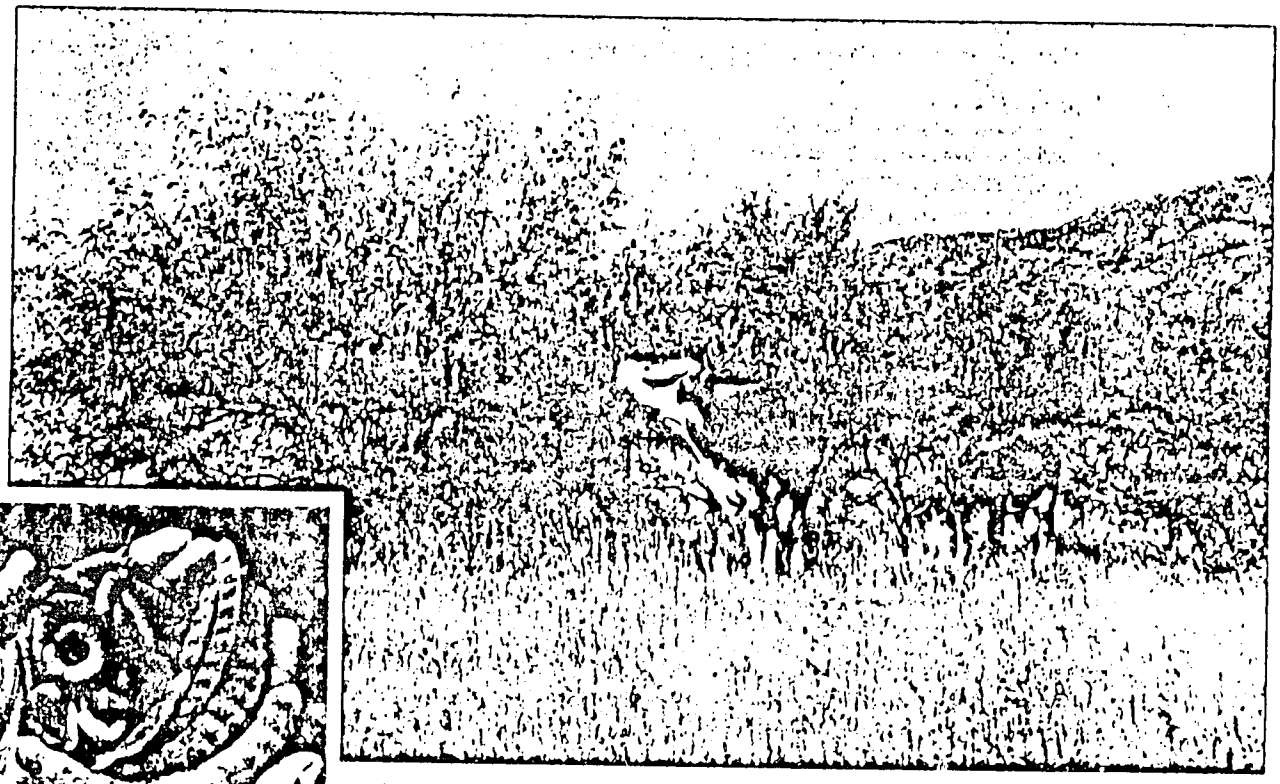
Amaranth Today
Winter 1987
Vol. 3, No. 1

A Profitable Pest



Nibbling contentedly at a mesquite pod, this Hereford cow doesn't seem to mind that the trees infest millions of acres of American rangeland. Depending on the species, pods can range in length from 1½ to 10 inches (inset), and plants can range in size from shrubs to trees.

ALBANY, Calif.—Mesquite trees, a range pest used mainly to grill steaks at trendy American restaurants, produce bean pods that can be turned into a variety of tasty, nutritious foods, says a USDA scientist.

"Even though mesquite has been used as a food source for hundreds of years, the bean pods are currently harvested from wild plants only on a very limited basis," says Dr. Robert Becker, a research chemist at USDA's Western Regional Research Center.

Using standard food-processing equipment, Becker and some of his colleagues have developed a simple, automated procedure for converting dried mesquite pods into a sweet, high-protein flour. The flour makes a tasty substitute for cocoa in brownies and other baked goods, and can be used as an "extender" in tea, coffee and hot chocolate. It also scored higher than conventional flours in USDA taste tests with crackers and tortilla chips.

As an added bonus, the pods contain a natural gum that Becker says is superior to the guar gum American food processors import as a thickener for ice cream, salad dressings, puddings and other foods.

Here To Stay—Literally

Of the more than 40 species of mesquite in the world, Becker says almost all produce edible pods. But their value has been largely overlooked for good reason: Mesquite is considered a pest in the United States. It infests millions of acres of rangeland in the Southwest, often forming dense thickets that crowd grasses needed for cattle grazing.

In fact, when cut down by ranchers, the trees often grow right back.

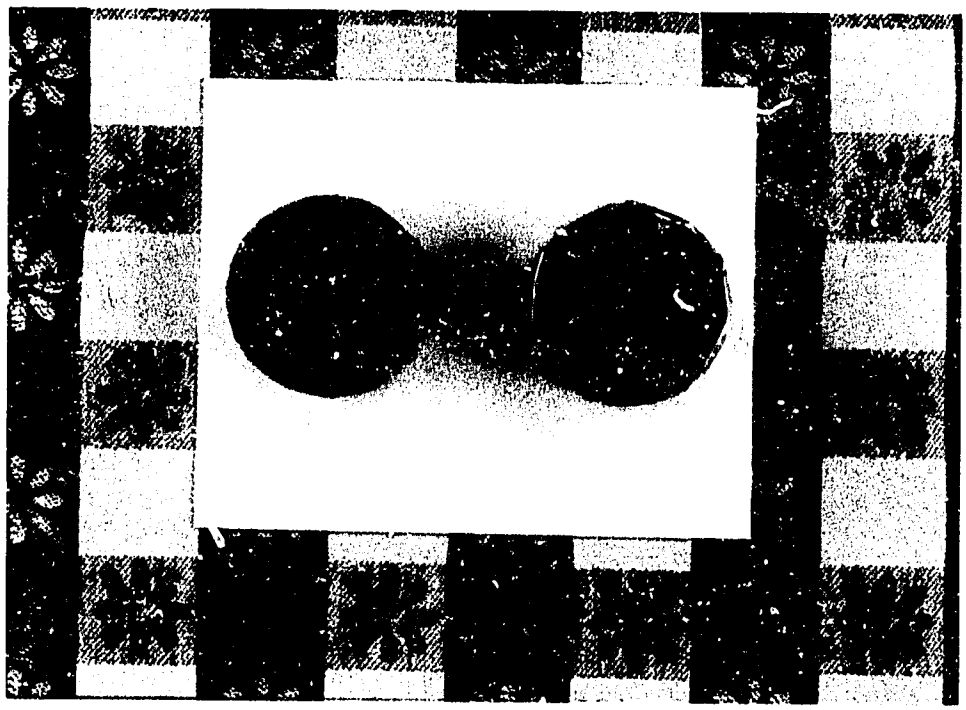
But that kind of persistence just may be an advantage, because once it's established, mesquite grows quickly and needs no fertilizer or irrigation. Certain species can even be grown in orchards where the climate and soil are suitable. "It's like citrus," says Becker, explaining that mesquite won't tolerate hard freezes.

Since mesquite currently must be harvested by hand, Becker says the new processing method may only be of immediate interest to countries in severe need of nutritious new food sources. A Mexican firm is now using the technique to produce a soft, sweet, high-energy snack food from compressed mesquite flour.

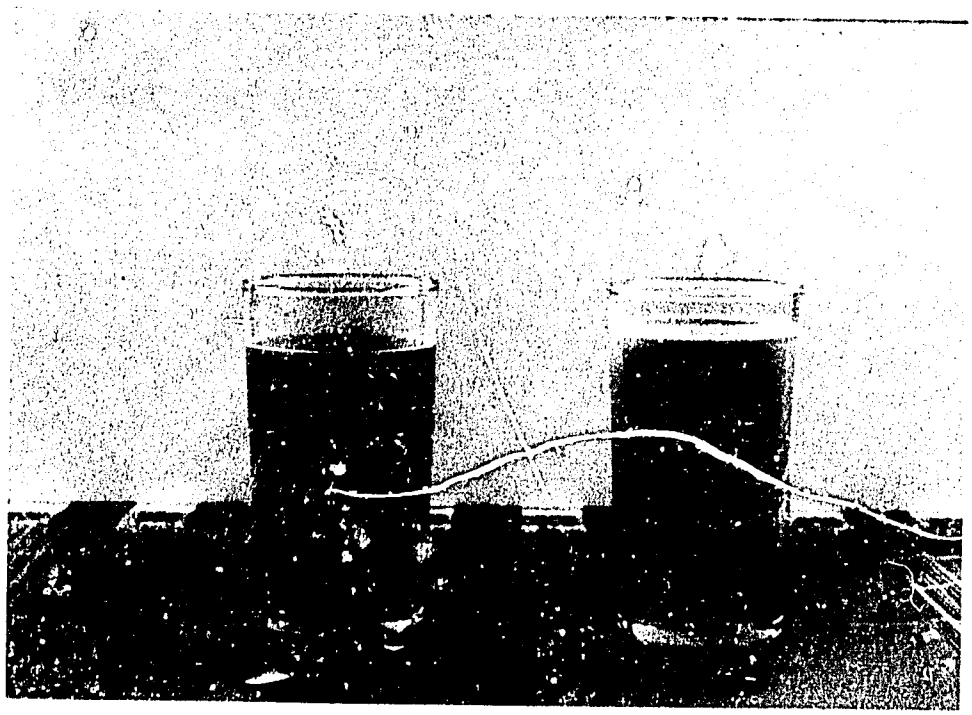
But does that rule out large-scale use by American food companies? "Not at all," he says. "It's just that we have not developed the orchards enough to get in there with mechanical harvesters."

With a little pruning and the right equipment (Becker suggests an almond picker), "I think it certainly could be mechanically harvested," he says.

APPENDIX IV: PRODUCTS



IV.b Mazapan Containing Mesquite Flour



IV.c Beverages Containing Mesquite