PD-AAT-053

931092

REPORT SUMMARY

1. Development of a Process for Preparation of Coconut Protein Products for Use in Foods. Contract csd/2804.

2. Project Coordinator, Karl F. Mattil, Principal Investigators: Carl M. Cater, J. W. Dieckert, Robert Hagenmaier, P. H. Quinitio, Texas Engineering Experiment Station, Food Protein R&D Center, Texas A&M University, College Station, Texas 77843.

3. Contract Period (as amended): 7/1/70 to 12/31/72.

000197

4. Period covered by Report: 7/1/71 to 6/30/72.

5. Total AID funding of contract to date: $334,180.00.

6. Total expenditures and obligations from inception to 6/30/71: $147,043.79.

7. Total expenditures and obligations from 7/1/71 to 6/30/72: $119,404.58.

8. Estimated expenditures for remaining contract period: $67,731.63.

NARRATIVE SUMMARY OF ACCOMPLISHMENTS AND UTILIZATION

There have been two signal accomplishments, accompanied by good forward progress over the entire broad front of this project. It can now be optimistically projected that the objectives of this contract will be fulfilled within the time period and funding stipulated. The first major accomplishment is the development of a practical, economically feasible process for the simultaneous recovery of oil and food grade protein products from fresh coconuts. The second is the evolution, as the major protein product, of a product that has analytical characteristics similar to non-fat dry milk at an estimated cost of 16¢ per pound. A pilot plant, necessary for the demonstration of commercial viability in a coconut producing country, has been designed. This information has been widely disseminated by several means, especially to key people in the coconut producing countries. There have been positive indications of their interest in moving promptly to the next essential level, i.e., the proposed pilot plant which is needed to produce sufficient sample material for a realistic product development and evaluation effort.

ANNUAL RESEARCH REPORT

A. General Backgroumd

Coconuts are an important agricultural crop in many tropical countries. In these countries large segments of the population consume diets which are inadequate in protein. It is generally believed that if their diets could be improved by supplying low-cost, nutritious protein foods, their total quality of life could be moderately to substantially improved with a cumulative benefit to the economic and social stability of their countries. The coconuts produced in 1971 contained 290 million kilograms of good quality protein. A small proportion of this protein is now used in home cookery, utilizing recovery techniques that are inefficient and wasteful. The greater proportion of the coconuts are converted to copra by techniques that render the protein unfit for human consumption. Copra is used for the recovery of coconut oil and the residual coconut meal is used in animal feeding. Coconut oil enjoys a good world market position and represents a major proportion of the export trade of the coconut producing countries. What is needed, and which is the objective of this project, is a commercially viable process for the quantitative recovery of good quality coconut oil as well as food grade protein products.

B. Statement of Project Objectives as Stated in the Contract

1. Conduct a thorough laboratory investigation, building upon the laboratory work conducted under AID Contract No. EA-84, of the physical characteristics and the chemical and nutritive properties of coconuts and/or processed coconut products;

2. Investigate the technical feasibility of key unit operations of each of the following processes: the expeller process, the dry and solvent extract process, and the wet process;

3. Evaluate the processing economics of the three above-proposed processes;

4. Investigate the food use potential of the protein products of each of the above three processes and disseminate information and limited quantities of material to other research groups in university, government and industry laboratories for product evaluation and development work;

5. Train selected scientists and engineers from coconut producing countries in the general techniques of oilseed processing and in the processing of coconuts for the recovery of food protein products;

6. Prepare selected scientists from coconut producing countries for the initiation of research activities on coconut processing at a research center in a major coconut producing nation;

7. Define the parameters for a pilot plant to demonstrate the commercial viability for the most favorable processing alternative, if warranted by investigation of the unit operations.

C. Continued Relevance of Objectives

Research to date has indicated that the over-all objective of this project is attainable. Therefore, the specific project objectives remain relevant.

D. Accomplishments to Date

There have been a number of other research groups in various places in the world who have sought to attain the objectives of this project. A cursory review of the literature would suggest that several successful processes had already been developed and that, in fact, some pilot plants and/or plants were operating. A critical survey, however, found that none of the processes ever really became commercially viable. The reasons for their lack of success varied. To a large degree an analyses of their problems and deficiencies has been a substantial assistance in planning the present research approach.

The present research approach has been to construct an anticipated process flow sheet and then identify the unit operations in the flow sheet that were preventing the process from becoming commercially successful. Research attention has been centered upon these unit operations. Economic considerations dictated that a nearly quantitative recovery of high-quality coconut oil is an essential criterion for success. Using this approach processes have been developed which appear to be technologically feasible.

It would be burdensome and non-productive to discuss the myriad of details that have gone into the evolution of the processes. Actually the processes per se are merely a means to an end. The ultimate objective of this research is marketable products. Therefore this review will

summarize quickly the evolved flow sheets of the processes; will indicate the innovations that have made the processes technologically feasible; and then will concentrate primarily upon a discussion of the products derived, including their characteristics, anticiptated costs and possible uses.

Because of current industrial activity in the Philippines, no work has been done with the expeller process and products derived therefrom. At least two Philippine companies that are producers of desiccated coconut are exploring the potential for new markets for food grade expeller-press cake. Therefore, a "wait and see" attitude has been adopted while these companies are involved in their market development efforts. Their products would be rather highly denatured and, consequently, not suitable starting materials for the preparation of protein isolates or protein beverage powders. However, this should not preclude their utility in many other types of foods, such as infant foods, some types of baked goods, and many snack items.

Our major effort and most significant accomplishment has been with an aqueous process for the separation of coconut oil and several derived protein and carbohydrate products. A simplified flow diagram for this process is appended as Page A-1. There are two alternate processes which can be accomplished in the same plant. The process to be used would be determined by the product mix that has the greatest market potential. In the process as shown, the primary target product is Number 3, called Coconut Fraction S. Note that in addition to coconut oil there are two by-products, the Fibrous Residue and the Protein Concentrate I. In the alternate process, the primary target product is

Coconut Protein AP. In this case the by-products would be the Fibrous Residue, Protein Concentrate I and Fraction AS. These primary products and by-products represent the total solids input of the process. The process was so designed for the dual reasons that it was felt that some value should be recovered for all of the solids and in so doing it would essentially eliminate any pollution potential. It is planned that the coconut shells will be used as the fuel for the plant.

The innovations that have been introduced to make this process technologically and economically feasible are listed in attachment A-2. One major problem that has been encountered by other research groups is the high absorbency of the Fibrous Residue for oil. Contrary to reported hypotheses it was found by microscopic examination that most of the oil was simply absorbed to the coconut fibers and could be nearly quantitatively removed by repeated washings. It is believed that some of the retained oil remains inside intact cells. From a practical point of view the number of washing must be limited, so we have set as our target the recovery of least 95% of the available oil. This and higher recoveries have been obtained. This recovery of oil is very important to the economics of the process and to the export economy of the coconut producing countries.

An unexpected observation was that centrifugation of coconut milk at pH 7 to 8, rather than near its isoelectric point, greatly facilitated moving both the protein and the oil into the phases where we wanted them to be. The practical recovery of coconut oil from the cream on a continuous basis was made possible by taking advantage of some fundamental principles of demulsification technology. That is, the emulsion was destabilized by inversion after adjusting the oil to moisture ratio.

Product specification sheets are appended for each of the products resulting from the aqueous process. Most of the information presented on these sheets is based on actual analyses and observations replicated often enough to provide a degree of confidence. The cost figures are shown in a way that presents the least favorable impression of the primary product. That is, all of the costs of the process have been assigned to the primary product assuming no value for the secondary by-products. Obviously, any value that could be obtained for the by-products would result, therefore, in a lowering of the cost shown for the primary product.

Coconut Fraction S (Product No. 3, appended as Page A-3) is the product presently under primary consideration. It is comprised of the soluble components of the coconut meats. By chemical analysis it resembles non-fat dry milk. Therefore it is anticipated that it may served as a substitute for non-fat dry milk in a number of uses. Fairly extensive analytical data, which should be of interest to nutritionists, are listed in the Appendix. Product No. 3 has solubility and heat stability properties that should make it suitable as a beverage base. At concentrations from 2 to 45% solids at pH 7 it was observed that 91$\pm$5% of the total solids were dissolved, as were 89$\pm$7% of the total proteins. Furthermore, an aqueous suspension at pH 7 could be heated to at least 70°C without significant heat coagulation of the proteins. As a beverage it can be fortified with appropriate levels of calcium without appreciable protein precipitation provided the calcium is added after pasteurization. No significant protein precipitation is caused by cooling an aqueous suspension to 3°C, a temperature which might be used

for storing and serving such a beverage.

Because Product No. 3 is hygroscopic it may prove to be more practical to market it as a syrup. A syrup containing 70% solids and 30% water has proven to be micobiologically stable at room temperature for in excess of one month. No solids settling or phase separation was observed in the sample. Such a syrup may prove to be a food product as well as a food ingredient.

Coconut Fraction S contains about 70% of the original protein of the coconut meats as well as most of the soluble carbohydrates and minerals. We believe it has considerable potential as nutritious, refreshing beverage. Based on reports from the literature the PER is estimated to be about 2.5. It has a sweet, fresh coconut flavor. If the beige color were considered undesirable, this could be eliminated by paring the coconuts. The cost to produce the dehydrated product is estimated to be 16¢ per pound.

Coconut Protein AP (Product No. 4, appended as Page A-4) is an alternate primary product. Were it not for the oil, this would be classed as an protein isolate. For many food uses, perhaps for most, the presence of the oil would not be a deterrent. Again, calculations were made which placed all of the burden of processing expense on this product and its cost on this basis is estimated at 59¢ per pound. If one or more food processors were to find that Coconut Protein AP had some unique and useful functional properties, this price may be no deterrent. However, viewed only as a nutritional supplement, the cost

of 59¢ per pound would not be competitive with other oilseed proteins. It should be borne in mind that in the production of Coconut Protein AP there are three by-products which have been assigned no value in arriving at this cost. Realistically, we believe that each of the by-products does have value and that the real cost will be substantially below the calculated 59¢ per pound.

The Fibrous Residue (Product No. 1 shown on Page A-5) will result as a by-product in any aqueous process. Analytical data plus microscopy indicate that this material consists mostly of fibrous, celluosic material. With its oil content and perhaps moderately digestible celluose, it probably could be used as an ingredient in animal feeds. Its good capacity for absorbing liquids could conceivably make it a useful ingredient in foods or other industrial applications. Although no value is presently being assigned to this product, we are confident that a production plant would be able to find a cash market for it.

Another by-product of either aqueous process is Protein Concentrate I (Product No. 2 on appended Page A-6). This is the portion of the solids suspended as insoluble matter in coconut milk at pH 7 and separated by centrifugation. Again, no value has been assigned to this product. With its high level of protein and substantial level of oil, it should ultimately find some market value.

Fraction AS (Product No. 5 shown on Page A-7) is a by-product of the alternate aqueous process only. This contains most of the soluble carbohydrates of the coconut meats. We have little information about this product at this time and cannot speculate as to its potential use and value.

The status of the aqueous process may be summarized as follows:

1. The key unit operations have been modified to be technically feasible.

2. The process economics indicate that Product No. 3 could be a low-cost alternate to non-fat dry milk, a beverage base or a confection.

The picture is less clear in the case of the solvent extraction of dehydrated coconut meats. Process data obtained thus far suggest that a modification of the commercial pre-press solvent extraction may be feasible. However, there are still several critical unanswered questions. The first of these is the production of a food grade raw material. It has been demonstrated that dehydrated coconut meats made by a modification of the commercial desiccation process can be used successfully. However, the desiccating plant and process are both quite expensive. Based on cost analyses there is a very strong motivation to develop a reliable system for producing food grade copra. Products made by both the Subrahmanyan acid-dip and the Bulder heat tent methods have been examined. Both methods are sufficiently promising that they bear further investigation. Neither has yet proved entirely satisfactory.

A second major problem is that some of the oil must be removed from the coconut meats prior to solvent extraction. The customary commercial method is by screw presses. As commonly practiced this pre-press effects substantial denaturation of the protein with a resultant loss in solubility. In addition to damaging some of the functional properties of the protein, the potential yield of a beverage base or an isolate would be reduced. It has been demonstrated that a substantial amount of the solubility of the

protein can be retained by modifying the operating conditions of the screw press so that they are less severe. This leaves more oil in the press-cake and has inhibited the rate of percolation of the solvent through the press-cake flakes. Further, all pre-pressing conditions which have been tested to date have effected some reduction in the protein solublity.

Summarizing, the solvent extraction process shows some promise but will recuire considerable further development work. The primary product of the solvent extraction process is Coconut Flour (Product No. 6, Page A-8). With the exception of its protein solubility, this is the same as one of the products now being manufactured in the Philippines and for which a market is being sought. The protein solubility is important in some functional applications and if the material is to be used as a base from which either a protein isolate or a protein beverage powder were to be extracted. It is estimated that the cost to produce the Coconut Flour from fresh coconuts would be 6.9¢ per pound and from food grade copra 2.6¢ per pound.

A plant for the production of protein isolate or beverage powder from coconut flour would be very much like the aqueous processing plant described above. The primary product of this process is Coconut Protein 90 (Product No. 7, Page A-9). This would be classed as a protein isolate and could be used as a supplement in dietary foods or as functional protein in appropriate food products. It is noteworthy that if this could be made from food grade copra, its cost would be about 15¢ per pound. From fresh coconuts the cost would be 50¢ per pound. It is our tentative conclusion that the economic viability of the solvent extraction approach

depends upon the technological and logistic feasiblity of producing a food grade of copra.

A continuing investigation of the physiological development of the ultra-structure of coconut meats has led to some observations which may ultimately be of considerable economic significance. Presently, coconuts are harvested on the basis of rather primitive criteria. Little thought seems to be given to harvesting the coconuts to optimize the return to the producer and the processor. While it is commonly stated that coconuts set new flowers once a month, it has been found in fact that the rate of production of inflorescences varied from 0.83 to 1.5 months over an 18 month interval of observation. Drought seemed to be the cause of the slowed inflorescence production. Two series of coconuts ovelapping in time of development provided a fortuitous experiment. In the first series the cavity of the coconut developed under favorable conditions, but the fruit matured under poor conditions. The result was a normal production of solid endosperm (meats), but early physiological disconnect (about 12 months) from the tree. In the second series the cavity of the coconut developed under poor conditions and the endosperm under good conditions. The cavity of the coconut failed to develop to normal size, but the endosperm developed at the normal rate (as measured by changes in the weight of endosperm per unit of surface area of the seed coat). The total weight of endosperm per coconut in the seeds with the stunted central cavities was much reduced. The time of physiological disconnect of the seed from the tree was about 15 to 16 months in the latter series. These observations suggest that harvesting decisions

should be based in part on the environmental conditions which have prevailed during the physiological development of the nut. It does not appear unreasonable to project that such an approach could effect a measurable increase in annual yield of both oil and protein per tree.

By electron microscopy it has been shown that the coconut meats have a maturation gradient extending from the seed coat to the central cavity of the seed. The cells bounding the central cavity appear to be undergoing dissolution, while those at the interface with the seed coat are metabolically very active. These living layers would usually be an integral part of the harvested coconut meats. Going toward the central cavity from the seed coat, the cells of the endosperm increase in size and degree of disorganization. This suggests that the tissue is undergoing senescence and that hydrolytic enzymes might be present that mediate the process. The degree of unsaturation of the fat of the cells decreases rapidly with distance from the seed coat. The character of the vacuolar protein also changes with the postion of the cells relative to the seed coat. The protein in the cells of the middle region and the inner region are in the form of crystals, but that in the cells near the seed coat is amorphous. These observations are still too preliminary to relate them to processing implications.

E. Dissemination and Utilization of Research Results

A positive effort has been made to disseminate the information obtained under this contract as widely as possible and particularly to key people in the coconut producing countries. The Quarterly Reports have been a primary mode of communication and the list of people to

whom copies are sent directly from our office is appended as Page A-10. It is our understanding that USAID/Washington also distributes copies to interested people. Mr. Philip Ruppert of the RED office in Bangkok has been summarizing the Quarterly Reports for distribution to members of the Asian Coconut Community.

Nine scientific papers have been prepared based on research conducted under this contract. These have been presented to meetings of the Third International Congress of Food Science and Technology, the Institute of Food Technologists, American Association of Cereal Chemists, American Chemical Society and the Chemical Society of the Philippines. Each has been submitted for publication in a reputable scientific journal. The abstracts of these papers are appended as A-11. Under separate cover we are forwarding four copies of each publication.

Several people from coconut producing countries have been involved in this contract research. For a period of 18 months just ended, we have been fortunate to have Mr. Peregrino Quinitio associated with this program. Mr. Quinitio was on leave from the Franklin Baker Company in the Philippines, where he is Technical Director and Quality Control Director. He is considered to be one of the leading authorities in the Philippines in the processing of coconuts. The fact that his company has been willing to assume the major loss of his services for 18 months is some measure of the degree of interest of this one food company. With this report we express to Mr. Quinitio our appreciation for his services as a project leader. In addition, we have had three trainees who have been screened and recommended to us by representatives of AID in Manila

and in Bangkok. These scientists, Miss Sukoncheun Verasestakul, Mr. Leo Mamicpic and Mr. Bernabe Mauban, were recent graduates in chemistry and were each employed in coconut-related work.

The only effective means to implement the use of the research results developed under this contract is to construct a demonstration pilot plant in a coconut producing country. The technological feasibility of the unit operations has been adequately demonstrated. What now needs to be done is a determination of the market potential of the projected products, particularly Product No. 3. To provide interested food companies with sufficient material for product development and consumer testing is beyond the scope of the presently available facilities at Texas A&M University. The proposed pilot plant would also serve to evolve optimum processing conditions, quality control procedures, definitive economic analyses and demonstration and training to interested people from any of the coconut producing countries. This pilot plant activity is beyond the provisions of the current contract and would require a new contractual arrangement.

F. Statement of Expenditures and Obligations and Contractor Resources

Summary of Costs by Category 7/1/71 - 6/30/72

Salaries and Wages*	$ 65,534.42
Fringe Benefits	2,766.63
Consultant Fees	50.00
Overhead - 44.24% of S&W	23,639.36
Travel and Per Diem	7,006.44
Equipment, Materials & Supplies	11,598.23
Participants	5,034.40
Other Direct Costs	3,775.10
TOTAL	$119,404.58

* $17,080.61 = Mr. Quinitio and Cooperating Nationals' Salary (No overhead charges)

G. Work Plan and Budget Forecast for Remaining Contract Period

With reference to the aqueous process the work plan for the remainder of the contract period includes the following:

1. Manufacture of product for evaluation and distribution. Progress on this will be impeded by unexpected delays in the installation of critical equipment and by the limited capacity of our unit operations.

2. Evaluation of the products will include organoleptic testing, chemical analysis, nutritional evaluation and product testing. It is anticipated that much of the product testing work will be done in food industry laboratories based on distribution of samples of limited size. The limitation in the size of samples will be a severe impediment on product development work and may serve to discourage food industry laboratories from any testing.

3. Establishment of microbiological control procedures for the unit operations.

4. Modification of unit operations to correct any observed product defects, to solve microbiological problems, to improve efficiency and to reduce costs.

5. Contact and coordination with nutritionists and food processors in coconut producing countries to determine potential markets for the proposed products and to provide limited samples for preliminary evaluation.

6. Arrangements will be made to procure a shipment of fresh coconuts direct from the area of production for processing by the aqueous method. This will be scheduled so that the coconuts would be approximately the same age as would be common in a commercial operation (coconuts which have been used to date probably were harvested several weeks prior to receipt).

In the area of solvent extraction the work plan includes the following:

1. Investigate the technological and logistic feasibility of food grade copra.

2. Arrangements have been made with the Crown Iron Works to process in their solvent extraction pilot plant desiccated coconut which has been pre-pressed under mild conditions to determine whether the anticipated reduced rate of percolation constitutes a serious practical problem.

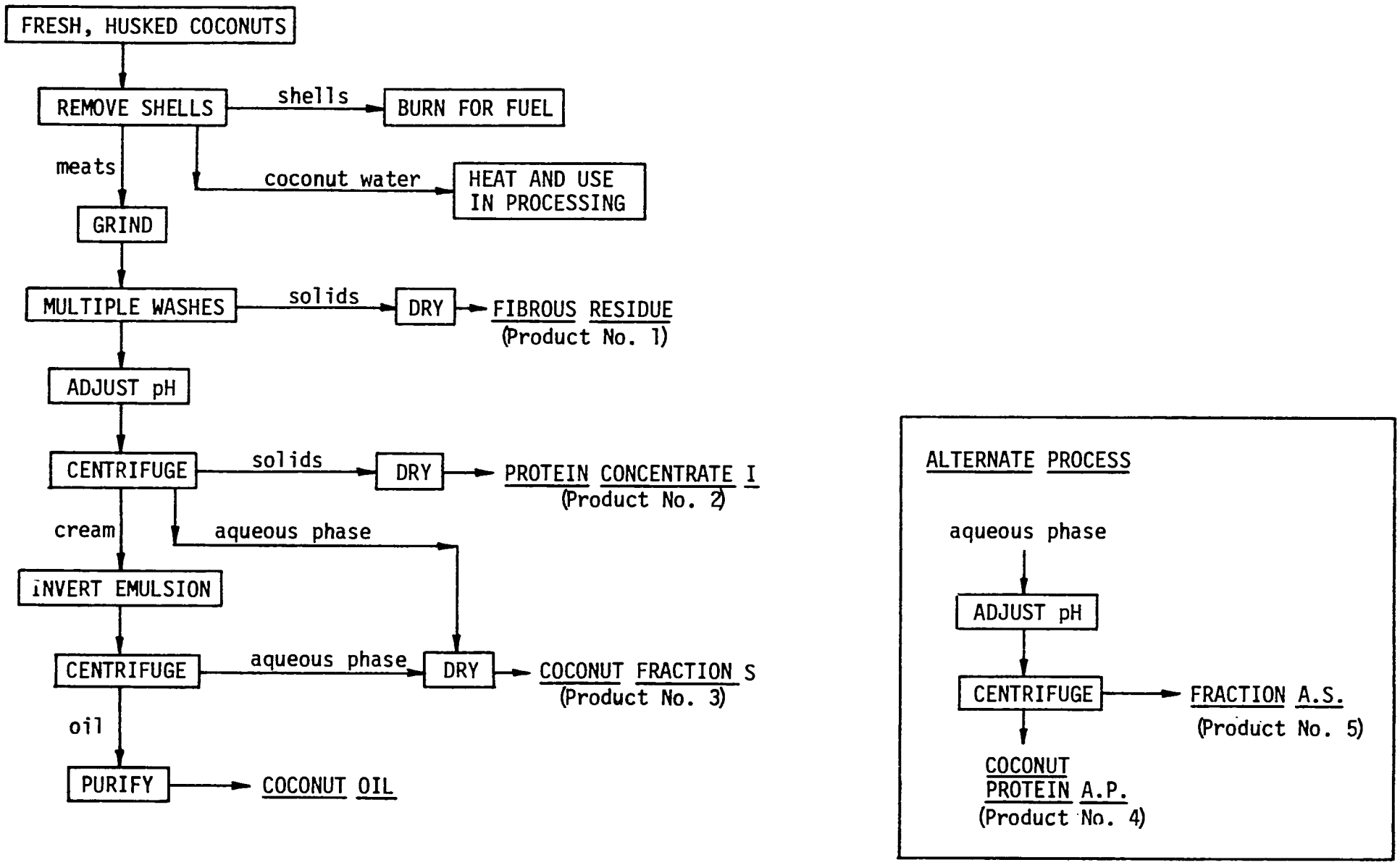
3. A determination of pre-pressing conditions that can produce an extractable, partially de-fatted coconut meat with little or no reduction in protein solubility.

The projected budget for the duration of the contract period is as follows:

Salaries and Wages	$25,000.00
Fringe Benefits	1,500.00
Consultant Fees	500.00
Overhead - 44.24% of S&W	11,060.00
Travel and Per Diem	5,000.00
Equipment, Materials & Supplies	15,000.00*
Participants	6,000.00
Other Direct Costs	3,671.63
TOTAL	$67,731.63

* Includes $8,000 for purchase of Evaporator-Concentrator for preparation of Product No. 3 as syrup.

SIMPLIFIED FLOW DIAGRAM FOR THE AQUEOUS PROCESSING OF COCONUTS WITH COCONUT WATER



INNOVATIONS: AQUEOUS PROCESSING

1. Combined a two-step grinding with multiple water washes to achieve at least 95% separation of oil from the fibrous residue at commercially practical rate of throughput.

2. Centrifugation of coconut "milk" at pH 7-8 rather than near isoelectric pH results in about half as much oil in Protein Concentrate I and simplifies oil recovery from cream.

3. Practical recovery of oil from cream made possible by adding oil with appropriate agitation to invert the emulsion.

4. Focus of attention on utilization of whey components (Fraction AS) in a potential beverage base (Coconut Fraction S) resulted in:

    1. Higher protein recovery in primary product.
    2. More favorable economics.
    3. Elimination of pollution potential.

PRODUCT #3 - COCONUT FRACTION S

PRODUCTION: Aqueous phase from the centrifugation of coconut "milk," dehydrated. Represented 4.4% of weight of husked coconuts, 70% of original protein when coconut water is used.

CHEMICAL COMPOSITION: (dry weight basis)

	Made With Coconut Water	Made Without Coconut Water
Protein (Nx6.25)	25%	30%
Soluble Carbohydrates	45%	37%
Oil	5.1%	6.2%
Crude Fiber	0.05%	n.a.
Ash	8.8%	9.2%
MINERALS		
Phosphorous	0.5%	0.5%
Calcium	0.17%	0.06%
Magnesium	0.26%	0.36%
Potassium	3.6%	3.3%
Sodium	0.9%	1.4%
Chloride	n.a.	1.6%
Iron	70 ppm	50 ppm
Copper	50 ppm	n.a.
Manganese	15 ppm	n.a.
Chromium	3 ppm	n.a.
Cobalt	<2 ppm	n.a.

AMINO ACIDS (Essential)	g/16gN
Isoleucine	2.6
Leucine	5.5
Lysine	4.8
Phenylalanine	4.0
Tyrosine	2.4
Cystine	1.4
Methionine	1.3
Threonine	2.4
Tryptophane	1.0
Valine	4.3

PHYSICAL CHEMICAL PROPERTIES: Color: light brown (due to testa)
85-90% soluble under most conditions
Hygroscopic - good heat stability

FLAVOR: Coconut, sweet

COST: Assigning total processing cost to product, cost to make is 16¢/lb. Any value recovered for Fibrous Residue and/or Protein Concentrate I would effect a reduction in cost of this product.

PROBABLE USES: Base for beverage, alternate for NFDM, gruel, confection, sweetener.

PRODUCT #4 - COCONUT PROTEIN AP

PRODUCTION: Solids separated by acid precipitation from aqueous phase. Represents 1.1% of weight of husked coconuts, 46% of original protein.

CHEMICAL COMPOSITION:

Crude Protein (Nx6.25)	65%
Oil	24%
Ash	2.0%
Crude Fiber	0.15%

MINERALS	
Phosphorous	0.5%
Calcium	0.06%
Potassium	0.2%
Magnesium	0.05%
Iron	0.01%
Sodium	0.1%

AMINO ACIDS (Essential)	g/16gN
Lysine	3.9
Threonine	2.8
Valine	5.4
Methionine	1.6
Isoleucine	3.4
Tyrosine	2.5
Phenylalanine	4.9
Cystine	1.3
Tryptophane	1.2
Leucine	6.8

PHYSICAL CHEMICAL PROPERTIES: Color: light tan

COST: Assigning total processing cost to this product, cost to make is 59¢/lb. Any value recovered for Fibrous Residue, Protein Concentrate I and/or Fraction AS would effect a reduction in the cost of this product.

PROBABLE USE: As a protein supplement and/or functional protein in food products.

VALUE: May be related, as a nutrient, to price of other indigenous protein foods. Also related to value to food processor of any inherent useful functional properties.

PRODUCT #1 - FIBROUS RESIDUE

PRODUCTION:	Produced as by-product of aqueous processing of fresh coconuts, without use of coconut water in the processing. The amount produced is 3.5% by weight of the husked coconut. This product consists of all solids not extracted from the coconut meats after grinding and pressing.
CHEMICAL COMPOSITION:(1) (dry weight basis)	Oil 24% Crude Fiber 25% Ash 0.6% Crude Protein (Nx6.25) 3.4%
PHYSICAL CHEMICAL PROPERTIES:	Low solubility Absorbent: good capacity for absorbing liquids
POTENTIAL USE:	Probably suitable for ruminant feed roughage and source of energy. Uses have not been explored.
COST:	No value has been assigned to this product in the economic analyses. Therefore, if protein product carries all the cost, this product is obtained at no cost.
POSSIBLE MARKET VALUE:	No basis for estimate at this time. Any value would reduce cost to make primary product.

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(1) Analysis for the product produced without the use of coconut water in processing. If coconut water were used in the processing, the composition would not change significantly.

PRODUCT #2 - PROTEIN CONCENTRATE I (INSOLUBLE)

PRODUCTION: Suspended solids separated on first centrifugation of coconut "milk" at pH 7. Represents 0.57% by weight of the husked coconuts, and 22% of the original protein.

CHEMICAL COMPOSITION: (dry weight basis)

Crude Protein (Nx6.25)	52%
Oil	19%
Ash	9.3%
Crude Fiber	2.0%
MINERALS	
Phosphorous	2.1%
Calcium	0.4%
Potassium	1.0%
Iron	0.06%
Magnesium	1.1%

AMINO ACIDS (Essential)	g/16gN
Lysine	2.7
Histidine	1.5
Agrinine	14.3
Threonine	3.2
Valine	4.6
Methionine	2.2
Isoleucine	3.7
Leucine	6.1
Tyrosine	2.8
Phenylalanine	4.0

PHYSICAL CHEMICAL PROPERTIES: Light brown in color (due to testa)
Protein <10% soluble, pH 3 to 8

PROBABLE USE: Uncertain at this time. Possible protein supplement.

COST TO MAKE: No value has been assigned to this product in the economic analyses. Therefore, if protein product carries all the cost, this product is obtained at no cost.

POSSIBLE MARKET VALUE: No basis for estimate at this time. Any value would reduce cost to make primary product.

PRODUCT #5 - FRACTION AS

PRODUCTION:	The solids from the aqueous phase recovered after separation of Coconut Protein AP. Represents 3.3% of weight of husked coconuts, 23% of the original protein.
CHEMICAL COMPOSITION:	Crude Protein (N x 6.25) - 13% Ash - 13% MINERALS Potassium - 4.1% Phosphorous - 0.5% Calcium - 0.08% Magnesium - 0.32%
PHYSICAL CHEMICAL PROPERTIES:	Color: light tan Very hygroscopic
COST:	No value is presently being assigned to this product.
PROBABLE USE:	This contains most of the soluble carbohydrates of coconut. May find use as an animal feed or as a food ingredient.
VALUE:	Uncertain at this time.

PRODUCT #6 - COCONUT FLOUR

PRODUCTION: Residue from solvent extraction of lightly pressed food grade copra or dehydrated coconut.

CHEMICAL COMPOSITION:

Crude Protein (N x 6.25)	-	24%
Moisture	-	5%
Ash	-	5.5%
Crude Fiber	-	7.8%
Oil	-	0.5%

MINERALS		
Calcium	-	0.38%
Sodium	-	0.05%
Potassium	-	0.62%
Phosphorous	-	0.14%
Magnesium	-	0.76%
Iron	-	0.005%

AMINO ACIDS	g/16gN
Lysine	4.4
Histidine	2.1
Arginine	16.1
Threonine	2.9
Valine	5.1
Methionine	1.8
Isoleucine	3.5
Leucine	9.7
Tyrosine	2.6
Tryptophan	1.2
Phenylalanine	4.3
Cystine	1.6

PHYSICAL CHEMICAL PROPERTIES: Color: Light tan (due to testa).

COST:

From fresh coconut	-	6.9¢/lb.
From food grade copra	-	2.6¢/lb.

PROBABLE USE: Two companies in the Philippines are now trying to develop market.

PRODUCT #7 - COCONUT PROTEIN 90

PRODUCTION:	Precipitated from alkaline extract of defatted coconut flour at pH 7.0.
CHEMICAL COMPOSITION:	Crude Protein (N x 6.25) - 90% Ash - 1.4% Crude Fiber - 0.1% Moisture - 5.0% Oil - 0.4%
COST:	From fresh coconut - 50¢/lb. From food grade copra - 15¢/lb.
PROBABLE USE:	As a protein supplement in dietary foods, or as a functional protein in selected food products.
VALUE:	Would be relative to other sources of supplementary protein, or other functional proteins.

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A Characterization of Two Chromatographically Separated Fractions of Coconut Protein. J. Food Sci., 37 (1972), 4-7. Robert Hagenmaier, Carl M. Cater and K. F. Mattil.

ABSTRACT

With a view toward developing a procedure for the aqueous processing of coconuts for food usage of the protein, pertinent properties of the coconut proteins were measured. The proteins were fractionated by exclusion gel chromatography into high and low molecular weight components The high molecular weight components (84% of total protein) had a value for intrinsic viscosity characteristic of globular proteins (5 cc/g), and were only about half dissolved in 0.1M NaCl in the pH range 5-9, with the dissolved portion starting to heat coagulate at about 70°C. The low molecular weight components, on the other hand, were completely soluble and heat stable over a wide range of conditions. Considerable differences in amino acid analyses of the two fractions were found. The low molecular weight components were particularly high in arginine and glutamic acid and very low in the aliphatic amino acids. The high molecular weight components contained reactive SH groups, whereas the low molecular weight components contained no detectable amount. Results suggest that processing temperatures of 70°C or lower are safe for the aqueous processing of coconut proteins and that the maximum safe temperature (without denaturation) would increase with addition of salt, or adjustment of pH away from the isoelectric range.

Critical Unit Operations of the Aqueous Processing of Fresh Coconuts. JAOCS, 49:3 (1972), 178-181. Robert Hagenmaier, Carl M. Cater and Karl F. Mattil.

ABSTRACT

An aqueous process was investigated for the recovery of oil and food grade protein from fresh coconuts. Efficient recovery of oil, which is very important for economical reasons, was related to three critical unit operations: separation of oil from the fiber, destabilization of an oil-in-water emulsion, and recovery of a protein product that is low in oil content. The material balance is reported for a laboratory process that satisfactorily separates oil and breaks the emulsion, and data are shown which has led to a process for recovery of a protein with low oil content.

Nutrition & Biochemistry of the Coconut. The Chemists Quarterly, 9 (1972), 32-40. A. S. Samson S.J.

ABSTRACT

Coconuts are an indigenous product and a major article of commerce in many countries of the world which are suffering from protein deficiency. In recent years the importance of adequate protein in the daily diet, especially for the growing child of pre-school age, has been better documented and appreciated. That the world's ever-expanding, some would say exploding, population may fast outgrow our conventional protein food sources and create a major protein crisis or widen the protein gap is highlighted for us by the concern of governments and nutritionists. For example, in 1967, the United Nations General Assembly passed a resolution calling for concerted and coordinated action by the organization of the United Nations to combat protein malnutrition. The Food and Agriculture Organization of the United Nations has directed its Director-General "to promote all efforts to fill the protein gap by maximum use of both conventional sources and the exploitation of new sources of proteins."

Extractibility of Coconut Proteins. J. Food Sci., 37 (1971), 725-728.

A. S. Samson S.J., R. N. Khaund, Carl M. Cater and K. F. Mattil.

ABSTRACT

Studies were made on nitrogen (protein) solubility of coconut meal in aqueous media over a range of pH's. The point of minimum solubility was found at pH 3.9 and nitrogen solubility increased toward the acidic and basic sides. Coconut proteins displayed a markedly different pH-nitrogen solubility in salt solutions, showing minimal solubility at acidic pH's (pH$\leqslant$3), a sharp rise of solubility and a maximum at neutrality. Coconut meal prepared from fresh coconuts with and without testa removed, from parings and from a sample of sun-dried copra showed comparable solubility characteristics. However, meal prepared from commercial desiccated coconut showed low solubility, even under acid and alkaline conditions (pH 2 and 10). The most efficient solvent-to-meal ratio was found at 20:1 (v:w) for a single extraction, and a two-step 15:1 process for multiple extractions. Extractions using salt solutions show that the efficiency of extraction is greatly dependent upon pH: concentrations $\geqslant$0.25M effect maximum extraction. Osborne classification studies of coconut meal indicate that 90% of the proteins would be classified as albumins and globulins.

Preparation & Characterization of Coconut Protein Isolates. Cereal Chemistry, 48:2 (1971), 182-190. A. S. Samson, Carl M. Cater and Karl F. Mattil.

ABSTRACT

The following protein fractions have been separated from dried, defatted fresh coconut meats: 1) soluble at pH 2, precipitated at pH 3.9; 2) soluble at pH 8, precipitated at pH 3.9; 3) soluble at pH 10.5, precipitated at pH 3.9; 4) extracted sequentially at pH 10.5 from pH 8 residue and subsequently precipitated at pH 3.9; 5) extracted at pH 7 by 1.0M NaCal and precipitated at pH 2; 6) soluble in water at pH 7.0; and 7) protein remaining in solution at pH 3.8. The recoveries were 1) 45 to 57%; 2) 39 to 53%; 3) 31 to 35%); 4) 14 to 19%; 5) 48 to to 54%; 6) 9 to 11%; and 7) 3 to 6%. Hydrocholric was the most effective precipitating acid of those tested, including sulfuric, phosphoric, acetic, and nitric. Each of the precipitated isolates was dried by lyophilization. While all of the isolates were quite soluble at pH 2, there were substantial differences in solubilities at pH 7, 8 and 10. All isolates were quite insoluble from pH 4 to 6. The amino acid composition of most of the isolates did not vary markedly from that of the original meal. The water-solubles were somewhat higher in lysine, arginine, and glutamic acid and lower in the remaining amino acids. The isolate extracted sequentially at pH 10.5 from pH 8 residue was lower in lysine and glutamic acid.

Heat Treatment of Coconut Meats and Coconut Meal. J. Sci. Fd Agric., 22 (1971), 312-316. A. S. Samson S.J.

ABSTRACT

In attempts to determine the heat tolerance of coconut meats and coconut meal, samples were subjected to several temperatures for varying lengths of time. Properties evaluated were browning (by visual observation), odour, lysine destruction, protein solubility at pH 2, 8, and 10.5, and nitrogen solubility index.

Solubility studies suggest that fresh coconut meats can tolerate up to 100°C air temperature (coconut layer temperature, 78-83°C) without significant loss of protein solubility. At 110°C air temperature, there is loss of solubility at pH 2 and 8, and at 120°C protein solubility significantly decreases under all the pH conditions examined. Data indicate a marked loss of lysine availability upon heating coconut meats with hot air at 120°C.

Coconut meat can tolerate 105°C air for at least 60 minutes without significant loss of protein solubility. At higher temperatures (120°C for 15 minutes or longer), protein solubility decreased. Unavailable lysine data indicate that heating at 120°C for 60 minutes markedly decreases lysine availability.

The Effect of Extraction and Drying Procedures on the Solubility Profiles of Protein Isolates Obtained from Coconut Meal. R. N. Khaund, Carl M. Cater and K. F. Mattil.

ABSTRACT

In earlier work reported from this laboratory, it was observed that the solubility profiles of protein isolates obtained from coconut meat by several different extraction procedures varied substantially. Two procedures produced isolates that had markedly reduced solubilities at neutral to alkaline pH's. Because all of the samples had been freeze-dried, it was suspected that the freezing might have caused the reduced solubility.

An experiment planned for statistical analysis has compared the protein solubilities of the isolates obtained by the five extraction methods, each of which was dried under vacuum both with and without pre-freezing.

The data indicated a good reproducibility in the amount of protein isolate recovered by any one of the five methods. The recoveries by the several methods varied substantially from each other. Freezing of the isolates prior to vacuum drying had no significant effect upon the solubility of the protein at the pH's measured, 2, 8, and 10. There was a significant reduction in the solubility at pH 8 and pH 10 of the proteins obtained by two methods, each of which involved subjecting the proteins to pH 2. It is evident from the data that the solubility profiles of proteins isolated from coconut meal vary according to the method of extraction and precipitation.

The Aqueous Processing of Fresh Coconuts: Processing, Cost Estimate and Gross Analyses of Products. Presented at 32nd Annual IFT Meeting, May 1972, Minneapolis, Minnesota. Robert Hagenmaier, C. M. Cater and Karl F. Mattil.

ABSTRACT

Fresh, husked coconuts were shelled, the meats ground with coconut water, and the mixture pressed to separate the solids (residue) from the liquid emulsion. The liquid emulsion was centrifuged to give three phases: a precipitate (insoluble protein). an aqueous phase and a creamy emulsion. The creamy emulsion was dilute with oil and agitated to produce coconut oil and more aqueous phase. The aqueous phases were combined and dried to give a soluble fraction, considered the main product. The soluble fraction contains 25% crude protein, 5.1% fat, 45% soluble carbohydrates, 9% ash, and 0.0% crude fiber. The cost of production of the soluble fraction is estimated to be $0.16/lb.

Solvent Extraction of Oil from Dehydrated Coconut Meats. Presented at the 32nd Annual IFT Meeting, May 1972, Minneapolis, Minnesota. P. H. Quinitio, S. P. Clark, Carl M. Cater and K. F. Mattil.

ABSTRACT

In the present coconut oil industry very little consideration is given to protection of the quality of the protein in either copra or in the screw press meal produced from the copra. If food grade copra or dried coconut were used and if a method for removing oil without excessive heating of solids could be developed, the residue would be a potential source of edible vegetable protein.