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SUMMARY REPORT OF CONTRACT AID/csd-1587

The genesis of this project was the nutrition survey of Chile conducted in August 1960 by the then Interdepartmental Committee on Nutrition for National Defense (I.C.N.N.D.) of the Public Health Service. The summary statement of the nutrition survey noted the high incidence of malnutrition in Chile, the presence of non-utilized protein sources in the country and the presence of groups within Chile whose interest lay in the alleviation of the problem of infant malnutrition. It was thus proposed that the research group of the University of Chile in pediatric nutrition be encouraged to investigate the problem of infant malnutrition more fully, and to determine whether or not it was possible to develop on a national scale a food material based upon indigenous food supplies which would combat this problem in Chile. The solutions arrived at in Chile would be applicable to similar areas in Latin America, and perhaps other parts of the world.

The initial research work proposed was a study of infant malnutrition in Chile and the measurement of the effect of nutritional deprivation upon infant populations. To this was added a study of the nutritional effectiveness of protein sources. This program centers itself in the Department of Pediatrics of the University of Chile, in cooperation with the interested individuals in the Department of Food Science and Technology, University of California.

Since UNICEF in the late 1950's developed in Chile a pilot-scale installation for the production of fish protein concentrate using a dual sol-

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vent system of hexane and methanol, it was decided that the initial experiments in developing food materials for use in the populations be conducted with fish protein concentrate. To this was added the study of other indigenous protein sources, such as sunflower seed meal and rapeseed meal, which are by-products of the edible oil industry of Chile, and which are available in abundance at low cost.

A PASA was written between A.I.D. Washington and I.C.N.N.D. to conduct an investigation of the effects of nutritional deprivation of children, the study of nutritional effectiveness of various indigenous protein sources and to make a start on the development of a food source to alleviate dependence on imported milk in the feeding of preschool children. A contract was negotiated between I.C.N.N.D. (P.H.S.) and the University of California to carry out these investigations. They involve the following points: 1) the investigation of the effects of early malnutrition in the preschool population in Chile; 2) the testing of fish protein concentrate, first in animals and then in human infants, to determine its nutritional effectiveness; 3) the measurement of the nutritional effectiveness of sunflower meal in animals, and subsequently in humans; 4) the development of a food supplement for preschool children which would decrease dependence upon powdered milk, which was distributed by the Chilean Public Health Service.

This contract was in force approximately one year when a second proposal was made to A.I.D. Early results under the first contract indicated that the materials being studied were effective and could be utilized in children as young as one month, that after some modification they possessed no toxicity, and thirdly, that it was imperative to develop the technological competence for the production of the supplemental food materials. It

was felt that a complete food for infants could be produced based upon protein sources already available in Chile which would be acceptable, non-toxic and nutritionally effective in the treatment of infant and preschool malnutrition, a problem which has been shown to be more prevalent and of greater severity than the original nutritional survey had shown. Thus a second proposal was developed to study the production of infant or pre-school foods utilizing Expander techniques. The expander was chosen as a suitable technological process since by using this technique one should be able to produce a product which is bacteriologically safe, easily transportable, easily digestible, and one in which various nutritional supplements such as vitamins and minerals could be incorporated. The investigation of the technological feasibility of producing such a product was to be conducted jointly by the University of California and the University of Chile. In Chile the group to be concerned with the technological production of the foods was to be the Institute of Food Science and Technology, an F.A.O.-supported institute just being developed. The Institute was to produce foods based upon various formulations (mixtures), among which the following ingredients were specifically noted:

a) Sunflower seed meal

b) Rapeseed meal

c) Fish Protein Concentrate

d) Raw fish

e) Corn

f) Wheat

g) Milk

The optimum processing conditions for these mixtures were to determined. They then were to be supplied to the Department of Pediatrics,

where they would be tested for nutritional effectiveness in animals, and subsequently in human infants. This was to be followed by larger scale testing of the best mixtures in selected preschool populations, supervised jointly by the two groups in Chile and coordinated by the University of California. The major factors to be considered in the evaluation of the various supplemental foods was the acceptability and nutritional effectiveness in the populations. It is to be noted that it is extremely difficult to change a dietary pattern of a population, and consequently the acceptability of a new or modified food, even in infant nutrition, is dependent to a large extent upon its acceptability to the population concerned.

In addition, studies were to be made to determine the following: 1) the most suitable packaging for product studies; 2) storage stability of the various mixes chosen for large-scale testing was to be determined under Chilean conditions; 3) techniques for enriching the extruder foods with vitamins and minerals would be determined.

At this point it was envisioned that the two projects be considered a joint program, generally covering the following: the continuation of nutritional evaluation of raw products in humans, the testing of indigenous protein sources, and the development and testing of manufactured foods over approximately a 3-1/2 year period. The two projects were to be conducted under two methods of funding: the Public Health Service contract by means of the PASA mentioned earlier -- for nutritional evaluation; and a direct contractual arrangement between A.I.D. and the University of California, for the technological phases.

Admittedly, the arrangement of two separate contracts produced some confusion as to what would be done by whom, and it may have appeared that there was overlap. As a consequence, it was decided in 1969 to combine both of these phases under a single contract. This avoided the problem of

the PASA with the Public Health Service, and put the overall project under one auspice.

The political situation in the University of Chile during 1967 and 1968 became a major stumbling block in carrying out the technological work on schedule and in phase with the nutritional and toxicological evaluations. The University of Chile experienced a student strike which shut down the major portion of the campus and included that area in which the technological investigations were to take place. The Pediatrics Department, since it is not housed upon University land, was not so affected, and thus could continue working. This situation delayed the products which could be processed through the expander, which were therefore produced by a dry mixing technique, which while it is cheap, does not lend itself to the production of a product possessing the best characteristics.

The overall contract was further modified in 1969 in order to consider the further development of the use of rapeseed meal. Rapeseed meal is toxic as it is normally produced, and cannot be used in animals as a major protein source in the diet. The toxic principle is thyrogenic. Since the rapeseed accounts for approximately 60% of the total oilseed meal produced in Chile and in many other temperate climates in Latin America and in other parts of the world, a potentially large source of protein is available provided a method can be developed which would eliminate the toxic factor in the rapeseed meal. If nothing else, the detoxification of the meal would allow its utilization in animal feed and thus free other oilseed proteins for utilization in human diets. In Chile the two oilseeds (as mentioned earlier) that are responsible for over 95% of the edible oils produced are rapeseed and sunflower. Sunflower seed meal has been traditionally used for animal feed. If this were utilized in human nutrition, one would run into a direct

conflict between the needs of the animal industry and human nutrition. By making available a non-toxic rapeseed which is now unutilized, one could effectively decrease the dependence of the animal industry upon sunflower, thus freeing it for human consumption. Thus the project was enlarged to add this consideration. If one considers the overall project, the aims and the accomplishments related to these aims can be identified. The following list notes the objectives of the project, and immediately thereafter the report that is related specifically to the aim. The large majority of the aims have been accomplished, and the results have been reported in the open literature. Reprints of the results of the project are therefore keyed to the listed objectives.

1) The study of the effects of malnutrition in early infance. (Papers 1, 2, 13, and 14. Bibliographic entries for all papers will be found in the Reference List at the end of this report. Copies of all these papers are attached, or will be sent as soon as they are available.)

2) The testing of the toxicity and nutritional effectiveness of mixtures of sunflower seed meal, fish protein concentrate, milk, and wheat. (Papers 1, 8, 9, and 10.)

3) The measurement of the effect of expander processing on various formulations not stated in 2) above, such as raw fish, corn, rapeseed, etc. (Papers 3, 4, and 12.)

The testing of other complete food materials by expander processing of selected materials is underway, but is not yet completed. It will require, as outlined, approximately one and one-half years to test the individual formulations for stability and

and acceptability. The technology has been developed and the aims of the contract with respect to these should be completed by September 1971.

4) The detoxification of rapeseed meal and its utilization. (Papers 5, 6, 7, and 15.)

5) Testing of the nutritional effectiveness of expander-processed foods (a mixture of FPC, wheat, sunflower meal and milk) in large-scale feeding experiments. This work has not yet been completed. Data is available for the first six months of a study of a large-scale population in Curico, a city just south of Santiago. Acceptability and nutritional effectiveness have been measured and the data is in the final stages of analysis. The data will be assembled for publication within the next six months.

6) The fortification of products during expander processing has been accomplished using vitamins A and D, calcium and iron, which are considered low in the Chilean diet. Initial toxicological and nutritional evaluations have been made and preliminary data has been reported at the Unternational Nutrition Congress in Prague. (Paper 8.)

7) The nutritional evaluation of other mixtures by expander processing utilizing mixtures including in this case rapeseed protein. Initial experiments along these lines have been initiated, and it is anticipated that testing of these foods in diverse populations both animal and human will be undertaken in the next year. Formulations differing in flavor attributes, consistency and fortification are being produced, and their evaluation is underway. This is only preliminary, and consequently this is a major aim which will have to be tested in the large-scale groups.

8) The modification and testing of formulations based upon the "Leche Alim" formula (mentioned in the reprints) is to be undertaken in areas in Chile which are not similar in dietary habits to the initial population groups tested. It is important in the development of formulations of this sort that the product be acceptable to large portions of the population. In this, at the present time this work is being closely coordinated with commercial groups in Chile in the hope that the product will also within this period of time be subject to a market test. This work should also be completed at the end of the contract period.

9) Packaging studies have been completed. Since the range of packaging materials economically available in Chile is small, this phase of the project was limited. From an environmental and price consideration a coated polyethylene package was determined best. These can be filled automatically (1 kg.) and can be shipped in by bagging or in cardboard cases.

10) The storage stability of the mixtures so far investigated has been determined. The products showed nutritional stability for the one year test period. Organoleptically, however, some staling was noted at 180 days when held in polyethylene. This was not considered serious, but attempts are being made to mask this change by the incorporation of flavor compounds.

The storage stability of mixtures under current investigation will be determined in the remaining period of the contract.

The overall objectives of the investigation, including both phases, should be available in the open literature by the end of the contract period. The contract as modified in 1969 calls for the contractual period to end in September 1971. By that time all of the aims of the original and modified contract should be achieved, and thus the technology, the nutritional evaluation, the acceptability, and possibly the marketing studies, should allow the various formulas to be utilized ultimately over a fairly large region of the world in which the indigenous protein resources fit the temperature pattern. The formulations and technologies evolved are not dependent upon the availability of fish protein concentrate, but can be modified to take advantage of protein sources available in the region in which the formulations are to be produced.

The Chilean government has recognized through its Ministry of Public Health the importance of the work that is going on, since they propose that the products produced under this contract be developed on a national basis to decrease the country's dependence upon external high-quality protein, particularly for its infant and preschool populations.

Budget

The proposed budget for the additional 18 months starting April 1, 1970 is as outlined in previous submissions of the contract, and is as follows. It is to be noted that in this case the budgetary requirements are lumped, although in previous submissions they were divided between the work to be done in the Department of Pediatrics and that to be conducted in the Institute of Food Science and Technology. Considerable support in both areas is obtained from the University of Chile through manpower being furnished by the University, and from the Chilean Department of Public Health through manpower being furnished for supervision of large-scale tests. The University of Chile also furnishes space and overhead for the work to be conducted in this area. The Corporation for Development (CORFO) also furnishes manpower and supplies to the project.

Proposed Budget: April 1, 1970 - March 31, 1971

Personnel	$37,950.00
Travel	4,900.00
Equipment	5,000.00
Publications	800.00
Consultants	2,000.00
Supplies	7,000.00
Animal Care	500.00
TOTAL	$58,150.00

Proposed Budget: April 1, 1971 - September 31, 1971

Personnel	$19,000.00
Travel	2,000.00
Equipment	1,000.00
Publications	1,000.00
Supplies	3,500.00
Animal Care	500.00

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ADDENDUM TO SUMMARY REPORT OF CONTRACT AID/csd-1587

It was indicated in the Summary Report in January 1970 that additional data on some of the aspects of expander processing would be submitted in the form of publications as soon as they were available. The work on expander processing of various protein mixtures has proceeded over the past year and one-half with excellent results. Rather than await publication, since the contract is to be reviewed, an addendum covering some of the results of expander processing is herewith submitted.

Components to be Investigated by Expander Processing.

a) Sunflower seed meal

b) Rapeseed meal

c) Fish protein concentrate

d) Raw fish

e) Corn

f) Wheat

g) Milk

These components were to be processed as mixtures which would have high nutritional values. The following mixtures of the components were processed and are partially evaluated:

a) Sunflower seed meal, fish protein concentrate, wheat;

b) Wheat, milk;

c) Wheat;

d) Whole fish, wheat;

e) Corn, milk, sunflower seed meal;

f) Wheat, sunflower seed meal, hydrogenated fish fat, milk, wheat.

The majority of work has been done on the most complete mixtures, since nutritional trials in infants and preschool populations had been

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conducted using these as test mixtures. Expander processing of these would be of major benefit in continuing and enlarging their distribution in Chile.

One of the more interesting mixtures that were attempted using expander processing was that of fish fillets, which were macerated in a colloid mill and mixed with wheat flour. No additional water was used in the expansion, and the expansion was carried on at a die-plate temperature of 240°F. Water removal was good (final moisture content was 16%). Protein content was adjusted to give a total value of approximately 19.5%. The moisture was reduced in this product to approximately 8% by drying and the product assayed for P.E.R. The P.E.R. approximated that of the control, casein (e.g., 2.71 to 2.60).

The flavor of the product was initially acceptable, but upon storage rancidity developed. A series of additional experiments are underway to reduce the possible storage instability by the addition of antioxidants, and to decrease some of the overall fishy flavor of the mix by the removal of skins, etc. Interestingly enough, the product was moderately acceptable to individuals who particularly like fish flavor. Thus the product may be acceptable in particular portions of the populations which enjoy fish flavor. Additional work is underway on other mixtures.

Nutritional Evaluation of Expander-Processed Products.

In the processing of cereal grains for the production of formula foods, high temperatures which can be encountered in the gelatinization of starch tend in general to decrease the available lysine and consequently the nutritional value of these foods. Some cereals are particularly sensitive to heat damage, wheat being one of these. Animal proteins are undenatured, insensitive to heating, except milk protein, which is extremely sensitive.

In a series of experiments using the above-mentioned formulas, the effect of jacket temperature on the expander was determined, and it was found that optimum processing conditions in general depended upon minimizing jacket temperature. This was expected, but until conditions for the particular product were determined, this method of processing could not be used for the development of protein-rich food for infants and preschool children. It was necessary to modify the expander in order to maintain as low a die-plate temperature as possible. It was also found that in the original installation of the thermocouples in the expander unit the temperatures indicated were not that of the product, but rather the external jacket temperature. By modifying the thermocouple wells we were better able to measure actual product temperature, and consequently better able to control temperature of the process. Tables I through III give the P.E.R. of various mixtures processed in the expander under different conditions. The P.E.R.'s were established by feeding groups of 10 weanling rats for 28 days. They were fed using the NRC method at 10% protein level. Casein was used as a control.

It is particularly to be noted that a change of 20-30°F in jacket temperature of the expander changed the protein efficiency ratio by 12%. We also found, however, that different wheat samples also modified the P.E.R. significantly. Trials at the initiation of the project were done with U.S. wheat, but secondary trials utilized Chilean wheat, which was less sensitive to changes in assessing conditions. By suitably modifying the equipment and the temperature control, the loss in protein efficiency ratio in the product was minimized. Under certain conditions, however, the loss in P.E.R. at 58% with a change of processing temperature of less than 20% is quite surprising. Table IV shows the loss in available lysine at low-temperature processing. It is to be noted that under the

optimum conditions for this mixture little or no available lysine is lost.

Additional of Fat to Processing Mixtures.

In infant foods it is important to achieve as high a caloric density as possible. In many cases, mixtures of cereal proteins with carbohydrates do not have a sufficiently high caloric density to serve as the sole source of food for human infants. It has been recommended that infant formulas contain a substantial amount of fat, which would increase the caloric density as well as supplying the essential fatty acids required for growth.

In expander operation, one of the major problems of expanding cereal grains is difficulty of control of the expansion when no lubricant such as fat is supplied. Consequently, expander runs were made utilizing the wheat-FPC-milk-sunflower mixture, with addition of fat. The types of fat used were either hydrogenated vegetable oil or hydrogenated fish oil. Either one is suitable in the mixture, but better shelf-life would be expected with hydrogenated vegetable oil because of its natural content of antioxidants; however, by utilizing BHT in the hydrogenated fish oil, its stability could be increased. Several runs were made utilizing the Leche Alim formula with 4-5% added fat. On storage in open containers for 4 weeks, no rancidity developed.

The best method for the addition of the fat to the cereal mixture consisted of melting it and spraying it into the dry mix. A secondary procedure was the addition of the melted fat in the pre-conditioner. This procedure was satisfactory, despite some lumping in the pre-conditioner. Addition of fat also had other desirable characteristics.

The through-out of the expander was increased by about 30% and a better cut was achieved by running the knives at higher speeds, thus

giving a flake which was well-expanded and more easily ground in subsequent operations.

Gelatinization of Cereals.

One of the important aspects of processing cereals prior to use is the conversion of starch to gelatinized products. Raw starch, particularly in young children and infants, is difficult to digest; therefore, a mixture containing starch should be gelatinized or cooked before feeding. Long cooking times decrease the available protein in the product, but cooking sufficient to gelatinize the starch generally renders the carbohydrate more available and increases the total digestibility. As an example, the P.E.R. of expanded wheat (gelatinized) (to which all of the other nutrients of the Leche Alim formula were added) was compared in P.E.R. to that of the raw formula. As can be seen in Table V, the P.E.R. of the formula is increased by cooking.

In order to investigate the gelatinization at the low temperatures used in our experiments with cereal grains, a sample of expanded Leche Alim formula was compared to an unexpanded sample, using a Brabender Viscograph. A suspension of 90 g of the product in 450 g water was stirred for 15 minutes. Such a suspension was necessary since the product contained skim milk, making it difficult to heat without foaming.

The viscosity was measured at 30°C. The temperature of the suspension was then raised at the rate of 1.5°C per minute, and the viscosity determined during the period of heating, until the maximum viscosity of the unexpanded product was obtained. The product was then allowed to cool while its viscosity was being measured. With the expanded product the initial viscosity was 180 BU, which decreased as the product was heated to 95°C to a value of 100 BU. During cooling the expanded sample entirely recovered its initial viscosity. In

comparison, the unexpanded product showed a value of almost zero initially, which increased during heating to 620 BU's. Upon cooling the viscosity decreased to approximately 340 BU's.

The degree of gelatinization in a product is proportional to the extent of cooking, and since gelatinization is proportional to viscosity, it is apparent that during the expansion of the cereals at 100-110°C in the unit, we have achieved (at least in this mixture) complete gelatinization. The product thus after processing would exhibit constant rehydration characteristics. It would not thicken upon standing, nor would it become fluid. From the standpoint of a product which is to be utilized as an easily suspended, readily rehydratable mix, it is desirable to have little or no viscosity change over a period of time, and to have no particular increase in viscosity during the heating to which the product may be subjected.

Figure 1 shows the results of the gelatinization experiments with the Leche Alim formula. Equivalent results were obtained on corn-milk mixtures, wheat-milk mixtures, and sunflower-wheat products.

Physical Characteristics of Expander-Processed Suspensions.

Studies were made of cereal mixtures which had been expanded versus those which had not been expanded. Leche Alim was used as the model mixture, since it contained a number of protein sources as well as cereal sources. The following analysis of the effect of expansion on the physical characteristics was made:

a) Consistency

b) Water absorption index

c) Water solubility

The water absorption index was defined as the weight of gel per gram of dry substance as determined by the following technique. A 2.5 g

sample of the ground product (smaller than 60 mesh) was suspended in 30 ml water at 30°C in a 50 ml centrifuge tube. It was stirred intermittently over a 30-minute period and centrifuged at 3000 X g for 10 minutes. The supernatant was removed and the remaining gel weighed to calculate the water absorption index.

Water solubility was obtained by determining the percentage of dry solids in supernatant liquid removed from the water absorption test.

Consistency was measured by a Bostwick consistometer.

Table VI illustrates the characteristics of both unprocessed and processed Leche Alim, as well as unprocessed and processed wheat and processed corn-milk-sunflower mixture. The processed Leche Alim was produced in flavored forms, which are covered in subsequent sections.

The data illustrates that the consistency decreased with an increase in process temperature, which could be expected from the increased gelatinization experienced by cooking.

Both the water absorption index and the water solubility index of the processed Leche Alim are higher than those of the unprocessed Leche Alim. Although these aspects might be expected from the general character of processing of cereal products, this data is consistent with the argument that processing of cereal-protein mixtures is of importance in order to increase the acceptability when consumed directly. The changes also may substantiate the argument that processing by expander methods increased the ease of use of the product as it may be distributed.

The processed wheat followed the same characteristics as the processed mixture and again indicated the advantage of processing, since it enabled the product to hold the other components (such as proteins and fortification substances) in suspension, and thus prevent segregation,

both in the container and upon rehydration.

The ability to hold denatured proteins such as fish protein concentrate or sunflower seed meal in suspension upon rehydration is particularly important, since this would allow the production of a suspension which would insure that the consumer utilized all of its components completely, rather than leaving the residue in the vessel from which it was consumed.

Sensory Evaluation.

The ability to process cereal and protein mixtures by expansion techniques also suggested the possibility of producing a variety of flavored components in which the flavor was an integral part of the expanded product. This would introduce a variety of flavors, which might make the product less monotonous to a school or preschool population consuming it on a continuing basis. We asked the flavoring manufacturers to produce a number of flavoring components which would be compatible with cereal mixtures and which might be able to undergo exterior processing. Of the approximately 25 samples which were obtained, three were suitable for processing.

In a similar manner food colors were obtained in order to vary the appearance of the product. No problems were encountered in incorporating these into the products. Red was used in the fruit flavors, brown in the toffee and cereal products.

A series of flavored Leche Alim formulations was made, using low-temperature expansion (to give maximum P.E.R.), and was compared with unprocessed Leche Alim formulations by sensory panels. The products were presented to taste panels in a suspension at 15% weight/volume in cold water. The processed Leche Alim, because of its gelatinization, was thicker than the unprocessed material. This factor was significant, since the thicker product was definitely preferred over the thinner.

In order to remove this from evaluation, processed Leche Alim (flavored and unflavored) was utilized as the comparison substance. It is to be noted however, that the processed, unflavored material was preferred over that of the unprocessed material. The panelists utilized were school children age 12-14 years old. Approximately 25 children were utilized in the ranking for appearance, and approximately the same number were used for flavor. The tests were replicated in order to substantiate the results.

The method utilized for the analysis was that of a paired comparison by association of two factors or attributes, e.g., flavor and appearance. Finally, a multiple comparison test was made of all samples.

The rating system on flavor was the 7-point hedonic scale, and a ranking system was used for appearance.

Table VII shows the ranking by appearance.

Table VIII illustrates the rating for flavor. On a 7-point scale, 4 is normally considered neither liked or disliked, and therefore is considered acceptable. Seven would indicate a strong liking; 1 would be considered disliking.

A multiple correlation of both flavor and appearance was developed and is shown in Table IX. It is apparent that both flavoring and coloring of the Leche Alim considerably increased its acceptability above that of the unflavored and uncolored product. A substantial increase in the acceptance of the fruit flavorings would indicate that these would at least from an initial standpoint be very acceptable. The data, when analyzed by the Kramer tables for appearance and variance analysis for flavor, would suggest that the flavor difference was "very significant" and the appearance difference was "significant".

It is thus apparent that a more acceptable product is obtained by both flavoring and color. Although the unflavored and uncolored product is acceptable, an introduction of a variety of products would thus tend to lead to a continuing acceptance.

The addition of the flavoring components is comparatively simple. They were added to the dry mix before the preconditioning step. The flavor was obviously not removed by the process.

Coloring matters were added by spraying diluted colorant into the premix assembly on the Wenger, using air pressure for atomizing the liquid. This resulted in a good distribution prior to expansion. The colorants used were those approved by Chilean regulations.

Microbiological Assay.

The following mixes or mixtures were assayed microbiologically for reduction in viable microorganisms by processing:

a) Leche Alim formula

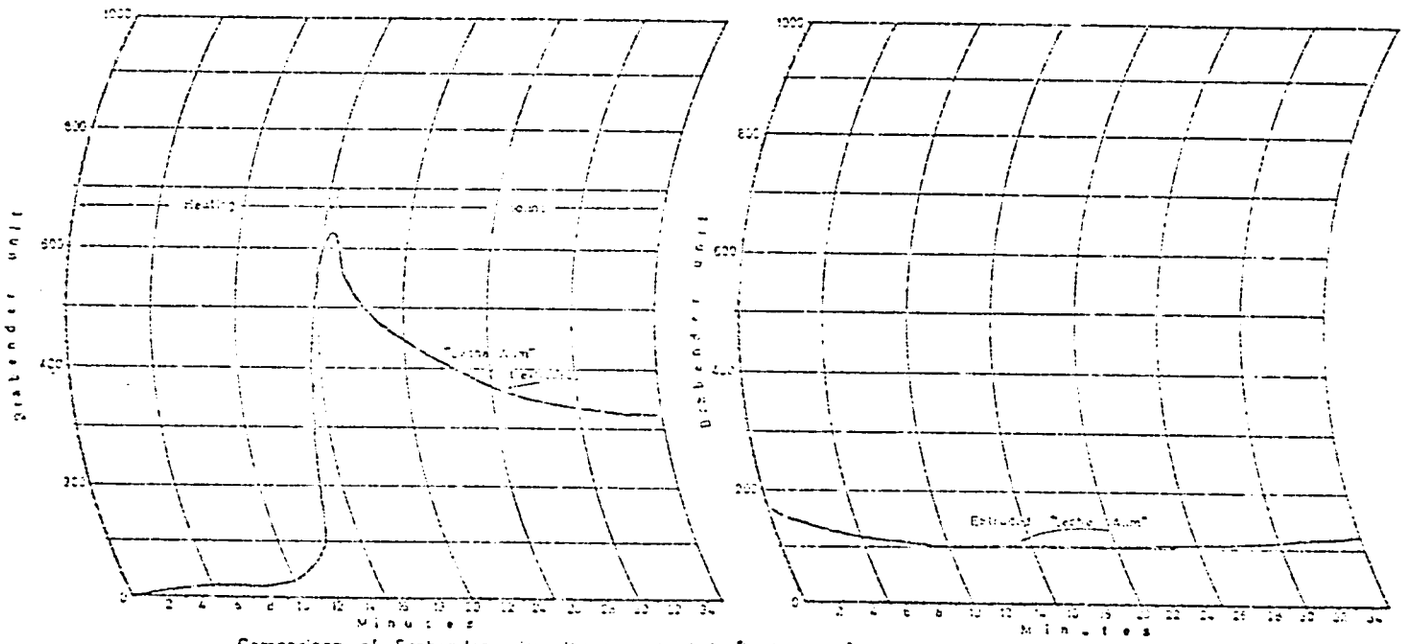
b) Wheat

c) Wheat, fish

d) Milk, wheat

Some difficulty has been encountered with microbiological assays, and these are being repeated. However, the initial data based upon total plate counts, showed a major reduction of viable microorganisms in the processed product as compared to the unprocessed. It would appear, however, that processing even under these mild conditions would result in a product close to sterile as it emerges from the expander, whereas the unprocessed products would contain the normal load of microorganisms that might be expected in untreated cereal products, e.g., ~ 100,000 to 500,000/gm

Since the Summary Report was submitted, an additional publication has been received and is appended.



Comparison of Brabender viscosity of extruded "Leche Alim" with unprocessed sample.

FIG. 1

TABLE I

Mixture: Wheat (Chilean) - Milk

Processing Temperature	P.E.R.
290°F	1.68
270°F	1.89
250°F	1.99
200°F	2.18
Casein	2.31

Mixture: Wheat (High-Protein) - Milk

290°F	0.61
270°F	1.41

TABLE II

Mixture: Wheat - FPC - Milk - Sunflower

Processing Temperature	P.E.R.
290°F	0.90
250°F	1.74
Modified Thermocouple	
250°F	1.76
Modified Thermocouple with Cooling	
200°F	2.42
Non-processed Mixture	2.56
Casein Control	2.63

TABLE III

Mixture: Rapeseed Meal - Non-Fat Milk

Processing Temperature	P.E.R.
220°F	2.6
Unprocessed	2.7
Casein Control	2.7

TABLE IV

Mixture: Wheat - FPC - Milk - Sunflower

Processing Temperature	Available Lysine
200°F	3.96
Unprocessed	3.99

TABLE V

Product	P.E.R.
Expanded Cereal + WPC + Sunflower Protein	3.12
Raw Mix	2.58
Casein Control	2.71