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SUMMARY

Research on the potential value of coconut was initiated at Geneva, while studies have continued on the acceptability of a soy-based beverage in the Philippines. Results on the amino acid composition of the coconut protein indicate it is deficient in several of the essential amino acids, in particular, the sulfur amino acids and isoleucine.

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I. Progress at Geneva

A. Engineering Studies

1. Disintegration of soybeans

Soy milk was previously prepared by hammermilling water-soaked whole beans, filtering the resulting slurry, homogenizing the filtrate, and then spray drying. The yield of dry soy solids was about 65% of the original material.

The present report deals with studies on the disintegration of whole soybeans so that the solids yield in the milk might be increased.

(a) Use of Rietz disintegrator

Method of operation. The feed, either soaked beans or dry beans, was introduced to the mill using a vibratory feeder at a fixed rate. Water was pumped either hot or cold depending upon the conditions desired. Two general soaked-bean techniques were tried--cold grinding and hot grinding, besides dry bean grinding, together with the proper amount of water to obtain the desired soy milk. A hammer speed of 9,000 rpm was used with three different screen sizes (.023, 1/16, and 1/8 in.).

Grinding of soaked soybeans with cold water. The Rietz mill can take a maximum load of 0.25 kg dry solids per min. At greater loads, the mill will overload. This is true for the fine and coarse screens and at the settings used. The losses on the secondary discharge of the mill can amount to 7% of all dry solids at a 1:10 dry beans:water ratio. The amount of foam at this dilution was 21.74% (v/v) or 1:3.6 foam:milk ratio. The effect of amount of water on the degree of fineness in grinding was more efficient for a low water ratio than a high water ratio. The amount of solids retained on a #4 Whatman filter paper and the amount of solids retained on a 100-mesh screen for a 1:4 and 1:10 water dilution gave values of 27.5 and 47.2% solids lost on the screen, respectively. All grinding operations were adjusted to a dilution ratio near 1:4 following the observations previously described. Low water dilution also had an advantage over the high water dilution technique for it produced considerably less foam. Foam was a problem early in the studies since difficulties were encountered in passing the foam through a 100-mesh screen, and, if the foam is discarded, the solids losses can amount to 24%. Cold grinding can produce a satisfactory slurry of soybeans and water with a solids concentration near 20%. This can be passed directly to a spray dryer or diluted to soy milk if the finest screen is used in the milling, or a larger screen is employed to grind the soybeans as a preparatory step for further operations. The flavor of the soy slurry produced

by the cold grinding procedure was undesirable. Therefore, the following studies were conducted using hot water during the grinding step.

Grinding of soaked soybeans with hot water. The same technique used in the cold grinding operations was employed in hot grinding except hot water and steam were used. In the early stages of the hot grinding method, hot water was used to offset the flavor defect production. However, the problem of foams necessitated the employment of steam, injected directly into the hammermill chamber. It was postulated that the foam was caused by the incorporation of air sucked by the mill, and, since the milk has a thick consistency, the foam was very stable. Steam was substituted for the air to eliminate the foam problem, since steam can condense when the whole slurry was cooled. The use of steam injection indicated that the foam problem was practically eliminated. Steam also aided in maintaining the temperature during the grinding step near 100°C. The resulting milk slurry was judged to be free from the objectionable off-flavor observed in the cold grinding. Samples were collected after the grinding and were analyzed for total solids and particle size distribution. Data indicate that the mill's performance was the same as in the cold grinding. However, the elimination of the foam and the off-flavor represents important improvements in the processing of soy. A larger screen in the mill produced a milk slurry which was judged easier to handle, and the losses in the secondary discharge were reduced to 1% of the total solids. This reduction in total solids losses may be due to the lower residence time of the beans in the hammermill chamber due to the larger holes in the screen, thus allowing the disintegrated beans to pass through at a more rapid rate.

The temperature of the milk obtained from hot grinding was near 100°C. The problem of rapid cooling to minimize the effect of high temperature on the physical and chemical properties of the milk, especially the protein fraction, had to be resolved. A pasteurizing effect on the milk can be obtained if the hot milk can be rapidly cooled.

Samples obtained from the mill were diluted to 10, 8, 6, 4, and 2% solids to observe the effect on the stability of the milk. All samples showed distinct solids layer on the bottom of the container after standing for 24 hr. The sediment was most pronounced in the most dilute solution. The concentrated samples (10 and 8%) had sediment layers but not as distinct as the low solids concentrations.

Grinding dry soybeans. The most acceptable method for grinding dry soybeans was a 1:10 dilution (dry beans: water). All other dilutions (1:8, 1:6, and 1:4) plugged the Rietz disintegrator. Overloading of the Rietz motor prevented further concentration of the dilution. Foam and off-flavors were

predominant in the final product from the Rietz since the above problems developed. No further studies were initiated to improve the dry soybean grinding.

(b) Use of attrition mill

The use of a single disc attrition mill has proven very successful in the production of granular products, hulling of oil bearing seeds, and the cracking, shredding, and blending of many types of materials. It is also suited for the manufacture of peanut and other nut butters.

Results obtained with the Bauer attrition mill indicate that particle size of soybeans was not reduced beyond the values obtained with the Reitz disintegrator. It was also necessary to pass the bean material through the mill three times. For each pass it was necessary to move the adjustable plate closer to the stationary plate, a definite operational disadvantage. The results obtained with soaked soybeans were similar to those just described for dry beans.

Rietz disintegration followed by Bauer attrition mill. The Bauer plate was adjusted according to the procedure previously described. The soy milk slurry obtained from the Rietz disintegrator was quickly and easily passed through the Bauer attrition mill. Only hot soy milk slurries were used. Throughput capacities from a .0625-in. screen were 1074.5 lb/hr. Some foaming of the slurry occurred, but it appeared to be minimal. No improvement was realized by passing the Rietz slurry through the Bauer.

(c) Use of colloid mill

The Morehouse colloid mill used in these studies is a laboratory model which uses carborundum discs to grind materials into particle sizes in the colloidal range.

Initial experimentation with the mill included gravity feeding slurries obtained from the Rietz that passed through the Bauer. Gravity feeding was slow and maintained low yields.

Clearance for operation of the Morehouse colloid mill had to be made while the mill was in operation in order to provide lubrication for the working faces as they were adjusted to about zero clearance. Further reduction of the clearance caused burning of the product. Yields of 26.4 lb/hr and bulk density of .84 g/cc were obtained on soy milk which was gravity fed through the Morehouse mill.

Pressure feeding of soy milk through the Morehouse was accomplished by pumping a soy milk slurry through a Moyno pump and a pressure head into the Morehouse mill.

Pressure feeding of soy milk through the Morehouse was necessary to increase throughput (yield) and prevention of product burning on the working faces. The increase of throughput shortens the time a given particle will be in contact with the working face. It was, therefore, necessary to reduce the distance between the working faces to about 0.005 in. to accomplish similar results as in gravity feeding. Pressure that can be applied to the Morehouse varies from 8 to 30 psi; however, in the studies, pressures of 8 to 10 psi were usually employed. Yields of the Morehouse colloid mill operation under pressure increased to 66.8 lb/hr with similar bulk density of gravity feed samples of 0.84 g/cc.

Slurries of the same batch were studied for comparison of grind (Rietz and Rietz-Bauer). Most of the solids passed through the 325-mesh screen (.044 μ). The Rietz-Bauer-Morehouse left a major portion of the remaining solids on 325- and above 160-mesh screens. The Rietz-Morehouse left only a small proportion of solids on the screens, indicating that the effect of particle size reduction by the Bauer was not improved but only a redistribution (thus eliminating the Bauer from the process).

2. Microscopic examination of soy milk

Beans passed through the hammermill (Rietz) equipped with a 1/16-in. screen contained from 650 μ to as much as 2,000 μ particles. Passing the slurry from the Rietz mill through the attrition mill resulted in particles of 400 μ to 1,000 μ in size. Samples obtained from milk passed through the colloid mill, gravity fed, reduced the particles down to 150 to 200 μ, where fibers were distinctly separated from some solid particles.

Later observations of samples from the hammermill and from the colloid mill showed the presence of aleurone cells intact and still filled with a solid-looking material which could be proteinaceous. Samples from these slurries were diluted down to 10, 8, 6, 4, and 2% solids and stored in the cold room for 1 day. Microscopic examination of both the diluted and the undiluted samples, showed that the diluted samples were devoid of the intact aleurone cells, and some fibrous-looking material remained. No other solids were present in the samples. The original thick slurry, however, contained the unbroken aleurone cells, even after 1 day's storage in the cold room.

The observation was repeated when both cooked and uncooked soybeans were processed in the Waring blendor. The aleurone cells were present in the milk prepared in the laboratory, from the cooked and uncooked beans, and these aleurone cells disappeared from the diluted samples after standing in the cold room. The cells were intact in the undiluted milk slurry.

3. Effect of soak time and temperature on water uptake

Harasoy 63 soybeans were soaked in 50°C (112°F) water for 2 hr using a bean to water ratio of 1:3. Six (6) kg of soybeans and 18 kg tap water were placed into a steam-jacketed kettle and the steam turned on until the temperature of the water reached 50°C. At the end of the soak period, the soybeans were emptied into a colander to drain the water. Drained weight was taken to determine per cent added moisture.

Initial investigations were made using Clark variety soybeans but we later changed to Harasoy 63 because of its known history and single lot number.

The effects of time (0 to 7 hr) and temperature (30, 40, 50, 60, 70, 80, and 90°C) on water uptake of soybeans (Harasoy 63) were evaluated. The results show that maximum hydration occurs at a rapid rate above 60°C. However, greater losses of solids also occur. A temperature of 50°C and a soak time of 2 hr appears to give rapid hydration with minimum solid losses.

B. Biochemical Studies

Powdered soy milk is easily transportable and preservable and, therefore, suitable for mass production. Accordingly, the manufacture of soy milk powder is one of the most important means for supplying it economically to underdeveloped countries. In general, however, the solubility of heat-treated soy milk is decreased on drying.

For the purpose of making water-dispersible soy milk powder, the effects of various conditions, under which the heat treatments of soy milk before drying are accomplished, on the redispersibilities after drying were investigated, using the technique described in the previous progress report. The concentrations of solids in soy milk during heating and before drying had a great influence on the redispersibilities after drying. The dispersible proteins increased markedly with a decrease in solids present in the soy milk. For example, decreasing the concentration of solids from 16 to 2% resulted in an increase in dispersible proteins from 20 to 80% for soy milk heated 20 min at 100°C. For similar concentrations in soy milk heated for 120 min at 100°C, the dispersible proteins increased from 30 to 90%. The pH of soy milk (starting material--freeze-dried soy milk, treated with NaOH to obtain desired pH) also had an influence on the redispersibilities. The dispersible proteins after drying increased with increasing pH in the freeze-dried starting material. For soy milk (pH = 6.5, 7.5, and 8.5, respectively) heat-treated for 120 min at 100°C, the dispersible proteins were 45, 55, and 65%, respectively, whereas similar milk heat-treated for 10 min resulted in only 25, 35, and 40% dispersible proteins, respectively.

The effects of additives were also examined. The addition of emulsifiers was effective to some extent. The hydrophile-lyophile balance (HLB) of the emulsifier which gives the maximum redispersibility was about 9.0, at which the dispersible proteins after drying increased from 25 to 30%.

The disulfide bond splitting reagents had a great influence on the redispersibility of the soy milk proteins after drying. Namely, the redispersibilities increased by the addition of Na_2SO_3, cysteine, and 2-mercaptoethanol. This indicates that the intermolecular disulfide bonds which are formed during drying are responsible for the insolubilization of the proteins in the dried soy milk. However, a very interesting phenomenon was observed with respect to the levels of disulfide splitting reagents. Namely, the dispersible proteins after drying increased from 25 to 60% for soy milk heated 20 min at 100°C after the addition of the 0.001 mol cysteine to the 6.5% soy milk, but it decreased to 20% after the addition of 0.005 mol. This is lower than the value obtained for soy milk without any addition of the disulfide splitting reagent (cysteine). The dispersible proteins increased again to more than 50% by further addition of cysteine. Similar behavior was also observed for Na_2SO_3 and 2-mercaptoethanol.

C. Flavor Studies

1. Soy milk studies

A study of the effects of soaking soybeans in sodium hydroxide solution as a pre-treatment for soy milk processing is being conducted. Four (4) samples were prepared by soaking soybeans in sodium hydroxide solutions of 0, .048, .076, and .097 normality. Soybeans were soaked for 2 hr at 50°C, then rinsed well with distilled water prior to grinding in a Rietz disintegrator. Sufficient water was used to obtain a 1:10 (bean:water) ratio. The slurry was then filtered. The filtered milk samples had pH's of 6.55, 7.37, 8.04, and 9.18, respectively. Filtration rate was observed to decrease with increasing pH. Hunter L value was also observed to decrease indicating a darker product with increasing pH. The flavors of the samples were evaluated by a 14-member taste panel. Results indicated that the sample with a pH of 7.37 was significantly better than the others at the 95% probability level. The panel was also asked to determine the difference in mouthfeel. Although the results of this panel were not significant at the 95% probability level, the ratings given by the panel did improve with increasing pH.

Studies are presently under way to determine the amino acid content and nutritional value of the various fractions from the four pH treatments.

2. Coconut studies

Qualitative and quantitative analyses of the volatile flavors of raw coconut meat are presently being conducted. This will serve as a basis for determining the changes in desirable or off-flavors as may be developed by different processing methods in the production of low-fat coconut flour.

One hundred (100) coconuts from Puerto Rico were purchased from a local store for preliminary studies on coconut meat.

Thirty-five (35) nuts have been cracked, peeled, finely shredded and freeze dried. This dried material is being fractionated into ether-soluble, water-soluble, and insoluble fractions. Chemical properties of these fractions will be measured when the fractionation has been completed.

D. Nutritional Studies on Coconut Flour

The amino acid composition of coconut flour (Carver-Greenfield Process, R403, 10-25-67) has been determined and indicates that the sulfur amino acids and isoleucine limit the nutritional quality of the protein. This further indicates that no over-all supplementary effect would occur between the amino acids of soy milk and coconut flour insofar as the biological utilization of the protein is concerned. Confirmation of this hypothesis has been checked using the modified essential amino acid index (EAAI). Coconut flour has an EAAI of 60.8, while the EAAI of soy milk is 75.1.

Combinations of 1:1, 1:4, 1:7, and 1:10 of coconut flour to soy milk, respectively, have been evaluated. Thus, a combination of 1 part coconut flour protein to 10 parts of soy milk protein results in a protein product which has an EAAI very close to that of soy milk. Therefore, a complimentary effect for some of the amino acids does occur; however, the sulfur amino acids prevent any improvement in the chemical estimate of protein quality above that for soy milk. When sufficient coconut protein is obtained, the nutritional value will be investigated with laboratory animals to determine if the <u>in vitro</u> (chemical) EAAI value is correct.

It should be further noted that a soy/coconut-based beverage would represent only a portion of the total protein in the Filipino diet. Investigations are under way to evaluate the impact of such a beverage on the over-all change in nutritional quality of the diet.

II. Progress at Los Baños

A. Pilot Plant

A new Food Science building and Pilot Plant, financed through loans from the World Bank, are scheduled presently to be out for bid about fall, 1968. It is unlikely that it will be available for occupancy before the end of 1969. Therefore, plans have been drawn to renovate the rear one-third of the main Chemistry Lecture Hall for a temporary pilot plant. The steam boiler, air compressor, and auxiliary equipment are to be housed in a small addition to be erected along the side of the pilot plant. Renovation is expected to begin before July 1. Certain pieces of electrical wiring, etc., were unavailable in the Philippines, and these are being procured in the United States through Cornell. It is estimated that the renovated pilot plant will be ready for occupancy by August 1, 1968.

B. Research on Soy-Coconut Milks

Three varieties of Philippine soybeans have been used: Davao, Hsieh-Hsieh, and Taichung. No appreciable differences have been observed in flavors of soy milks produced from the three varieties.

A highly acceptable soybean milk has been produced from Philippine soybeans using the following process:

1. The beans are hydrated in dilute alkali (2 g sodium hydroxide/liter) for 4 hr at room temperature (approximately 30°C).

2. The beans are drained and washed with fresh water.

3. The beans are ground with hot water (170°F) in a ratio of 1:10 [dry beans (w) to water (v) allowing for the water absorbed during hydration]. The beans are ground in a Waring blendor for 5 min.

4. The soybean milk slurry is filtered under vacuum through a standard milk filter pad.

5. Various flavoring ingredients and/or coconut milk are incorporated in the soy milk.

Coconut milk is prepared by removing fresh coconut meat, grinding it in a Waring blendor with water (100 ml water/100 g coconut meat), and filtering the milk through cloth.

Coconut milk is combined with soybean milk in proportions of 1:4, 1:9, and 1:19 (coconut milk to soy milk, v/v).

C. Flavor Studies

Earlier taste panels showed that only about one-third of Filipinos tasting unsweetened soy milk liked it. Addition of 5% sugar resulted in approximately 48% of elementary school children rating it as "liked". Addition of 9% sugar resulted in 82% of the children indicating a liking for it. Addition of 0.1% vanilla with 9% sugar increased the percentage of school children liking the product to above 90%. With 0.1% vanilla, the percentage of sugar could be decreased to 7%, and still the soy milk received an above 90% "like" rating. Addition of chocolate (5%) or coconut milk (10%) resulted in the soy milks being rated as "like" by 96 to 97% of the school children. This represents as high a degree of acceptance as any new product can achieve.

The present investigations were concerned with soy milk sterilized in 7-oz soft drink bottles for 12 min at 121°C with and without coconut milk as an adjunct. Samples were supplied in various flavors to approximately 335 elementary students in five schools.

Students in some barrio schools, such as Sta. Ana, were much more critical, especially when coconut milk, a flavor with a low prestige value in the coconut-producing areas, was incorporated. Mothers also at Sta. Ana were more critical of the soy milk flavor.

The results indicate that the variously flavored soy milks were very acceptable to the children when the milks were given to them. The question that naturally followed was whether the children would buy them if they were made available to the school canteens and the children had to pay for the milks in competition with soft drinks and other snack items. Two highly acceptable soy milk formulations were tried. The first contained 9% sugar and 0.1% vanilla, a low-cost flavoring combination. The second contained 9% sugar, 0.1% vanilla, and 5% chocolate. This formulation costs about 2 times the first formulation.

It was found that children, particularly in the private school (Maquiling) did buy the sterilized, bottled soy milk in reasonable quantities. In the public schools, however, most of the bottled soy milk was sold to teachers, as the majority of the children did not bring enough money to school each day to purchase a whole bottle of milk costing 15 or 20 centavos.

At this point, it had become very clear that we needed some economic data regarding the amount of money children bring to school each day. There is no need to manufacture products which sell beyond the economic means of the student consumers. A survey of the amount of money brought to school by students in

four schools was made. It was found that the majority of the students brought less than 10 centavos (2.5¢ U. S.) to school per day. From 12 to 24% of the students brought no money to school on a given day.

In addition, the results showed that at barrio schools, such as Sta. Ana, higher percentages of the children (27 to 44%) brought no money, and the majority of the students brought 5 centavos (1.5¢ U. S.) or less per day. Getting nutrition supplements to this group of students require that supplements either cost 5 centavos or less or that they be subsidized.

Soy milks prepared in the Department of Food Science and Technology (Cornell University, Geneva) from Harasoy soybeans with and without added flavoring were compared with soy milks prepared from Philippine soybeans using Filipino taste panels in the Department of Agricultural Chemistry (University of the Philippines, College of Agriculture, Los Baños). It was observed that the Harasoy soy milk was much whiter in color than that prepared from Philippine (Davao) soybeans. However, the Filipino taste panels preferred soy milk prepared from Davao beans at U.P.C.A. containing 8% sugar over similar milk prepared from Harasoy beans at Cornell.

The Geneva group sent samples of Harasoy soy milk with various flavors as follows: 8% sucrose plus banana, passion fruit, pineapple, cinnamon, anise oil, coconut, vanilla custard, or vanilla powder. None of these were rated higher by the Filipino taste panel than the simple formula 9% sucrose plus 0.1% vanilla.

Research at Geneva indicates that the use of alkali during the preparation of soy milk results in an improvement in flavor and results in a darker color. The difference in preparation (use of alkali during the soaking step in the Philippine samples) probably accounts for the greater acceptance of the Philippine soy milk over that made in Geneva, since these particular Geneva samples had been prepared by the "standard" method, not incorporating the alkali treatment.

D. Soy-Coconut Candy

It was observed that a popular snack item in the school canteens was ice candies costing 5 centavos each. These are flavored sugar water frozen in plastic bags. They contain no protein. Our soy milks were placed in similar narrow plastic bags (60 ml/bag), frozen, and offered for sale in the school canteens. It was found that they sold "like hotcakes". We were unable to satisfy the demand at a public school (Lopez). In the barrio school (Balayhangin) offered in direct competition with commercial ice candies, the soy milk candies outsold the commercial product.

An excellent candy was developed by the following procedure: 100 g ground whole soybeans, 100 ml coconut milk, and 100 g sugar are mixed and brought to a boil. The mixture is boiled with constant stirring until the sugar is carmelized. Thirty (30) g pieces are wrapped in waxed paper. The candy contains approximately 20% protein. Each piece, therefore, contains nearly as much protein as a 7-oz bottle of soy milk. It represents an alternate way of getting protein to children in a form liked by children.

E. General Conclusions from Philippine Studies

1. Elementary school children, in the schools tested, will buy the bottled chocosoy or plain soy milk if they have enough money.

2. Most children have only 5 or 10 centavos to spend at the school canteen each day. Toward the end of the week, they have less to spend. If maximum distribution is desired, particularly in the barrios, the price per unit product should not be above 5 centavos.

3. Soy ice candies at 5 centavos are the most popular soy product developed to date.

4. Preliminary studies at two schools suggest that soy ice candies, if available, will outsell present commercial ice candies.

III. Pilot Plant Equipment for Soy Milk Production at the University of the Philippines, Los Baños

The following equipment was purchased for experimental soy milk production, tested in operation at the Geneva pilot plant, crated, and shipped to the Philippines:

Item	Purchase Price	Cost of Accessories	Total Cost
Steam jacketed kettle	$ 566.00	$ 37.00	$ 603.00
Disintegrator	3,928.00	50.00	3,978.00
Homogenizer	1,990.60	145.40	2,136.00
Screw pump	772.00	180.00	952.00
Air compressor	486.00	34.00	520.00
Water softener	205.80	--	205.80
Steam boiler	1,475.40	1,304.60	2,780.00
Water heater	267.40	18.00	285.00
Canning retort	1,257.65	62.35	1,300.00
			$12,759.00
Labor involved in ordering, assemblying components, making modifications, and crating for shipment			2,712.00
FINAL COST			$15,471.00

Mr. Jesus V. Melgar, while studying for his Masters degree in Food Science at Cornell, spent six months in the pilot plant at Geneva learning processing techniques and becoming thoroughly familiar with the equipment being shipped to Los Baños. During that time he installed much of the plumbing, electrical and control accessories on the various units, tested the units under operating conditions, and prepared operational manuals. In some cases only electrical switches with suitable overload protection had to be added to the units, while others, such as the steam boiler and retort, required structural modifications and the design of control circuits.

The smaller, more compact units were crated ready for operation on arrival in the Philippines. Larger pieces of equipment, such as the steam boiler and the connecting pipe to the water heater and softener, were disassembled coded to facilitate reassembly.

Mr. Melgar has returned to the College of Agriculture at Los Baños and will assist in the renovation of a building to house the equipment and place it in operation.