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AQUEOUS PROCESSING OF FRESH COCONUTS FOR RECOVERY OF OIL AND COCONUT SKIM MILK

INTRODUCTION

COCONUT PROTEIN represents a substantial source of potentially available food protein in a number of tropical countries. Currently, worldwide growth of coconuts results in about 200,000 metric tons of coconut protein annually (USDA, 1971). This protein is currently not usable as food because of unsanitary processing of copra. Consequently efforts have been undertaken to process fresh coconuts to recover food-grade protein. However, the processes developed have been marked by inefficient recovery of oil and protein (Rajasekharan and Sreenivasan, 1967).

The purpose of this work is to describe an economical method for the pilot plant processing of coconuts. The processing is designed to produce coconut skim milk, a nutritious product currently produced in the kitchen or on a larger scale by rather rudimentary technology (Salon and Maniquis, 1969). The pilot plant processing as presented is a development of preliminary work involving bench-scale processing (Hagenmaier et al., 1972).

EXPERIMENTAL

Pilot plant operation

A simplified flow diagram for the process is shown in Figure 1. Pilot plant operation was performed on a scale of approximately 100 lb of coconut meats per day. The coconuts were purchased as husked nuts from a local grocer, shelled manually and the coconut water saved for use in processing. Washed meats were ground in a hammer mill (The Fitzpatrick Co.) with 0.25 in. diam holes in the screen, followed by grinding in a disc attrition mill (Bauer Bros. Co.) with the discs set at minimum clearance.

The ground coconut was briefly mixed with heated coconut water (80°C), or with a corresponding amount of heated tap water, when the coconut water was not used. The mixture was pressed at 50 psi in a pulp press, against a screen with holes 0.01 in. diam. Extraction with hot water, followed by the pressing, was repeated twice more. The two materials resulting from the pressing operation are the liquid filtrate (called coconut milk), and the solids (called residue). The residue came from the press at 70 ± 10% moisture, and was dried in a rotary dryer, in a flow of hot air (inlet air is ca. 100°C). The dried residue is a final product.

The coconut milk was filtered through a vibrating screen (120 mesh) to remove the last traces of residue. The pH of the filtered milk was raised to 7.0 (from 6.3) with sodium hydroxide. The milk was pasteurized (ca. 1 hr at 60°C), then centrifuged in a three-phase, desludging type separator (Westfalia). This model develops a centrifugal force of 4,700 × G at the radius of the hole in the disc stack, has a bowl capacity of 3.2 liters and was operated with a feed of 8 liters per minute. The milk was centrifuged until the solids capacity of the bowl was reached, the feed to the separator stopped, and the bowl flushed with aqueous phase for 4 min before desludging. Complete desludging was performed once for every 20 kg of coconut meats used.

Three phases emerge from the separator: (1) The lightest phase, usually called coconut cream, which is ca. 65% oil on a wet basis; (2) The aqueous phase, usually called coconut skim milk, which is a solution of the soluble components of the coconut, with some suspended particles. With counter-current washing of the residue, the aqueous phase would contain ca. 9.5% solids as it comes from the separator; and (3) A solids phase, consisting mostly of insoluble protein, which is dried to give a final product.

The coconut cream is an oil-in-water emulsion with average oil globule size of ca. 10 μm in diameter (Hagenmaier et al., 1972). This emulsion was diluted with oil to reduce the moisture content, then agitated with a high velocity pump to invert the emulsion. Best results were achieved when the temperature was raised to ca. 80°C before the agitation. After inversion of the emulsion, oil and water were separated by first allowing a gravity separation (which took several minutes) into two phases: an aqueous phase and an oil phase. The aqueous phase,

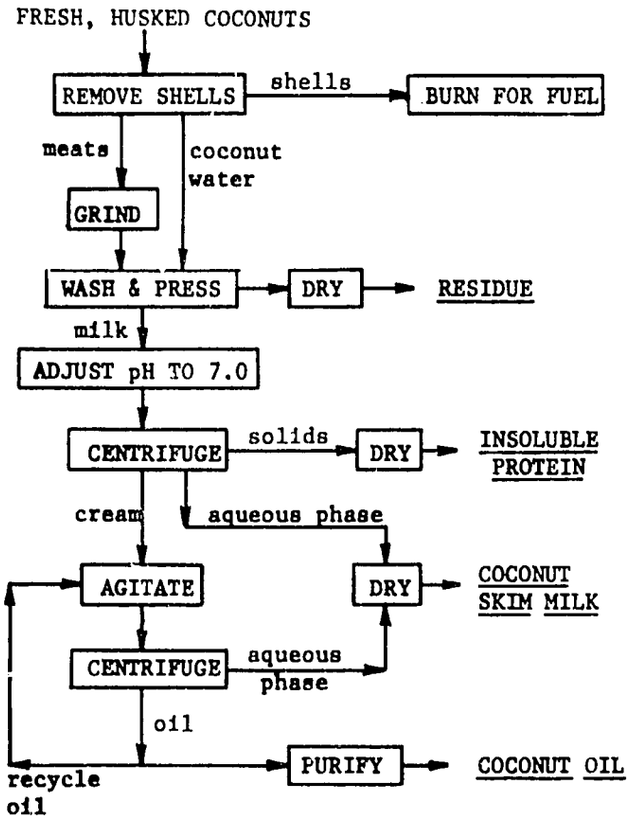

Fig. 1 - Simplified flow diagram for the aqueous processing of coconuts. The shells were discarded in our operations, but would be burned for fuel in commerical processing.

after centrifugation, has approximately the same composition as the aqueous layer from the three-phase separation of the milk. The oil phase was purified by centrifugation, heating to drive off residual moisture, and decanting the oil from settled solids.

The insoluble protein recovered from centrifugation of coconut milk was dried by freeze drying. The coconut skim milk was dried by spray drying, with an air outlet temperature of ca. 85°C, and air inlet temperature of ca. 170°C.

Analytical methods

Standard methods of analysis were used for nitrogen and crude fiber. Crude fat was based on ether extraction of dried samples, except for the soluble coconut fraction, which required extraction with a chloroform-methanol mixture (Bligh and Dyer, 1959). Ash analysis followed heating for 2 hr at 600°C, except for the soluble coconut fraction which was ashed overnight at 550°C. Soluble carbohydrate was determined by measurement of reducing sugars in a clarified aqueous extract. The measurement followed inversion for 1 hr at 60°C in 0.7M HCl.

RESULTS & DISCUSSION

Products

The gross analyses of the products are shown in Table 1. All values are the averages of measurements on at least two independently prepared samples. The reliability expressed represents the estimated 95% confidence level for the sum of both analytical errors and variations in analyses due to small changes in processing parameters.

The analysis of coconut oil is not included in Table 1. Analysis of the final oil product showed it to contain 0.4 ± .1% free fatty acids, with an iodine number of 7.5. The oil was centrifuged to clarity in the laboratory and some precipitate was obtained, with the amount of nonoil solids being 0.4 ± .2%. Coconut oil from aqueous processing is therefore superior to oil obtained by crushing copra, which varies widely in analysis. A typical value for free fatty acid content of crude coconut oil from copra would be ca. 5%.

The residue is a fibrous material, which contains small particles of dark testa. Preliminary work shows that the testa can be separated to give a very light-colored product. The protein products are light brown or tan. All products can be obtained almost white if the coconuts are pared.

The products from processing of coconut meats are shown in Table 2. Any product losses that may result from spray drying are not included, because spray-drying losses are expected to be almost negligible in a commercial operation. All results are the averages of at least two independent experiments, performed after many preliminary experiments that were done to determine optimum procedures and operating parameters. The results reflect the product losses resulting from multiple transfer of material between containers and processing equipment.

It is presumed that such losses would be negligible in a continuous process. Therefore a material balance was assumed to calculate the products from the continuous, large-scale aqueous processing of fresh coconuts, with coconut water being used to extract coconut milk from the fiber (by counter-current extraction). Fresh husked nuts are assumed to be 44% meats, 31% water and 25% shells (wet weights). The results of this calculation are shown in Table 3.

These results indicate that 69% of the total protein is in the skim milk fraction, and 99% of the crude fiber is in the residue fraction. This separation of protein from crude fiber is considered one of the principal advantages that aqueous processing has, as compared to dry processing of coconuts.

Similar calculations show that the coconut skim milk also contains 83% of the salts (as estimated from ash analyses) and 97% of the soluble carbohydrates of the coconut. The skim milk fraction therefore contains the bulk of salts, sugars and protein of the coconut.

The preparations of products was performed repeatedly, with slight changes in

Table 1—Typical compositions of dried products

	Residue	Insoluble protein	Skim milk[a]
% Crude protein (N × 6.25)	3.4 ± 0.6	52 ± 10	25 ± 2
% Crude fat	24 ± 3	19 ± 9	5.1 ± 1.5
% Crude fiber	25 ± 4	2.0 ± 0.5	0.03 ± 0.03
% Ash	0.6 ± 0.1	9 ± 2	9 ± 1
% Moisture	5 ± 3	4 ± 2	0.5 ± 0.3
% Carbohydrate, total[b]	60 ± 3	unknown	unknown
% Carbohydrate, soluble	0.3 ± 0.05	7 ± 3	45 ± 3

[a]Composition with coconut water used in processing. See text for composition without use of coconut water. Dehydrated skim milk was stored in desiccator to maintain low moisture content.
[b]By analysis, after digestion in 72% sulfuric acid

Table 2—Experimental recovery of different components in the processing of coconut meats[a]

Product \ Component	Fraction of component in product (%)		
	Total mass	Oil	Protein
Residue	17[b]	5.8	7.0
Insoluble protein	2.5	0.7	20
Skim milk	16	1.2	65
Oil	59	85	0
Total % recovered	94	93	92

[a]For pilot plant processing of coconut meats only; coconut water was not used in the processing.
[b]The standard deviation for each result is approximately 2% of the value in the table.

Table 3—Products from processing, as calculated from experimental recovery, product compositions and material balance

Product	Mass of product	Protein in product	Oil in product
Residue	43 kg[a]	1.5 kg	10 kg
Insoluble protein	5.7	3.6	0.7
Skim milk	44	11.8	0.6
Oil	142	0.0	142
Totals	234	16.9	153

[a]All results are on a dry weight basis. The starting material is 1000 kg of husked coconuts (wet weight basis).

the processing. The observations considered most significant are the following:

Effect of pH. Coconut milk was centrifuged at pH values from 6.4–8.1. The protein content of the skim milk fraction was observed to be independent of pH over this range. Furthermore, no significant change in composition of the insoluble protein was observed from pH 7.0–8.0.

Use of coconut water. It was observed that only the skim milk fraction was significantly changed in composition if coconut water was not used in the processing. When coconut water was discarded, instead of being used in processing, the skim milk fraction contained 30 ± 2% crude protein; 37 ± 3% soluble carbohydrates; and 9 ± 1% ash (see Table 1).

Temperature. Milk temperatures of 60 ± 5°C were used in the processing. Laboratory results indicate that significant heat coagulation of coconut protein does not occur below 75°C in the solvent system of the aqueous processing (pH 7.0, 8% suspension of the skim milk fraction).

The temperature used during spray drying (air outlet temperature of 85°C) did not reduce protein solubility. Based on four measurements each, it was observed that 89 ± 5% of the nitrogen was dissolved for a spray-dried sample, versus 85 ± 5% for a freeze-dried control and 88% for a single measurement on an undried control (at 25°C, pH 7.0, ca. 6% solids in suspension).

Estimation of product costs

In making the cost estimate oil and the skim milk fraction were considered to be the main products of the aqueous processing of coconuts, and were made to carry all costs. Cost of the skim milk fraction was calculated as total costs minus income from oil sales. Total costs were taken as raw material costs plus processing costs. The costs were calculated for a hypothetical processing plant, operating in the Philippines, which would process 125 metric tons per day of husked coconuts.

Purchase prices of fresh, husked coconuts in the Philippines from 1962 to 1971 averaged $34.20 per metric ton, according to information from the United Coconut Assocation of the Philippines (1971) and Emata (1972). This price includes $0.70 per metric ton estimated as transportation costs. Crude oil prices in the Philippines, also for the period 1962–1971, averaged $0.113 per lb.

Processing costs for the hypothetical processing plant were estimated to total $15.80 per ton of husked coconuts processed. This cost includes labor, equipment depreciation, interest on borrowed capital, maintenance, utilities, administration and other miscellaneous expenses. The manual shelling of coconuts is the largest processing expense, accounting for 22% of total processing costs. The estimated total equipment cost is $650,000. The total installed plant cost is taken as 2.5 times the equipment cost or $1,600,000.

Based on these estimates, which conservatively assume 90% recovery of oil (results in Table 3 indicate 93% oil recovery) and 69% recovery of protein, it was estimated that the dried skim milk fraction would cost $0.16/lb to produce. It should be borne in mind that any income from other products would reduce the estimated cost of the soluble fraction. It might also be pointed out that assumption of zero income from products 1 and 2 has merely been a bookkeeping operation. It is anticipated that products 1 and 2 would, in fact, be marketable commodities.

An alternate process

An alternate process has also been considered, in which the skim milk fraction is sub-fractionated into two components: an acid-precipitated fraction, and an acid-soluble fraction. Our results have indicated that pH 4.3 is optimum for protein precipitation. This agrees well with data of Khaund (1971) on preparation of islates from hexane-defatted coconut meal.

The pilot plant separation of the two fractions was accomplished by adjustment of the aqueous phase to pH 4.3, followed by centrifugation at ca. 50°C. The freeze-dried, acid precipitated fraction, prepared without using coconut water in the processing, contained 65 ± 6% crude protein, 24 ± 4% oil, 2 ± 1% ash, 0.15 ± .05% crude fiber and 3.5 ± 1% soluble carbohydrates. The acid soluble fraction (also prepared without using coconut water) contains 13 ± 2% crude protein and 13 ± 3% ash. It is estimated that with use of coconut water the acid-precipitated fraction would not change significantly in composition, but the acid soluble fraction would change to a composition of 10% crude protein and 13% ash. From experimental data and material balance considerations, it was estimated that 46% of the total coconut protein would be recovered in an acid-precipitated protein fraction. If 1000 kg of husked coconuts were processed, 12 kg of the acid-precipitated fraction would be recovered, which would contain 7.8 kg of crude protein (see Table 3).

Production costs for this alternate process would be about the same as for the process resulting in the coconut skim milk. If oil and the acid-precipitated protein are taken as the only marketable products, then the cost of producing the acid-precipitated fraction would be $0.59 per pound.

In future reports, detailed chemical analysis of the products will be given, together with some biological evaluation, information on stability and physical properties, and discussion of possible food uses.

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