Coconut Flour: Technology and Cost of Manufacture

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ABSTRACT

Processing operations are described for production of oil and coconut flour from fresh coconuts. The nuts first are made into white desiccated coconuts in drying plants, and then prepressed, flaked, and hexane extracted in a central facility. White coconut flour that is produced contains 25% protein and only 0.5% oil. The process would be commercially feasible in the Philippines if a coconut flour price of $315 per metric ton were assumed.

INTRODUCTION

Coconut flour is the name commonly applied to the food-grade product made from the coconut endosperm by drying to make desiccated coconut, followed by removal of oil by pressing and/or solvent extraction to give coconut meal. The coconut meal is finally milled to give the flour. A bench scale preparation is described by Claudio, et al. (1). In many cases, the brown seed coat, ot testa, is pared off to give white coconut meats before the endosperm is dried.

The composition of coconut meal, which includes the brown seed coat or testa, has been reported by Samson, et al., (2) to be 25% protein (Nitrogen x 6.25), 7.7% crude fiber, and 4.7% ash, moisture and oil-free basis, and average values for 3 preparations.

Coconut flour has good nutritive value and contains no known substances present at toxic levels, as do some other oilseeds. Miranda, et al., (3) reported corrected rat assay protein efficiency ratio (PER) at 10% diet protein level, true digestibility (TD), and net protein utilization (NPU) values. For coconut flour without testa the values of PER, TD, and NPU were 2.8, 81, and 52 respectively. However, the 2 samples were prepared from different coconut sources by different methods. Butterworth and Fox (4) report TD of 78 and NPU of 46 for meal containing testa which was prepared with maximum processing temperature of 40 C. However, they reported lower nutritive value for samples of meal heated to 90 C or above. Rao, et al., (5) reported TD of 83 and biological value of 70 with human subjects (children) with coconut meal containing testa.

Food preparations containing coconut flour have been developed by the National Institute of Science and Technology (Manila). These foods include noodles, snacks, weaning foods, and some native recipes (6). In addition, coconut flour has been used at the 3-5% level in large scale preparation of the Nutribun, a bread-like product (7).

The production of coconut flour is viewed as an alternative to copra manufacture, which results in a protein product, copra meal, that is dirty, unsanitary, scorched, and, in general, unfit for human consumption. Potential world production of coconut flour without testa, at 5% moisture is equal to 40% of world production of coconut oil, which in recent years has been over 2 million metric tons annually.

Despite published information concerning nutritive value and food applications, the current commercial production of coconut flour is zero. Commercial production appears to be contingent upon more food applications research, and also on knowledge of costs and technology of production. The purpose of this paper is to present information on cost and technology of production of low fat coconut flour, with the goal of developing coconut flour as a food product.

It should be noted that the low fat coconut flour herein referred to contains only ca. 0.5% oil. Coconut flour with 15-20% oil has sometimes been referred to as low fat flour in the literature (3). In discussions with knowledgeable persons, it has become apparent that coconut flour with 15-20% oil would have somewhat less market potential.

METHODS AND MATERIALS

Most of the coconut samples used were supplied by the Franklin Baker Company of the Philippines (Manila, Philippines), manufacturers of desiccated coconut. The samples were produced in the plant whose operations were described in some detail by Woodroof (8). In normal production, the coconuts are manually shelled and pared, washed with water, shredded, steam blanched, and dried in a conveyor dryer. Besides samples of commercial type desiccated coconut, Franklin Baker Company supplied desiccated coconut samples prepared without the blanching step. Samples of both blanched and unblanched coconut were dried at each of 2 different temperatures: a) constant air inlet temperature of ca. 85 C; or b) commercial drying conditions, which consist of initial air inlet temperature of 110 C followed by adjustment to ca. 85 C.

A sample of presscake also was supplied. This consisted of white unblanched coconut that was dried, then pressed in a commercial Anderson screw expeller to give a presscake with oil content of 17%. In the pressing operation, the press was cooled and the feed rate controlled in order to limit temperature of presscake to 80 C as it was exiting from the expeller.

Samples from the Philippines were shipped to Texas A & M University for further processing and analysis, which took place at the Food Protein Research and Development Center of Texas A & M University, and also at test facilities of Crown Iron Works Company (Minneapolis, MN).

Presscake was reduced in size by cracking rolls or hammer mill. The presscake particles then were adjusted to ca. 10% moisture and formed into flakes of 0.3 mm thickness with one pair high flaking rolls. The flakes (bulk density of 0.29 gm/cc) were extracted with hexane at 60 C in a Crown Iron Works Company pilot plant extractor with residence time of 15-60 min, which reduced oil content to 0.4-0.7%. The extracted flakes were desolventized in a steam jacketed ribbon conveyor and finally ground with an impact stud mill to give a white flour, of which 85% passed through a No. 80 sieve.

The desiccated coconut used for comparative solvent extraction was white and unblanched with a moisture content of 5%. It was not flaked, but ground to a small particle size so that 92% passed through a No. 20 screen. The flaked presscake was as described.

The samples were column extracted for 15 min at 50 C, using 0.9 liters of sample and 4 liters of hexane, with recirculation, except that the first liter collected was not recirculated. In addition, one liter of fresh hexane was poured through the column just before draining and air desolventizing. For time dependence of extraction, the data in Figure 1, 0.2 liters of sample were column extracted with 0.5 liters of 50 C hexane, without recirculation. The column used measured 4.8 cm inside diameter (ID) by 60 cm tall. The bottom was fitted with perforated plate and sealed on funnel connected to tygon tubing. Oil contents are reported on a dry wt basis.

Protein solubilities of coconut samples were determined by mixing 5 g hexane extracted meal with 100 g water. The pH was adjusted, and the samples stirred for 1 hour, with

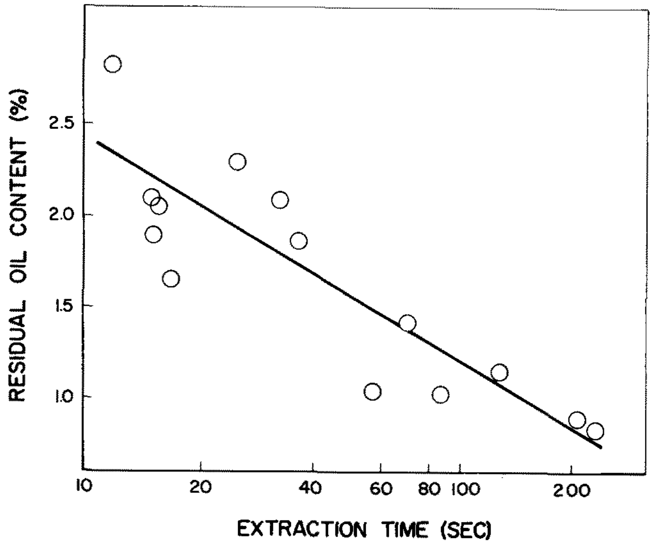

FIG. 1. Extraction of oil from flaked presscake. Initial oil content was 17%. Samples were extracted with fresh hexane at 50 C for time indicated. Each point represents one observation.

TABLE I

Composition and Properties of White Coconut Flour[a]

	Average value	Range
Crude protein (N x 6.25) (%)	25	21-28
Crude fiber (%)	9	7-11
Oil (%)	0.5	0.1-0.7
Ash (%)	5	4-6
Bulk density (g/cc)	0.33	0.30-0.36
Hunter color values[b]		
L	91	90-93
a	-0.6	-0.7 to -0.5
b	7	5-8

[a]Based on 5% moisture content; 3 samples, each analyzed twice.
[b]L = Measure of whiteness, from 0 (black) to 100 (white); a = measure of redness=plus, green=minus; b = measure of yellowness =plus, blue=minus.

periodic readjustment of pH with NaOH solutions. Samples were centrifuged 15 min at 16,000 g, then filtered. Nitrogen content of filtrate was determined by Kjeldahl analysis. Fraction of nitrogen extracted was assumed equal to fraction of protein extracted.

Laboratory analyses followed 1970 Association of Official Analytical Chemists (AOAC) methods. For oil content determination, samples were extracted 2 hours, ground, then extracted 2 more hours. Color measurements were made with a Hunter color difference meter. Reported results are the average of at least 2 observations, except where noted.

Equipment manufacturers were contacted to determine suitability, prices, capacity, and energy consumption for the major processing steps of grinding, drying, transporting dried coconut, pressing, preparing flakes, extracting with solvent, recovering solvent, and milling to a flour. The dryers are Proctor and Schwartz, Model SCF Conveyor Dryers, which are those commonly used for manufacture of desiccated coconut.

The proposed plant is assumed to be located in the Philippines because of the quantity of coconuts produced there. Local costs in the Philippines were estimated with the help of information from San Miguel Corporation (Manila, Phillipines), Franklin Baker Company (Manila, Phillipines), and others. The prices of buildings were estimated directly; however, costs of shipment, import duties, and installation were estimated with factors (9,10). Factors and equipment prices were based on price trends and observed correlation between prices of fresh coconuts and coconut

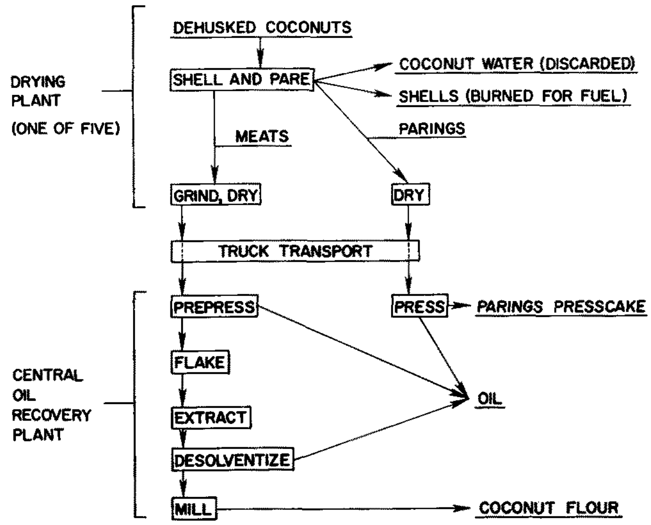

FIG. 2. Flow diagram for proposed process.

oil, as previously computed (11). All prices and costs are on a mid-1974 basis. Large taxes recently imposed on coconut processors in the Philippines have been ignored in this analysis in an attempt to free the estimates from local tax laws, and hopefully make the estimates applicable to processing in other countries as well.

For purposes of estimating production, it was assumed that the coconuts processed contain 25% shells, 31% coconut water, and 44% meats with testa. The meats with testa are 50% moisture and contain 69% oil on a dry wt basis. The relative wts of meats, shells, and water are quite variable for different types of coconuts (12); however, the values used are average values for Philippine coconuts (13).

RESULTS AND DISCUSSION

The process as described consists of unit operations well known in the oilseeds processing industry, for which standard equipment is available. The drying step is patterned after desiccated coconut operations, and the extraction step is patterned after prepress solvent extraction of copra. The process here proposed consists in combining these operations so as to produce a white, low-fat, nutritious coconut flour, with high protein solubility, if possible. Coconut flour with high protein solubility could be used for further processing to produce isolates. In addition, flour with high protein solubility may prove to have superior functional properties, although this never has been demonstrated.

The normal desiccated coconut process includes 2 heating steps considered critical to product properties. These are the blanching and drying steps. The effect of blanching was determined by comparing samples dried with and without blanching. With 85 C air inlet temperatures or with commercial drying conditions the results were the same. The protein in blanched samples was 26% soluble at pH 7.5, whereas, the protein in unblanched samples was 58% soluble. The unblanched samples had protein solubility equal to that previously reported for coconut dried at 40 C (2), which indicated that protein solubility was not reduced when coconut was desiccated commercially.

However, blanching caused a large decrease in protein solubility. If product specifications for coconut flour require high protein solubility, it presumably will be necessary to replace the blanching step with some other microbiological kill step. Two possibilities are milder heat treatment or use of chemical bacteriocide.

Another critical unit operation in the oil recovery plant is the pressing operation. It is a well known fact that severe pressing can produce oilseed cakes that have dark color and

TABLE II

Anticipated Plant Capacities in Metric Tons

	Each Plant		All 5 Plants
	Tons/hr	Tons/day	Tons/yr
Drying Plants[a]			
Input			
Coconuts, without husk	10.4	228	285,000
Intermediate products			
Shells	2.6	57	71,000
White meats (50% moisture)	4.0	87	109,000
Parings (50% moisture)	0.6	13	16,000
Output			
Coconut water	3.2	71	88,400
Dried white meats (5% moisture)	2.1	46	57,000
Dried parings (5% moisture)	0.3	6.7	8,400
Extraction plant[b]			
Input			
Dried white meats	8.0	191	57,400
Driec parings	1.2	28	8,400
Intermediate product			
Prepressed white meats (5% moisture, 17% oil)	3.0	72	21,700
Output			
Oil[c]	6.0	143	42,900
White flour (5% moisture, 0.5% oil)	2.5	60	17,900
Parings presscake (5% moisture, 10% oil)	0.4	10	2,900

[a]Assuming 250 days/year x 22 hr/day.

[b]Assuming 300 days/year x 24 hr/day.

[c]Oil from 3 sources: 75% from prepressing white meats, 20% from pressing of parings, and 5% from extraction.

TABLE III

Estimated Equipment Costs and Energy Consumption

	Equipment costs (dollars)	Electricity consumption (kw)
Drying plants (per plant)		
Prebreaker and cutting mills	52,000	35
Dryers (conveyor)[a]	220,000	115
Boiler 7m tons steam/hr[b]	40,000	0
Miscellaneous[c]	70,000	50
Total equipment	382,000	200
Buildings (2,500m^2) and land	180,000	
Central oil recovery plant		
Screw prepresses[d]	260,000	160
Screw press for dried parings[d]	60,000	420
Cracking and flaking mills	57,000	70
Solvent extractor[e]	230,000	20
Flour mill	35,000	50
Oil storage tanks (10 day.s output)	140,000	0
Boiler (3m tons steam/hr)[b]	30,000	0
Miscellaneous	100,000	75
Total	912,000	795
Buildings (6000m^2) and land	450,000	
Transportation equipment		
Trucks[f]	470,000	0

[a]Assuming separate dryers for white meats and parings.

[b]The boiler burns coconut shells for fuel.

[c]Includes equipment for conveying, laboratory, shop, and offices, and electricity for lighting and ventilation.

[d]Includes conditioning equipment, conveyors, and oil handling equipment.

[e]Includes solvent recovery system and meal desolventizer.

[f]Ten hopper bottom pressurized bulk trucks, capacity 28 m^3 (7m tons) each.

low protein solubility. Work (S. Verasestakul, private communication, 1973) has shown that processing can reduce coconut protein solubility without markedly affecting color.

Presscake with 17% oil content, prepared as described, was observed to be white and have protein solubility of 94% at pH 10.5, 56% at pH 8.4, and 42% at pH 6.0. These data indicate good protein solubility when compared to published data for solubility of coconut meal prepared without excess heat (2). The data suggest that commercial type screw prepresses be used to give presscake with ca. 17% oil. The work by Miranda, et al., (3) indicated that coconut presscake had good nutritive value.

Therefore, if blanching were eliminated and pressing were controlled, coconut flour with high protein solubility could be prepared by minimizing processing heat. However, the effect of protein solubility on food applications has not been determined. No evidence is available that high protein solubility is superior to low solubility.

Efficient extraction of oil is primarily of importance from the viewpoint of economics, oil being the principal product. However efficient extraction is also necessary for the production of low fat flour.

Comparisons were made in the residual oil content of desiccated coconut and flaked presscake. After extraction

TABLE IV

Estimation of Total Invested Capital

Fixed Capital	Drying[a] plants (drs x 10^3)	Central oil recovery plant (drs x 10^3)	Transportation of dried coconut (drs x 10^3)	Total (drs x10^3)
Equipment (fob cost)	1,910	912	470	3,292
Shipment and import duties	325[b]	155[b]	80	560
Buildings and land	900	450	0	1,350
Equipment installation	764[b]	547	0	1,311
Distribution of power, water, steam	382[b]	274	0	656
Miscellaneous	382[b]	182	0	564
Engineering and overhead	669[b]	365	47	1,081
Subtotal	5,332	2,885	597	8,814
Working capital				
Raw materials, accounts payable (1 month)				900
Labor, utilities, and supplies (2 weeks)				70
Inventory and accounts receivable for products (1 month production				1,300
Subtotal				2,270
Total capital: fixed capital and working capital				11,084

[a]Cost of 5 identical plants.

[b]Calculated as percentage of equipment cost.

TABLE V

Annual Operating Expenses (1974)

Personal services for 5 plants[a]	Amount ($)
Direct	
Shelling (1430)	700,000
Paring (1430)	700,000
Other operating (300)	175,000
Supervisors (75)	90,000
Maintenance (30)	23,000
Indirect	
Administrative (35)	110,000
Technical (20)	60,000
Purchasing (11)	35,000
General (50)	35,000
Other	
Coconuts ($35.28/ton)	10,055,000
Transportation to factory[b]	984,000
Maintenance supplies	106,000
Electricity ($0.037/kw hr)	200,000
Miscellaneous	200,000
Insurance and property taxes[d]	160,000
Subtotal	13,633,000

Personal services for oil recovery plant[a]	Amount ($)
Direct	
Operating labor (70)	40,000
Supervisors (10)	10,000
Maintenance (20)	15,000
Indirect	
Administrative (30)	100,000
Technical (15)	45,000
Sales and purchasing (30)	100,000
General (30)	20,000
Other	
Flour packaging material ($0.01/kg)	175,000
Hexane losses ($0.20/liter)	106,000
Maintenance supplies[c]	60,000
Electricity ($0.018/kw hr)	210,000
Diesel fuel for trucks ($0.13/liter)	65,000
Insurance and property taxes[d]	87,000
Miscellaneous	100,000
Subtotal	1,133,000

[a]Includes cost of transporting dried coconut and fringe benefits. Numbers in parentheses indicate number of personnel.

[b]Assuming average distance hauled of 30 km, at $0.09/km-ton, plus $0.75/ton handling costs.

[c]2% of fixed capital.

[d]3% of fixed capital.

as described, the oil content of the desiccated coconut was reduced to 10%; whereas, the oil content of presscake was lowered to 0.6%. These were averages of 4 observations with a standard deviation of oil content of 10% of the reported result.

The hexane flow through the flaked presscake was 0.4 ± 0.1 liters/min, which was only 35% of the flow through desiccated coconut. However, the flow through the flaked presscake was fast enough for the commerical type solvent extractor used.

The results shown in Figure 1 indicate that only ca. 2 min of extraction were required to reduce residual oil in presscake flakes to 1%. In contrast, desiccated coconut had residual oil of ca. 10% after 15 min extraction. These data suggested that prepressing and/or flaking resulted in sufficient cell disruption to facilitate hexane extraction of remaining oil.

Attempts to flake desiccated coconut without prepressing resulted in failure. The flaking rolls became covered with oil. However, in early work, a fine powder was produced by successively passing desiccated coconut through 2 pairs of roller mills, spaced at 0.3 mm and 0.05 mm. This material, when extracted with hexane, had residual oil content of 0.8%. For the extraction of this finely ground material, the sample was slurried with hexane for 30 min, poured onto a fine mesh screen, and the solids washed with fresh hexane.

The slow percolation of hexane through the roller milled desiccated coconut, and also the passage of fines into the hexane filtrate, raised some doubts about the feasibility of processing without the prepressing operation. For these reasons the prepressing step was included in the proposed process.

The data in Table I give analysis of coconut flour without testa. These and other data, not shown, suggested that composition was somewhat variable. The factors responsible for this variability seemed to be maturity and variety of coconut processed. The oil produced is a premium oil without the high free fatty acid content of coconut oil derived from normal copra. Although this article emphasizes the coconut flour product, the coconut oil was the principal product of coconut processing, both in quantity and commercial value. The operation described is a vegetable oil plant, which produces coconut flour as a by product.

The process costed out consists of a combination of the described unit operations as depicted in Figure 2. The hypothetical arrangement consists of five identical drying plants and one centralized oil recovery plant. The drying operations are dispersed for two reasons; to reduce cost of hauling fresh coconuts and to permit utilization of laborers over a wider geographical area.

The plant capacities, shown in Table II, are based on typical coconut compositions and assume no losses of material in processing. Coconuts rejected as spoiled were expected to constitute ca. 1% of the total. It was assumed that spoiled coconuts are dried and sold as copra, with the income from copra buying the fresh nuts. This being an equal trade off, it was not entered in the cash flow.

The figures shown in Table III are direct estimates of equipment costs, energy consumption, and building costs. Equipment costs were based on FOB US prices of mid-1974. However, inflation rates undoubtedly will make these numbers obsolete in a short time, and local costs will vary with location.

Total invested capital was estimated as shown in Table IV. Annual operating expenses are shown in Table V, and annual cash flow in Table VI. The selling price of coconut flour was adjusted to give 20% pre-income tax rate of return, which was the same rate of return calculated for aqueous processing of coconuts (11), also calculated for mid-1974.

The selling price of coconut flour so calculated was \$315/m ton. This compared to the price of \$500/m ton calculated from coconut skim milk solids obtained from aqueous processing of coconuts (11). However, this comparison was somewhat misleading because no income was assumed from sale of the high fiber product obtained by aqueous processing. On the other hand, in the prepress solvent extraction process, the fiber is sold as one of the components of coconut flour. A more meaningful comparison of the 2 processes would seem to be value added, calculated as income from oil and protein product minus farm price of coconuts. In both processes the value added was ca. \$25/mT of husked coconuts. However, it should be noted that this comparison is highly dependent on market value of the protein products, which have not yet been determined.

The economic data pertinent to coconut processing are dependent on inflation rates, taxes, and other local costs, especially labor. These are all highly variable and can have important effects on actual return on investment. However, the estimates as presented are sufficiently general to give an indication of the major expenses anticipated for processing in the typical coconut producing country.

One of the largest direct costs is transportation of the fresh coconuts to the drying plants. Furthermore, the costs of the drying plants represent 60% of the total fixed capital, and, as such, contribute substantially to overhead costs.

A system in which coconuts were dried with smaller drying units positioned nearer the coconut trees would be expected to reduce transportation and drying costs substantially, albeit at the expense of more difficult sanitary and quality control, particularly if the meats were pared to make a white product. Such a system, for making food grade copra, is currently under investigation at Texas A & M University. Coconut flour made from food grade copra would be expected to require much lower price to give a comparable return on investment.

TABLE VI

Calculation of Rate of Return

	Amount (\$)
Annual revenue	
Oil (42,900 tons at \$275.1[a])	11,802,000
Coconut Flour (17,900 tons at \$315[a])	5,639,000
Parings meal (2,900 tons at \$60[a])	175,000
Total revenue	17,616,000
Annual expenses	
Operating expenses	
Drying plants (includes coconuts)	13,633,000
Oil recovery plant	1,133,000
Depreciation (8% sinking fund)	
Drying plants (10 years)	368,000
Oil recovery plant (10 years)	199,000
Trucks (5 years)	102,000
Total expenses	15,435,000
Net return	2,181,000
Rate of return (pre-income tax)[b]	20%

[a]Bulk prices, fob plant.

[b]Net return plus total capital.

Of all the economic data presented, that with the highest uncertainty is the market value of the protein product, namely white coconut flour. For the process as analyzed, with large drying plants, the flour price of \$315/metric ton is about the minimum value to permit a reasonable return on investment. However, the real market value of coconut flour can only be determined after more samples are made and evaluated.

Most evaluations of coconut flour to date have been limited to nutritional analysis. This paper has been devoted to technology and cost of production. More information is needed now regarding food uses and market value of the coconut flour.

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