Aqueous Processing of Coconuts: Economic Analysis

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ABSTRACT

A process previously has been developed at Texas A&M University for aqueous processing of coconuts to produce oil and a concentrated skim milk. This paper details the costs for that process and concludes that 20% of rate-of-return can be realized if the market price of coconut skim milk solids are assigned the value of $0.50/kg (bulk price).

INTRODUCTION

The aqueous processing of fresh coconuts to recover oil and dehydrated coconut skim milk has been described recently (1). A more recent publication has been devoted to the description of the coconut skim milk so obtained (2), and a flow diagram is presented in Figure 1. The purpose of the present article is to provide information for eventual commercialization by an estimate of processing costs. The Philippines, which is the largest producer of coconuts, was selected as the site for the hypothetical plant.

An economic evaluation was made by Edmonds, et al., (3) for an aqueous coconut process developed by Tropical Products Institute (TPI, London, England), and described recently by Dendy and Timmins (4,5). The proposed TPI process consists of aqueous extraction of ground coconuts, followed by acidification of the milk and gravity creaming. The resulting cream phase is centrifuged to give oil, an aqueous phase, and protein solids. The protein solids are vacuum-dried and extracted with alcohol to yield an isolate containing 80% protein. Edmonds, et al., concluded that the TPI process would be uneconomic in Malaysia or Sri Lanka. In their evaluation, the protein isolate was valued at only $0.29/kg.

Aqueous processing of coconuts is not currently commercial. In discussions with industry people, it has become apparent that aqueous coconut processing would be considered a high risk venture, demanding a high return on investment and short expected project life. Consequently, some assumptions were made which minimized investment, although at the price of increasing processing costs: (A) fuel and electricity would be purchased; (B) by-products (residue and insoluble protein) would be disposed of wet at the factory door rather than dried, packaged, and solid; and (C) no processing equipment would be added to recover additional oil from the residue by hexane extraction.

Alternate assumptions would operate if the project was to be considered a low risk venture. Shells would be burned for fuel; by-products would be dried and packaged, and additional oil would be recovered from the residue by hexane extraction.

METHODS

Estimates of equipment were obtained by contacting equipment manufacturers. All prices were updated to mid-1974 by using indices of inflation published monthly in *Chemical Engineering*.

Estimates of local costs in the Philippines, including costs of building, utilities, transportation, and wages, were made on the basis of unpublished data from P. Quinitio and also from San Miguel Corp., Manila, Philippines. Data regarding Philippine prices of fresh coconuts and coconut oil were provided by United Coconut Association of the Philippines (UCAP) via unpublished data and from *Coconut Statistics* (6).

Estimate of total installed plant cost was based upon an approach similar to that used by Weaver, et al., (7) and by Hackney (8). In estimation of total installed plant cost, the costs of equipment and buildings were estimated directly, and other contributions to fixed costs were estimated with factors.

The pattern used for economic analysis was the rate-of-return pattern as described by DeGarmo (9), which is recommended for cases with a single investment followed by constant revenue and cost data for the duration of the project. In using this method, the salvage value of fixed capital was assumed to be negligible, which is a reasonable assumption for equipment situated in an economically underdeveloped country. The rate-of-return pattern calculates return to the investor in terms of interest paid annually, while allowing for pay-back of capital invested at project's end. For purposes of comparison, the discounted cash flow pattern (also described by DeGarmo [9]) was applied to the simple case but not, in general, used for sensitivity analysis.

The return on investment is reported to the nearest tenth percentage to show more accurately the change in return caused by different assumptions. However, no pretense is made for 0.1% accuracy.

DESCRIPTION OF PLANT

Preliminary estimates of processing costs for different sized plants led to selection of a plant which processes 250 m tons/day of dehusked coconuts. The capacities for the plant are given in Table I, with yields from Hagenmaier et al., (1) and from more recent data of the authors (unpublished).

ESTIMATION OF FIXED CAPITAL

The fixed capital investment for the plant was estimated to be $1,910,000., with working capital of $800,000. The

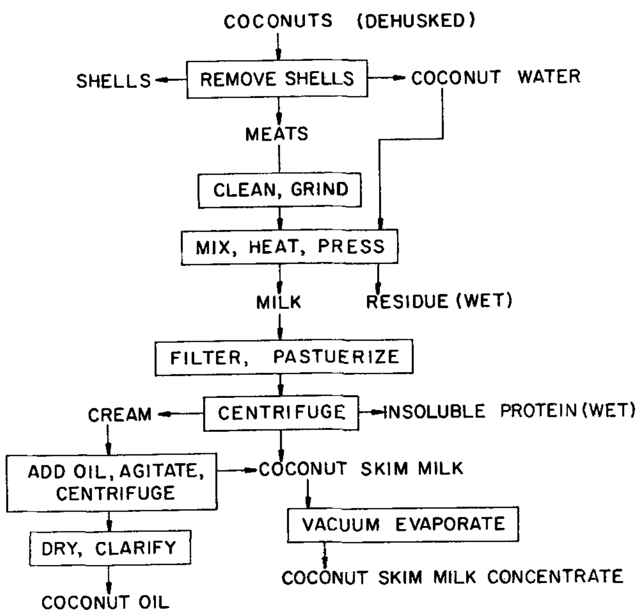

FIG. 1. Flow diagram for processing plant.

TABLE I

Capacity of Processing Plant

Material	Capacity in m tons		
	Per year	Per day[a]	Per hr[b]
Input			
Coconuts (weighed without husk)	62,500	250	12.5
Copra equivalent (at 8% moisture)	14,900	59.7	3.0
Intermediate products (wt undried)			
Shells	15,600	62.5	3.1
Coconut water	19,400	77.5	3.9
Meats[d]	27,500	110	5.5
Milk	37,000	152	7.6
Cream phase (at 65% oil)	13,500	54	2.7
Coconut skim milk (before evaporation)	28,200	113	5.6
Final products			
Coconut oil (91% recovery) (dry)	8,700	34.8	1.74
Coconut skim milk, as produced (30% moisture)[e]	3,930	15.7	0.79
Dry wt basis	2,750	11.0	0.55
Residue, as produced (68% moisture)	8,100	33.9	1.8
Dry wt basis	2,690	10.7	0.54
Insoluble protein, as produced (68% moisture)	523	3.1	0.23
Dry wt basis	356	1.4	0.071

[a]Assuming 250 working days/year.

[b]Assuming 20 working hr/day.

[c]Represents 75,000,000 nuts/year. If coconuts were purchases with husks, they would weigh 50% more.

[d]Includes seed coat or testa, which comprises 12% of wt of meats.

[e]Yield is based upon process that uses coconut water, with 60% of coconut water solids accumulating in the coconut skim milk, which contains 25% protein (N x 6.25) on a 3% moisture basis.

TABLE II

Estimation of Equipment Costs and Energy Requirements

Processing steps	Equipment cost ($)	Electrical energy (kwh/hr)	Steam (m tons/hr)
Cleaning of meats and coconut water[a]	38,000	11	0.3
Grinding of meats	38,000	125	0
Heating and mixing prior to pressing	36,000	16	0.5
Counter-current pressing to separate residue from milk	55,000	90	0
Filtration, pasteurization of milk[a]	32,000	4	0.2
Centrifuge	46,000	20	0
Break emulsion and separate oil	53,000	20	0.1
Clarify and dry oil	29,000	9	0.1
Evaporate aqueous phase to 45% solids[a]	94,000	24	1.8
Evaporate aqueous phase to 70% solids and package[a]	30,000	12	0.2
By-product drying and packaging[b]	0	0	0
Finished product storage	30,000	0	0
Pumps and conveyors	37,000	12	0
Boiler	20,000	1	0
Energy required for ventilation, lighting and conveying	---	95	0
Totals	538,000	440	3.2

[a]Prices include appropriate holding tanks.

[b]For flash drying of residue and packaging, estimated values are $35,000, 20 kw, 2.0 m tons/hr. For drum drying and packaging of insoluble protein, values are $39,000, 12 kw, 0.2 m tons/hr.

bases for these estimates are detailed in Tables II and III.

ESTIMATION OF CASH FLOW FOR 1974 OPERATIONS

The cash flow is given in Table IV. Of critical importance to the cash flow are prices paid for coconuts and finished products, and these prices now will be discussed in some detail.

Average monthly domestic prices for crude coconut oil and copra at 8% moisture are published by UCAP (6), and the prices from January 1967-December 1973 were analyzed by linear regression. The copra and oil prices had a correlation coefficient of 0.995, with a regression equation of:

$$\text{copra price (\$/m ton)} = (0.5906 \pm 0.013)(\text{crude oil price} - 234.5) + (136.0 \pm 1.5), \qquad [\text{I}]$$

where original data in pesos had been converted to U.S. dollars by the conversion $1.00 = ₱6.70, where 0.013 and 1.5 represent 95% confidence intervals, and 234.5 and 136.0 represent average crude oil and copra prices, respectively.

According to unpublished data from UCAP, the price paid for fresh coconuts, exclusive of handling and transportation charges, equals 22% of the Manila (domestic) price of copra at 8% moisture. The price of fresh coconuts exclusive of handling and transportation will, henceforth, be referred to as "farm" price for fresh coconuts. From substitution into equation I:

$$\text{farm price for coconuts (\$/ton)} = 0.130\,(\text{crude oil price} - 234.5) + 29.92 \qquad [\text{II}]$$

To calculate coconut prices, it is next necessary to

TABLE III

Estimation of Total Capital Outlay

Capital	Cost ($)	Percent of total
Fixed capital (FC)		
Equipment (f.o.b. manf)	538,000	28
Overseas shipment of equipment (16.7% of 1.)	90,000	5
Import duties and taxes (20% of 1.)[a]	110,000	6
Buildings (3,500 m^2) and land	340,000	18
Equipment installation		
Materials (including instruments)	180,000	9
Labor	72,000	4
Distribution of product, power, water, steam		
Materials	200,000	10
Labor	110,000	6
Yard work (materials and labor)	18,000	1
Engineering and overhead	180,000	9
Miscellaneous	72,000	4
Total FC	1,910,000	100
Working capital (WC)		
Raw materials accounts payable (1 month)	200,000	
Labor and utilities accounts payable (2 weeks)	20,000	
Inventory (1 month's supplies, 2 weeks' product)	190,000	
Finished product accounts receivable (1 month)	390,000	
Total WC	800,000	
Total capital investment = FC + WC =	$2,710,000	

[a]See ref. 10.

TABLE IV

Operating Expenses and Revenue (1974 Operations)

Expenses and Revenue	Dollars
Expenses	
Personal services[a]	
Direct	
Shelling (300)	150,000
Other operating (90)	52,000
Supervisory (25)	29,000
Repair (8)	6,000
Indirect	
Administrative (11)	35,000
Technical (5)	15,000
Sales and purchasing (11)	35,000
General (drivers, watchmen) (10)	7,000
Subtotal	329,000
Materials, supplies, utilities, transportation	
Coconuts (62,500 tons at $35.38)	2,205,000
Transportation of coconuts to factory[b]	221,000
Packaging ($0.02/kg for skim milk concentrate)	78,000
Maintenance supplies (2% of fixed capital)	38,000
Fuel (at 0.08/liter, 0.85 thermal efficiency)	82,000
Electricity (0.017/kwh)	42,000
Miscellaneous	50,000
Subtotal	2,716,000
Insurance and property taxes (3% of fixed capital)	57,000
Total operating expenses	3,102,000
Revenue	
Oil (8,700 tons at $275.1)	2,393,000
Coconut skim milk (2,750 tons dwb at $500)	1,375,000
Total revenue	3,768,000

[a]The numbers in parentheses indicate the number of personnel employed. Sample annual rates used (including fringe benefits) were $500 for unskilled labor, $700 for skilled, $1000 for foreman, $4000 for second level staff, and $6500 for manager.

[b]Assuming average distance hauled is 31 km, at cost of $0.09/km-ton, plus $0.75/ton handling costs.

choose a value for 1974 crude oil prices. Regression analysis was performed with yearly average exported oil prices from 1964-1973. Export prices were used in this case to get prices in U.S. dollars (domestic prices were published in pesos only), with all data from UCAP (6). The regression equation calculated was:

$$\text{crude oil price (\$/m ton)} = (1.41 \pm 12.4)(\text{time} - 1969.0) + (267.9 \pm 35.7) \qquad \text{[III]}$$

TABLE V

Sensitivity Analysis for Rate-of-Return

Assumption varied	Values chosen	Rate-of-return
Plant capacity (dehusked coconuts, m tons/day)	100	10.5
	250[a]	19.7
	400	21.9
Price of Coconut skim milk solids ($/kg)	0.70	40.0
	0.50[a]	19.7
	0.35	4.4
Quantity of oil produced (efficiency of recovery)	100%	28.4
	91%[a]	19.7
Project life (years)	5	12.5
	10[a]	19.7
	15	22.0
Price of crude coconut oil ($/m ton)	500	24.3
	275.7[a]	19.7
	200	18.1
Quality of road network (with average distance coconuts hauled)	Ideal (11 km)	23.8
	Medium (31 km)[a]	19.7
	Poor (51 km)	15.5
Fixed capital (U.S.,$)	1,610,000	24.2
	1,910,000	19.7
	2,210,000	15.5
Days/year plant operated	300	25.7
	250[a]	19.7
	200	13.7
Inflation	None[a]	(22.1)[b]
	As described in text	(24.6)

[a]Value for assumed parameter that was used in Tables II, III, IV, and VI.

[b]The numbers in parentheses were calculated as discounted return on investment, rather than rate-of-return.

TABLE VI

Sample Calculation of Pre-Income Tax Rate-of-Return

Item	Amount
Amount paid out	
Operating expenses (from Table IV)	$3,102,000
Depreciation (8% sinking fund, 10 years)	$ 132,000
Subtotal	$3,234,000
Income	
(from Table IV)	$3,768,000
Net return	$ 534,000
Rate of return[a]	19.7%

[a]Net return ÷ total capital, or $534,000 ÷ 2,710,000.

where "time" indicates data (e.g. mid-1974 is 1974.5) and where 267.9 gives the average oil price. The low correlation coefficient of 0.09 indicates that oil prices are quite independent of time, and, therefore, the high oil prices of today do not lead to the conclusion that oil prices will be high in the future. Standard deviation about the regression line was $49/ton.

The mid-1974 price used for crude coconut oil was calculated from equation III to be $275.7/m ton, which is considerably lower than the actual market price prevailing in mid-1974. The sensitivity analysis in Table V indicates that the prevailing oil price would give a higher estimate of return than that estimated from the calculated mid-1974 oil price.

The price paid in mid-1974 for fresh coconuts was next calculated by equation II to be $35.28/m ton, which is the value used in Table IV.

The income from oil next must be related to crude oil prices. The oil from aqueous processing has been found to contain only ca. 0.2% free fatty acids. The price premium for oil is assumed to be the same as for copra. Premium of 0.5% for each 1% of free fatty acid below 3.5%, down to 1% free fatty acid, plus 0.75% for each 1% of free fatty acids below 1%, according to 1969 trading rules as cited by Woodroof (11). The calculated premium is 1.85% of selling price. In the Philippines there is a "millers tax" for production of coconut oil, equal to 2% of the value of the product. Therefore, the oil income will be:

$$\text{oil income (\$/m ton)} = 1.0185 \times 0.98 \times \text{crude oil price} = 0.998 \times \text{crude oil price} \qquad [IV]$$

For crude oil price of $275.7/ton, the oil income would, therefore, be $275.1/ton, which is the value used in Table IV.

The next important point is market price of coconut skim milk solids, which have composition and properties intermediate between those of nonfat dry milk and whey solids. The mid-1974 market prices for non-fat dry milk and cheese whey solids were $1.36/kg and $0.26/kg, respectively (for bulk quantities, free on board factory, U.S. prices). Based upon these observations, the market price of the coconut skim milk solids was assigned the value of $0.50/kg.

Calculation of Rate of Return

The rate of return was calculated according to the procedure outlined in Table VI, and was found to be 19.7% (pre-income tax).

To express the results in terms of the often used discounted cash flow pattern (internal rate of return pattern), the return on investment (pre-income tax) was so calculated and found to be 22.1%. The explanation for the difference between the two results is that in the rate of return pattern, 8% interest was assumed for the sinking fund for depreciation, whereas in discounted cash flow no separate funds were set aside for depreciation.

Sensitivity Analysis

It is considered important to know the effect upon return caused by variation in the assumptions made in the cost estimate to determine which assumptions are most critical. The effect upon return of variation in certain assumptions is shown in Table V.

For analysis of different plant capacities, it was assumed that fixed capital cost and indirect labor were proportional to square root of plant capacity and that working capital and direct labor were proportional to capacity. The average distance coconuts were transported was estimated to be 22, 31, and 48 km for the 3 plant sizes.

For variation in efficiency of oil recovery, no change in costs were assumed for processing the different amounts of oil. For change in market value of oil and coconut skim milk, no changes in working capital were assumed.

For the quality of road network, two situations were visualized. In the ideal case, all coconuts are transported by straight line from tree to processing plant. In case of poor roads, the plant was assumed to be located on a main road, only accessible by 2 km long feeder roads spaced 1 km apart. The compromise case is an average of the two extreme cases. The land surrounding the processing plants was assumed to be planted 20% in coconuts (average for Philippines) for a yield of 77 m tons of husked nuts/year/square km. Transportation costs were taken as $0.09/km ton plus $0.75/ton handling and were calculated to be $1.71/ton, $3.53/ton, and $5.33/ton for the ideal, compromise, and poor road network, respectively.

To consider the effect of inflation, both income from oil and cost of fresh coconuts were assumed to inflate at an annual rate of 1% (based upon equation III). Labor rates were assumed to inflate at 5% annually, based upon Philippine labor rate indices. Market price of coconut skim milk also was assumed to inflate at 5%. All other costs also were inflated at the 5% rate. Working capital also was increased by 5% annually.

The sensitivity analysis indicates that, of the parameters examined, selling price of the coconut milk solids is the most critical. Also of considerable importance are plant capacity and quantity of coconut oil produced. Other variables have a lesser effect upon return.

Not included in Table V is effect upon return of spray-drying. If the product were spray-dried instead of being evaporated to a syrup, the added equipment cost would be $120,000, and added annual operating costs would be $71,000. With spray-drying, the rate of return would drop from 19.7% to 14.7%. This decrease in return is a reflection of the fact that spray-drying is uneconomical for such a small plant. If product specifications called for spray-drying, it would seem to be more economical to spray-dry in a central facility that services a group of 250 ton/day plants.

For the processing plant described in Tables I-IV, the foregoing analysis has resulted in an estimated 20% annual rate of return. Based upon discussions with industry people, 20% is ca. the minimum acceptable return for new ventures. Therefore, the profitability of the venture would depend rather critically upon assumptions made in the cost estimate, and, in particular, upon cost of coconut skim milk solids. In addition, realization of income from by-products would improve the profitability of the process. The coconut residue is of particular interest as a by-product. Its quantity is equal to that of the coconut skim milk solids. The residue is characterized by its large crude fiber content, and as such might be of interest in increasing the fiber content of the diet.

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