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The Choice of Technology and Scale in Coconut Processing in the Philippines

by

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Article-length Version

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The viewpoints expressed here are those of the author and not necessarily those of Appropriate Technology International (ATI). The author would like to thank Paul Bundick (ATI) for his assistance in arranging this study and Julian Banzon (Professor Emeritus, University of the Philippines, Los Banos), Marita Cuano (Filipinas Foundation), and Arturo Jimenez (Consultant to the Filipinas Foundation) providing essential data. Helpful comments on this draft were received from Paul Bundick, Mike O'Donnell, Glenn Patterson, and John Slavics.

ABSTRACT

This paper describes the scale and location of the existing coconut processing industry in the Philippines. The second part describes two types of technologies producing a variety of different products, the dry (copra) process and an alternative wet process at different scales of operation. A comparative financial and economic analysis is included for 8 mills, 1 separate refinery, and 1 integrated mill/refinery.

Introduction

Nearly 94% of the Philippine coconut crop is converted into copra for subsequent processing into oil, soap, and animal feed (UCAP 1986). This dry process is usually done in large-scale plants, but can be scaled down to meet a local demand. Since some coconut-growing areas are small or remote and cannot support a large-scale processing plant, farmers are dependent on several layers of middlemen to market their crop to centralized mills.

An alternative method, the wet process, can yield additional products such as foods for human consumption and soap without a reduction in edible oil output, in contrast to the dry process. Diversification of the product mix could provide greater stability in the incomes of coconut farmers. A village-scale version of the wet process can be designed to be labor intensive for maximum employment generation. This paper compares the economics of the dry and wet processes at various scales of production in the Philippines.

In 1985, 77% of the volume of Philippine coconut products sold was exported. The main exports are crude coconut oil, copra, desiccated coconut, and coconut meal/cake. Real unit prices for these exports fluctuated a great deal over the period

1970-1985. Overall, the trend has been downward as the peaks became lower and the troughs deeper. The long-term trends are not optimistic due to substitution of other oils (especially palm and palm kernel oils), increases in coconut production from an expansion of the planted area and greater reliance on high-yielding varieties, and tariffs or other trade barriers imposed by importing countries (Hyman submitted).

Total daily fat consumption in the Philippines is 30-40 g per person, well below the 50 g minimum recommended for good nutrition (Banzon 1987). Coconut oil is the predominant oil in the Philippine diet. However, per capita consumption of edible coconut oil in the Philippines amounted to only 2.77 kg in 1985, a year of abundant supplies on the domestic market (UCAP 1986). It is expected to increase with income and population growth.

Laundry soap from coconut oil is popular with rural and urban consumers, who often use it for bathing and cleaning as well. Rural consumers pay higher prices for the commercial brands of soap and oil due to greater transport costs, a larger number of middlemen in distribution, and lower volumes of purchase by local stores. The domestic market for coconut products as well as farmgate prices for coconuts and copra largely reflect world prices.

Due to the depressed state of coconut farming caused by world market conditions and mismanaged government policies, the new administration of the Philippines was forced to lift the ban on exports of unprocessed copra. As a result, copra prices increased substantially, benefiting coconut farmers and adversely

affecting the milling industry. Coconut mills found that their input costs had increased without a proportional increase in product prices for oil and soap.

Description of the Dry (Copra) Process for Milling

Figure 1 shows the dry process for coconut oil production in a medium- or large-scale mill; it may be simplified in a small-scale mill. After grading, remedial drying is done to reduce the moisture content of the copra to 6%. The copra received by mills may have up to 16% moisture, although the majority has 8-12% (Jimenez 1987). Before extraction of the oil, the copra is cleaned and inspected.

In the Philippines, the most commonly used technology for medium- and large-scale coconut oil extraction is a high-pressure expeller, also known as a continuous screw press. Before being fed into the expeller, the copra is usually ground in a hammermill or grinder. For a high extraction efficiency, the copra then undergoes precooking, cooking, and conditioning before expelling.

Some mills with a single expeller feed material through twice instead of using a cooker/conditioner, but that is slower. An expeller has a shaft with a spiral flight ("worm") that turns horizontally in a cage with barrel bars. As copra is pushed forward by the screw, pressure forces oil out through the perforated sides of the cage and the cake is released at the end of the cage ("choke"). Cooking and conditioning are often combined with expelling in a dual expeller. However, a dual

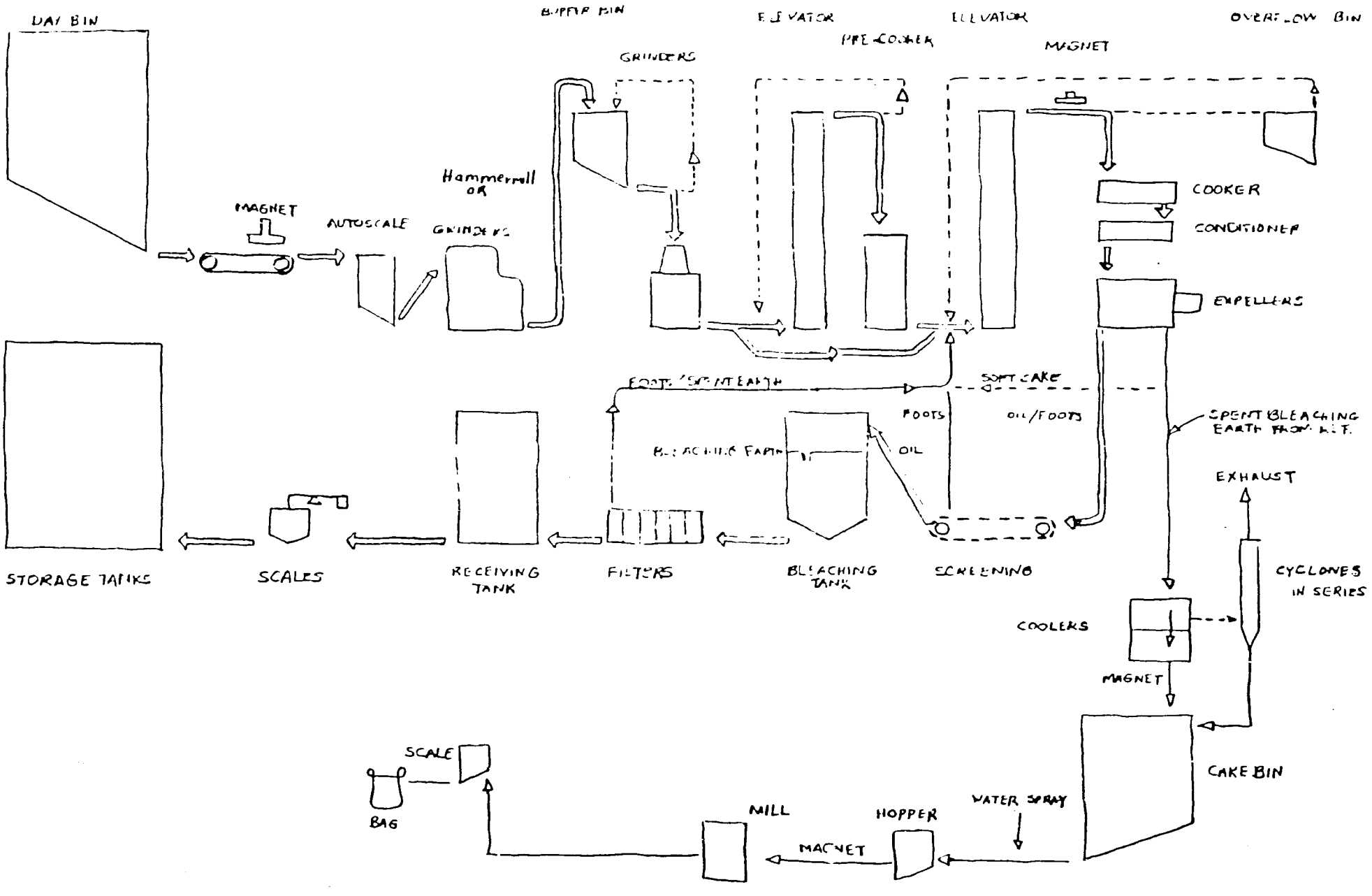

Figure 1. The Copra Process for Medium- and Large-Scale Oil Milling

expeller yields a dark copra cake that makes a poor animal feed because much of the protein is denatured.

After expelling, the oil is screened, filtered, and sent to storage tanks. Pieces of copra cake mixed in with the oil ("foots") are removed and fed back into the expeller with new copra. The rest of the cake passes through coolers and is moistened to prevent spontaneous combustion by molds that generate heat.

With a medium- or large-scale expeller and precooker, high quality copra with a 6% moisture content yields 61.5-62.5% oil and 33.5-34.5% cake by weight. This cake would have a residual oil content of 6-7%. Thus, an efficient expeller can extract 96-97% of the total oil in the copra. Accounting for the additional loss in refining, the oil extraction efficiency drops to 91-92%. Consequently, it usually takes 1.68-1.71 kg of copra to produce 1.00 kg of refined oil. However, some inefficient mills in the Philippines leave as much as 14-16% residual oil in the cake (Jimenez 1987).

Continuous expellers do not require downtime for charging and discharging. However, they are relatively expensive, difficult to operate, and consume a lot of electricity. A positive feed system is needed to maintain a sufficient pressure and a cooling system is needed to avoid damaging the oil. Medium- and large-scale mills also use magnetic separators in series to isolate tramp iron mixed with the copra to avoid damaging the equipment. Since copra is abrasive and parts of the expeller are subject to high pressures and heat generated from

friction, maintenance costs are high and breakdowns are frequent. If the electric supply to a large expeller is interrupted for 20 minutes or so, it is necessary to open up the cage and remove the hardened copra (Banzon and Velasco 1982; Jimenez 1987).

Hydraulically operated, mechanical batch presses are rarely used now for coconut oil extraction. Since these presses have a low output rate and leave 8-10% of the oil in the cake, they generally cannot compete with expellers. They also require much attention by skilled operators (UNIDO 1977).

Solvent extraction can yield 98-99% of the oil in the copra, leaving only 1-2% oil in the byproduct meal (Hagemaier 1980; Jimenez 1987). For maximum efficiency, expellers are often used in pre-pressing copra to reduce the oil content to 30-35% before solvent extraction. However, solvent extraction is too expensive to be economically efficient in the Philippines.

Copra expeller cake is a major feed for ruminants and feed supplement for swine and poultry. Although it contains 18-25% protein, copra cake is unsuitable as a food for people because much of the protein is denatured by the high temperatures and pressures. Also, the unsanitary conditions of copra preparation and storage generally result in microbial contamination and rancidity of residual oil in the cake.

Crude coconut oil from the copra process is dark; turbid; high in free fatty acids (FFA), phosphatides, and gums; has an unpleasant odor; and may be contaminated by bacteria and molds. It requires extensive refining which is only done in large-scale,

capital-intensive facilities. Typically, 5% of the weight of the crude oil is lost in refining (Dendy and Timmins 1973), but the loss can be as high as 7.5% (Hagenmaier 1980). Most of the coconut oil for export is in crude form; it is refined in importing countries to avoid reversion in transport and storage. Edible oil for the consumer market in the Philippines is refined domestically. Copra process oil from a small-scale mill is more difficult to refine than the oil from a large-scale mill because of its higher content of FFA and other impurities.

Refining consists of neutralization, bleaching, and deodorization. Neutralization reduces the FFA to improve the taste and appearance of the oil. Sodium hydroxide (NaOH) is added to react with the FFA and form a precipitate that is insoluble in oil. After the precipitate settles out, it is removed and may be used as soapstock or chemical feedstock. Phosphatides and gums are removed by spraying hot water on the oil The oil is then dried under vacuum.

Bleaching takes out most of the dissolved or colloidal pigments responsible for the color of crude oil. Either activated carbon or bleaching earths such as bentonite or diatomite are added to the neutralized oil under a vacuum while heating it to 95-100°C. Sometimes, sulfuric or hydrochloric acids are added to the bentonite. Afterwards, the bleaching agents are removed by passing the oil through a filter press.

Deodorization removes volatile odors and flavors as well as peroxides that affect the stability of the oil. It is done by passing 185-190° steam through the oil for 4-5 hours under a

vacuum (Banzon 1987; Jimenez 1987).

The equipment for refining is expensive since it must be made of stainless steel. Moreover, the process has to be monitored closely (Woodroof 1979). Refining often reduces the vitamin E content of the oil (Banzon 1987).

Description of the Wet Process

The wet process for coconut oil extraction differs from the dry process in its use of fresh coconut rather than copra and in the nature of the products. The coconut meat is grated and coconut milk squeezed from it. Oil is obtained by breaking the oil/water emulsion of the coconut milk. In addition to the oil, other products can be obtained by separating the skim milk, protein ("latik"), and fibrous ("sapal") portions of the coconut.

The wet process is a modification of the traditional kitchen process for extracting coconut oil. Relatively little R & D has been done to upgrade its efficiency. The main bottleneck is in breaking the emulsion. A variety of methods have been tried including enzyme treatment, boiling, addition of chemicals, fermentation, vacuum evaporation, or freezing followed by melting.

In the early 1970s, the Tropical Products Institute did research on the extraction steps, but their medium-scale process was not economical (Edmonds, Edwards, and Mars 1973). Hagenmaier (1980) tried to reduce the costs of oil recovery and on a medium scale and increase revenues through addition of high-tech food byproducts such as spray-dried coconut milk.

However, little has been done to optimize the equipment for a commercial venture and Hagenmaier's process has higher capital costs than a large-scale copra mill. Appropriate Technology International and the Filipinas Foundation have been supporting efforts to make a labor-intensive wet process commercially viable on a village scale.

What are the advantages of the wet process? First, the crude wet process oil is the equivalent of semi-refined ("Cochin") oil from the dry process. It can be used directly for human consumption with only minimal refining that can be done on a small scale. Refining losses should be only 1-2% of the crude oil (Banzon 1987). Wet process oil has a lower FFA content, less color, and greater stability than copra process oil. Its light odor and flavor are preferred by Philippine consumers. More of the vitamin E content of the oil can be retained with the wet process if excessive heating is avoided in processing and post-treatment.

Second, unlike the copra process, the wet process allows recovery of foods for human consumption and soap without a loss in edible oil production. The skim milk contains most of the usable protein of the coconut, but spoils rapidly and must either be consumed immediately or processed in a relatively expensive evaporator or spray drier. The remaining protein in the cream ends up in the latik and becomes denatured if the emulsion is broken by boiling. This problem could be avoided if centrifugal separators are used, but they are also capital intensive. The greater flexibility of the wet process allows the

product mix to be changed in response to market demand with little retrofitting.

The purchase of whole coconuts facilitates commercial production of other byproducts such as fiber, rope, charcoal, and products from coconut water. This is the case for either the wet process or dry process mills that make their own copra. However, if coconut water is not consumed within a few hours of splitting the coconut, it must be processed to avoid spoilage.

Simple wet process methods do not require expensive equipment. Most of this equipment can be made to order domestically, but more sophisticated methods would require imported equipment. Equipment for the dry process is available ready-made, but is often imported and relatively inflexible in scale. By avoiding the use of high-pressure expellers, the wet process is less prone to downtime from frequent equipment breakdowns.

The main disadvantage of the wet process is its low oil extraction efficiency, 70% or less if simple equipment is used. This results in low earnings from sale of oil. Also, the high oil content of the sapal makes it less palatable to animals. The sapal could be roasted and pressed again to yield lower-grade oil for soapmaking, increasing the extraction efficiency to 80%. More sophisticated equipment can be used to raise the efficiency of a single extraction to 87%. If an expeller or solvent extraction were used in the second stage of extraction, the oil yield could even be higher than with the dry process. Another disadvantage is that fresh coconut must be processed within a few

hours to avoid bacterial spoilage. The wet process would reduce labor time in copra making, but generally, this is an unpaid chore for members of the farm household, which does not increase household income very much.

The wet process may be best suited to islands or remote areas with poor transportation infrastructure. In these areas, commercial brands of copra process oil are scarce or expensive and farmers have few outlets for sale of coconuts.

Financial and Economic Analysis

Types of Mills Analyzed

Nine types of mills and one refinery are analyzed here: six are village-scale, two are medium-scale, and one is large-scale by the ILO classification. One medium-scale and two of the village-scale mills rely on the wet process. The rest use the conventional copra process for milling, which must be combined with refining. One of the village-scale copra mills initially tried to produce edible oil, but switched to oil for soapmaking because of the difficulty of refining.

The large-scale mill analyzed has a capacity of 150 t of copra per day. The second plant is a stand-alone refinery with a capacity of 70 t of crude coconut oil per day. The third plant is a medium-scale, integrated mill and refinery for smaller markets. Because of the refining requirements for copra process oil, any economic advantages of having a smaller, decentralized copra mill could be outweighed by extra transport costs to the refinery and back to rural markets. Recently, a workshop in the

Philippines began offering a package plant with a milling capacity of 13 t of copra per day (8 t of crude oil) and a refining capacity of 6 t of crude oil per day. Except for the motors, all of the equipment is locally made (Yu 1987).

Keddie, Allal, and Das (1983) analyzed three village-scale technologies for copra milling in one country: a power ghani, baby expeller, and a small package expeller. None of these alternatives is currently in use in the Philippines, but these data have been adjusted to reflect inflation (NEDA 1986; U.S. Bureau of Labor Statistics 1987) and for consistency of assumptions with the other alternatives.

A power ghani mill is an upgraded version of the traditional, Indian technology. The traditional ghani consisted of a wooden mortar and pestle rotated by animals to press 0.1 t of copra per day. The power ghani has a cast iron mortar and pestle driven by a diesel motor. A double ghani includes two ghanis run off a single 3-hp motor. A double ghani can process 0.56 t of copra per day. For a higher extraction efficiency, a small hammermill with a capacity of 0.1-0.2 t per hour is used and 1% gum acacia is added before pressing in a ghani. The yield by weight is 57% for oil and 38% for copra cake. The oil from a ghani requires filtration and settling before consumption. Because its residual oil content may exceed 18%, the byproduct cake spoils in a few days unless properly treated, packaged, and stored. Thus, the overall extraction efficiency with a power ghani is nearly 90%. Power ghani mills have been successful in India where government policy encourages cottage industries, but

have not worked well in Tanzania where the local capacity for manufacturing, maintaining, and repairing the equipment is limited (Ibid.).

The baby expeller mill includes a swing beater crusher, a 2-h.p. scorcher, and a 3-h.p. single-pass expeller. The crusher can reduce 0.1 t of copra to pieces 6 mm square in 1 hour. The scorcher heats the material in open pans over an enclosed fire for 20-30 min at 60-90°C as it is stirred. Scorching is important in maximizing the yield of oil and decreasing wear on the expeller. The capacity of this mill is 0.4 t per day. The oil yield can reach 61% with a cake yield of 34%. The cake has a residual oil content of 8.0%. Thus, the oil extraction efficiency is 96%. Post-treatment of the oil and cake from a baby expeller is similar to that for the ghani mill (Ibid.).

The small package expeller mill is a scaling up of the baby expeller mill to double its capacity to 0.8 t per day. It consists of a larger crusher, two scorchers with a mechanical stirrer, and one dual expeller. The extraction efficiency is the same as for the baby expeller mill. Unlike the ghani or baby expeller mills, the package expeller mill requires electricity rather than diesel fuel (Ibid.).

Innovators for Rural Development (IRD), a Philippine NGO, received a grant from A.I.D. in mid-1984 to establish a small-scale copra processing plant at Santa Ana, Tagaloan in the province of Misamis Oriental on Mindanao. Originally, this plant was to produce edible oil, copra cake, soap, vinegar, charcoal, and texturized vegetable protein. At present, this plant is only

producing laundry soap, bath soap, powdered soap cuttings, and charcoal (IRD n.d.) Edible oil production was abandoned because of the difficulty and cost of refining copra process oil on a small scale. Vinegar production from filtered coconut water was found to be unprofitable.

The IRD plant buys whole coconuts and makes its own high-quality copra in a flue dryer fueled by coconut husks. The copra is ground in a hammermill and then a disk grinder before the oil is extracted in a manual screw press. In a single extraction, this screw press yields 0.55 t of crude oil and 0.38 t of copra cake.

For comparability with the other mills analyzed, some of the input costs of the IRD plant have been adjusted and updated. The analysis of the IRD technology is based on the rated capacity of 0.38 tpd. However, the actual capacity use rate was only 26% at this plant in 1986, its second year of operation, due to serious managerial and marketing problems (Mendoza 1987; Neri 1987; Ortigas 1987).

In 1980, Hagenmaier analyzed a prototype medium-scale, wet process mill (figure 2) and his findings have been updated here. This plant can process 25 t of white coconut meat per day in triple shifts. The main byproducts are either spray-dried protein or coconut skim milk powder and coconut meat or flour. This plant is more capital intensive than a large copra mill because of the sophisticated food processing equipment for the high-value byproducts. A reliable supply of electricity is critical for this plant because power interruptions can cause

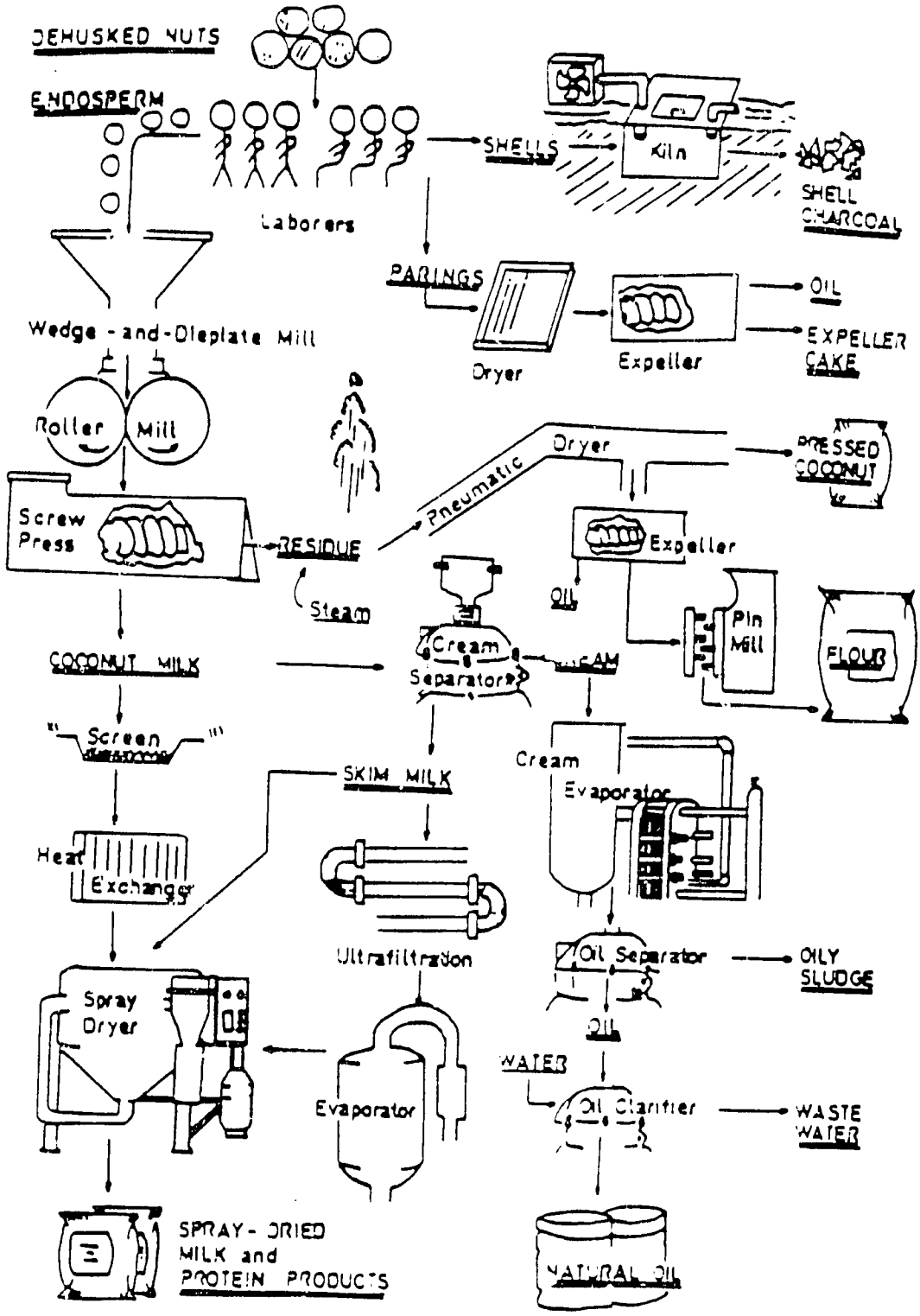

Figure 2. A Medium-Scale, Capital-Intensive Wet Process

Source: Hagenmaier 1980.

excessive bacterial growth in some wet, intermediate products.

With support from a venture capital fund established by Appropriate Technology International (ATI), the Filipinas Foundation (FFI) provided equity financing for 70% of the capital costs of a village-scale, wet coconut processing plant. A private entrepreneur provided the rest of the initial capital. This plant, located at Tagbanon, Cadiz in the province of Negros Occidental, has a capacity of 2,000 whole coconuts per day --the equivalent of 0.38 t of copra (Filipinas Foundation 1986). In late 1986, the Tagbanon plant began trial production of edible oil, laundry soap, sapal cake for animal feed, and charcoal. Production of other potential food byproducts was not done.

Each batch of oil took 3 days to produce (figure 3). The first day's activities included dehusking, cracking, grating, pressing, and settling. Cooking was done on the second day and simple refining on the third day. It took 1 minute for a worker to dehusk 3 coconuts or crack 4 coconut shells. The coconut meat was grated in a motor-driven spindle grater with 6 work stations. At each work station, one laborer grated the meat from 1 coconut in 1 minute. A hydraulic screw press extracted the coconut milk from 30 kg of grated coconut meat in a 20-minute cycle. To get a higher yield of coconut milk, a second extraction was done with some of the coconut water added to replace the liquid removed in the first extraction.

Next, the coconut milk was allowed to settle for 2 hours to separate the cream portion from the skim, reducing the cooking time by 3-4 hours. The skim milk could undergo further

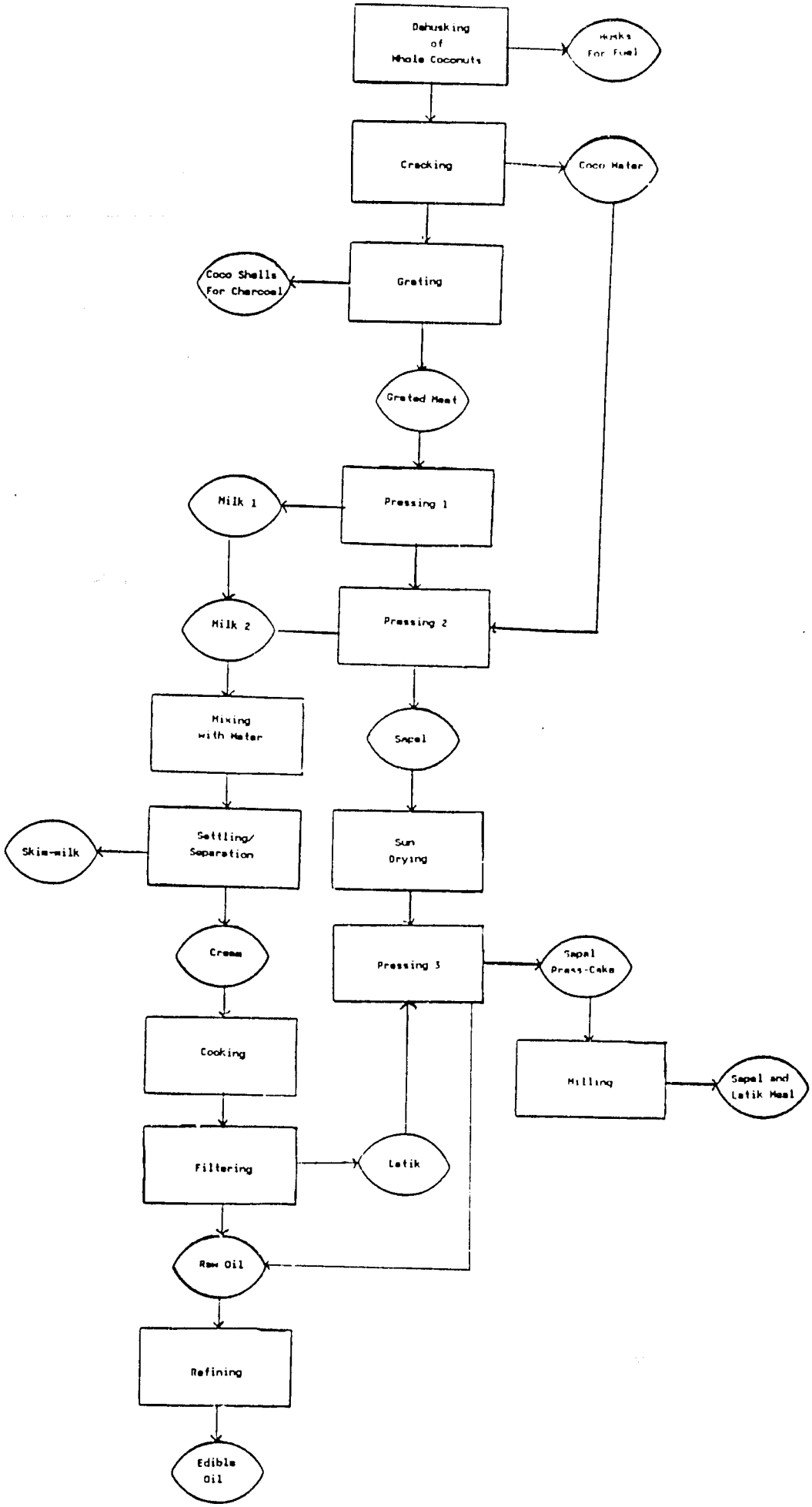

Figure 3. The Wet Process for Coconut Oil at the Tagbanon Plant

processing for beverage or confection products, but was instead discarded because it quickly spoils in the settling vats. The washed cream was heated to break the oil in water emulsion and evaporate the water, leaving behind raw oil and latik. The portion of the milk containing the solids was heated for a longer time. Since high heating was used to break the emulsion, much of the protein in the latik became denatured and thus unsuitable for human consumption. With other variants of the wet process, latik protein can be recovered for food. The Tagbanon plant used a simple process of alkali refining, steam deodorization, and washing to improve the quality of the edible oil. The lower grade oil recovered from re-pressing the latik and dried sapal was used for laundry soap making.

The Tagbanon plant used a cold process for making soap (figure 4). Complete saponification was achieved at room temperature with a strong alkali solution. The soapstock oil was combined with NaOH and other chemicals for 1 hour in a locally fabricated, mechanical mixer. Perfumes such as citronella and oil of wintergreen were added along with blue coloring. The mix was poured into wooden molds and left to harden for 24 hours. It was then removed from the mold and cut into long bars and branded. The soap was aged for at least a week before sale. The product was intended for the rural poor as it was supposed to be less expensive than the commercial brands, although it was less sudsy and did not have as fine a grain. A boiling process would produce better quality soap than the cold process, but at higher fuel and labor costs.

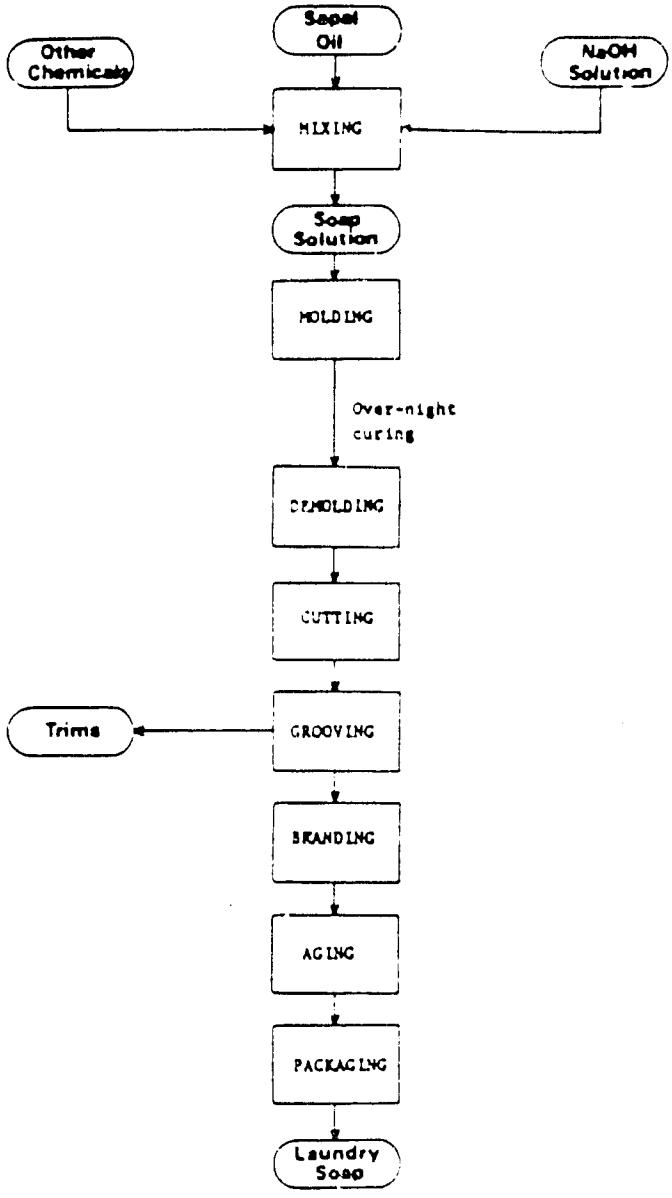

Figure 4. The Production Process for Laundry Soap at the Tagbanon Plant

Trial production stopped at Tagbanon in the spring of 1987, following an analysis of the commercial problems. Although the plant used simple, labor-intensive equipment, mostly of local fabrication, some inefficient choices were made in selection of equipment. As a result, the yield of edible oil was lower than expected, only 51% of the oil content of the coconuts. Another 20% of the potential oil was extracted in a form suitable for soap making (Francisco 1987). The reasons for the low yield are that the mechanical press concentrated pressure on the edges of the bag of material placed on the plate instead of distributing it evenly, and the refining loss was too high (Jimenez 1987). Because of this, it was difficult to undercut the price of commercial laundry soap and make a profit. Another source of problems at the Tagbanon plant was lack of a staff person there who understood the technology well (Banzon 1987).

An improved village-scale wet process plant could have a higher efficiency if more appropriate changes in equipment and process were adopted. An improved plant with a processing capacity of 5,000 coconuts per day, could yield 530 kg of raw oil. A few of these changes are simple and inexpensive. For example, the sapal cake could be roasted and pressed again in the hydraulic press to raise the total extraction efficiency from 71% to over 80%. Another easily resolved problem is that too much NaOH was added in refining, resulting in saponification rather than neutralization of the FFA and an unnecessary loss of oil. Since the amount of NaOH needed depends on the characteristics of the oil, each batch should be tested through titration. Also,

the NaOH should be sprayed into the oil rather than being added in one lump.

The soap from Tagbanon exhibited oozing of oil due to incomplete reaction with the NaOH. Consequently, it was recommended that a semi-boiled process for soap replace the cold process. The fuel costs for this would be low if coconut husks were burned. Since the limiting factor in making soap has been the quantity of sapal oil, the time required for heating would not reduce production (Jimenez 1987).

However, some expensive additions would be needed for an improved village-scale wet process: (1) a hammermill with a capacity of 2-3 t/hour, (2) an expeller with a crushing capacity of 400-500 kg per hour, and (3) a 24" x 24" filter press with a capacity of 700-800 kg/hour. A hammermill would grind the material up more finely so it can can be expelled more efficiently. An expeller operates at a higher, more even pressure than the hydraulic press. These changes would eliminate the need for the spindle grater, hydraulic press, stoves for used for breaking the oil/water emulsion, and the drying stage for the sapal (Ibid.).

Major changes have also been recommended in the equipment for refining: the addition of a boiler, neutralizer, and deodorizer. As a replacement for the autoclave, a boiler could produce a more efficient and economical supply of steam. The Tagbanon system of heating oil by direct steam injection under atmospheric pressure did not deodorize the oil and increased the FFA content through oxidation and hydrolysis. Deodorization

should be done through steam distillation at high temperatures under reduced atmospheric pressure. A vacuum would increase the volatility of substances with undesirable odors and flavors, and protect the oil from oxidation and hydrolysis. Steam distillation would also increase the stability of the oil by destroying peroxides and other oxidants. To do this, a neutralizer tank with a stirrer, closed coil heating, and low pressure or vacuum facilities would be needed (Ibid.).

Assumptions

The financial and economic analyses cover production at an average capacity use rate and a higher level. Full capacity is based on three shifts per day and 300 days of operation a year at large- and medium-scale mills, and 1 shift for 260 days per year at village- and small-scale mills. However, the capacity use rate is assumed to be 60% for the larger mills and 80% for the smaller mills. In a sensitivity analysis, an 80% capacity use rate is taken for the large- and medium-scale mills and 100% for the village-scale mills.

The financial and economic analysis of the various scales and types of coconut oil mills are based on costs and revenues for early 1987. The financial analysis includes a fixed capital loan at an interest rate of 1.5% per month and a repayment period of 5 years with a 1 year grace period. The working capital loans have no grace period and are payable in 1 year. The working capital covers 10 days of the basic raw material (copra or whole nuts for the mills and crude oil for the refineries). The

economic returns are independent of the means of financing and exclude subsidies.

The financial analysis includes capital and replacement costs when incurred. Straight-line depreciation is used to reduce taxable income; the tax rate is 35% of net profits. Other taxes or customs fees borne by exporters are already accounted for in the ex factory price offered by the traders. Taxes are not deducted in the economic analysis.

It is assumed that the large- and medium-scale plants export the same proportion of their output as the national average for the industry in 1985 -- 78% for coconut oil and 82% for copra cake. The village-scale plants would only produce for the domestic market.

The basic scenarios incorporate the current price of P4,120 per tonne of copra delivered to the mill warehouse. The price of whole coconuts, P0.75 each is derived from the copra price plus the incremental costs of transporting whole coconuts rather than copra, less the costs of copra preparation. Crude coconut oil currently sells for P8,600/t delivered, or P7,600/t ex factory. The price of 1 t of refined oil is P12,950 delivered or P11,950 ex factory. Semi-refined oil from the wet process wholesales at a 6% premium over crude coconut oil. Wet process oil is sold in rural areas at the same wholesale price as refined copra oil, P13,858 per tonne. A village-scale, wet process plant can command a larger share of this price, P12,700 by circumventing several layers of middlemen. Copra cake is valued at P1,800 per t and charcoal at P1,500 per t ex factory.

The village-scale, wet process cake sells at a small premium because of its higher oil content (Cuano 1987; UCAP 1987). Table 1 lists the assumptions behind the analysis.

Findings

Table 2 summarizes the findings, which reflect the current relatively low prices for coconut oil and high prices for copra or whole coconuts. At an average capacity use rate, the large- and medium-scale technologies for both the copra and wet processes were financially and economically profitable. Coconut oil refining was substantially more profitable than copra milling. None of the small-scale copra process technologies analyzed were financially viable.

The Tagbanon village-scale, wet process mill also proved unprofitable. An improved, village-scale, wet process mill would be economically viable even though it would operate at a financial loss due to taxes. If other byproducts besides soap, charcoal, and animal feed were produced, the results could be more favorable for the village-scale wet process. The same pattern of profits and losses holds under the high capacity use rate, with one exception. In that case, the improved wet process mill would be both financially and economically viable.

Research Needs for New Food Products

The commercial viability of the wet process could be enhanced if cost-effective technologies are available for making additional byproducts that have a sufficient market. New food

TABLE I

Assumptions for the Financial and Economic Analysis

	Large-Scale Copra Mill	Large-Scale Refinery	Medium-Scale Mill/Refinery	Double Ghani Mill	Baby Expeller Mill	Small Package Expeller	Village-Scale Copra Process Soap Plant	Hagenmaier Medium-Scale Wet Process Mill	Tagbanon Village-Scale Wet Process Plant	Improved Village-Scale Wet Process Plant
Operations										
Copra equivalent capacity (t/d)	150	0	13	0.56	0.40	0.80	0.38	10.5	0.38	0.95
Crude oil refining capacity (t/d)	0	70	6	0	0	0	0	0	0	0
Capacity use rate (%)	60	60	60	80	80	80	80	80	80	80
Operating hours/d	24	24	24	8	8	8	8	24	8	8
Operating days/y	300	300	300	260	260	260	260	300	260	260
Capital										
Land (@ P30/m2) (P)	600.000	300.000	75.000	3.000	2.700	4.500	21.000	150.000	27.000	40.500
Buildings and storage facilities (P)	6.000.000	3.000.000	1.100.000	67.178	53.198	93.877	258.300	7.449.000	150.000	225.000
Capital equipment (P)	30.999.000	12.685.000	7.429.500	93.562	439.274	820.185	120.445	47.244.650	125.643	525.377
Working capital (P)[a]	370.800	3.612.000	321.360	18.458	13.184	26.368	12.000	247.640	12.720	31.800
Licenses and permits	10.000	10.000	10.000	1.000	1.000	1.000	1.000	10.000	1.000	1.000
Monthly Production										
Crude oil (t)	1.384	0	30	5.54	4.23	8.46	0.77	0	0	0
Copra cake (t)	754	0	65	3.69	2.36	4.72	2.50	0	0	0
Refined oil										
Tins (17.3 kg)	0	34.613	5.202	0	0	0	0	0	0	0
Bottles (0.915 kg)	0	436.284	0	0	0	0	0	0	0	0
Laundry soap (0.48 kg) long bars)	0	0	0	0	0	0	5.200	0	2.816	7.766
Powdered laundry soap rejects (1 kg bars)	0	0	0	0	0	0	953	0	0	0
Reject laundry soap pieces (t)	0	0	0	0	0	0	0	0	0.104	0.325
Grade A bath soap (100 g cakes)	0	0	0	0	0	0	1.451	0	0	0
Grade B bath soaps (100 g cakes)	0	0	0	0	0	0	161	0	0	0
Charcoal (t)	0	0	0	0	0	0	2.774	60	1.768	5.097

	Large-Scale Copra Mill	Large-Scale Refinery	Medium-Scale Mill/Refinery	Double Ghani Mill	Baby Expeller Mill	Small Package Expeller	Village-Scale Copra Process Soap Plant	Hagenmaier Medium-Scale Wet Process Mill	Tagbanon Village-Scale Wet Process Plant	Improved Village-Scale Wet Process Plant
Semi-refined oil										
(t)	0	0	0	0	0	0	0	18	0	0
(17.3 kg tins)	0	0	0	0	0	0	0	0	130	353
Dried coconut milk (t)	0	0	0	0	0	0	0	172.5	0	0
Preused coconut	0	0	0	0	0	0	0	54	0	0
Copra from reject coconuts (t)	0	0	0	0	0	0	0	0	0.265	0.662
Sapal cake (t)	0	0	0	0	0	0	0	15	2.496	16.781
Monthly Revenues[b]										
Crude oil (P7,600/t)	10,518,400	0	228,000	42,104	32,148	64,296	5,852	0	0	0
Copra cake	1,357,200	0	117,000	6,642	4,248	8,496	4,500	0	0	0
Refined oil										
Tins (@ P207)	0	7,164,891	1,138,914	0	0	0	0	0	0	0
Bottles (@ P18.18)	0	7,538,988	0	0	0	0	0	0	0	0
Laundry soap bars (@ P6.50)	0	0	0	0	0	0	31,200	0	18,304	50,479
Powdered reject laundry soap	0	0	0	0	0	0	11,893	0	0	0
Reject laundry soap pieces	0	0	0	0	0	0	0		520	1,625
Grade A bath soap	0	0	0	0	0	0	4,518	0	0	0
Grade B bath soap	0	0	0	0	0	0	402	0	0	0
Charcoal (P1,500/t)	0	0	0	0	0	0	4,161	90,000	2,652	7,646
Semi-refined oil										
Tonnes (@ P8,060)	0	0	0	0	0	0	0	145,080	0	0
Tins (@ P220)	0	0	0	0	0	0	0	0	28,626	77,660
Dried coconut milk	0	0	0	0	0	0	0	4,198,650	0	0
Pressed coconut	0	0	0	0	0	0	0	328,590	0	0
Copra from reject coconuts										
high oil content (@ P4,120/t)	0	0	0	0	0	0	0	0	1,092	2,727
Sapal cake (@ P2,000/t;										
low oil P1,900/t)	0	0	0	0	0	0	0	30,000	4,992	31,884
Total	11,875,600	14,703,879	1,483,914	48,746	36,396	72,792	62,526	4,792,320	56,186	172,021

	Large-Scale Copra Mill	Large-Scale Refinery	Medium-Scale Mill/Refinery	Double Ghani Mill	Baby Expeller Mill	Small Package Expeller	Village-Scale Copra Process Soap Plant	Hagenmaier Medium-Scale Wet Process Mill	Tagbanon Village-Scale Wet Process Plant	Improved Village-Scale Wet Process Plant
Monthly Labor Costs										
Management	25,000	20,000	16,000	3,500	3,500	3,500	3,500	6,744	3,500	3,500
Administrative support	18,000	15,000	12,000	2,281	2,281	2,281	2,281	6,843	2,281	2,281
Skilled workers	3,415	13,660	10,245	1,500	1,500	1,500	1,500	28,493	1,500	1,500
Unskilled workers	36,000	24,000	54,000	2,240	2,240	3,360	8,960	92,414	15,680	34,720
Security	15,456	15,456	7,728	2,240	2,240	2,240	2,240	15,456	2,240	2,240
Total	97,870	88,116	99,973	11,761	11,761	12,881	18,481	149,950	25,201	44,241
Monthly Fixed Costs										
Administrative supplies	4,000	4,000	4,000	300	300	300	300	4,000	300	750
Insurance[c]	44,548	19,606	9,933	202	617	1,144	475	65,242	345	938
Interest										
Physical capital loan[d]	564,135	239,925	129,218	2,471	7,443	13,793	6,146	822,805	4,555	12,355
Working capital loan[e]	55,620	54,180	4,820	277	198	396	1,000	3,715	191	478
Other supplies	0	0	0	1,866	1,866	1,866	0	0	0	0
Total (yr. 1)	104,168	77,786	18,753	2,645	2,981	3,706	7,786	72,957	836	2,166
(yrs. 2-6)	612,683	263,531	143,150	4,839	10,226	17,103	6,786	892,047	5,200	14,043
(yrs. 7-20)	48,548	23,606	13,933	2,368	2,783	3,310	775	69,242	645	1,688
Monthly Variable Costs[f,g]										
Copra (P4,120/t)	9,270,000	0	803,400	39,998	28,570	57,139	0	0	0	0
Whole coconuts (@ P0.75)	0	0	0	0	0	0	26,004	619,099	27,564	68,911
Chemicals[h]	3,000	80,400	8,651	0	0	0	22,685	1,071,381	7,128	18,618
Electricity (P3/kwh)	202,500	135,000	60,750	0	0	3,912	2,835	4,500	650	5,197
Fuelwood (P0.35/kg)	36,750	18,375	0	0	182	426	0	0	0	0
Coconut husks/shells for fuel[i]	52,500	26,250	20,475	0	0	0	0	0	0	0
Filter cloths (21.7m2/100t @P20/m^2)[j]	6,007	4,557	911	24	18	37	14	78	10	68
Packaging materials	0	2,309,406	52,020	3,200	2,450	4,890	1,519	25,785	1,240	9,033
Crude coconut oil	0	9,030,000	0	0	0	0	0	0	0	0
Diesel fuel	0	0	0	757	757	0	0	0	0	0
Marketing	0	99,800	0	0	0	0	772	0	0	0
Other	0	0	0	0	0	0	0	1,720	0	0
Total	9,570,757	11,703,788	946,207	43,979	31,977	66,404	53,829	1,722,563	36,592	101,827

	Large-Scale Copra Mill	Large-Scale Refinery	Medium-Scale Mill/Refinery	Ghani Mill	Expeller Mill	Package Expeller	Copra Process Soap Plant	Medium-Scale Wet Process Mill	Scale Wet Process Plant	Scale Wet Process Plant
Monthly Maintenance and Repair Costs (Annual/12)										
yrs.1,2,4,8,11,13,16,17, 19,20	289,207	0	0	0	0	0	0	0	0	0
yrs. 5,10,15	298,374	0	0	0	0	0	0	0	0	0
yrs. 7,14	322,540	0	0	0	0	0	0	0	0	0
yrs. 1-20	0	0	29,679	560	222	409	0	36,047	675	1,500
yrs. 1,3,5,7,9,11,13,15,17,19	0	57,857	0	0	0					
yrs. 2,4,6,8,10,12,14,16,18,20	0	60,190	0	0	0	0	443	0	0	
Depreciation[k]	191,318	78,379	49,026	1,085	3,903	7,267	3,294	310,062	2,890	4,608
Loan Replacements										
Physical capital	626,817	266,583	143,575	2,746	8,270	15,326	6,829	914,228	5,061	13,728
Working capital	309,000	301,000	26,780	1,538	1,099	2,197	1,000	20,637	1,060	2,650
Monthly Replacement Costs (Annual/12)										
yr.2	0	0	375	0	0	0	812	0	890	911
yr.3	50,000	0	5,000	0	0	0	0	0	0	0
yr.4	0	0	375	0	0	0	7,823	0	909	930
yr.5	92,333	7,083	11,917	0	0	0	0	0	8,594	5,938
yr.6	50,000	0	39,542	220	176	353	813	0	890	911
yr.7	0	0	0	0	0	0	1,692	0	0	0
yr.8	33,333	0	7,042	0	0	0	7,823	0	909	930
yr.9	50,000	0	5,000	0	0	0	0	0	0	0
yr.10	97,333	286,250	131,917	7,797	36,606	68,349	1,334	486,712	10,452	29,263
yr.12	50,000	0	39,543	220	176	353	7,823	1,668,395	909	930
yr.14	0	0	0	0	0	0	812		890	911
yr.15	325,667	79,167	112,625	0	0	0	0	0	8,594	5,938
yr.16	33,333	0	7,042	0	0	0	9,516	0	909	930
yr.18	50,000	0	0	0	0	0	812	0	890	911
Salvage value (end of period)	2,100,000	1,611,667	955,667	881	704	1,410	2,901	6,139,749	0	3,400

[a] 10 days supply of copra for dry process or whole nuts for wet process at stated capacity use level.

[b] Prices are ex-factory.

[c] 1.5% of equipment and buildings and storage facilities.

[d] Interest rate of 1.5%/month (19.56%/year), repayment period of 5 years, 1 year grace period, covers 100% of costs of equipment, buildings and storage facilities, and land.

[e] Interest rate of 1.5%/month (19.56%/year), repayment period of 1 year, no grace period, covers costs of coconut raw material for 10 days at stated capacity use rate.

[f] Transport is not included here because all product prices are ex-factory and the prices for copra and whole coconuts include delivery.

[g] The plants are located where groundwater or surface water supplies can be tapped directly, rather than purchasing municipal water.

[h] Large-scale copra mill: NaOH. Large-scale refinery: NaOH, activated carbon, H_2SO_4, soda ash, salt. Medium-scale integrated mill: NaOH, activated carbon, and other. Village-scale copra process soap plant: NaOH, soda ash, sodium silicate, perfumes, colorings, sugar, citric acid, and other. Medium-scale wet process mill: casein, syrup. Village-scale wet process mill (Tagbanon and improved type): NaOH, sodium silicate, perfumes, coloring, soda ash.

[i] Coconut husks are available at no cost. Coconut shells are bought at P0.70/kg, if whole coconuts are not purchased.

[j] Tins @ P10.0, plastic bottles @ P4.50. Large-scale refinery: 346,127 tins; 1,963,279 bottles. Medium-scale integrated mill/refinery: 52,020 tins. Double shani: 320 tins. Baby expeller: 245 tins. Medium-scale wet process: laminated foil for dried coconut milk, recycled sacks for charcoal and sapal cake, polyethylene film for other products. Tagbanon village-scale wet process: recycled packaging materials for oil, charcoal, and feeds. Improved village-scale wet process: 15 kg sacks for sapal @ P2.50, wrappers for soap bars @ P0.25, 10 kg sacks for charcoal @ P1.50, tins @ P10.0.

[k] Depreciation is used as a deduction against taxes, which are 35% of net profits.

[l] Salvage value pertains to capital equipment only.

TABLE 2

Summary of the Financial and Economic Analysis

	Large-Scale Copra Mill	Large-Scale Refinery	Medium-Scale Mill/Refinery	Double Ghani Mill	Baby Expeller Mill	Small Package Expeller	Village-Scale Copra Process Soap Plant	Hagenmaier Medium-Scale Wet Process Mill	Tagbanon Village-Scale Wet Process Plant	Improved Village-Scale Wet Process Plant
Capital costs (P)	37,609,000	45,995,000	8,614,500	164,740	496,172	919,562	409,745	54,853,650	303,643	823,677
Unskilled and semi-skilled employment (no.)	30	24	33	4	4	5	11	88	17	34
Capital costs/employee (P)	1,253,633	666,458	261,045	41,185	124,043	183,912	37,250	623,337	17,861	24,22
Net present value (average capacity use)										
Financial	31,672,803	93,654,613	6,620,264	(915,592)	(1,515,903)	(2,229,351)	(1,462,985)	57,858,318	(1,089,867)	(181,120
Economic	84,568,867	170,103,693	17,413,693	(812,809)	(1,202,768)	(1,645,077)	(1,191,323)	131,947,664	(823,453	631,944
Net present value (high capacity use)										
Financial	85,133,660	136,110,496	17,577,211	(864,997)	(1,469,001)	(2,161,551)	(1,370,678)	101,300,082	(681,903)	563,894
Economic	138,029,724	212,559,576	28,370,641	(762,214)	(1,155,867)	(1,577,277)	(1,099,017)	175,389,429	(615,489)	1,376,958
Benefit/cost ratio (average capacity use)										
Financial	0.842	5.855	0.769	-5.558	-3.055	-2.424	-3.570	1.555	-3.589	0.220
Economic	2.249	10.635	2.021	-4.934	-2.424	-1.789	-2.908	2.405	-2.712	0.767
Benefit/cost ratio (high capacity use)										
Financial	2.264	8.519	2.040	-5.251	-2.961	-2.351	-3.345	1.847	-2.904	0.685
Economic	3.670	13.289	3.293	-4.627	-2.330	-1.715	-2.682	3.197	-2.027	1.672

[a] Capacity use rate of 60% on triple shifts for large-and medium-scale plants, and 80% on single shifts for village-scale plants.

[b] Capacity use rate of 80% on triple shifts for large-and medium-scale plants, and 100% on single shifts for village-scale plants.

[c] (Net present value/capital costs). A positive value indicates a project is worth doing in the absence of a budget constraint.

items could make a contribution to nutrition among the rural and peri-urban poor if they can become an accepted part of the diet.

Table 3 lists possible food products of the dry and wet processes. With the dry process, food products made from granulated coconut or coconut flour could only be obtained from copra at the expense of oil production. Furthermore, protein isolates and copra cake/meal from the dry process in the Philippines are unsuitable for human consumption because of the unsanitary conditions of copra preparation and storage and denaturing of proteins as a result of the high temperatures generated in expellers. If copra production were centralized at a dry process mill or the wet process used, coconut water could be tapped as a potential food resource. Other products of coconut milk, skim milk, cream, and sapal flour could be produced with the wet process. However, many of these products still require further research and adaptation work before commercialization. In addition, the marketing of new food products can be slow and expensive.

On a village scale, the processing of a large number of food products in one plant may become too complicated to manage effectively. Some of these products could be sold in bulk to avoid difficulties in obtaining packaging or sterilizing bottles. Production could also be simplified by subcontracting or by selling intermediate products to other enterprises.

Conclusions

There are substantial economies of scale in coconut oil production. Even though the total capital costs of a large-scale

TABLE 3
Alternative Food Products From Coconuts

A. DRY PROCESS

Granulated Coconut	Coconut Flour	Protein Isolates (CPI)	Meal (stable)
Confectioneries	Confectioneries	Infant formula	Condiments
Ice cream	Ice Cream	Meatless spread	Bakery products
Peanut butter	Peanut butter	Canned vegetable loaf	
Cakes	Cakes		
Cookies	Cookies		
Other baked goods	Noodles		
	Crunchy Snacks		
	Cereals		
	Rolls		
	Other baked goods		

B. DRY PROCESS WITH CENTRALIZED COPRA MAKING OR WET PROCESS

Coconut Water
Mushroom production
Food yeast
Vinegar
Nata de coco
Carbonated and noncarbonated beverages
Coconut water concentrate
Coconut milk (gata)

C. WET PROCESS

Coconut Milk	Skim Coconut Milk	Coconut Cream	Sapal/Coconut Flour
Canned coconut milk	Instant skim coconut milk	Canned coconut cream	Bakery products prepared with coco flour and banana flour
Coconut milk powder	Coconut protein isolate (CPI)		Meat and fish analogues prepared with coco flour
Coconut milk and protein isolate-based products	Simulated dairy milk		Coco flour noodles
Coconut jam/spread	CPI-based, meat substitutes		Coco pretzels
Coconut spread enriched with legume flour	CPI-based, cereal weaning flakes		Coco crunchies or shrimp crackers
Coconut syrup	Sweetened condensed coconut skim milk		Coco-burger
Coconut tofu substitute	Coconut honey		Soy sauce type of condiment
Coconut cheese	Fruit- or chocolate-flavored beverages		Dried Sapal hydrolysate
	Protein isolate		
	Sodium salt of coconut protein		

Source: Adapted from Gonzalez 1986, pp 39 and 52.

copra mill are high, the equipment is used intensively and the fixed costs are spread over a large volume of production. However, the profitability of a large-scale mill depends on production at a high capacity use rate for 3 shifts per day.

At present, small- and village-scale copra processing technologies have inherently low oil extraction rates. Relatively little R & D work has been done to increase the productivity or decrease the costs of these technologies. Their profitability is poor despite the low capital costs because they are generally operated on just a single shift per day. Intensive operation of village- and small-scale plants would require skillful managers, a plentiful supply of raw materials and a sufficient market. With proper selection of equipment and scale of operation, the wet process can be economically viable in remote coconut growing areas that are poorly served by the distribution system for products of large-scale industry.

The wet process offers greater flexibility of product line and this potential is really the main justification for choice of this process over the copra process. The profitability of the village-scale, wet process could be substantially better with production of one or more byproducts that have a positive gross margin and good marketability. Further work is needed in developing and testing such products as well as intermediate-scale equipment, such as a low-cost expeller and a cream separator.

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