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Technology, Scale, and the Coconut Industry in the Philippines

by

Eric L. Hyman, Ph.D.[1]

[1]Evaluation Economist
Appropriate Technology International
1331 H St., NW
Washington, DC 20005

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ABSTRACT

This paper begins by discussing the importance of coconut production and processing in the Philippines, and trends in coconut product prices. It then describes the scale and location of the existing processing industry. The second part describes two types of technologies producing a variety of different products, the dry (copra) process and the 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.

At present, the coconut industry in the Philippines is adversely affected by low product prices and high input costs. Considerable retrenchment has occurred in the medium- and large-scale sector, but the industry is currently profitable. However, prospects are not good for the village- and small-scale copra process plants. With proper selection of equipment and a high capacity use rate, a village-scale wet process plant could be economically viable in remote areas where it does not compete with the products of large-scale industry. Nevertheless, the main justification for choice of the wet process is in the potential for additional byproducts, and further product development and testing work is needed in this area.

INTRODUCTION

Coconuts are one of the most important crops in the tropics. They grow best between 20° N and 20°S in sandy soils at elevations below 180 meters. They prefer mean temperatures between 24-29°C and a minimum temperature of 20°C with high relatively humidity and an annual rainfall of 1500 mm evenly distributed. These conditions are often found on islands and the shores of continents (Woodroof 1979).

Most of the world's coconut crop is converted into copra for subsequent processing into oil, soap, and animal feed. 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 soap and foods for human consumption 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.

IMPORTANCE OF THE COCONUT INDUSTRY IN THE PHILIPPINES

Planted Area and Crop Size

In the Philippines, coconuts are grown on 3.28 million hectares (ha), which is nearly 28% of the total area planted to agricultural crops. The area devoted to coconuts increased 104% between 1965 and 1985. Although the Philippines has the largest planted area for coconuts in the world, production per hectare is low because the number of trees per hectare and the yields per tree are low.

In 1985, 1 ha of coconut land in the Philippines contained an average of 126 trees -- a 16% decrease over the past two decades as a result of increased spacing to allow interplanting of other crops (UCAP 1986c). The average number of trees per hectare varies from 103 to 172 across regions of the country (Valiente et al. 1979).

About 351.32 million coconut trees are bearing. At present, 85% of the trees are productive, an increase of 10% over 20 years ago (UCAP 1986c). The rest are immature; senescent; or unproductive due to pests, diseases, typhoon or drought damage, or poor cultural practices (Santos 1986). Coconut trees begin bearing after 5-8 years and reach high levels of production after 20 years. By age 50-60, the yield declines. After 70-80 years, the trees may become unproductive. An average of 30 coconuts are harvested per tree, resulting in a total of 3,800 nuts per hectare. This yield is low compared to other countries and half what it could be at maximum productivity (UCAP 1986b; Banzon

1987). Farmers harvest coconuts every 1 to 3 months. The peak season is August to November and the lean season occurs in April and May.

The amount of coconut harvested and products processed is expressed in terms of copra equivalents. A tonne (t) of copra equivalent consists of 6.28 t of whole coconuts (table 1). This requires an average of 5,240 whole nuts, but can range from 3,270 to 10,000 nuts depending on the variety, maturity, and growing conditions (Woodroof 1979).

The harvest varies considerably from year to year. In 1985, it was 2.051 million t of copra equivalent (UCAP 1986c). That was up 30% from the drought-affected previous year and 29% higher than the 1965 level, but down 12% from the peak in 1981 (figure 1). During 1985, 63.2% of the harvest was in Mindanao, 16.0% in the Visayas, 13.4% in the Southern Tagalog region, 6.0% in the Bicol, and 1.4% in Northern and Central Luzon (UCAP 1986b).

The contribution of the coconut industry to the gross value added in agricultural crops fluctuates with production and prices of coconuts and competing products. It was 8.0% in 1985, compared to 13.2% for the previous year and an average of 12.0% since 1970 (NEDA 1986). Although the coconut industry's share of gross value added seems low given its proportion of total agricultural land, other crops are often interplanted on the same land and coconut farming requires little effort or cash cost.

Export Earnings

Grades and standards exist for coconut product exports from the Philippines (table 2). Crude oil is the unrefined product of the dry process for oil extraction. Cochin oil is a quality grade equivalent to semi-refined and bleached dry process oil or unrefined wet process oil. RBD oil is fully refined, bleached, and deodorized for human consumption. Coconut oil is generally exported as crude or Cochin since refined oil does not store as well because some of the natural antioxidants in the oil are destroyed in refining (Banzon 1987). Crude oil remains fresh for several months, but importers would have to do additional refining of refined oil due to reversion during transport and storage. The bulk of crude coconut oil exports are for industrial purposes rather than edible oil. RBD oil is primarily for the domestic market. Acid oil, a byproduct of refining crude oil, is used in soap.

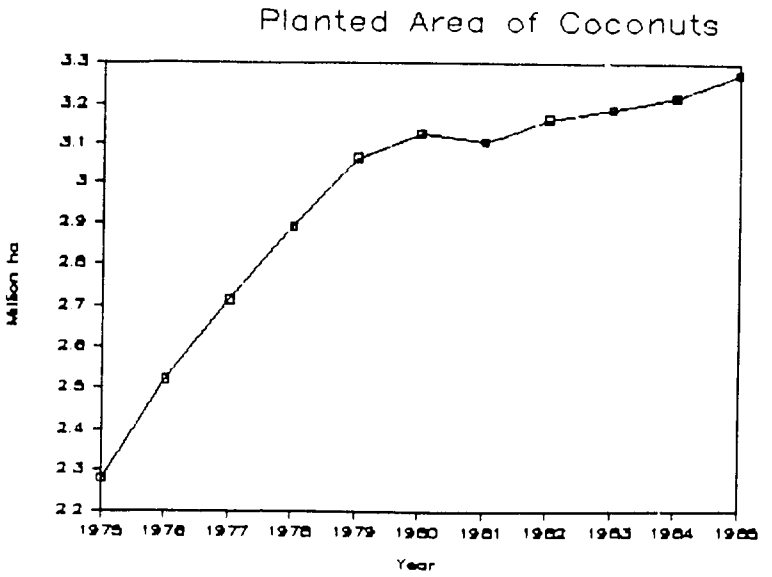
Moisture content is the most important factor for raw copra exports because it affects the oil yield by weight, storage losses from bacteria and fungal attack, and the degree of refining needed to remove FFA from the oil. Copra cake is the byproduct of pressing copra in an expeller, while copra meal is the residual after solvent extraction. A maximum level of moisture is specified for copra cake and meal since these are sold by weight and water is added to prevent spontaneous combustion.

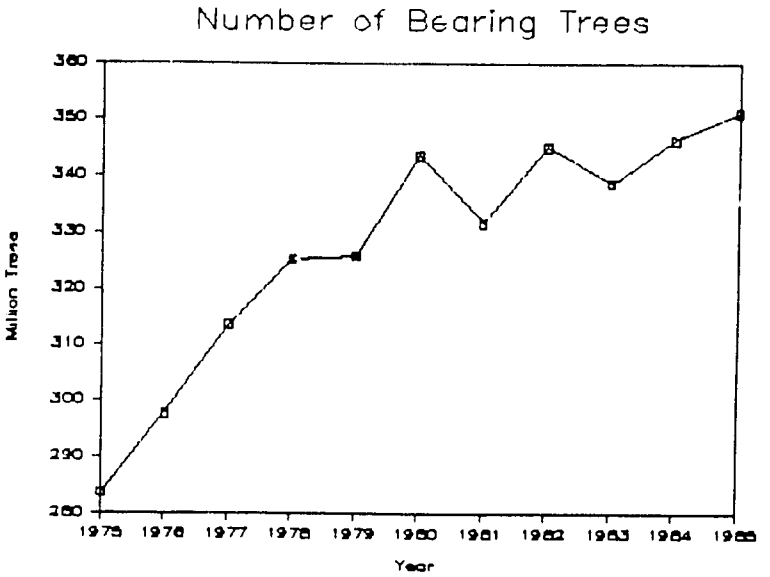
In 1985, 77% of the volume of Philippine coconut products sold was exported -- lower than the 85% share in 1975 and 83%

TABLE 1

COCONUT CONVERSION TABLE (metrie tonnes)

COCONUT PRODUCTS	Fresh Coconut Meat	Copra	Coconut Oil	Copra Cake/ Meal	Desiccated Coconut	Coconut Shell	Shell Charcoal	Whole Nuts	Husked Nuts	Coconut Water	Number of Nuts Required
1 mt fresh coconut meat	1.000	0.530	0.334	0.164	0.343	0	0	3.333	2.222	0	2,778
1 mt copra	1.887	1.000	0.630	0.310	0.647	0	0	6.289	4.193	0	5,241
1 mt coconut oil	2.994	1.587	1.000	0.492	1.027	0	0	9.980	6.653	0	8,316
1 mt copra cake/meal	6.098	3.232	2.036	1.000	2.091	0	0	20.284	13.550	0	16,938
1 mt desiccated coconut	2.916	1.546	0.974	0.479	1.000	0	0	9.718	6.479	0	8,096
1 mt coconut shells	0	0	0	0	0	1.000	0.278	6.667	4.444	0	5,555
1 mt shell charcoal	0	0	0	0	0	3.597	1.000	23.810	15.873	0	19,841
1 mt whole nuts	0.300	0.159	0.100	0.049	0.103	0.150	0.042	1.000	0.667	0.217	833
1 mt husked nuts	0.450	0.239	0.150	0.074	0.154	0.225	0.063	1.499	1.000	0.321	1,250
1 mt coconut water	0	0	0	0	0	0	0	4.608	3.115	1.000	3,840
1000 whole nuts	0.360	0.191	0.120	0.059	0.124	0.180	0.50	1.200	0.800	0.260	1,000





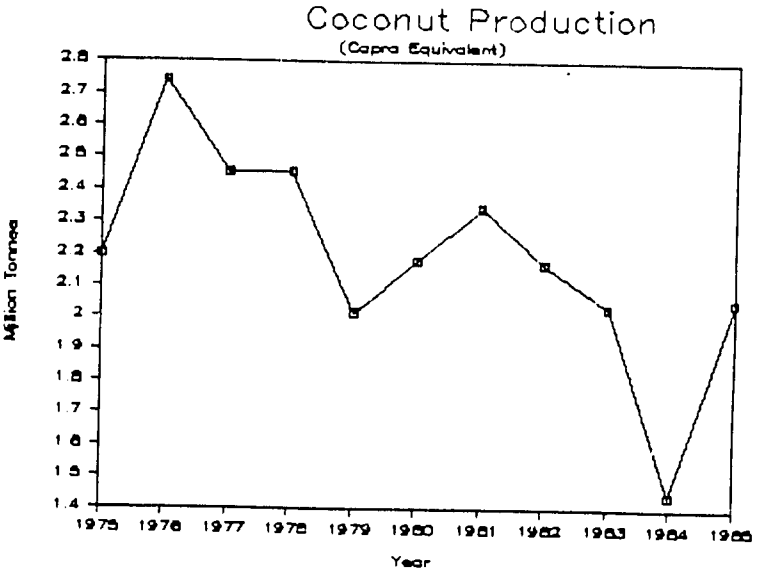


Figure 1. The Philippine Coconut Harvest

Sources: UCAP 1986b, 1986c.

TABLE 2.
Grades and Standards for Philippine Coconut Products

COPRA

	Food Grade	Fair Merchantable	Domestic
Moisture	5% max.	8% max.	15% max.
Oil	66% min.	60% min.	58% min.
FFA (as oleic)	0.5% max.	4% max.	5% max.
Appearance of oil	White to pale white	Brown to dark brown	-
Color of oil	2 red & 12 yellow, max.	9 red & 50 yellow, max.	-
Extraneous matter	-	0.75% max.	1% max.
Other specifications	Edible/good grade; cut into halves or quarters.	-	-

COCONUT OIL AND PRODUCTS

	Crude Oil	Cochin Oil	RBD Oil	Paring Oil
Moisture	1.0% max.	0.2% max.	0.1% max.	Standards for crude, cochin, and edible oils apply.
FFA (as oleic)	5.6% max.	0.1% max.	0.1% max.	
Color	75 yellow & 12 red	10 yellow & 1 red	10 yellow & 1 red	
Saponification value	250-264	250-264	250-264	251 max.
Iodine value	7.5-10.5	7.5-10.5	7.5-10.5	13.7
Odor	-	Soapy	Odorless	-

COCONUT ACID OIL
(Acidulated Coco Oil)

Saponifiable matter	95% min.
Moisture & impurities	2% max.
Iodine value	17 max.
Saponification value	250 min.
FFA (as oleic)	25% min.
Color	Gardner 12 maximum
Acid value	0.5 max.
Hydroxyl value	7.0
Iodine value	15.0 max.
Water	0.1% max.

TABLE 2 (cont'd)

DESICCATED COCONUT

	Coarse, Medium, Fine, Macaroon and Extra Grades	Special Grades
Moisture	3.0% max.	4% max.
FFA (as oleic)	0.3% max.	
Oil	60% min.	
Other specifications	Must meet acceptable bacterial contamination levels.	
Visual grading:	1. Color of meat shall be clear natural white, except toasted desiccated coconut which shall be burnt brown. 2. Tastes and smells sweet, pleasant and free from cheesy, smoky, soapy, sour or other undesirable flavors. 3. Free from all foreign matters including shells, coconut fibers, metal particles, textile fibers, and brown specks due to paring.	

COPRA MEAL/CAKE PELLETS

	Expeller or Paring Cake/Pellets	Solvent Cake/ Pellets
Moisture	10% max.	12% max.
Oil	12% max	5% max.

COCONUT SHELL CHARCOAL

	Metallurgical Grade A	Commercial Grade A	Commercial Grade B
Fixed carbon	80% min.	75% min.	65% min.
Ash	3% max.	3% max.	3% max.
Moisture	10% max.	10% max.	10% max.
Volatile combustible matter	20% max.	20% max.	20% max.
Sieve analysis	Not more than 5% shall pass a 1/4 inch mesh sieve.	Not more than 5% shall pass a 1/4 inch mesh sieve.	Not more than 5% shall pass a 1/4 inch mesh sieve.

Source: UCAP 1986b.

in 1965. The export share of the total volume of production in 1985 was lower, 61%, because of a large increase in inventories resulting from a bumper crop (figure 2). Some of these inventories were exported later as is indicated by a large increase in the volume of coconut product exports during the first half of 1986. The EEC is the largest importer of Philippine coconut products with a 32% share, closely followed by the U.S. at 31%, and next by Asia other than Japan at 14% (UCAP 1986c).

The composition of export production changed substantially over the past two decades (figure 3). The traditional export products are copra, oil, desiccated coconut, and meal/cake. Copra amounted to 64% of the export volume in 1965, but had declined to 45% in 1975 following expansion of the oil milling capacity in the country. Copra exports were banned between September 1982 and March 1986. In the first six months of 1986, copra comprised less than 2% of the volume of exports, but this is expected to increase. Some EEC importers prefer to buy copra instead of crude oil because they can obtain a higher yield of oil with solvent extraction and also get the byproduct animal feed. In addition, tariff rates are lower for copra than oil in many countries.

The Philippine coconut oil industry is now well established. Crude oil rose from 29% of coconut product exports in 1965 to 51% ten years later and 83% in twenty years. The weight of coconut oil exported was 655,499 t in 1985. Although labor costs are lower for processing oil in LDCs than in importing countries, this savings is small because large-scale copra mills are not very labor intensive. However, transport and loading costs are much lower for oil than for copra and oil is easier to store. Desiccated coconut amounted to 7% of coconut product exports in both 1965 and 1985, but had been only 4% in 1975 due to a large increase in the total exports (UCAP 1986b).

As a byproduct, the output of copra cake and meal is proportional to oil production. In 1985, 82% of copra cake/meal was exported, but the proportion varies with annual demand (Ibid.). Most of the cake/meal is traded in bulk. Importers prefer pelletized cake because the air space between pellets reduces the risk of spontaneous combustion. However, many mills have stopped pelletizing the cake since there is no price premium for this extra step.

The Philippines did not sell cocochemicals abroad until 1979, but that is now the fastest growing segment of the export market. Almost 10% of the coconuts processed for export went into cocochemicals in 1985 (UCAP 1986c). The main competition for cocochemicals is from petroleum and natural gas products.

Production for Domestic Consumers

About 23% of coconut product sales in 1985 were for the domestic market. Manufactured oil accounted for 79% of domestic production in 1985, compared to 80% in 1975, and 85% in 1965.

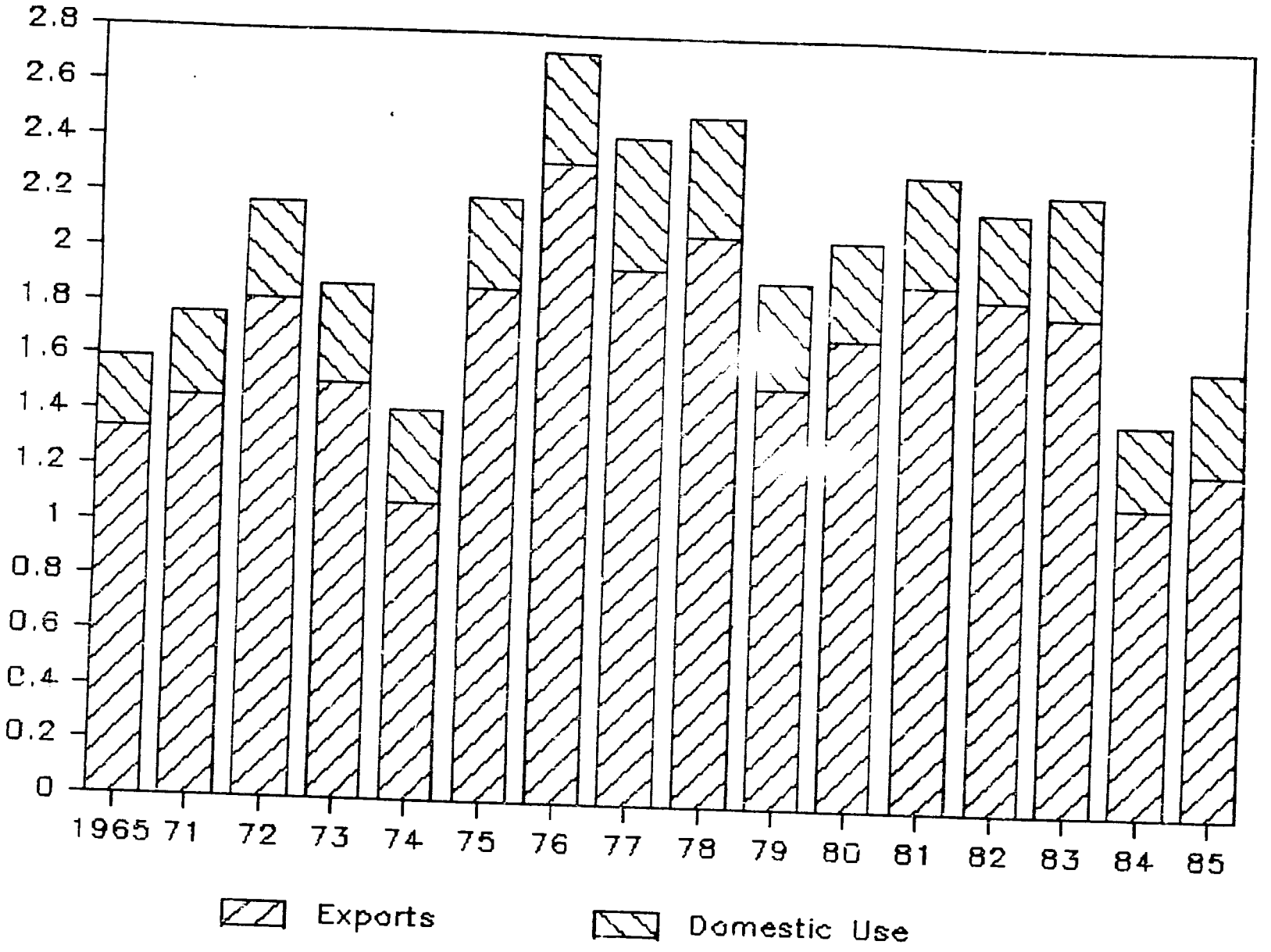


Figure 2. Exports and Domestic Utilization of Coconuts, Philippines (million t of copra equivalent)

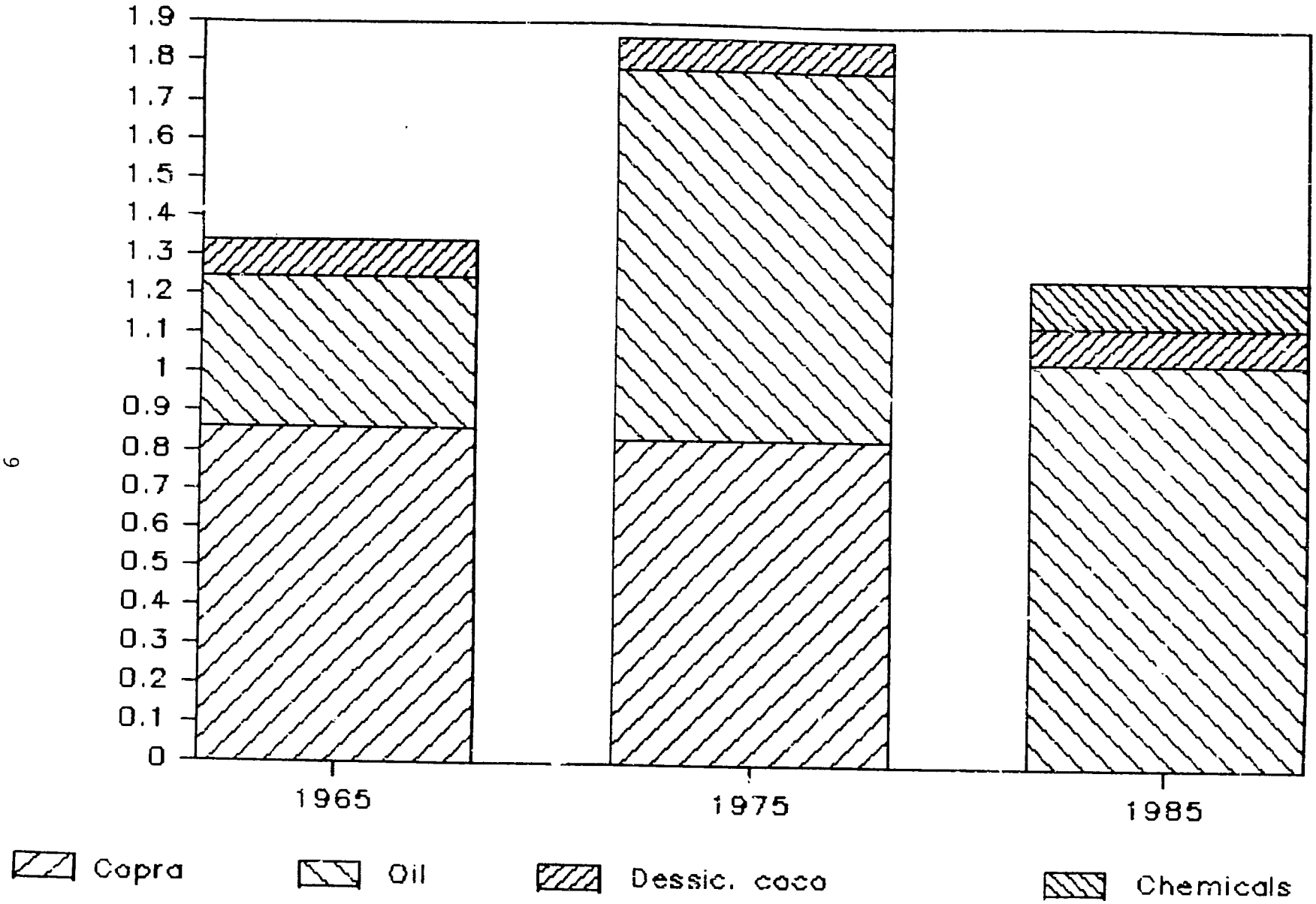


Figure 3. Composition of Coconut Exports, Philippines (million t Copra equivalent)

Food nut consumption used 13% of domestic production in 1985 and 1975, up from 9% in 1965. The demand for coconut products as traditional foods is low in the Philippines, unlike other producing nations such as Sri Lanka. Homemade oil consumption was relatively stable at 8% of the domestic demand in 1985, 7% in 1975, and 6% in 1965 (figure 4). Fully 76% of the coconuts marketed domestically (excluding home oil and foodnuts) went into cooking oil, 7% in shortening, 4% in margarine, 8% for other food products, and 5%. for laundry or bath soap (UCAP 1986b).

In commodity terms, domestic consumers purchased 133,590 t of edible oil, 13,867 t of shortening, 7,336 t of margarine, 333 t of desiccated coconut, 171 t of coconut cream, 7,257 t of laundry soap, 6,258 t of bath soap, and 24,031 t of other products in 1985. In addition, 99,071 t of copra cake were sold for animal feed within the country. Compared to the previous year, domestic consumption of edible coconut oil rose sharply due to lower prices, while shortening and margarine demand increased at about the same rate as population. Also, laundry soap sales fell 27% as synthetic detergents continued to gain ground, the market for bath soap grew 22%, and copra cake use skyrocketed due to the bumper crop of coconuts (UCAP 1986c).

Oil consumption is low in the Philippines. In particular, the rural poor do not consume enough oil for proper nutrition. Certain fatty acids are essential in metabolic processes and fats are needed for effective absorption of fat-soluble vitamins such as A, D, E, and K. In most households, total daily fat consumption is 30-40 g per person, well below the recommended amount of 50 g per person (Banzon 1987). Rural households usually buy oil by "dip out" at local markets, bringing their own containers to be filled from bulk stocks. The most commonly used container is the "lapad", a reused glass bottle that holds 375 ml and lasts for 2-3 days in an average rural household of 5-6 people.

Coconut oil is the predominant oil in the Philippine diet. Most rural consumers there prefer refined oil because it is odorless, bland-tasting, clear, and perceived to be more hygienic. By contrast, consumers in Indonesia and Moslem areas of the Philippines want fried foods to have a strong flavor of coconut oil as assurance that lard was not used in cooking. In some other countries such as Sri Lanka, the rural demand is for cheaper, unrefined coconut oil (Banzon 1987).

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. The 1985 level was a large increase over the previous year's of 1.93 kg, but is in line with the five-year average of 2.57 kg per capita. This was below the sixteen-year average of 3.19 kg (UCAP 1986c). The recent decrease occurred because the domestic price controls and subsidies for coconut oil had been cut back while the market share of corn and soybean oils among urban consumers had increased. On the other hand, there has been a shift in domestic consumption from shortening toward oil (UCAP 1986b).

Oil consumption per person is likely to increase with income

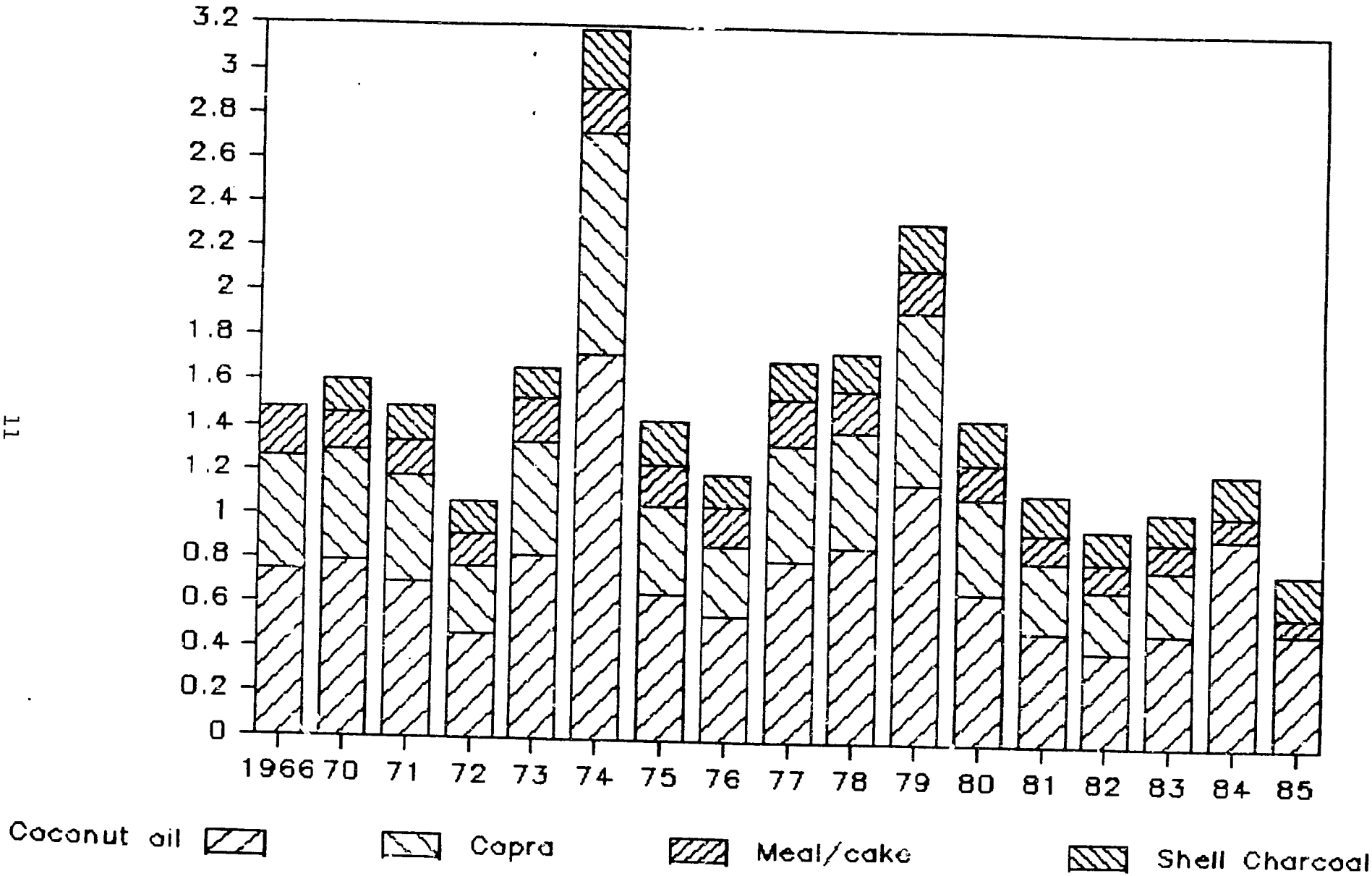


Figure 4. Composiiton of Domestic Production, Philippines (1000 t copra equivalent)

growth. Per capita income in 1985 values (adjusted for changes in the Consumer Price Index) ended up at about the same level in 1985 as it was in 1970, P8,800 versus P8,980 (In early 1987, there were 20.5 Philippine pisos, P, per U.S. dollar). After reaching a peak of P11,280 in 1978 and 1980, consumer spending power declined yearly (calculated from NEDA 1986). The total demand for edible oil is also rising with population growth, which is currently 2.4% (U.S. Department of State 1986).

Over time, other edible oils may gain a significant, but small share of the market due to concerns on the part of some middle-income consumers over the health effects of highly saturated coconut oil. An oversupply of less saturated temperate zone vegetable oils on the world market is also expected. However, coconut oil will remain dominant in rural markets due to its lower cost and the government is likely to maintain tariff protection to prevent large inroads in urban markets.

Copra expeller cake is less dusty than solvent-extracted meal and more palatable to animals (UNIDO 1977). Although the cake contains 18-25% protein (Woodroof 1979), it is unsuitable for human consumption because much of the protein is denatured by the high temperatures and pressures in expelling. It is also deficient in some essential amino acids such as tryptophan, lysine, methionine, and histidine. Furthermore, the unsanitary conditions of copra preparation and storage generally result in microbial contamination and rancidity of residual oil in the cake. Because copra cake is softer and absorbs water more rapidly than other oilcakes, it does not keep as well (Grimwood et al. 1975). Copra cake should only be a major part of the diet for ruminants because it is too fibrous for other animals (Dendy and Timmins 1973). Nevertheless, some is fed to pigs and chickens in the Philippines. Some farmers believe that a high oil content is important in animal feed, but a high extraction efficiency in milling is more important because crude oil has a higher value outside the cake. The domestic market for copra cake is mainly for a small number of large users.

Laundry soap bars are another important coconut oil product for rural consumers, who often use it for bathing and cleaning as well. Laundry bars are more economical and last longer than powdered soaps or detergents. In the Philippines, 9 major manufacturers produce 43 million kg of laundry soap per year (NSTA 1985). The commercial brands are popular in both urban and rural areas, but rural consumers pay higher prices for them due to greater transport costs, a larger number of intermediaries involved in distribution, and lower volumes of purchase by local retailers. Rural consumption of soap in the Philippines is 2.6 kg per person per year (Ibid.).

PRICES AND SUSCEPTIBILITY TO FLUCTUATIONS

Real unit prices of Philippine coconut exports fluctuated a great deal over the period 1970-1985. The peak years for coconut oil prices were 1974, 1979, and 1984, while the trough years were

1972 and 1982. Overall, the trend has been downward as the peaks became lower and the troughs deeper (figure 5). Since 1985, export prices have continued to fall. At the end of February 1987, c.i.f. prices per tonne to Europe in current dollars were $387.50 for crude coconut oil, $134.00 for expeller cake, $120.00 for copra meal, and $275.00 for copra F.O.B. prices per t were $167.50 for shell charcoal and $858 for desiccated coconut. Animal feed prices tend to be highest during the winter in importing countries when agricultural residuals are less available. Adjusted for changes in the U.S. Producer Price Index for Intermediate Materials, the export price of coconut oil has fallen 24% since 1985 although copra cake prices have risen. (UCAP 1986b, 1987; U.S. Bureau of Labor Statistics 1987).

As a result of low prices in 1985, the real value of traditional coconut product exports declined to U.S. $441 million (f.o.b) from $679 million in the previous year -- well below the $745 million total in 1981, the $895 million in 1976, and the $803 million in 1966 (figure 6). Coconut products have fallen in relative importance to 10% of merchandise export earnings in 1985, compared to 14% in 1984, 13% in 1981, and 21% in 1976. Nevertheless, the value of traditional coconut product exports still exceeds that of forest, sugar, or mineral products (UCAP 1986b). Nontraditional coconut products added another $71.6 million in export earnings in 1985; 72% of this from cocochemicals (UCAP 1986c).

The domestic market for coconut products largely reflects world prices. Real domestic prices (adjusted for changes in the Philippine Wholesale Price Index) have cycled up and down over the period 1975-1985. The peak years were 1979 and 1984, while 1981 and 1985 were trough years. There seems to be a downward trend as the peaks became lower and the troughs deeper during this period (figure 7). For the most part, the declines continued between 1985 and early 1987. However, copra prices recovered in 1986 after the lifting of the ban on direct exports of unprocessed copra.

Because of their cyclical nature, export and domestic prices for coconut products may recover from their current low levels. However, some systemic factors may lead to a downward long-term trend in prices. These factors include changes in supply and demand for coconut products, and government policies in producing and importing countries.

Changes in supply from year to year explain much of the variation in coconut product prices. For example, from 1971 to 1985, world production of coconut oil ranged between 2.24 and 3.3 million t, with an average of 2.80 million t and standard deviation of 0.31 million tonnes. Philippine production was relatively low in 1970, 1974, 1979, and 1984 and high in 1972-73, 1975-78, 1981-83, and 1985-86 (UCAP 1986b).

Due to its market share, the size of the Philippine harvest has a major effect on world prices. The Philippines is the largest exporter of copra and coconut oil, providing 62% of the world's traded volume in 1985 on an oil basis. However, the country's share has varied from 69% in a big harvest year like

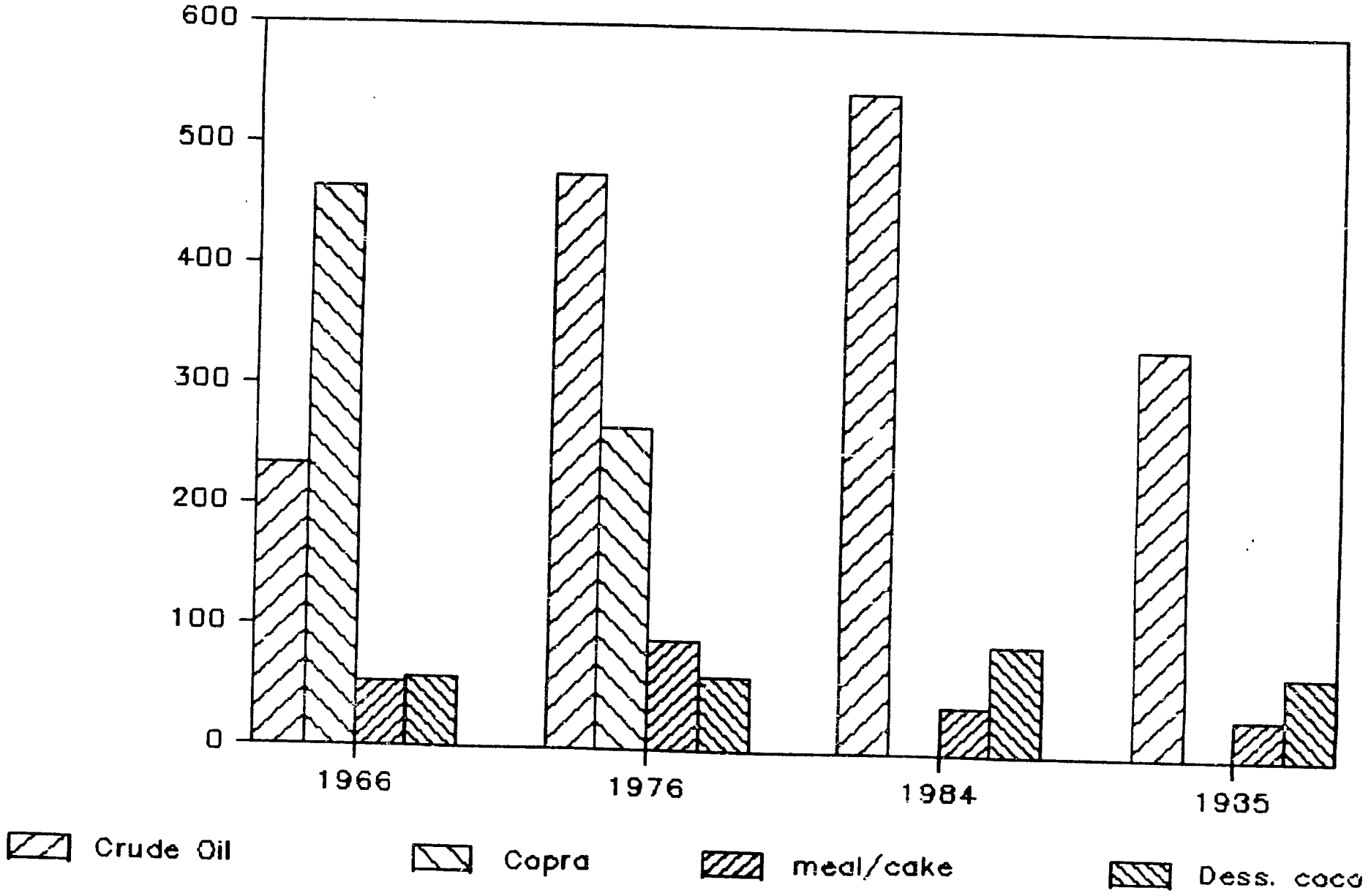


Figure 5. Real Prices of Coconut Exports

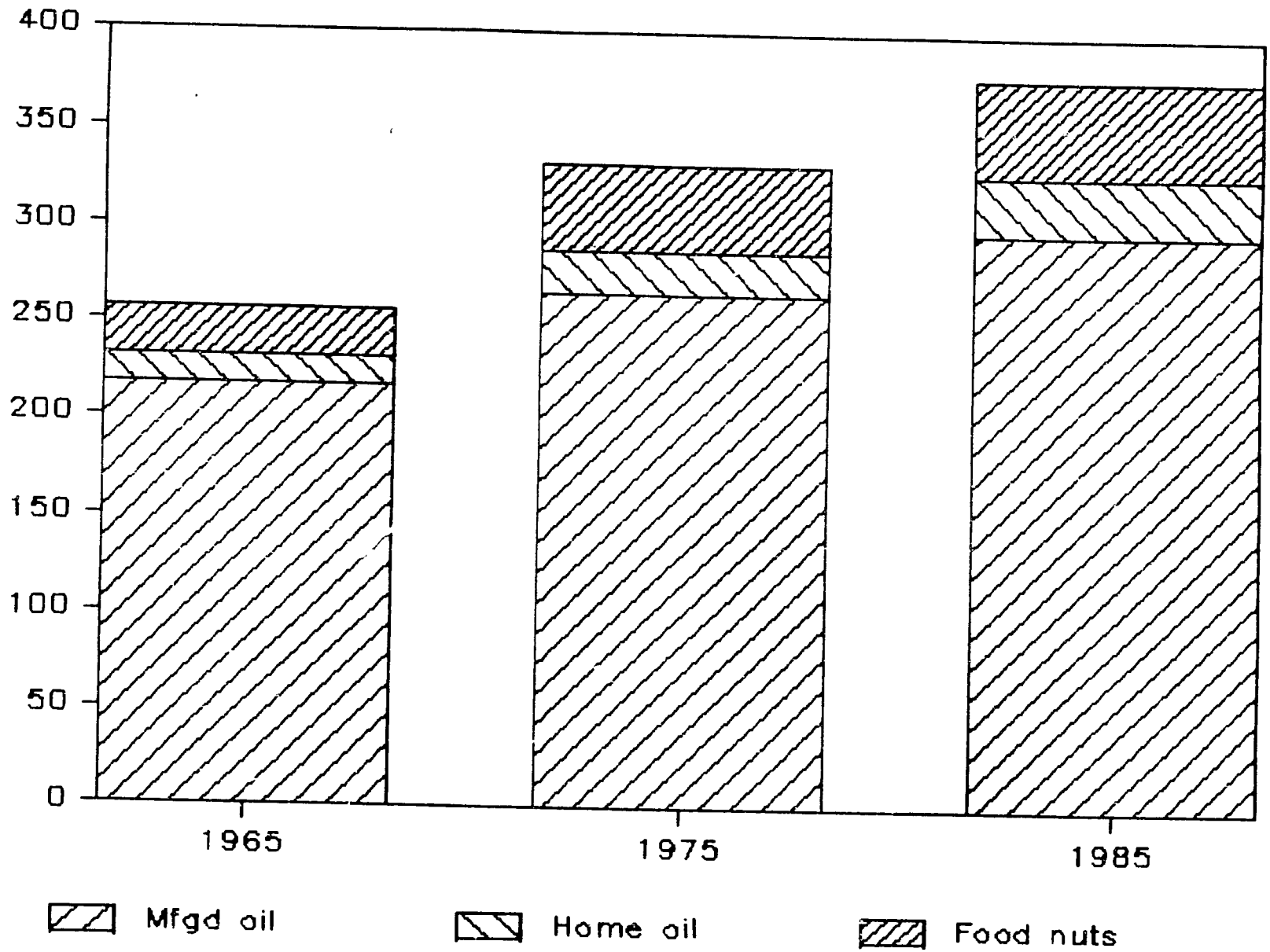


Figure 6. Real Value of Traditional Coconut Exports (f.o.b., $1000 U.S. in 1986 values)

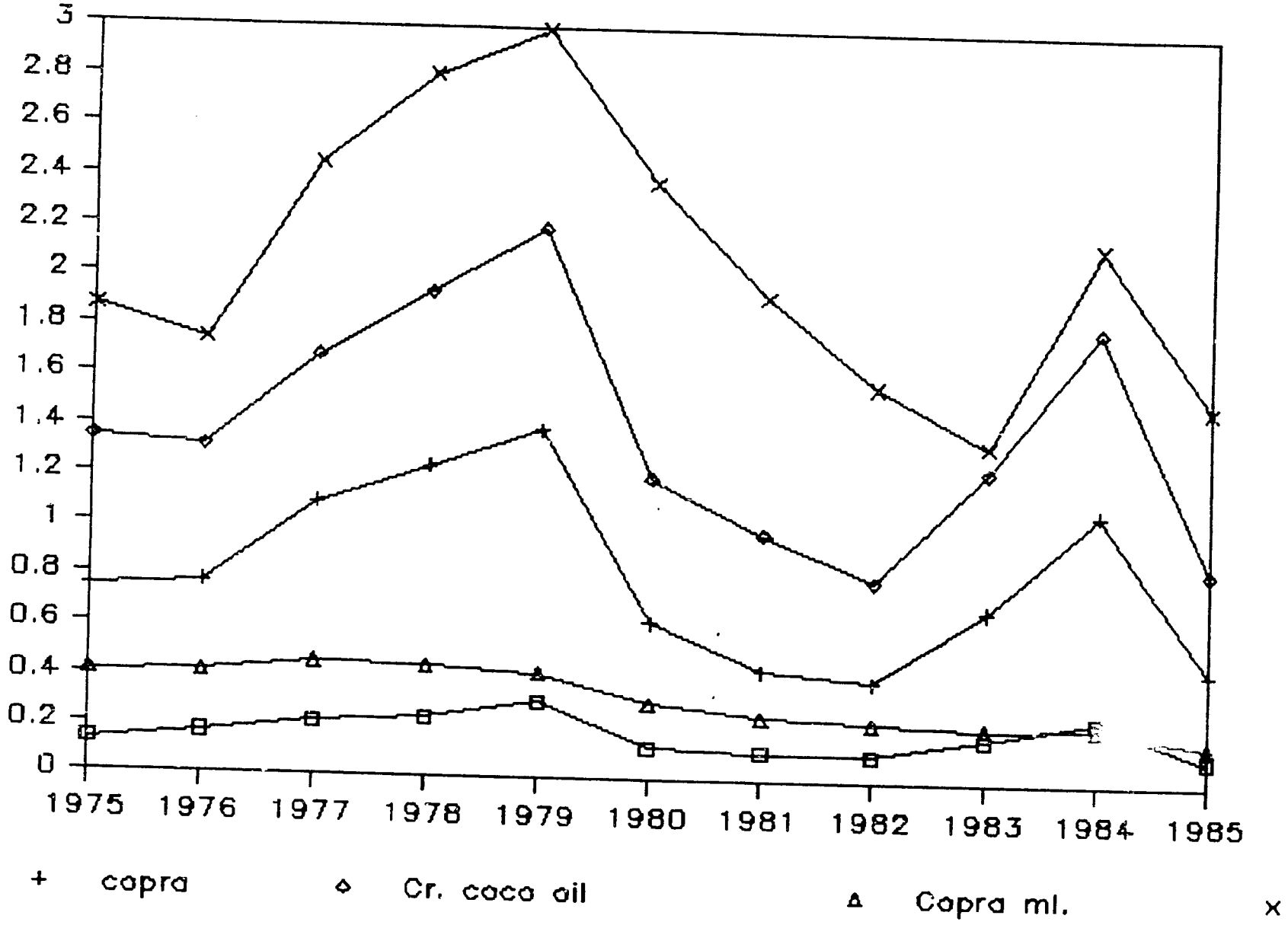


Figure 7. Real Domestic Prices of Coconut Prices of Coconut Products (1985 values, P/100 kg)

1983 to 51% in a poor harvest year like 1984. No other exporting nation approaches these levels. Indonesia's share is 13%, while other large exporters such as Sri Lanka, Papua New Guinea, the Pacific Island nations, Malaysia, and Singapore are all in the 5-6% range (UCAP 1986b). Although India and Indonesia are major producers of coconuts, they export relatively little because of their large domestic demand for oil and foodnuts (Woodroof 1979).

World coconut production is expected to increase due to an expansion in the planted area and higher yields per tree. Between 1946 and the early 1970s, most of the production increase was due to rising hectarage (Santos 1986). Now, hybrid dwarfs are available that yield 2.18-3.16 t of coconuts per ha, compared to 0.59-1.61 t per ha for standard palms. The hybrids also begin bearing after 5-6 years, which is 1-2 years earlier than the existing varieties (Lamothe and Rognon 1986). Following major typhoon damage in 1984, the government ordered replanting with hybrids. The higher yielding varieties are expected to have a significant effect on Philippine coconut production in the 1990s (UCAP 1986b). Competition from other countries for the export market may also increase.

The world demand for oil varies with the general level of industrial activity. Recessions in 1974-75 and 1980, resulted in price declines for vegetable oils. The demand for coconut oil is also affected by the supply of substitutes. Total world production of major oils and fats has increased from 39.9 million t in 1975 to 52.0 in 1980 and 59.3 in 1985.

Coconut oil offers several advantages in food processing. For example, it has a desirable bland flavor and odor. Since 90% of the fatty acids of coconut oil are saturated, it resists rancidity from oxidation even with exposure to air. Its relatively high melting point and high gloss allow it to be used as a solid coating for confections and baked goods.

The price elasticity of demand is high for edible oil because different types of oil are largely interchangeable after processing (UNIDO 1984). Nevertheless, the demand for coconut oil is more stable than for most other edible oils because it does not require extensive processing for special uses. Moreover, the bulk of coconut oil exports are not used for edible oil. Modern food technology has overcome the previous disadvantages of soybean oil such as difficulties in refining, flavor reversion, low extraction efficiency, and susceptibility to rancidity (Banzon 1987).

Coconut, palm, and palm kernel oils are the only major vegetable oils with a high content of lauric and myristic acids. Soaps from these oils are excellent surfactants that foam well even in a cool temperature wash or with hard or saline water. Fatty acid molecules with less than 12 carbon atoms do not have good surface activity and those with more than 18 carbon atoms are not sufficiently soluble in water. Because coconut oil does not yellow with age, it is useful in the processing of white leather and glossy, white, bath soap. This bath soap lathers easily and has a pleasant aroma, but the lather does not last long and may irritate the skin of sensitive individuals (Thieme 1968).

Coconut oil is commonly used in hair care products because it does not dry out the hair. Unlike detergents, laundry soap from coconut oil is biodegradable (Banzon and Velasco 1982). Coconut oil derivatives have many pharmaceutical uses: a solvent for vitamins; carrier for injections and aerosols; thickening agent for creams, lotions, and ointments; and coating for delayed action tablets (Woodroof 1979). In the United States, 57% of the lauric acid processed is used in soaps; 22% in rubber, plastics, and elastomers; and the rest in chemicals, particularly esters (Jimenez 1986).

Coconut oil has some disadvantages for other uses. It is low in certain essential fatty acids necessary for human health and has twice the saturated fat of dairy cream and thus may promote atherosclerosis (Woodroof 1979). Unsaturated fatty acids are also needed in paint oils (Banzon and Velasco 1982). Soybean and palm oils are the principal competitors in the edible oil market.

Since the characteristics of specific oils are more critical for industrial applications, the potential for substituting other vegetable oils for coconut oil are more limited. Palm oil and palm kernel oils are the main substitutes for coconut oil for industrial purposes. However, in the United States, tallow is the main source of fatty acids for soapmaking. Extensive refining has to be done to remove the color and odor of palm oil.

World production of oils and fats has been increasing, but the supply of coconut oil has not grown as fast as some of its competitors (figure 8). Coconut oil's share of world production of major oils and fats fell from 7.8% in 1976 to 5.5% in 1980 and to 5.0% in 1985. During this period, palm oil increased its share from 7.0% to 9.3% and then 11.9%. Palm kernel oil's share was 1.2% in 1976, declined to 1.1% in 1980, and then rose to 1.6% in 1985. Research and intensive management have brought about large increases in oil palm yields, especially in Malaysia. The importance of soybean oil has varied from 23.5% of world oils and fats production in 1976 to 25.5% in 1980 and 22.8% in 1985 (UCAP 1986b). Further increases are expected for palm oil in Malaysia and soybean oil in Brazil and Argentina (Banzon 1987). Still, coconut oil and palm oil are subject to droughts or bad harvests that occur an average of once every 5 years (Arndt 1985).

Coconut oil generally sells at a premium over palm and soybean oils (figure 9). Palm kernel oil is priced only slightly lower than coconut oil and is subject to similar fluctuations because both oils have comparable characteristics and industrial uses. Improvements in processing technologies (e.g. hydrogenation, transesterification, refining, deodorizing, and fractionation) have reduced the advantages of coconut oil over other fats. At the same time, the supply of the substitutes has been increasing. Consequently, price has become a more important criterion in selection of oils and the size of the premium for coconut oil has been shrinking.

Research is also being conducted on other plants such as Cuphea in the Lythraceae family, which can yield diverse fatty acids for surfactants, drugs, dyes, and perfumes without

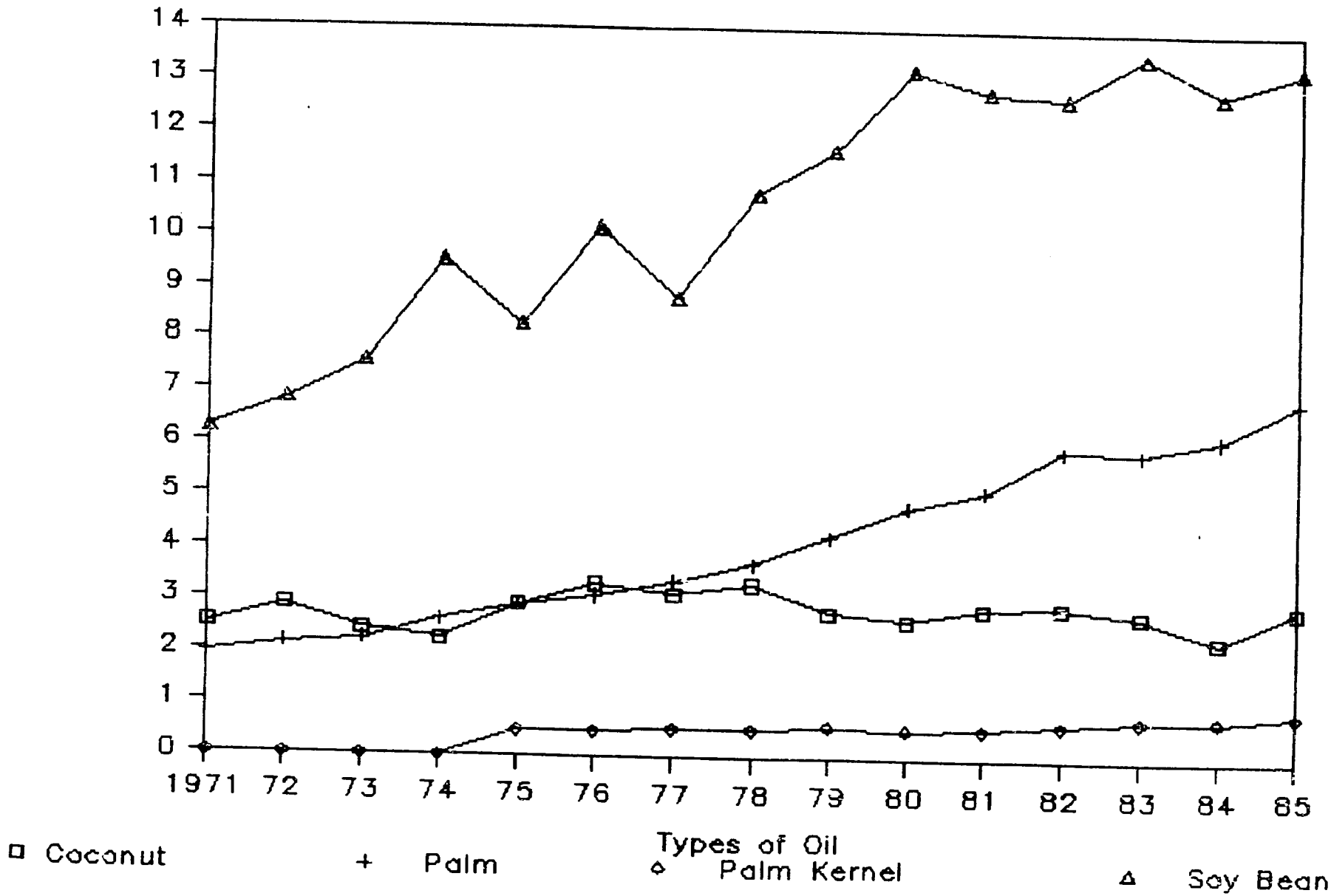


Figure 8. World Production of Coconut Oil and Its Principal Substitutes

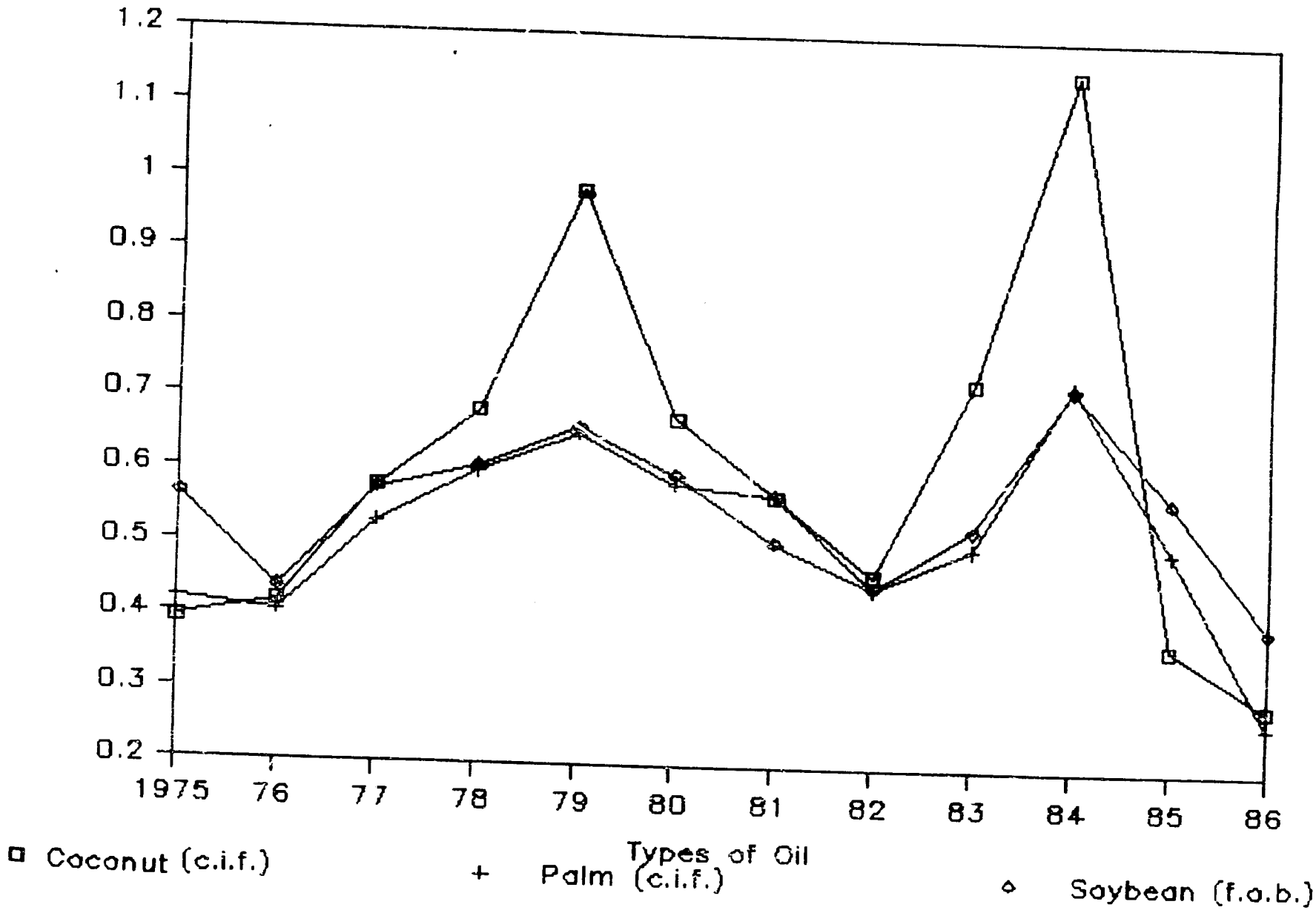


Figure 9. Nominal Prices of Coconut, Palm, and Soybean Oils (U.S. $/t at European Ports)

fractionation (UCAP 1986a). These herbaceous plants grow wild in the temperate and subtropical Americas and the seeds of different species have a lauric acid content ranging from 38% to 83% of total fatty acids and averaging 65%, compared to 45-50% for coconut oil. Other species have high concentrations of capric, caprylic, and myristic acids. Advantages of Cuphea include the ability to grow well in stands, adapt to different climates including those of parts of the United States, and have a large yield as an annual crop. Although current annual yields from wild plants average 200-800 kg/ha, the potential yields may be 1,000-2,000 kg per hectare. American and German agronomists are conducting research on these plants. There is also a potential for transferring the genes responsible for production of the short chain fatty acids to another species (Arndt 1985).

EFFECTS OF GOVERNMENT POLICIES

Government policies of importing and producing countries have had a largely negative effect on the coconut industry. The main exception is tariffs levied in the Philippines on importation of edible oils and oilseeds. The Philippine tariff rate is 10% for soybeans and 60% for other oilseeds and copra.

Other countries' tariffs and trade barriers increase the instability of coconut product prices by limiting the international market's ability to absorb bountiful harvests. Tariffs are generally higher in most countries for semifinished goods like crude coconut oil than for unprocessed copra. The EEC places a tariff of 25% on margarine and shortening, 8% on refined coconut oil for industrial use, and 15% on edible coconut oil (UCAP 1986b). The EEC plans to sell 400,000 t of surplus butter over the next two years to animal feed compounders, which will affect the market for fatty acid distillates.

Overly stringent product quality standards also constitute a trade barrier. The EEC has proposed tightening the present aflatoxin in copra from 50 ppm to 20 ppm and setting a standard of 10 ppm for expeller cake from coconut processing (UCAP 1986b). At present, aflatoxin levels in expeller cake are typically 20-30 ppm in the Philippines, and only one-third of existing copra process mills could meet this proposed standard (Jimenez 1987). Also, the EEC has not proposed a strict standard for groundnut byproducts for animal feeds, which are imported from former French colonies in West Africa and are even more likely to have high aflatoxin levels. Although aflatoxin is a serious health risk, it is removed from coconut oil in the refining process.

Philippine government policies also affect the export and domestic markets for coconut products. Price ceilings for edible coconut oil were established in March of 1973, lowered in October of 1973, and raised in January and May of 1974 and June of 1978. In 1978, the price ceilings were lifted for bulk oil and the consumer subsidy was limited to households.

As world copra prices rose, the domestic price ceilings led to increased exports of copra in the face of a domestic shortage of oil. This shortage and the desire to stimulate the local

processing industry resulted in a ban on copra exports in mid-1982. Due to the decline in the coconut industry caused by world market conditions and mismanaged government policies, the copra export ban was lifted in early 1986 to stimulate competition and boost farmgate prices for coconuts. The trade liberalization succeeded in tripling copra prices for farmers, but hurt the domestic mills because coconut oil prices did not rise proportionately.

During the Marcos years, farmers bore several levies on the first domestic sale of copra. The Coconut Consumer Stabilization Fund (CCSF) was established in 1973 to subsidize domestic consumption and manufacturing of coconut products. It had been as high as P100 per 100 kg of copra equivalent, but was later reduced to P15 before it was abolished. From 1971 to 1980, there was a Coconut Industry Development Fund (CIDF) levy of P60 per 100 kg for financing the replanting of coconut lands. The CIDF was replaced by a Coconut Development Projects Fund (CDPF) levy of P55 per 100 kg of copra. The DCPF was imposed on exporters of coconut products and the funds were used by government to purchase coconut planters banks, mills, and trading companies. Finally, a Coconut Industry Stabilization Fund levy (CISF) was instituted in 1981 for replanting, scholarships, life insurance, and funding of the Philippine Coconut Association and Cocofeed. The CISF of P50 per 100 kg of copra was paid directly by exporters and millers. The various levies raised the cost of copra for millers and together with price controls on domestic oil reinforced the problems faced by the milling industry. There were also allegations that the coconut levy funds were mismanaged.

Coconut products were subject to the 9% export tax on agricultural products prior to 1985; the tax was lowered to 5% in 1985 and eliminated in 1986. In 1981, the export tax on coconut products were removed, but a 7% export tax was re-established in 1982 just on copra (Manuel and Maunahan 1982). Before 1985, there was an additional export duty of 7.5% on copra, 5% on coconut oil, and 4% on copra meal/cake or desiccated coconut. In 1985, the coconut oil duty was reduced to 1% and the duties on copra meal/cake and desiccated coconut were removed. There is still a 5% customs duty on coconut product exports (Jimenez 1987). Oil mills and exporters are subject to the corporate profit tax of 35% of net income. Cottage industries with a capitalization of less than P100,000 that are registered with NACIDA are exempted from the income tax for 5 years. However, even the village-scale coconut processing plants discussed in this paper are beyond that scale.

In 1985, many regulations affecting the coconut industry were liberalized. Administrative Order 1 called for reducing government intervention in the marketing of coconut products and allowed any entity to export them if the foreign exchange proceeds are remitted in accordance with Central Bank regulations. Executive Order (E.O.) 1016 withdrew some inspection, commodity, and export clearance requirements. Presidential Decree (P.D.) 1972 allocated funds from the export

duties on coconut products to restart the government's replanting program for coconut farms smaller than 24 ha, especially those devastated by typhoons. P.D. 1997 authorized incentives of up to P30,000 per ha per year for private replanting of coconuts. These incentives could include income tax credits; duty rebates on capital equipment; and 10-year exemptions from property taxes for land, improvements, and machinery. E.O. 1075 exempted coconut oil sold to government agencies as a substitute for imported fuel from special fund imposts as well as taxes on millers, manufacturers, sales, and fuels. E.O. 1074 benefited a competing product by exempting 60,000 ha of oil palm plantations from all taxes, duties, and fees.

PRE-PROCESSING ACTIVITIES

Cultivation and Harvesting

Coconut farming requires relatively little labor--an average of 19-23 person-days per hectare. Half of this is labor for harvesting, husking, and hauling, and much of the rest is for copra preparation (Valiente et al. 1979; Tan 1970). Additional labor would be needed if farmers interplant other crops. Therefore, coconut farmers have a lot of time for off-farm employment or raising other crops or livestock. Most of this labor is needed for harvesting and copra preparation. Although land clearing and planting costs are significant, the trees can bear for 60-80 years once established. Some weeding is necessary in the early stages of growth, but little cultivation is done unless intercropping is carried out. Fertilizers and pesticides are rarely used. Small farms usually rely on unpaid household sources of labor, but large farms may hire workers on a daily basis.

A coconut reaches full size at 160 days and the shell begins to harden after 220 days. The meat is fully formed after 300 days, but the shell is not fully hard and the nut ripe until 360 days. A palm may produce a mature bunch every 25-30 days (Grimwood et al. 1975). If younger than 330 days, a coconut will produce a small amount of copra that yields inferior quality oil. When the coconut is fully mature, it contains little water and sounds hollow when tapped (Woodroof 1979).

The peak harvest season in the Philippines is August to November and the lean season is during April and May. Farmers usually harvest coconut every 1-3 months. Coconuts may be harvested by cutting them with a knife on a long bamboo pole, through climbing and hand picking, or allowing them to fall to the ground naturally. For good quality copra, the coconuts should be mature. Copra from immature nuts has more water, less oil and is difficult to dry completely. This gives it a rubbery texture and makes it susceptible to insect attack and difficult to mill (Grimwood et al. 1975). However, to save labor, immature coconuts often are harvested at the same time as a bunch of mature ones. Usually, the immature coconuts are stored for 2-4

weeks before copra preparation to increase their quality and uniformity. Near mature coconuts also benefit from a few days of storage in the shade for easier dehusking and shelling, a lower moisture content, and greater thickness of the meat. Mature coconuts that have fallen from trees may germinate if stored too long.

Careful storage of coconuts before copra preparation is important to reduce mold growth, drying out, discoloration, and development of off-flavors. The coconuts should be piled above the floor on pallets to keep out insects and rodents and maintain air circulation. Temperatures should be kept low, around 2°C and the relative humidity at 45-55%. The storage area must be clean, dry, well-ventilated, dark, and free of materials with odors or a high moisture content. Under these conditions, coconuts can be stored for up to 24 months before copra preparation. At a 50% relative humidity, the storage life falls off rapidly with temperature: to 11.5 months at 10°C, 6 months at 21°C, 2.5 months at 32°C, and 1 month at 38°C. If it is anticipated that coconuts will be stored for more than 3 months, it is best to remove the husk and coat them with shellac or paraffin (Woodroof 1979).

Copra Preparation

Nearly 94% of the coconut harvest in the Philippines is converted into copra (UCAP 1986c). For the most part, copra is made on the farm using household labor. Although some dry process mills buy whole coconuts and make their own copra, most of the farmgate market is for copra. Copra preparation involves dehusking, shelling, drying, bagging, and storing. These steps are labor intensive, but not very financially rewarding for farmers. Dehusking is generally done manually because mechanical methods are not cost-competitive. By hand, one worker can dehusk 1,000-1,200 coconuts in 8 hours (Dendy and Timmins 1973). The husk is removed by impaling the coconuts on an iron stake fixed in the ground.

The next step is to cracking the shell and drain the coconut water completely. The split nuts are then left face down for 1-2 hours. Sometimes, they are rinsed in cold water. Drying should be done immediately after draining to prevent bacterial spoilage that results in discolored copra. For example, the proportion of white copra falls from 82% when dried immediately to 36% after 12 hours, 10% after 24 hours, and 0% after 48 hours (Thampan 1975). It is recommended that the moisture content of copra be reduced from 55% to 35% within 24 hours, to 20% over the next 24 hours and to 5-6% in the following 24 hours (Keddie, Allal, and Das 1983). Fresh coconut has an oil content of 35%; this is increased to 60-65% in copra after drying (Woodroof 1979).

The main drying alternatives for copra are (1) sun drying; (2) smoke curing or direct hot air drying; and (3) indirect hot air drying. Simple, improved methods of copra production at the farm or mill site can produce much better quality copra than

the traditional methods at low cost. Sun drying can produce good quality, white copra if done properly. Another advantage is that there is no fuel cost. The split nuts are turned face up. Sun drying takes 5-8 days. After 3-6 days, the coconut meat is scooped out and dried for an additional 2 days. The drying can be done on bamboo racks, but concrete floors are best. Usually, the drying area is covered with bamboo screens and coconut stalks to keep out most of the rain. During the rainy season or in areas of steady rainfall throughout the year, sun drying can be difficult and the copra prone to spoilage. This is a problem in most coconut-growing areas in the Philippines. One solution is to use plastic tents, but this is not often done.

Direct hot air dryers produce copra faster, taking 2-3 days, and can be used in the rainy season. Most serious coconut farmers in the Philippines use this type of dryer. However, direct drying smokes the copra, resulting in poor quality oil and cake. When coconut meat is dried too rapidly at a high temperature, it becomes scorched and the oil extracted from it will be discolored. Or, if the coconut meat is stacked too thickly for good air circulation, the top layers will not dry and the lowest layers undergo case hardening, which prevents moisture from leaving the interior portions. Since the average moisture content of copra may be as high as 22% after direct heat drying, further air drying to 10% or less is necessary in the warehouse before oil expelling at the mill (Banzon and Velasco 1982).

The common "tapahan" in the Philippines is a direct hot air dryer. The tapahan has a grill platform of split bamboo with a hearth below. It does not have a chimney. The construction cost is low. The fuel cost is little or nothing as coconut husks and shells are used. Coconut husks generally are not marketed in the Philippines and have little alternative value even as compost, but the shells can be made into charcoal.

Three types of tapahans exist in the Philippines to meet different local conditions. The Pagsanjan tapahan is used in hilly areas where a pit can be excavated at one level and an open flue rises from the hearth at the lower level. The usual materials are bamboo slats and earth. Occasionally, stone, gravel, galvanized iron, or steel bars are used. The flue may be open or covered with an iron plate or a stone. The Sariaya tapahan is for flat, well-drained soils. The Sariaya tapahan consists of 2 pits, one wide and shallow and the other narrow and deep. Both are connected by an underground flue to direct the hot gases under a grill holding the coconut meat. A corrugated galvanized iron roof covers the grill. The Sariaya has a more even draft and shelters the fire from the wind. The Tayabas tapahan is suited for flat, low, sandy areas. It has a hearth in a shallow pit directly under the grill. The pit is enclosed by walls of woven, split bamboo (Grimwood et al 1975). The traditional tapahans do not allow good temperature control and distribution, and they are smoky (Lozada 1979).

FAO has produced some improved designs for direct hot air kilns that can produce copra of comparable quality. Lozada (1979) developed one for the Philippines that has become widely adopted.

The Lozada dryer is smokeless because it burns husk charcoal. It has an even distribution of heat because the fuel is burned under the entire drying platform. The burner is enclosed and double wall sidings reduce heat losses. Since the fuel only needs recharging every 6 hours, less tending is required than for a tapahan. The Lozada dryer can dry copra to a 10% moisture content in 24 hours and produces a more uniform product. However, it is more expensive to construct than a tapahan.

Indirect hot air dryers keep the coconut meat out of contact with combustion gases and smoke so that the copra can be of high quality. This may be accomplished by using blowers for forced, hot air or steam pipes to circulate the heat to a drying rack. Simple, indirect dryers can be easily constructed with prefabricated materials. In more complicated ones, the coconut meat moves continuously counter to the current of the hot air. The main disadvantage of indirect heating is the higher capital cost, which makes it feasible only for large-scale copra production. Although the energy efficiency may be lower, this is unimportant if the fuel is free.

Modern commercial dryers operate more quickly, but are usually only economical where there is a market for edible-grade, desiccated coconut (Grimwood et al. 1975). A domestically manufactured, modular copra dryer made of structural steel is available at P400,000 per line. Each line can dry 3 t of copra in 14-16 hours. A medium-scale mill making its own copra might have 1-6 lines (Yu 1987).

High-grade copra is uniform, free of dirt, and smooth with a brown outer surface and greyish white inner surface. The pieces break sharply and are not leathery and the broken edges are white. Most of the copra produced in the Philippines is of poor quality, mainly because of the drying techniques and dampness in storage and transport. As a result, bacterial and fungal contamination of copra reduces the oil content and increases the FFA and aflatoxin levels. Rancidity is accelerated if the moisture content of the copra exceeds 4%. Copra often has a moisture content of 8-12% and at these levels, molds can flourish (Keddie, Allal, and Das 1983). One mold, Aspergillus flavus, can destroy as much as 30-40% of the oil in copra and increase the FFA of the rest (Banzon and Velasco 1982). The typical oil loss from storage of copra is 10% (Hagenmaier 1980). It is difficult to avoid mold contamination unless copra is quickly dried to a 5% moisture content or chemical treatments are applied (Banzon and Velasco 1982). The Subramanian treatment using alkali and soda ash has been tried in large-scale copra preparation, but is rarely used now (Jimenez 1987). The market does not provide enough incentive to make it worthwhile to produce high-quality copra for oil milling purposes.

Wet and dry copra should not be stored together. Temperature and humidity changes should be minimized. The storage area should have smooth walls and floors for easy cleaning. Bagged copra is best stored raised above the floor and away from the walls (Keddie, Allal, and Das 1983). Protection against insects and rodents is important.

Farmer Incomes From Sales of Copra or Whole Nuts

Coconuts are an important source of income in 35 of the 73 provinces of the Philippines (Manuel and Maunahan 1982). There were 709,600 coconut farms in the Philippines in 1980 (NEDA 1986), and most are small-scale and owner-operated. Nearly 71% of them are less that 5.0 ha, 21% are 5-20 ha, and only 8% are larger than 20 hectares (UCAP 1986b). A survey of 2,850 farmers nationwide found that the mean planted area in coconuts was 3.9 ha, but this varied from 1.4 to 6.7 depending on the region (Valiente et al. 1979).

Over 4 million owner/operators and tenants directly depend on income from coconut farming (Deomampo and Pisigan 1984). Farmers often view long-lived coconut trees as an easy income source for their old age. In addition, many landless laborers find occasional work on coconut farms although this is not a very labor-intensive crop.

Most farmers dehusk their own coconuts and dry the meat into copra before selling it, but a few sell whole nuts with or without the husks. When farmers have an immediate need for cash, they are sometimes forced into advance sale arrangements at a lower price reflecting an implicit interest rate and discount for risk. In 1981, farmers who did not contract to sell copra in advance received an average of 12% more for their crop (Manuel and Maunahan 1982). It is also possible to enter into contracts to sell unharvested nuts off the trees, with the buyer bearing the costs of harvesting and dehusking.

On average, the nearest buyer is located 4 km from a coconut farm, but this varies from 1 to 9 km by region. There are usually 2 or 3 buyers at the barrio or small town level (Valiente et al. 1979). These buyers may resell to assemblers or dealers in larger towns or to oil mills; copra exporters; or producers of desiccated coconut, cocochemicals, charcoal and activated carbon, and coir. At the level of assemblers and wholesalers, entry is limited due to high initial costs for storage, transport, and working capital (Tibayan 1983). The copra marketing system is relatively inefficient due to the dispersion of producers, involvement of several layers of traders, and poor infrastructure (Deomampo and Pisigan 1984). One study found an average gross margin for coconut dealers of 46% on copra and 35% on coconuts, about half of that being net profit (Manuel and Maunahan 1982). Some mills do buy copra directly from farmers and pay a bit more than the middlemen do.

Local prices for copra or whole coconuts vary. Prices tend to be low in remote areas where transport costs to distant mills are high and few buyers compete for the crop. Since most coconut farmers are small scale, they are price takers. A bumper crop does not always translate into a good year for coconut farmers unless harvests in another region are poor because lower prices can offset an increase in the quantity sold.

The classification basis for pricing copra is "resecada" grade with a 6% moisture content. Resecada copra contains 61.5% oil, compared to 70% for completely mature and fully dried copra,

and as low as 43% for poor quality copra subjected to attack by insects, fungus, or bacteria (Jimenez 1987). Because of the lower oil content, buyers pay a lower price for copra with a high moisture content. The average price received by farmers is 12.5% below the resecada price to account for the moisture content (Manuel and Maunahan 1982). Some buyers also consider deterioration and maturity in setting prices. Transport costs may be borne directly by the seller, but buyers often pick up the produce from the farm and pay a lower price to compensate for this service.

In early 1987, the price of copra at provincial buying stations was P3,700-4,100 per t, resecada. Mills outside of Metro Manila paid an average of P4,120 per t of resecada copra delivered to their warehouses ("bodegas"). Traders who delivered copra to mills in Manila received P4,700 per t resecada, a gross margin of 15-27% (UCAP 1987). Domestic prices for dehusked nuts follow a pattern similar to copra prices. The delivered price of husked coconuts in the Southern Tagalog region ranged from P140-170 per tonne. A tonne of crude oil wholesaled at P7,750-8,270, expeller cake at P2,320, and desiccated coconut at P16,500. Cagayan de Oro buyers paid P1,700 for 100 kg of coconut shell charcoal sold to the activated carbon industry (UCAP 1986b, 1987).

Given the typical density of 126 trees per ha and the average annual yield of 30 coconuts per tree, 1 ha produces 3,780 nuts a year. This harvest can be converted into 0.721 t of non-resecada copra and sold for P2,330-2,590 at provincial buying stations. A farmer with 2.5 ha of coconut trees would earn a gross annual income of at least P5,825 from the sale of copra. Farmers with high-yield varieties of coconuts could earn twice this much. The net cash returns almost equal the gross returns because of the low cash costs of raising coconuts.

The typical income from coconuts is below the per capita income for the country as a whole, which includes the rich and urban dwellers who earn a great deal more than the average rural person. Also, interplanting of other crops in the large space between coconut trees could significantly increase farmer incomes. Although intercropping is becoming more common, it has only been done on a small portion of coconut land -- 12% in the Southern Tagalog region (Olalo 1975) and 39% in part of Laguna province (Pujanes 1978).

The price of whole coconuts is derived from the copra price. Although transport costs are higher for whole nuts than for copra, this may be outweighed by the value of the coconut water, shells, and husks the buyer gets with the whole nuts. These byproducts could be used by either a wet process mill or a dry process mill that makes its own copra from whole nuts. If these mills paid the copra equivalent price for whole coconuts, small-scale farmers would earn the same cash income that they would from copra. However, households would save labor time required for copra preparation. The value of this time depends on how productively it is used by the household. Large-scale farmers who hire workers would earn more profit from selling whole nuts at

the copra equivalent price because labor costs of P0.1 per nut are avoided. This savings would total P375 per ha per year. However, in a market equilibrium, it can be expected that buyers would offer a lower price for whole coconuts than copra to reflect the labor cost savings.

Farmers who make copra discard the coconut water because it is not storable and they do not have enough of it to warrant commercial processing. The husks are not even used for compost although some is burned as fuel if artificial drying is done. Many farmers do use the shells in charcoal making.

SCALE AND LOCATION OF THE PROCESSING INDUSTRY

Milling refers to the extraction of oil either through the copra process or the wet coconut process. UNIDO has classified oil mills by scale (table 3), but this classification neglects an intermediate scale between the "village" and "small" scales. Also, the upper range of the "small" plants is really a medium-scale plant in the Philippine context. The ILO has a different classification based on raw materials crushed per year: "village-scale" -- less than 1,050 t, "small" -- 1,050-2,400 t, "medium" -- 2,400-6,000 t, and "large" -- greater than 7,500 tonnes.

Large- and medium-scale mills have to be run at a high capacity use rate to be commercially viable because of their high capital costs. Large mills are intended to operate 24 hours per day for 300 days per year. Small mills typically operate 8 hours per day, 250 days per year. Since obtaining a sufficient supply of coconuts for a large mill can be a problem, these mills are generally located in urban areas with good transportation infrastructure. The cost and reliability of power is another major factor in mill location decisions, favoring areas with abundant hydroelectric or geothermal power. Diesel fuel can be substituted for electricity with either the dry or wet process, but is more expensive. Both medium and large-scale mills require a high level of skills in operation and management.

In mid-1986, 43 commercial milling units were operating in the Philippines, including 16 in the Southern Tagalog region, 13 in Mindanao, 8 in Metro Manila, 4 in the Visayas, and 2 in the Bicol. They provided a total crushing capacity of 3.63 million t of copra per year, which could produce 2.27 million t of crude coconut oil. Mindanao had 47.3% of the copra crushing capacity, the Southern Tagalog region had 18.8%, Metro Manila had 16.8%, the Visayas had 9.5%, and Bicol had 7.6% (UCAP 1986b). Most mills in the Philippines sell crude oil on forward sales contracts, but a few trading companies lease mills.

The operating mills have capacities between 7,500 to 300,000 t of copra per year (UCAP 1986b). This range encompasses the small, medium, and large scales by the UNIDO definition, but all of these mills are large by the ILO definition. The mean capacity is 84,000 t per year, and the median is 66,000 t per year. The mean exceeds the median because of a few very large

TABLE 3
Classification of Oil Mills by Scale

Scale	Operating Time (hours/year)	Hourly Capacity (tonnes crushed)[1]	Annual Capacity (tonnes crushed)[1]
Village	100-1,000	0.001-0.015	0.100-15
Small	2,000	0.025-10	50-20,000
Medium	2,000-7,200	10-25	20,000-180,000
Large	7,200	25-170	180,000-1,224,000+

[1]Copra equivalent

Source: UNIDO 1984

plants. The plants in Mindanao tend to be relatively large and the ones in the Southern Tagalog region relatively small. Over the past 15 years, some of the smaller mills have closed after being bought out by government monopolies. Some larger mills have been abandoned or taken over by banks (Banzon 1987).

Alviar's (1982) academic model of the industry concluded that it would be optimal to have only 35 mills with about half the current capacity, with fewer mills in the Southern Tagalog region and Mindanao and more in the Visayas. The model implies an optimal, average capacity period of 42,000 t per year.

Only three Philippine mills rely on solvent extraction for copra process oil; the rest use imported, large, continuous expellers. Three-quarters of the mills have Anderson Superduo expellers (U.S.), but a few have large expellers made by Krupp (Germany), Rose-Down Thompson (U.K.), or D-Smet (Germany). The Superduo has a rated capacity of 1.0 t of copra per hour although it can be operated at 1.3 t per hour. A median-sized mill in the Philippines would have nine large expellers, while most small, commercial mill would have only one.

The ILO states that the smallest economical capacity for a conventional expeller mill is 3.33 t per day operating on a single shift (Keddie, Allal, and Das 1983). However, smaller motorized expellers are also available; for example, the Hander Co. makes one with a capacity of 0.1 t of copra per hour. Previously, a Japanese firm made the small, hand-operated, Cecoco expeller, but it is no longer manufactured. The Cecoco expeller required much attention in use because the cake hardened in 10-15 minutes if workers stopped for awhile (Jimenez 1987).

The capacity use rate for the Philippine copra industry was 40% in 1985, and many mills were financially ailing at this level. Since 1970, the use rate has ranged between 37% and 78% (UCAP 1986b), with an average of 60% and a standard deviation of 12%. The capacity use rate for medium- and large-scale mills is based on triple shifts. It has fluctuated so much because of the structure of the industry. When a large oil mill is built or expanded, the industry's capacity increases substantially. Once established, government restrictions previously made it difficult for large firms to enter or exit the industry.

Small-scale mills usually run single shifts per day, but can operate at a higher proportion of that capacity. Small mills may be decentralized for a better match between local supply and demand for oil and other products such as soap. They can also be installed in modules to allow for gradual future expansion. A small mi. is particularly desirable for islands or remote areas where farmers have difficulty marketing coconuts or are offered very low prices. In these areas, consumers generally pay relatively higher prices for processed coconut products. Production costs may also be relatively low for decentralized coconut oil mills due to lower wage rates and reduced transport costs for raw materials and the final product. However, any transport cost advantage may be lost if the oil has to be shipped out for refining and back in for sale, as is the case with the

copra process but not the wet process. Small firms can produce laundry soap equivalent in quality to the kind made by large firms.

Crude oil made through the copra process requires extensive refining before it meets Philippine specifications for edible oil. It is dark; turbid; high in FFA, phosphatides, and gums; has an unpleasant odor; and may be contaminated by bacteria and molds. The FFA content of crude copra process oil is 3-5% in the Philippines although countries using better copra making processes such as Sri Lanka can reduce this to 1% (Ranasinghe 1987). This degree of refining is expensive and 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). Since exports are usually in the form of crude coconut oil, the refineries serve the domestic market. With the copra process, oil from a village or small-scale plant is more difficult to refine than oil from a large-scale plant because of a higher content of FFA and other impurities.

By contrast, the wet process produces the equivalent of semi-refined oil with a mild flavor. This oil can be used directly for human consumption. The minimal refining recommended for the wet process can be done at the mill on a cottage or small industry scale, and only 1-2% of the raw oil is lost in refining (Banzon 1987).

Sixteen oil milling firms in the Philippines do some of their own refining; these firms have a refining capacity of 833,500 t of crude oil per year. In addition, nine other firms that only do refining have a capacity of 347,000 t of crude oil per year. The domestic refining capacity is 1.18 million t per year, 32% of the milling capacity (UCAP 1986b). Accounting for a 5% refining loss, the nation could produce a maximum of 1.12 million t of refined oil in a year.

DESCRIPTION OF THE TECHNOLOGY

The Dry (Copra) Process for Milling

The dry process for coconut oil production consists of the following basic steps:

1. Pretreatment of copra
   a. Grading
   b. Remedial drying
   c. Storage
   d. Cleaning and inspection
   e. Crushing
   f. Cooking and conditioning
2. Extraction alternatives
   a. Pressure expelling
      1. Continuous
      2. Batch

b. Solvent
3. Post extraction treatment of oil
   a. Screening
   b. Filtering
   c. Settling
   d. Packaging
   e. Storage
4. Handling of byproduct cake
   a. Grinding or pelletizing
   b. Addition of moisture
   c. Bagging
   d. Storage
5. Refining of oil
6. Testing and grading of oil
   (Thieme 1968; Keddie, Alal, and Das 1984)

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). The copra is then stored. 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. 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").

Before being fed into the expeller, the copra is usually ground to 0.125-0.250 inch pieces in a hammermill or larger grinder. For a high extraction efficiency, the copra then undergoes precooking, cooking, and conditioning before expelling. A precooker is an optional, piece of equipment separate from the expeller. Use of a precooker allows recovery of 2 percentage points more of oil that would otherwise remain in the cake. Some mills with a single expeller feed material through twice instead of using a cooker/conditioner, but that is slower.

Cooking and conditioning are often combined with expelling in one piece of equipment known as a dual expeller (e.g. the Anderson Super-Duo). A dual expeller has two cages. The first is a vertical cage that cooks and conditions the raw material and reduces its moisture content to 2% by heating it under low pressure. The second cage is horizontal and does the expelling under high pressure (Jimenez 1987). However, a dual expeller yields a dark cake that makes a poor animal feed because it denatures much of the protein.

After expelling, the oil passes to a screening tank and is then 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 to decrease the temperature to 130-140°C. Next, water is added to increase the moisture content from 2% to 10-12% to prevent spontaneous combustion caused by molds that generate

heat. The process is basically the same for both medium- and large-scale copra mills, but may be simplified for village- and small-scale plants (Figure 10).

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. An expeller requires a cooling system to avoid overheating the oilcake and damaging the oil. The barrel is cooled by spraying in oil kept cool via a heat exchanger, and cooling water is also passed through the center of the worm. 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 the cage and remove the hardened copra (Banzon 1987; 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% in the byproduct meal (Hagenmaier 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 (Jimenez 1987). Although the most technically efficient process, solvent extraction is too expensive to be economically efficient. Byproduct meal from solvent extraction only contains 1-2% oil.

Refining of Copra Process Oil

Refining consists of neutralization, bleaching, and deodorization. Neutralization reduces the FFA and other impurities 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

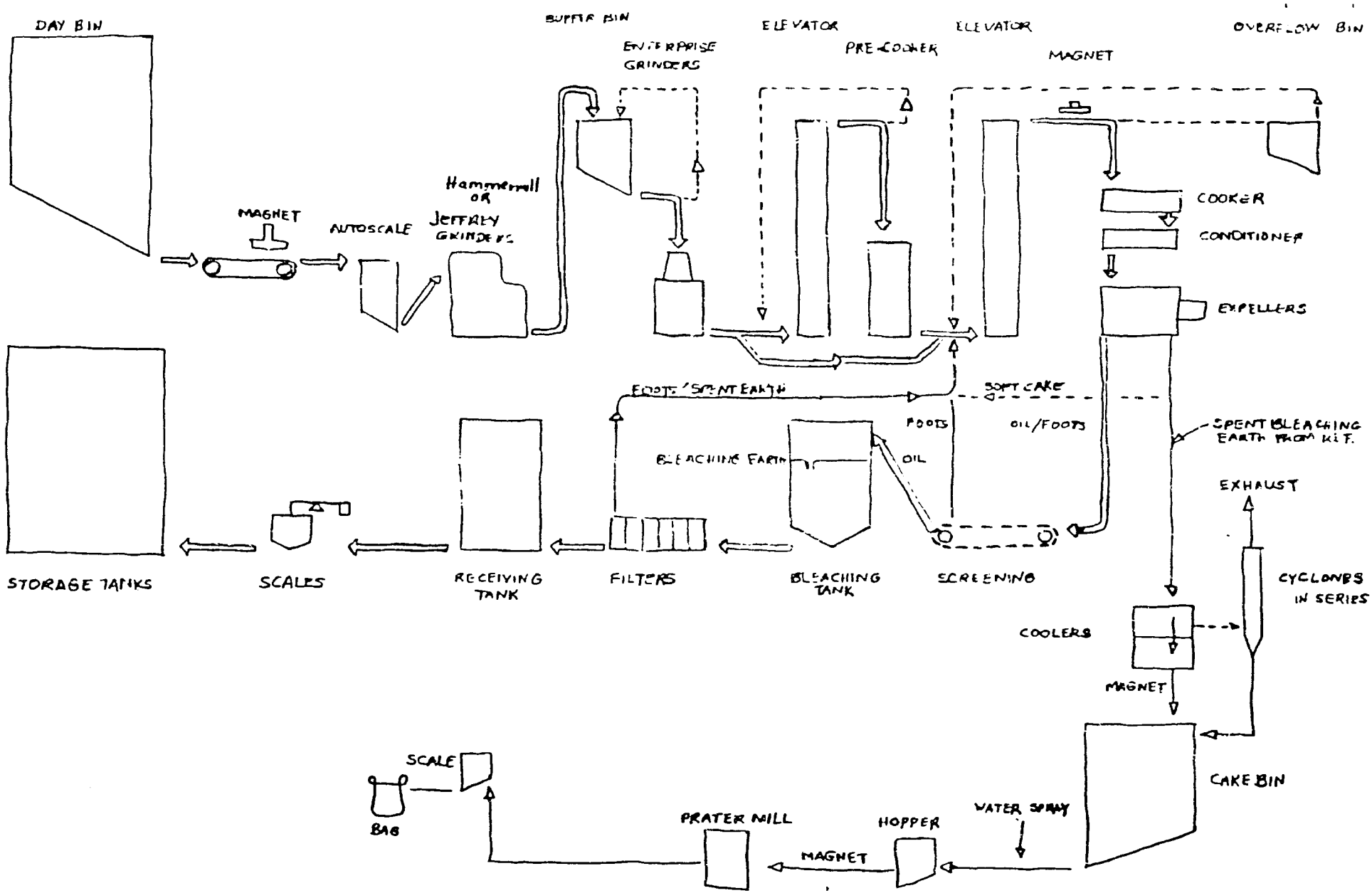


Figure 10. The Copra Process for Oil Milling

Source: Jimenez 1987.

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 steam stripping for 4-5 hours -- passing 185-190°C steam through the oil 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).

The Wet Process for Coconut Oil Extraction

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 (called "gata" in the Philippines) 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 protein, fibrous, and water-soluble portions of the coconut.

The traditional kitchen method for making coconut oil is a primitive form of the wet process. It involves grating the coconut, adding water, and then squeezing or pressing it through cloth to get the milk. The milk is boiled to separate the oil from the protein curd ("latik"). The kitchen process has a low yield, only 50% of the weight of the oil in the wet meal, but it can be higher if a second and third pressing with additional water are done. It may also leave a burnt odor and taste in the oil, which can become rancid in a few days. The latik is brown and oily and not usable. Moreover, the kitchen process is time-consuming and requires a lot of energy per unit output because all of the milk is heated rather than just the cream portion (Hagenmaier 1980). Thus, it is not suitable for even a village-scale enterprise.

Although it is the oldest method for extracting coconut oil, relatively little R & D has been done for the wet process. Improvements over the kitchen method date back to 1921 with the use of a centrifuge to separate the coconut cream from the skim milk, and an autoclave to break the stable oil/water emulsion of coconut cream. Interest in the wet process revived in the 1960s and early 1970s. The main bottleneck in the wet process is developing an efficient and inexpensive way to break the emulsion. A variety of methods have been tried including enzyme treatment, boiling, addition of chemicals, fermentation, vacuum

evaporation, or freezing followed by melting (Banzon and Velasco 1982). The Tropical Products Institute did research on the extraction steps, but their process was not economical (Edmonds, Edwards, and Mars 1973). Subsequent work has been done on reducing the costs of oil recovery and expanding the benefits through development of byproduct foods (Hagenmaier 1980), but little has been done to optimize the choice of equipment for a commercial venture. Hagenmaier's process has higher capital costs than a large-scale copra mill.

Some mills in India are using a crude wet process that consists of pounding fresh coconut to a pulp, throwing it in boiling water, and skimming oil off as it floats on the surface (Woodroof 1979). With support from the Filipinas Foundation and Appropriate Technology International, Prof. Emeritus Banzon of the University of the Philippines - Los Banos has been trying to make a labor-intensive wet process commercially viable. As a direct result of this research, the Philippines is the only country where an improved wet process is currently in use in private enterprises. Two such plants are operating now and a third is awaiting improvements as a result of the experience from production trials.

What are the advantages of the wet process? First, the oil can be used directly for human consumption without undergoing extensive refining because it is equivalent in quality to semi-refined oil from the copra process. Wet process oil has a lower FFA content, less color, and greater stability than copra process oil. It also has a pleasant, light coconut odor and flavor that is preferred by Philippine consumers (Banzon 1987). If the FFA content is 0.2% or less, alkali refining is unnecessary, but some deodorization may be desirable. Otherwise, a simple refining process using low concentrations of sodium hydroxide is all that is needed. In addition, the residual cake from the wet process ("sapal") can meet the strict, proposed EEC standards for aflatoxin of 10 ppm more easily than copra cake can (Jimenez 1987).

Second, more of the vitamin E content of the oil can be retained with the wet process because extensive refining is not necessary. Unprocessed coconut oil contains 913 mcg of vitamin E per gram of oil; after expelling from copra, 777 mcg are left. Alkali refining reduces this to 318 mcg and steam deodorization decreases it to just 55 mcg (Banzon and Velasco 1982). However, if care is not taken in processing and post-treatment with the wet process, much of the vitamin E can also be destroyed as appears to be the case during early operations at the Tagbanon plant (Jimenez 1987).

Third, the wet process allows the recovery of other food items fit for human consumption in addition to edible oil. The unsanitary conditions of copra production and storage make this infeasible under the dry process. The coconut water can be consumed as is within a few hours of splitting the coconut or processed; one possibility is a frozen confection. The skim milk contains most of the usable protein of the coconut, but it must either be consumed directly immediately before it spoils or

processed with relatively expensive equipment (e.g. an evaporator and 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 can be avoided if centrifugal separators are used, but they are expensive. Some of the potential new foods require further product development and market promotion to ensure their acceptance. Nevertheless, the greater flexibility of the wet process allows the product mix to be changed in response to market demand with little retrofitting. For example, desiccated coconut, coconut milk and cream, or soap may be emphasized when edible oil production is less profitable.

Fourth, the central accumulation of whole coconuts facilitates commercial production of other byproducts such as fiber, rope, charcoal, and vinegar. This is so for both dry process mills that make their own copra as well as for wet process mills. Although there may be higher costs in transporting whole coconuts, they should be outweighed by the extra revenues from these byproducts. Vinegar might not be marketable in many areas due to its abundance from other sources; it is not currently made at the Tulong plant (Banzon 1987).

Simple wet process methods do not require expensive equipment, but some of the equipment might have to be made to order in local workshops. More sophisticated methods may 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 is its low oil extraction efficiency, 70% or less if simple equipment is used (Banzon 1987). This results in low earnings from sale of oil and a high oil content in the sapal, making 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%. A second pressing was supposed to be done at the Tagbanon plant, but was only tried there once although it is done routinely at the Tulong plant. Alternatively, more sophisticated equipment could be used to raise the efficiency of a single extraction to 85% (Edmonds, Edwards, and Mars 1973) or 87% (Hagenmaier 1980). 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. The wet process does avoid the 5% refining loss and other oil losses due to deterioration of copra in production and storage. Nevertheless, fresh coconut must be processed right away to avoid bacterial spoilage; it can become badly contaminated in 6 hours at 35°C.

Immature nuts yield much less oil than mature ones; an 8-9 month old coconut may have only a few grams of oil, compared to 150 g in a mature 1 kg coconut. If farmers produce copra themselves, they avoid harvesting the coconuts too soon because that would reduce copra yields. However, farmers do not have an economic incentive for harvesting at the proper time if they sell whole coconuts. Over-ripe coconuts have slimy meat with a soapy

flavor shipment thoroughly. Immature coconuts have to be discarded, but over-ripe ones can be separated and converted to copra (Hagenmaier 1980).

The wet process would reduce employment in copra making, but this is usually an unpaid chore for members of the farm household, which does not increase household income very much. The commercial viability of the wet process may depend heavily on the market prospects for the additional byproducts besides oil and sapal. 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

Nine types of mills and one refinery are analyzed in this study: 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 mill designs rely on the wet process to produce semi-refined, edible oil that can be consumed directly, as well as soap and other products. The rest use the conventional copra process for milling, which must be combined with refining to meet the specifications for edible oil on the Philippine market. 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. In addition to the above plants, several other scales of operation are discussed in less detail.

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. To amortize the higher capital costs, the large and medium-scale plants have to be managed more intensively than small plants and must keep an expensive inventory of spare parts to avoid downtime. However, on average, the large- and medium-scale mills only achieve 60% of their maximum capacity. A village-scale plant can meet its less ambitious capacity target more easily, but an 80% capacity use rate would be a reasonable assumption for these 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.

At a 60% capacity use rate, the large-scale plant would process 27,000 t of copra in a year. After refining in a separate facility, this would produce 15,775 t of edible oil annually assuming a crude oil recovery rate of 61.5% and a refining loss of 5%. The medium-scale, integrated mill and refinery would convert 2,340 t of copra into 1,370 t of refined oil. At an 80% capacity use rate, the village-scale copra mill would use 79 t of copra in making almost 30 t of laundry soap and 1.7 t of bath soap. The village-scale, wet process plant would consume the same amount of coconuts as the comparable-sized copra

mill, but would produce 27 t of semi-refined edible oil as well as 16 t of laundry soap.

A low-income rural household in the Philippines with an average of 5.5 people consumes 192 g of oil daily, or 0.070 t per year (Banzon 1987). If the large-scale mill did not export most of its production, it would take 22,400 rural households to consume all of its output. The medium-scale plant could meet the annual demand of nearly 19,500 rural households. The village-scale soap plant based on the copra process would provide sufficient laundry soap for almost 2,100 low-income households. By contrast, the village-scale wet process plant is well matched to a small, local demand as it only requires the buying power of nearly 400 rural households. The oil from a plant of this size could easily be sold within a 20-km radius. In addition to the edible oil, this plant could meet the laundry soap requirements of over 1,100 low-income, rural households consuming 0.014 kg per year (NSTA n.d.). Middle-income rural households consume an average of 0.220 t of edible oil and 0.461 t of laundry soap per year (Cuano 1987).

How much land would be needed to supply coconuts for these various mills at the likely levels of capacity use? Average yields of coconuts range from 0.72- 1.44 t per ha, depending on the variety. Thus, the large-scale mill would require the annual harvest of 18,720-37,440 ha of coconut farms. Similarly, the medium-scale mill would need to be supplied by 1,620-3,240 ha of coconuts. The harvest of only 55-110 ha of coconuts has to be obtained within an economic radius of either of the two village-scale plants.

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 loan financing of fixed capital costs by development banks at an interest rate of 1.5% per month, a positive real rate at the current level of inflation. The repayment period on loans for fixed capital is 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 only includes straight-line depreciation to reduce taxable income, and the tax rate is 35% of net profits. Any 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 economic analysis allocates capital costs to the period in which they are incurred, rather than depreciating them.

The basic scenarios incorporate the current price of P4,120 per tonne of copra delivered to the mill warehouse. This copra price is equivalent to a price of P0.69 per whole coconut after

deducting the costs of copra preparation. Including the higher transport costs for whole coconuts than for copra, this price would be P0.75.

The domestic price of coconut oil is determined by the export market. Crude coconut oil currently sells for P8,600/t delivered, or P7,600/t ex factory (UCAP 1987). One kg of coconut oil is equivalent to 1.11 liters (l). The factory price of 1 t of refined oil is taken at 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 t (P240 per 5-gallon container holding 17.318 kg). The village-scale plant can command a larger share of this price, P12,700 (P220 per 5-gal container) ex factory by circumventing several layers of middlemen. In the analysis, 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).

The national minimum daily wage is P45 in industries outside Metro Manila and P30 for agricultural workers, including the cost of living allowance. The employer's share of social security and medicare payroll taxes varies with the wage rate. Employers are also required to pay a bonus of one month's pay to workers at the end of a year. All told, the monthly wage rate in coconut milling and refining amounts to P1,288 for 25 work-days and P1,120 for 21.67 work-days. The total wage bill is P3,415 for a manager and P2,281 for administrative support.

A Large-Scale Copra Mill

Table 4 lists equipment needs for a large-scale copra mill with 6 expellers. This mill has a capacity of 150 t of copra per day. Estimated repair and maintenance costs are in Table 5.

A Large-Scale Refinery

Although most coconut oil mills do not have their own refinery, refining is necessary before dry process oil is consumed on the domestic market. A refinery with a capacity of 70 t of crude oil per day could process three-quarters of the whole output of a mill with a capacity of 150 t of copra per day. More likely, however, it would serve the portion of production intended for the domestic market from several mills with a total capacity of 315 t of crude oil per day. Tables 6 and 7 list equipment costs and repair and maintenance costs for this refinery.

A Medium-Scale, Integrated Copra Mill and Refinery

Because of the refining requirements for copra process oil,

TABLE 4
Equipment Requirements for a Copra Mill With a Capacity of 150 Tonnes of Copra Per Day[1]

Item	Initial Cost (₱)	Expected Lifetime (years)
Hammermill (10 t/h)	400,000	8
Grinders (2 at 3 t/h)	600,000	3
Precooker (1)	600,000	20
*Boiler (70 BHP)	1,750,000	10
Compressor (150 ft^3/min)	400,000	5
*Expellers (6 at 1 t/hr)	12,000,000	20
Electromagnets (3 w/ 1 ft diam.)	120,000	20
Filter presses (2 w/ 45 plates and frames)	700,000	5
Elevators (2) & conveyors	3,000,000	10
Storage tanks (2 w/ 1,000 t)	3,000,000	20
Cooling tower & heat exchanger (10,000 gal)	1,500,000	15
Overhead water tank (15,000 gal)	1,000,000	20
Well construction (40 ft)	6,000	20
Centrifugal pump (5 hp)	8,000	5
Tank & pipings	1,500,000	10
Spares held on hand		
*Horizontal shaft (3)	105,000	20
*Vertical shaft (1)	85,000	20
Electromagnet (1)	40,000	20
SUBTOTAL		
*Workshop equipment		
Welding machine (oxyacetylene)	150,000	10
Welding machine (electric arc)	400,000	10
Lathe	350,000	15
Shaper	350,000	15
Pneumatic jack	85,000	10
Drill machine	75,000	10
SUBTOTAL		
Office equipment	400,000	10
Laboratory	75,000	20
*Vehicles	2,300,000	
TOTAL	30,999,000	

[1] Where multiple items are needed, their total cost is listed rather than the cost per item.

* Indicates imported items.

Source: Jimenez 1987

TABLE 5
Repairs and Maintenance for a 150 TPD Copra Mill

	Cost (₱)	Frequency (months)
Replacement of hammers for hammermill (24)	10,800	1
Replacement of hammers in grinders (72)	28,800	1
Motors		
Hammermill (60 hp)	80,000	12
Grinders (2 at 60 hp)	160,000	12
Vertical shaft (6 at 40 hp)	260,000	4
Horizontal shaft (6 at 50 hp)	300,000	4
Cooker/conditioner (6 at 10 hp)	120,000	4
Precooker (60 hp)	80,000	12
Paddle for precooker	40,000	60
Gears		
Precooker (6)	300,000	24
Expeller (6)	90,000	48
Rebuilding of horiz. shaft (6)	24,000	1
Boiler tubes	400,000	60
Boiler cleaning	250,000	12
Replacement filter plates (2)	40,000	12
Screens for grinders (4)	14,000	3

Source: Jimenez 1987

TABLE 6
Equipment Requirements for A 70 TPD Coconut Oil Refinery
(1987 costs)

Item	Cost (P)	Expected Lifetime (years)
*Boiler 70 BHP, 4,000 lbs of steam/h)	1,750,000	20
Neutralizer/bleachers (2 w/ 10 t capacity)	3,000,000	25
Overhead tanks for caustic soda and hot water (2 w/ 2,000 l capacity)	100,000	25
*Motors (5 w/ 5 hp)	75,000	5
Filter press (36" x 36")	350,000	10
Storage tanks for caustic solution (3 w/ 20 t capacity)	150,000	10
Storage tank for crude oil (250 t capacity)	750,000	15
Deodorizer (2 w/lot capacity)	3,000,000	25
Storage tank for refined oil (2 w/ capacity of 10 t)	375,000	25
Machine for filling and packing	15,000	10
Tools	10,000	5
*Vehicles	2,300,000	10
Office equipment	400,000	10
Water supply infrastructure	200,000	15
Laboratory	75,000	20
TOTAL	12,550,000	

* Indicates imported items

Source: Jimenez 1987

TABLE 7
Maintenance and Repair Requirements for a 70 TPD Refinery

	Cost (₱)	Frequency (months)
Motors	21,500	6
Boiler cleaning and maintenance, tubes replacement	350,000	12
Replacement filter plates (7 @ ₱ 6,000)	42,000	18
Neutralizer/bleacher, storage tanks, deodorizers, packing machines, and tools	300,000	12
Vehicles	200	12
Office equipment	120	3

Source: Jimenez 1987

any economic advantages of having smaller, decentralized copra mills could be outweighed by extra transport costs to and from the refinery. To meet the demand of remote or geographically separate areas such as islands or mountainous settlements for edible oil at reasonable cost, a medium-scale, integrated mill and refinery could be built if warranted by the size of the market. 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, including the two small expellers are locally made. Tables 8 and 9 list equipment costs and repair and maintenance costs for this mill/refinery.

Other Village-Scale Copra Mill Designs

The ILO analyzed several 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. The ILO concluded that the double power ghani mill had a higher ratio of annual revenues to annual costs (including depreciation) than mills with a baby expeller, small package expeller, or even a medium-scale or large-scale expeller (Keddie, Allal, and Das 1983). To meet the requirements of the domestic market in the Philippines, edible oil from these village-scale copra mills would have to undergo refining at a separate facility.

A power ghani mill is an upgraded version of the traditional, animal-driven technology in India. The traditional ghani consisted of a wooden mortar and pestle rotated by bullocks, buffalos, or camels. A traditional ghani can press up to 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 mill can process 0.56 t of copra per day. For a high extraction efficiency, a small hammermill with a capacity of 0.1-0.2 t per hour is used first 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 main equipment for the baby expeller mill is 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

TABLE 8
Equipment Costs for a 13 TPD, Copra Mill and 6 TPD Refinery

Item	Cost (₱)	Expected Lifetime (years)
Mill		
Hammermill (5 t/h)	200,000	10
Breaker/roller	60,000	10
Expellers (2 at 300 kg/h)	1,000,000	15
Flaker	65,000	10
Conveyors (2)	35,000	10
Rotolifts (2)	30,000	10
Crude oil filter pump	8,000	10
Screening tank	65,000	15
Unfiltered oil tank	80,000	20
Spares held on hand		
Horizontal shaft (2)	60,000	3
Crude oil filter pump	8,000	5
SUBTOTAL	1,611,000	
Refinery		
Crude oil pump	8,000	5
Neutralizer/bleacher/stirrer	30,000	5
Bleach pump	8,000	5
Bleaching filter press (300 kg/h, 18 plates 18" x 20")	58,000	10
Bleached oil pump	8,000	5
Deodorized oil pump	8,000	5
Deodorizer	1,800,000	25
Finishing filter press (300 kg/h, 18 plates 18" x 20")	58,000	10
Edible oil pump	7,500	5
Washwater tank	20,000	15
Hot water tank	8,500	15
Vacuum pump	8,500	10
Steam generator	80,000	8
Thermal oil burner	15,000	5
Thermal oil pump	11,000	5
Expansion tank	10,000	5
Cooling water pump	12,000	10
Condenser water pump	5,000	5
Water pump	4,500	5
Caustic soda pump	60,000	6
Caustic soda tank	5,000	5
Boiler	1,750,000	20
Soapstock pump	87,500	20
Soapstock tank	15,000	10
Air compressor	6,000	10
Sump pump	350,000	6
Cooling tower	5,000	10
SUBTOTAL	4,438,500	

TABLE 8 (cont'd)

Miscellaneous		
Crude oil tank (20 t)	120,000	20
Bleached oil tank (20 t)	120,000	20
Finished oil tank (20 t)	120,000	25
Laboratory	75,000	20
Machine for filling and packing	100,000	10
Tools	15,000	5
*Vehicles	575,000	10
Office equipment	200,000	10
Water supply infrastructure	55,000	15
SUBTOTAL	1,380,000	
TOTAL	7,429,500	

*Indicates imported items

Source: Yu 1987; Jimenez 1987

TABLE 9
Maintenance and Repair Requirements for a 13 TPD Integrated Copra Mill and 6 TPD Refinery

	Cost (₱)	Frequency (months)
*Motors		
Hammermill	20,000	12
Breaker/ roller (15 hp)	20,000	12
Expellers (2 at 40 hp)	90,000	12
Hammers for hammermill (72)	10,800	3
Screen	750	3
Rebuilding of horizontal shaft (2)	4,000	1
Office equipment	120	3
Vehicles	200	3
Refinery equipment	130,665	12

Sources: Yu 1987: Jimenez 1987

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.).

The original ILO analysis was based on a 100% capacity use rate and operation for 8 hours per day, 270 days per year. The ILO data are adjusted here to be consistent with the capacity use assumptions and format of the analysis in this study. This analysis also substitutes in the current Philippine prices for copra, electricity, crude coconut oil, and copra cake. In addition, the interest rate on loans is raised from 10% to 18%. Capital costs have been escalated from early 1983 dollars to early 1987 values using a factor of 1.0932 derived from the Producer Price Index for Capital Equipment (U.S. Bureau of Labor Statistics 1987). The escalation factor for variable costs other than copra is 0.9994, reflecting the U.S. Producer Price Index for Intermediate Materials Excluding Food (Ibid.). All costs were then converted from U.S. dollars to Philippine pisos.

A Village-Scale, Copra Processing Plant for Soap Production

Innovators for Rural Development (IRD), a Philippine NGO, received a grant from AID in mid-1984 to establish a small-scale copra processing plant. The plant is located at Santa Ana, Tagaloan in the province of Misamis Oriental on Mindanao. It began operations in 1985. The total project budget was P1,572,368, with 73% provided by AID and the rest to be shared by IRD and recovered through profits and sale of stock to association members.

Originally, this plant was to produce edible oil, copra cake, soap, vinegar, charcoal, and texturized vegetable protein. Other objectives of the project were to organize an association of at least 100 farmers that would eventually own and operate the plant, and to increase the household income of the members by 50%. The project plan anticipated processing 2,000 coconuts per day in the first year (0.38 tpd), 3,000 in the second year (0.57 tpd), and 4,000 from year 3 on (0.76 tpd). At full capacity, the plant was to produce 150 t of edible oil, 150 t of copra cake, and 96 t of charcoal per year (IRD n.d.).

For comparability with the other types of mills analyzed here, some of the input costs of the IRD plant have been adjusted so that the assumptions are consistent, including those for the price of coconuts and financing. The capital costs have been

escalated to mid-1986 values using the Wholesale Price Index for Machinery and Transport Equipment (NEDA 1986). The piece wage rates have been adjusted up to the legislated daily minimum for industries. Also, the average commercial rate for electricity has been substituted for the cheap, local hydroelectric power. The analysis of the plant's potential is based on the minimum capacity of 0.38 tpd and an 80% capacity use rate (79.0 t per year). However, due to serious managerial and marketing problems the Santa Ana plant only processed 20.7 t of copra (a 26% capacity use rate) in 1986, its second year of operation. For ideological reasons, the enterprise is buying coconuts at a higher than market price.

At present, this plant is only producing laundry soap, bath soap, powdered soap cuttings, and charcoal. Edible oil production was abandoned because of the high capital and operating costs of refining copra process oil on a small scale relative to the revenues. Since the time of the project plan, the price of copra has increased more than the domestic price of edible oil. Vinegar production from filtered coconut water was tried until it was found to be unprofitable. The coop sells a long bar of laundry soap (approximately 450 g in 4 sections) for P6.00 ex factory and P7.00 at retail. Comparable commercial soap brands retail for P8.40. Cottage industries in the area produce cheaper, inferior quality laundry soap, which is often bought by the rural poor and used for bathing. The bath soap sells at the same price as the commercial brand, but the cakes are about 10% larger.

Despite the lower unit prices, soap production at the IRD plant is limited by the lower than expected demand in the community around the project, and little effort has been made at broadening the market radius and marketing channels. The plant is only producing now on the basis of orders from larger buyers. As a result of these problems, the farmer's association has not been organized, the enterprise is not currently in a position to repay capital loans to IRD, and no stock has been sold to farmers.

All of the equipment was fabricated at the plant, except for the pump and motors. The major pieces of equipment include a flue dryer (with a capacity of 4,000 nuts in 36-40 hours), pump, 2 hammermills for preliminary grinding (120 kg/hr at 2,000 psi), 2 disk grinders for finer grinding (40 kg/hour) 2 manual screw presses (35 kg/hr at 7,000-9,000 psi), 1 sand filter, cooking implements, 12 plastic pails, and other plastic containers.

The IRD plant buys whole coconuts and makes its own high-quality copra in a flue dryer fueled by coconut husks. On a dry basis, this copra may have an oil content of over 70% (Jimenez 1987). The coconut shells are converted into charcoal in metal drums. 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 (Neri 1987). The cake has a residual oil content of 20-25%, judging by its appearance (Jimenez 1987). Thus, the oil extraction efficiency is probably 85-88%.

Next, the cake is dried and the oil is washed, steamed, filtered, and cooled. This oil is then made into soap using a semi-boiling process. A mixture of oil, NaOH, soda ash, and other chemicals is heated to 60°C (Neri 1987). After solidification and cutting, the soap is aged 2 weeks for hardening. The semi-boiling process only requires simple, low-cost equipment. Yet, it does not allow recovery of glycerol, which can be obtained through the boiling process (Thieme 1968).

Other Village-Scale Copra Expellers

Cruz (1980) designed a copra expeller with a capacity of 0.4 tpd (50 kg/h), which was made in a local machine shop for research purposes. This expeller has an oil recovery rate of 56% in a single pass from copra with an 8% moisture content. In two passes, the oil recovery rate is raised to 59%, but the production rate is slowed to 28 kg of oil per hour. Although the design is not complicated, this expeller is not in commercial production in the Philippines.

It was not until 1985 that a locally made, village-scale expeller became available. The Simplextractor has a capacity of 0.32 t of granulated copra per day (0.04 t/h) and an oil recovery rate of 55%. This expeller is run by a 1,740 rpm, 60 cps, 2 h.p. motor. The chamber was designed to facilitate collection of extracted oil and cake and for easy cleaning. Unskilled workers can operate this machine easily. Its modular construction reduces maintenance and repair costs. The only imported parts are the motor and bearings. The expeller sold for P48,750 in mid-1986, including sales tax (Simplex Engineering Co. 1986).

The same firm manufacturers a crusher to break copra down to a suitable size. It is powered by a 0.5 h.p. motor. The crusher has a slightly larger hourly capacity than the expeller. The cost of the crusher was P7,940. Repair and maintenance costs for the two pieces of equipment are estimated at P500 per month (Ibid.).

Solvent Extraction

Another method of releasing oil from copra is solvent extraction. This method was first used in Germany during World War II (Woodroof 1979). It is now used on a large-scale in developed countries. It is only done on a limited basis in the Philippines by firms mainly involved in corn oil extraction but also producing some coconut oil. At current prices and production costs for coconut oil, extraction through imported solvents is too expensive to compete with expellers (Jimenez 1987).

Solvent extraction can remove 99% of the oil from copra. Although the resulting copra meal has a lower animal feed value than copra cake from an expeller, a larger quantity of oil is produced and that has a higher value. In addition, flour

production from copra meal would be facilitated (Banzon and Velasco 1982).

Hexane is the most commonly used solvent for coconut oil extraction. Other hydrocarbons, acetone, diethyl ether, carbon sulfide, carbon tetrachloride, and alcohols are also suitable. A desirable solvent (1) has a high affinity for the type of oil at hand; (2) does not leave toxic residues in the oil or interact chemically with the oilseed, oil, or containers to produce toxics; (3) has a low specific gravity, specific heat, latent heat of vaporization, and boiling point; and (4) is not flammable or explosive (Ibid).

A Medium-Scale, Wet Process Mill

The Tropical Products Institute (TPI) did work on a medium-scale, wet process for coconut oil extraction, but the capital costs and energy consumption were high (Dendy and Timmins 1973). This plant would consist of a slicer, 2 mincemasters, a slurry vessel, a vibratory sieve, a hydraulic press, a dryer, 3 creaming vessels of 1,000 gal, a jacketed vessel of 500 gal, 2 centrifuges, a vacuum dryer, 2 solvent extractors, and a colloid mill. The capital costs for this equipment amounted to $75,000 in 1973 dollars, over 50% more than the $49,500 for a copra mill of similar capacity (Edmonds, Edwards, and Mars 1973; Standard and Poor's 1985). Adjusted for inflation using the U.S. Producer Price Index for Capital Equipment, this wet process mill would cost over $193,000 in 1987 dollars (U.S. Bureau of Labor Statistics 1987). This mill would have a daily production capacity of 6 t of oil, 0.424 t of protein, and 2.49 t of charcoal.

The TPI concluded that it generally would not be commercially viable. It would only have positive economic benefits under conditions of high coconut oil prices and shadow pricing of labor, coupled with inefficient copra production methods for the alternative dry process. Actually, the TPI wet process is not really economically beneficial at all because it would be cheaper to improve copra production methods (Edmonds, Edwards, and Mars 1973).

Hagenmaier (1980) developed another medium-scale, wet process designed to be more commercially viable than the TPI process, and did a financial analysis based on trial production at a pilot plant in the Philippines. Figure 11 shows the process. Hagenmaier looked at three alternative spray-dried, protein products and found that dried coconut milk was more profitable than dried protein or skim milk powder, but that it did not matter much whether pressed coconut meat or coconut flour was produced. His estimates have been updated below and adjusted for consistency of assumptions with the comparative analysis in this study.

The Hagenmaier plant can process 25 t of white coconut meat (the endosperm without the brown parings from the testa) in triple shifts. It would take 55,031 coconuts to obtain this much

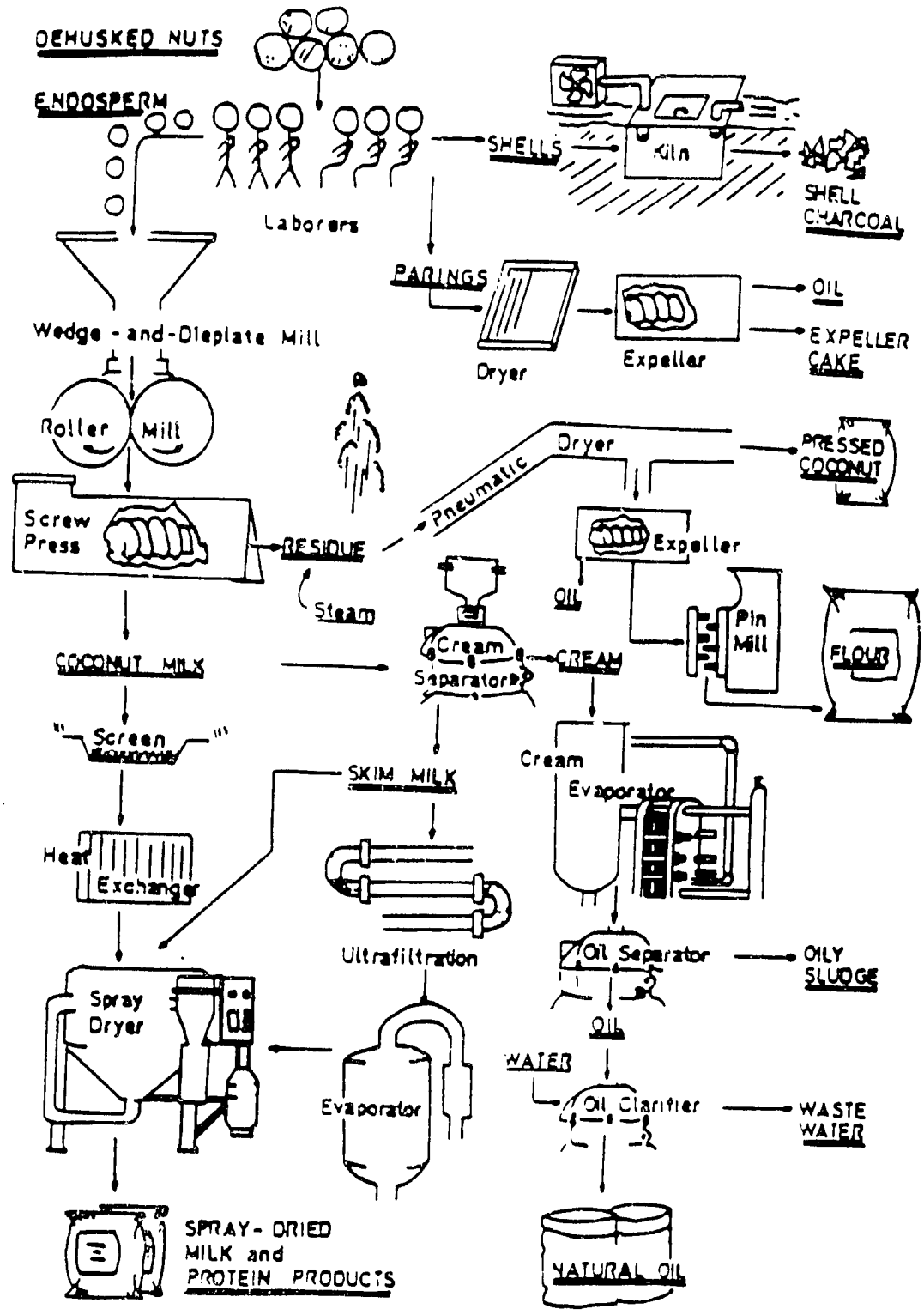


Figure 11. Flowchart for the Hagenmaier Process

Source: Hagenmaier 1980.

meat. This is the equivalent of 10.5 t of copra per day, a bit smaller than the integrated copra mill/refinery discussed earlier. Table 10 lists the equipment requirements for this plant, with costs escalated from early 1980 to mid-1986 values. 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 excessive bacterial growth in some wet, intermediate products.

The Tagbanon Village-Scale, Wet Process Plant

With support from a modified, 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 is located at Tagbanon, Cadiz in the province of Negros Occidental (Region VI) and has a processing capacity of 2,000 whole coconuts per day (the equivalent of 0.38 t of copra per day). It is a modification of a similar plant established at Tulong in Negros Oriental (Region VII) by a private entrepreneur who had received technical assistance from FFI. The Tulong plant opened in mid-1985. In late 1986, the Tagbanon plant began trial production. As a result of this experience, further improvements are being made in the process and choice of equipment.

During the production trials, the Tagbanon plant was making edible oil, laundry soap, sapal cake for animal feed, and charcoal. Vinegar production was also considered, but it would be difficult to market due to its abundance from other sources in the area. Figures 12 and 13 show the process for production of edible oil and laundry soap. The sapal drying and charcoal making techniques are straightforward.

Each batch of oil took 3 days to produce. 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. Some of the coconut water was used later in the extraction process, but most was discarded. 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. The press handled 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 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. Settling reduced the cooking time by 3-4 hours. The skim milk could have undergone further processing for beverage or confection products, but was discarded instead because it quickly spoils in the settling vats. The washed cream was heated to break the oil/water emulsion and

TABLE 10
Capital Costs for a Medium-Scale Wet, Process Mill With Spray Drying Facility[1]

Item	Cost (₱)	Expected Lifetime (years)
Wedge-and-Dieplate Mill	419,300	10
Roller mill	718,800	10
Screw press	2,096,500	20
Residue dryers	509,150	10
Expellers (2 at 4 tpd)	2,695,500	20
Cream separator	1,976,700	20
Cream evaporator	479,200	20
Oil separator	1,497,500	20
Oil clarifier	1,497,500	20
Ultrafiltration unit (8.5 m^2 membrane area)	748,750	12
Evaporator for protein (120 kg/h)	898,500	12
Spray dryer (450 kg water/h)	11,980,000	12
Misc. operations equipment (charcoal kiln, heat exchangers, oil dryer, surge tanks, pumps, pin mill, mixer, vibrating screen etc.)	3,893,500	12
Oil storage vats (600 t)	1,497,500	25
Boiler (15 t of steam/d)	1,048,250	20
Misc. auxiliary equipment (yard and passenger equipment, truck scale, shop equipment, laboratory, office, water treatment, electrical distribution, pipings and fittings, etc.)	4,193,000	10
Office equipment	200,000	10
Vehicles	2,300,000	10
SUBTOTAL	38,649,650	
Engineering/installation	8,595,000	-
TOTAL	47,244,650	

Source: Adapted from Hagenmaier (1980).

[1] Capital costs for equipment have been escalated using the Philippine Wholesale Price Index for Machinery and Transport Equipment. Other costs were adjusted using the Wholesale Price Index for All Items (NEDA 1986).

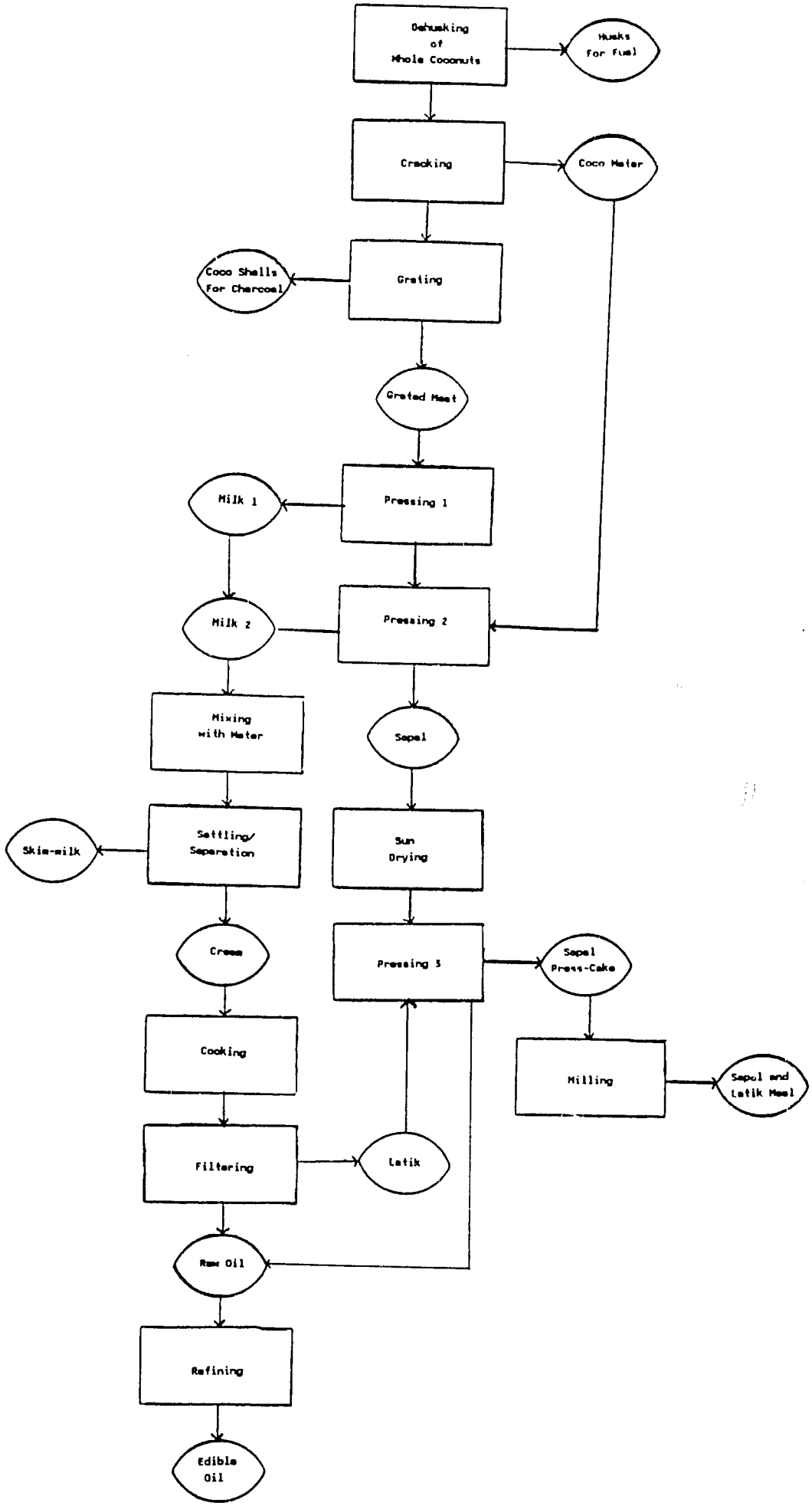


Figure 12. The Production Process for Edible Oil at the Tagbanon Wet Coconut Plant

Source: Cuano 1987.

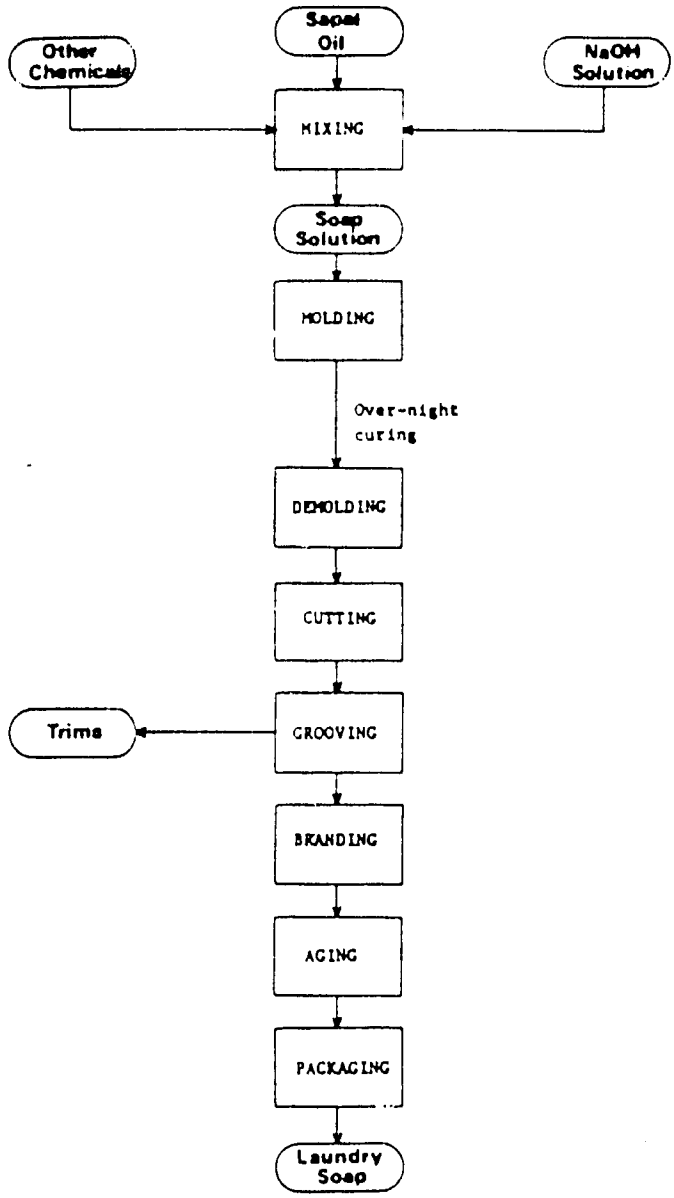


Figure 13. The Production Process for Laundry Soap at the Tagbanon Wet Coconut Plant

Source: Cuano 1987.

evaporate the water, leaving behind raw oil and latik. The portion of the milk containing the solids was heated for a longer time. When heat 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 proteins could 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. Thus, there was no loss in edible oil output as a result of soap production, by the wet process, in contrast to the copra process.

The Tagbanon plant used a cold process for making soap. 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 also less sudsy and did not have as fine a grain. A boiling process would produce better quality soap than the cold process, but would entail higher fuel and labor costs.

The Tagbanon plant used simple, labor-intensive equipment (table 11). Most of the equipment was fabricated locally although imported stainless steel is required since some of the products are for human consumption. Questions have been raised about the technical efficiency of some of this equipment (Jimenez 1987).

Table 12 compares the results of the production trials to the expected yields. In general, the yields were disappointing. Too much of the valuable oil was left in the sapal, and this also made it less palatable as animal feed. In addition, the refining loss was higher than the 1-2% that it should be (Banzon 1987).

The Tagbanon plant was paying more for coconuts, P0.95-1.00 each delivered, than the prevailing market price of the equivalent amount of copra in the area, P0.75. Delivery costs by rented truck and driver would amount to P0.14 per coconut. The buyer made little effort to negotiate on price. Moreover, the purchased coconuts contained an average of 300 g of fresh meat, 20% less than the average size grown (Cuano 1987). Given that price for coconuts and the low technical efficiency of the equipment, it was difficult to undercut the price of commercial laundry soap and still make a profit. The Tagbanon plant tried to cut costs by paying workers on piece rate or a salary below the minimum wage without fringe benefits.

By selling directly to local consumers and market vendors, the plant was able to capture a larger part of the retail value of the products since several layers of middlemen may be avoided. For example, edible oil retailed at P240-245 per 5 gal can

TABLE 11
Equipment Costs of the Tagbanon Village-Scale, Wet Process Plant (mid-1986 values)

Item	Cost (₱)	Expected Lifetime (years)
Preparation		
Dehuskers (2)	900	10
Shelling Knives (3)	450	5
Coconut Water Collectors (3)	700	5
Spindle grater (6 stations)	3,766	5
Electric motor for grater (2 hp)	2,365	5
Coconut meat collectors (8)	1,400	5
Oil Production		
Hydraulic press	27,024	5
Coconut milk collectors (5)	875	5
Cream separators (7)	840	5
Cooling pans (2)	2,600	10
Heating control	5,000	5
Steaming kettle	6,000	10
Steam boiler	15,925	5
Latik containers (5)	1,000	5
Filters pans (4)	4,500	5
Clay stoves (3)	2,500	5
Plastic drums (7)	1,890	5
Settling tanks (35)	3,850	5
Deodorizer tank	3,987	5
Pasteurizing tank	3,987	5
Soap		
Mixer	8,735	5
Soap molds (2)	4,000	5
Cutting tables (2)	1,404	10
Stamper	1,000	5
Miscellaneous		
Small weighing scales (2)	490	2
Large weighing scales (2)	5,000	5
Thermometer	5,000	2
Glassware	4,000	2
Clock	225	4
Push carts (2)	250	2
Drying beds (4)	705	10
Oil container racks (2)	945	2
Chimney	4,330	5
Total[a]	125,643	

[a] Excludes equipment for making vinegar due to the low marketability of the product.

Sources: Filipinas Foundation 1986; Cuano 1987

TABLE 12
Yields of the Tagbanon Wet Process Plant Per Day (Intermediate and Final Products)[a]

Item	Expected	Actual
Coconuts grated (pcs/day)	2,000	2,000
Grated meat (kg)	720	720
Coconut milk (kg)	418	404
Milk extraction (%)	67.0	64.7
Raw oil (kg)	158.2	140
Conversion of milk to raw oil (%)	37.8	34.6
Edible oil (kg)	155	135
Loss in oil refining (%)	2.0	3.5
Coconuts/kg edible oil (no.)	12.9	14.9
Sapal oil (kg)	55	34
Latik oil (kg)	18	16
Soap from sapal oil and latik oil (kg)	143	84
Reject soap (kg)	10	6
Grade A soap (kg)	133	78
Wet sapal (kg)	304	266
Dried sapal (kg)	165	144
Charcoal (kg)	120	102
Theoretical oil content (kg)	266	266
Oil extraction efficiency (%)	87.1	71.3

[a]Normalized to the average size in the Philippines, 360 g of fresh meat per coconut. Reject coconuts (6%) culled and used for copra making.

containing 17.318 kg, the equivalent of P13,860-14,150 per tonne. The Tagbanon plant sold its oil at 90% of the retail price. Similarly, a long bar of laundry soap retailed for P8 and the plant could sell it for 81% of the retail price (Francisco 1987).

An Upgraded Village-Scale, Wet Process Plant

The main problem with the Tagbanon plant was its low oil recovery rate. Its yield of edible oil was only 51% of the theoretical oil content in the coconuts, although another 20% was suitable for soap making. A second reason for problems at the Tagbanon plant has been the lack of a staff member there who understands the technology well (Banzon 1987).

Some changes in equipment and process at the plant could improve the efficiency, and a few of these changes are simple and inexpensive. For example, the sapal cake should be roasted and pressed again in the hydraulic press to raise the total extraction efficiency from 71% to over 80%. This step is being done at the Tulong plant, but has not been done routinely at Tagbanon. A simple rotating drum dryer with a capacity of 400-500 kg/batch could be fabricated locally out of mild steel for P200,000 and should last for 5 years (Ibid.).

Another easily resolved problem was that too much sodium hydroxide was being added in refining, resulting in saponification rather than neutralization of the FFA and an unnecessary loss of oil. The oil loss at this stage should be less than 1%. If the FFA of the oil is 0.1-0.2%, the concentration of NaOH should be 0.1% per 100 l of oil. Since the amount needed depends on the characteristics of the oil, each batch should be tested through simple titration techniques. The NaOH should be sprayed into the oil rather than being added in one lump (Ibid.).

The oil for soapmaking does not need to be refined. During the production trials at Tagbanon, the soap exhibited oozing of oil due to incomplete reaction with the NaOH. Consequently, it was recommended that a semi-boiled process for soap be used instead of the current cold process. The fuel costs of heating the mixture of oil and chemicals to 50-60°C would be low if coconut husks were burned. Since the limiting factor in soap production has been the available quantity of sapal oil, the time required for heating would not reduce the amount of soap produced (Ibid.).

However, some expensive changes are needed to make the plant commercially viable. Better equipment could increase the oil extraction rate and the amount processed. The Tagbanon plant relies on a manually operated mechanical method press to recover liquid/cream from fresh coconut meat. The efficiency of this method depends on the force and distribution of pressure on the material. Since fresh coconut meat has a high moisture content, it is necessary to both press out the liquid portion and break the strong emulsion that binds it to the oil. The mechanical press concentrates pressure on the edges of the bag of material

placed on the plate, instead of distributing it evenly. As a result, much of the liquid/cream was retained in the pressed coconut meat (Ibid.).

It has been recommended that the mill obtain a (1) 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 pressure than a mechanical press and the pressure is even throughout the material being expelled. With this equipment, the mill could process 300-400 kg of coconut meat per hour -- the equivalent of 6,700-8,900 coconuts per 8-hour day instead of 2,000. These changes would eliminate the need for the spindle grater, hydraulic press, and stoves used for breaking the oil/water emulsion. If an expeller were used in the wet process, it would not be necessary to dry the sapal (Ibid.).

It might also be desirable to add a small, stainless steel centrifuge with a capacity of 150-200 kg per hour. A centrifuge would decrease the processing time, increase the oil recovery rate, improve the clarity and purity of the oil, and allow extraction of protein suitable for human consumption through filtration. It might also allow elimination of the neutralization step for edible oil due to improved quality of the raw oil(Ibid.).

The disadvantage of this additional milling equipment is the high capital cost, particularly for the expeller and centrifuge. A medium-scale, imported expeller would cost P1,300,000 and could last 10 years. Replacement of barrel bars for the expeller would cost P1,320 every 2 months and a spare horizontal shaft would cost P60,000. It might be possible to obtain a larger, used centrifuge (2-3 t/hour capacity) for approximately half its original cost of P600,000-700,000. A used centrifuge could last another 5 years. Centrifuges are not made domestically in the Philippines. The hammermill would cost P200,000 (Ibid.)

Major changes have also been recommended in the equipment for refining at Tagbanon -- e.g. addition of a boiler, neutralizer, and deodorizer. Even at FFA levels as low as 0.15-0.25%, edible oil will rapidly deteriorate in quality due to oxidation. For maximum stability, the FFA should be as low as possible. The autoclave now being used for heating is unsuitable as a steam generating unit because of the poor quality and low heating capacity of its steam and the inability to control the pressure and steam flow effectively. Instead, a boiler is recommended for an efficient and economical supply of steam. The boiler should be capable of producing steam at 120 psi. It would cost P450,000-500,000 and could be fired with coconut shells or wood. Replacement of 2-4 boiler tubes per year would be necessary at a cost of P150-200 each (Ibid.)

For proper deodorization of the oil, improvements have also been suggested. The previous system of heating oil by direct steam injection under atmospheric pressure did not deodorize the oil. In fact, it caused rapid deterioration of the oil by increasing FFA through oxidation and hydrolysis.

Deodorization should be done through steam distillation at high temperatures under reduced atmospheric pressure. A vacuum increases the volatility of substances with undesirable odors and flavors, and protects the oil from oxidation and hydrolysis. Steam distillation also increases 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 is needed (Ibid.).

Table 13 lists equipment costs for a potential plant incorporating some of the above changes. This plant has a processing capacity of 5,000 coconuts per day and can yield 530 kg of raw oil. If 70% of the raw oil were converted to edible oil with a 5% loss in refining, the plant could produce 352 kg of edible oil per day at full capacity. The rest of the raw oil, 159 kg per day, would be used in making 477 long bars of soap. The total oil extraction efficiency would be 78%. This plant could also produce 968 kg of sapal and 294 kg of charcoal (Ibid.).

COMPARATIVE ANALYSIS

Table 14 lists the assumptions used in the financial and economic analyses of the ten coconut processing units discussed above. Table 5 summarizes the results of the analysis. It should be noted that they 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 and economically viable.

Since the pilot plant had shut down because it was not meeting expectations for oil extraction efficiency, it is not surprising that 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 plant would be both financially and economically viable.

ADDITIONAL BYPRODUCTS OF THE WET PROCESS

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. An advantage of the wet process over the copra process is that byproduct foods can be obtained without a direct tradeoff in

TABLE 13
Equipment Costs of the Improved Village-Scale, Wet Process Plant (1987 Values)

Item	Cost (₱)	Expected Lifetime (year)
Preparation		
Dehuskers (5)	2,250	10
Shelling knives (4)	600	6
Coconut water collectors (8)	1,867	5
Coconut meat collectors (20)	3,500	5
Motorized grinder	30,000	5
Oil Production		
Presses (2)	100,000	10
Coconut milk collectors (13)	2,275	5
Cream separators (18)	2,160	5
Expeller	65,000	10
250 l mixing tanks with agitators (2 w/250 l)	36,000	15
Steam boiler (10 BHP)	85,000	20
Plastic drums (18)	4,860	5
Settling jars (10)	3,000	5
Deodorizer tanks (2 w/250 l)	36,000	20
Vacuum pump w/ heat exchanger	87,500	10
Filtered oil tanks (2)	17,000	25
Soap making equipment	18,000	5
Miscellaneous		
Small weighing scales (2)	490	2
Large weighing scales (2)	5,000	5
Thermometer	5,000	2
Glassware	4,000	2
Clock	225	4
Push carts (4)	500	2
Dry beds (4)	705	10
Oil container racks (2)	945	2
Charcoal pits (2)	6,000	10
Other (cabinets, racks etc.)	7,500	10
Total	525,377	10

Sources: Cuano 1987; Jimenez 1987.

TABLE 14

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)	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

TABLE 14 (cont'd)

	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

TABLE 14 (cont'd)

	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	3.726	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 (₱4.120/t)	9.270.000	0	803.400	39.998	28.570	57.139	0	0	0	0
Whole coconuts (@ ₱0.75)	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 (₱3/kwh)	202.500	135.000	60.750	0	0	3.912	2.835	4.500	650	5.197
Fuelwood (₱0.35/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 @₱20/m^2)	6.007	4.557	911	24	18	37	14	78	10	68
Packaging materials[j]	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

TABLE 14 (cont'd)

	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	7,923	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	79,137	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

TABLE 14 (cont'd)

[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 ghani: 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 15

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	(881.903)	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	8.510	2.040	-5.251	-2.961	-2.351	-3.345	1.647	-2.904	0.685
Economic	3.670	13.289	3.293	-4.627	-2.330	-1.71[illegible]	-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.

edible oil production. However, at a village scale, the wet process cannot extract as much of the oil from the coconut as can the copra process. New food items could make a contribution to nutrition among the rural and peri-urban poor, but further product development and promotion work are needed before they would become an accepted part of the diet. Cultural preferences are particularly strong in food selection. Coconut oil is very salable; yet, the marketability of new foods is less certain.

Table 16 compares possible food products of the dry and wet processes, but not all of these products are feasible. Since most copra preparation in the Philippines is decentralized and done by smallholders, sufficient quantities of coconut water are not available in one place for processing. If copra were produced at centralized, mills, coconut water products could also be obtained with the dry process. However, at a dry process mill, 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 generally 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.

The types of foods that could be made through wet processing of coconuts include beverages; confectionery items; baked, steamed, and fried goods such as noodles and composite flour; fermented products such as vinegar, nata de coco, and alcohol; and meat extenders and dairy analogues. With the wet process, these products are derived from coconut water, coconut skim milk, latik, and sapal rather than the whole coconut milk used for edible oil production. Some 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.

Coconut water is the liquid inside the cavity of the coconut. An average-sized coconut contains 260 ml of coconut water (UCAP 1986c). It has only 0.55% protein and is mainly a source of potable water, sugars, and electrolytes. Coconut water is less tasty in mature coconuts.

Coconut water ferments into vinegar naturally, but the process can be speeded up by adding sugar and acetic acid bacteria culture. The Tagbanon plant had difficulties reaching a high enough concentration of acetic acid and stopped making vinegar quickly due to lack of a market for this abundant product.

Prospects may be better for using the coconut water to make nata de coco, although this was not tried at Tagbanon. Nata de coco is a white, gelatinous cellulose material formed by Acetobacter xylinum growing on a medium of coconut water mixed with sugar and acetic acid (Gonzalez 1987). In producing nata de coco, care must be taken to avoid contamination by other bacteria (Jimenez 1987). However, the final product does not require pasteurization and is storable (Banzon 1987). To avoid having to pack it in small containers under sanitary conditions at a

TABLE 16
Alternative Food Products From Coconuts

DRY PROCESS

Granulated Coconut

- Confectioneries
- Ice cream
- Peanut butter
- Cakes
- Cookies
- Other baked goods

Coconut Flour

- Confectioneries
- Ice cream
- Peanut butter
- Cakes
- Cookies
- Noodles
- Crunchy snacks
- Cereals
- Rolls
- Other baked goods

Protein Isolates (CPI)

- Infant formula
- Meatless spread
- Canned vegetable loaf

Meal (stable)

- Condiments
- Bakery products

DRY PROCESS WITH CENTRALIZED COPRA MAKING OR WET PROCESS

Coconut Water

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

TABLE 16 (cont'd)

WET PROCESS

Coconut Milk

Canned coconut milk
Coconut milk powder
Coconut milk and protein isolate-based products
Coconut jam/spread
Coconut spread enriched with legume flour
Coconut syrup
Coconut-based tofu substitute
Coconut cheese

Skim Coconut Milk

Instant skim coconut milk
Coconut protein isolate (CPI)
Simulated dairy milk
CPI-based, meat substitutes (e.g. canned meatless spread, sausages, luncheon meat, dehydrated textured product)
CPI-based, cereal weaning flakes
Sweetened condensed coconut skim milk
Coconut honey
Fruit and chocolate flavored beverages
Protein isolate
Sodium salt of coconut protein

Coconut Cream

Canned coconut cream

Sapal/Coconut Flour

Bakery products prepared with coco flour and banana flour - brownies, bars, soda biscuits, cracks, crunchies, figs, loaf bread, pastellya, tarts, pan de sal
Meat and fish analogues prepared with coco flour (e.g.coco-fish sausage, coco-fish sticks, banco meat balls or sauce banco jam siopao, Banco siopao sauce)
Coco flour noodles
Coco pretzels
Coco crunchies or shrimp crackers
Coco-burger
Soy sauce type of condiment
Dried sapal hydrolysate

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

village-scale plant, it could be sold in bulk.

Coconut water can also be used to culture food yeast such as Saccharomyces fragilis. This yeast is rich in amino acids and B vitamins has been approved by the U.S. Food and Drug Administration. It grows best at tropical temperatures, but has been grown on a small scale in the United States (Grimwood et al. 1979).

Coconut milk is the oil/water emulsion obtained by pressing grated, fresh coconut meat. It should not be confused with coconut water and is not high in protein. It is used fresh in cooking and is canned for export. Without refrigeration, coconut milk develops a high bacteria count after 4 hours (Salon and Maniquis 1969). Fresh coconut milk lasts 3-4 days under refrigeration (Banzon and Velasco 1982). The export product is homogenized with added emulsifiers and stabilizers, and then sterilized and canned (Gonzalez 1986). Sterilization through heating reduces the flavor of the milk since it coagulates at 80°C. Because the milk contains much of the original oil of the coconut, there is a tradeoff between production of coconut milk and edible oil.

Fresh coconut milk and brown sugar are the main ingredients in coco jam. This high-fat item is a popular food in the Philippines for desserts or as a spread for bread. It could be enriched with 2.5-7.5% legume flour for extra protein. Another processed product is coco syrup made by boiling the milk with sugar and disodium phosphate. The syrup is ready to use for rice cakes and cooked fruit or tubers (Ibid.).

Most milk sold in the Philippines is filled milk -- a reconstituted product of imported skim milk powder mixed with coconut oil instead of butterfat. The flavor of unfilled, reconstituted skim cow's milk is not popular in the Philippines. Although it has not yet been tried commercially, coconut milk could replace the oil. Sweetened, condensed filled milk keeps well and is popular in rural areas of the Philippines as a spread for bread (Banzon 1987). Coconut milk can also substitute for some of the butterfat in cheese and yogurt. Another possibility is a cheese product from a mixture of 50-60% coconut milk and nonfat dairy cow's milk. Tahu, a high-fat tofu substitute, can be made from coconut milk, gelatin, and skim milk powder (Gonzalez 1986).

Whole coconut milk is difficult to dry due to the oil, which tends to separate out. Coconut milk with added maltodextrin and casein can be spray dried. The additives encapsulate the oil and make the powder less hygroscopic (Hagenmaier 1980). Evaporators and spray driers are expensive. The dried product contains 60.5% fat, 27.3% carbohydrate, and 6.9% protein. As a powder, it is free-flowing and can be mixed with water. It can also be used as a substitute for fresh coconut milk in cooking (Gonzalez 1986). To date, there have been few successful attempts at commercializing coconut milk due to costs, marketability, development of off flavors in pasteurization, and the difficulty of obtaining suitable packaging (Grimwood et al. 1979).

Coconut skim milk is the liquid portion of coconut milk

after the oil-rich portion is removed. The composition of the skim milk varies depending on the extraction method. A sample from one process contained 90% water, 2.7% protein, and 0.6% fat (Gonzalez 1986). The skim milk provides certain amino acids that are low in many diets in LDCs such as lysine, cysteine, and methionine (Hagenmaier 1980), but isoleucine, methionine, and tryptophan are limiting (Woodroof 1979). On average, 400-500 ml of skim milk can be obtained from the meat of one mature coconut (Filipinas Foundation 1987).

The skim milk makes a good beverage when fresh or it can be prepared into a frozen confection. Unfortunately, it spoils in a few hours in its natural form. If pasteurized, fresh skim milk will last 1 day without refrigeration or 3-4 days with refrigeration. To avoid denaturing proteins into insoluble form, the pasteurization temperature should be less than 75°C (Hagenmaier 1980). If suitable containers are available, pasteurized skim milk should sell for a lower price than sodas. Sanitary conditions at some village-scale plants such as the one at Tagbanon might not be adequate for sale of fresh skim milk. Pasteurized skim milk can be sweetened and frozen into ice candy (Banzon 1987). Sterilization and canning of skim milk are expensive. Although water can be removed to prepare condensed or spray dried skim milk, these processes are capital intensive and require a lot of fuel.

A pancake syrup called coco honey can be made by cooking the skim milk with sugar and corn syrup. Coco honey is relatively easy and inexpensive to make, but does not have a strong coconut flavor when fresh and loses more flavor in storage. Unless cans are tightly sealed, mold will grow in coco honey (Hagenmaier 1980).

Protein can be isolated from whole or skim coconut milk by heat coagulation, isoelectric precipitation, co-precipitation with calcium salts (Gonzalez 1987), or acid coagulation (Banzon and Velasco 1982). A more recent technology, ultrafiltration, can be used to extract protein from the skim milk by separating solutes of high molecular weight on the high-pressure side of a semi-permeable membrane from the low molecular weight portion (Hagenmaier 1980). Enzymes that can extract a high proportion of the protein may become more cost-effective through new biotechnologies.

Dried coagulated skim milk is not an attractive food in itself, but the protein could be used as a base or ingredient in beverages; meat analogues such as spreads for bread, luncheon meat, sausages, and texturized vegetable protein; or roller-dried weaning food when mixed with rice flour and mung bean flour (Gonzalez 1987). However, the marketability of protein extract in LDCs has not been demonstrated, and other sources such as cottonseed, soybeans, and groundnuts are higher in protein than coconut byproducts (Edmonds, Edwards, and Mars 1973). In the Philippines, U.S. AID has promoted a soy-protein enriched wheat flour called "nutribun" (Banzon 1987).

Coconut cream is the viscous, high fat part of the emulsion obtained by centrifuging coconut milk or allowing it to settle

(Hagenmaier 1980). Sometimes, canned, sweetened coconut milk is marketed as coconut cream. In some places, cream is the name for the coconut milk concentrated through acidification or heating (Grimwood et al. 1979).

Latik is a curd that forms when the coconut oil/water emulsion is broken by heating. The yield of latik is about 5% of the weight of the fresh coconut. Its form varies from a colloidal solid to a granular substance and it may be white or brownish. Latik contains a significant part of the 9 grams of protein present in the whole coconut (Filipinas Foundation 1986). The protein content of latik is 40%, but much of this becomes denatured if subject to a long heating process. Latik tastes like toasted coconut (Filipinas Foundation 1987). If latik is processed in a way that does not denature the protein, it could be redispersed in skim milk (Banzon and Velasco 1982). Although use of latik for human food was one of the original objectives for the Tagbanon plant, this objective has been deemphasized due to denaturing of the protein and the need for more product development research.

Sapal from a simple wet process can have an oil content of up to 35%. At that level, animals find it unpalatable, but if reheated until brittle and pressed again, the oil content can be reduced to 20% (Banzon 1987). Use of the sapal, the press cake after extraction of the coconut milk, for human food is one of the main areas in product development research to advance the wet process.

Sapal can be converted into a flour through dehydration and solvent extraction. This low-protein flour can be used in baked goods, meat analogues, noodles (as 15-25% of the composition), pretzels, crackers, soy sauce, and dried hydrolysate (Gonzalez 1986). However, the carbohydrate in sapal has no nutritive value for humans. Sapal is richest in fiber although it does contain some protein and oil (Banzon and Velasco 1982).

Desiccated coconut is a major export product with an established market, but it can only be made at the expense of oil production. Also, it must be prepared and subsequently handled under sanitary conditions. Since salmonella can be a problem in desiccated coconut (Woodroof 1979), the wet meat must be pasteurized before comminution. A wet process mill or a dry process mill that makes its own copra might want to diversify into production of desiccated coconut when oil prices are low. Other products that could be made from fresh coconut meat include toasted coconut chips; granulated coconut; and a finely ground, de-oiled, high-protein flour.

Proteins vary in quality, according to their amino acid balance and solubility. The Protein Efficiency Ratio refers to the gain in weight per gram of protein consumed. This ratio is 2.42 for hydraulic-pressed, desiccated coconut flour; 2.55 for the above product further processed through solvent extraction; 2.20 for coconut skim milk protein; and 1.50 for latik defatted by solvent extraction. There are other measures of protein absorption and retention such as the indexes of Biological Value, True Digestibility, and Net Protein Utilization, but the rankings

of foods on indexes would be similar to those from the Protein Efficiency Ratio (Aliwalas et al. 1969).

Nonfood byproducts are also possible. For example, charcoal from coconut shells can be made at mills that buy whole coconuts, whether wet or dry process. The yield of charcoal from coconut shells is 25-30% of the weight carbonized, depending on the method used (Grimwood et al. 1979). Coconut shell charcoal made in a portable metal kiln typically has the following specifications: heating value --7.00 kcal/kg, moisture content --4.6%, total volatiles --14.8%, ash -- 0.6%, and fixed carbon -- 84.6%. The heating value can vary from 6,500-7,600 kcal/kg, compared to 3,800-5,000 kcal/kg for Philippine hardwoods (Banzon and Velasco 1982).

Charcoal is consumed locally for fuel and, in some areas, converted to activated carbon for export. Shell charcoal burns well and is smokeless, but is easily crushed in transport and handling unless briquetted. Activated carbon is produced either by heating charcoal at a high temperature and removing the tar and volatiles from the pores with steam, or by chemical treatment with phosphoric acid or zinc chloride and heating (Banzon and Velasco 1982).

Alternatively, coconut shell flour can be made by grinding clean shells. This product is usable as a filler for thermoplastic molding powders, phenolic glues for plywood, and insecticides, and as a mild abrasive in cleaners. However, there is little market for coconut shell flour and much competition from various fibers, minerals, and other agricultural or silvicultural waste products (Grimwood et al. 1979).

For 1 t of fresh coconut meat, 0.67 t of husks with a heating value of about 4,000 kcal/kg can be obtained (Hagenmaier 1980). Coconut husks make a smoky fuel that irritates the eyes. The husks are high in soot and fly ash. If converted into charcoal, briquetting would probably be necessary for many uses. The heating value of husk charcoal is similar to that of shell charcoal.

About 30% of the husk can be processed into coir fiber; the rest of the husk consists of short fibers and dust that pose a disposal problem. Coir fiber is used for making mats, ropes, and bristles. The fiber is extracted commercially from only 1% of the coconut husks available in the Philippines (Banzon and Velasco 1982). However, coir fiber is an important product in other countries such as Sri Lanka (Ranasinghe 1987).

Ethanol-based rubbing alcohol is a nonfood product that could be made from the skim milk, sugar, and yeast. There is some concern that people would drink it because it is nontoxic unlike methanol. A substance could be added to make it taste bad (Banzon 1987).

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 in sterilizing bottles. Production can also be simplified by subcontracting or by selling intermediate products to other enterprises.

CONCLUSIONS

Coconut oil is a product with substantial economies of scale in processing. Even though the total capital costs of a large-scale 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 operation 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 the products of large-scale industry.

The coconut industry is subject to major oscillations in supply and demand from year to year. At the time of this analysis, product prices for oil and animal feed were low, while input prices (copra and whole coconuts) were high. Although further ups and downs are likely in this volatile market, it is difficult to count on a steady improvement in the terms of trade in this industry due to substitution of other oils. Because coconut production and processing is so important to the economy of the Philippines, it would be desirable to increase the diversification of products made from this perennial crop.

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 research is needed in developing and testing such products as well as intermediate-scale equipment, such as a low-cost expeller and a cream separator.

REFERENCES

Aliwalas, A. et al. 1969. "A Study of the Wet and Dry Methods of Extracting Oil From Coconut Meat." Philippine Journal of Science 38, No. 2: 139-149.

Alviar. M. 1982. Optimum Number, Size, and Location of Coconut Oil Mills in the Philippines. Los Banos: University of the Philippines, Master's thesis.

Arndt, Sara. 1985. "Cuphea: Diverse Fatty Acid Composition May Yield Oleochemical Feedstock." Journal of the American Oil Chemist's Society 62, No.1 (January): 6-12.

Banzon, Julian (Consultant). 1987. Personal communication.

Banzon, Julian and Jose Velasco. 1982. Coconut Production and Utilization. Manila: Philippine Coconut Research and Development Foundation.

Bielenberg, Carl. 1986. "Innovative Elements in the RSID Wet Coconut Processing Technology." Washington, DC: ATI (memo, February 21).

Cruz, Ibarra. 1980. "A Study and Evaluation of a Small Capacity Oil Expeller." Philippine Journal of Coconut Studies 5, No. 2 (December): 1-11.

Cuano, Marita (Filipinas Foundation). 1987. Personal communication.

Dendy, D. and W. Timmins. 1973. Development of a Wet-Coconut Process Designed to Extract Protein and Oil from Fresh Coconut. London: Tropical Products Institute.

Deomampo, N. and C. Pisigan. 1984. "State of the Art Coconut Economics Research." Presented at the Symposium on Coconut Research and Development, Los Banos: Philippine Council for Agriculture and Resources Research.

Edmonds, M., D. Edwards, and P. Mars. 1973. An Economic Evaluation of the Wet Coconut Process Developed at the Tropical Products Institute. London: Tropical Products Institute.

Estanislao. Jesus. 1973. The Coconut Industry - A Preliminary View of Problems and Prospects. Manila: Center for Research and Communications.

Filipinas Foundation. 1986. Village Coconut Processing Project: Investment Plan. Manila: Filipinas Foundation.

Filipinas Foundation. 1987. Project Proposal: Research and Development for Coconut Byproducts. Manila: Filipinas Foundation, submitted to ATI.

Francisco, Tess (Filipines Foundation). 1987. Personal communication.

Gonzalez, Olympia. 1986. "Coconut for Food." Coconuts Today 4, No. 1: 35-53.

Grimwood, Brian et al. 1975. Coconut Palm Products: Their Processing in Developing Countries. Rome: FAO.

Hagenmaier, Robert. 1980. Coconut Aqueous Processing. Cebu City, Philippines: University of San Carlos Publications.

Ignacio, Leonardo, Jr. 1978. "Semi-Refined Coconut Oil." Paper Presented at the World Trade Institute Conference.

Ignacio, Leonardo, Jr. n.d. "Coconut Oil Refining." UCAP Processing Handbook. Manila: United Coconut Association of the Philippines.

Innovators for Rural Development. n.d. Project Proposal: Copra Oil Making. Manila: IRD. Submitted to the U.S. Agency for International Development.

Jimenez, Arturo (Consultant). 1987. Personal communication.

Jimenez, Rodolfo. 1986. "Oleochemicals -- Improving Utilization of Coconut Oil" Coconuts Today 4, No. 1:56-64.

Keddie, J.; M. Allal; and A. Das. 1983. Small-Scale Oil Extraction From Groundnuts and Copra. Geneva: International Labor Office, Technology Series, Technical Memorandum No. 5.

Lamothe, M. and F. Rognon. 1986. "A Choice Based on Results: Hybrids or Talls." Coconuts Today 4, No.1: 69-76.

Lozada, Ernesto. 1979. "The UPLB Copra Dryer". Manila: Proceedings of the Fifth Session of the FAO Technical Working Party on Coconut Production, Protection, and Processing.

Manuel, P. and M. Maunahan. 1983. Coconut/Copra Marketing System -- Its Structure, Conduct and Performance. Los Banos: Philippine Council for Agricultural Resources Research and Development.

Mendoza, Celeste (Innovators for Rural Development). 1987. Personal communication.

NEDA. 1986. 1986 Philippine Statistical Yearbook. Manila: National Economic and Development Authority.

Neri, Emilio (Innovators for Rural Development). 1987. Personal Communication.

NSTA. 1985. Laundry Bar Soap From Coconut Oil. Manila: National Science and Technology Administration.

Olalo, C. 1975. An Analysis of Resource Productivity and Credit Needs of Coconut Farmers in Southern Tagalog. Los Banos: University of the Philippines, Undergraduate thesis.

Ortigas, Milagros (Innovators for Rural Development). 1987. Personal communication.

Philippine Standards Association. 1982. PHILSA Standard Specification for Unsweetened Coconut Milk. Manila: PHILSA.

Pujanes, O. 1978. Farm Management Study of Inter-cropped Coconut Farms in Alaminos, Laguna. Los Banos: University of the Philippines, Undergraduate thesis.

Ranasinghe, T. 1987. Business Plan for Village Coconut Processing Project. Colombo, Sri Lanka: Lalini Enterprises, Proposal Submitted to Appropriate Technology International.

Rao, P.V. Shrikanta. 1980. A Search for an Appropriate Technology for Village Oil Industry. Lucknow, India: Appropriate Technology Development Association.

Salon, Dionisio and Pacita Maniquis. 1969. "Development of a Village Process of Preparing Coconut Skim Milk Beverage for Feeding Children." Philippine Journal of Nutrition 22, No. 3: 164-170.

Santos, G. 1986. "State of the Art: Coconut Production in the Philippines." Coconuts Today 4, No.1: 77-86.

Simplex Engineering Co. 1986. "Simplextractor Coco-oil Expeller: Products Profile", Manila: Simplex Engineering Co.

Standard and Poor's Statistical Service. 1985. Banking and Finance. NY: Standard and Poor's.

Tan, V. 1970. Farm Management Analysis of Selected Coconut Farms in Cantilan, Surigao del Sur. Los Banos: University of the Philippines, Undergraduate thesis.

Thampan, P. 1975. The Coconut Palm and Its Products. Cochin, India: Green Villa Publishing House.

Thieme, J. 1968. Coconut Oil Processing. Rome: Food and Agriculture Organization of the United Nations, Agricultural Development Paper No. 89.

Tibayan, A. 1983. Market Structure, Conduct, and Performance of Copra Marketing System in Selected Towns of Bicol Region. Los Banos: University of Philippines, Master's thesis.

UCAP. 1986a. Concept Paper for a Coconut Industry Development Strategy. Manila: United Coconut Association of the Philippines.

UCAP. 1986b. Coconut Statistics Annual, 1985. Manila: United Coconut Association of the Philippines, Vol. VI, No. XIX.

UCAP 1986c. "1985 Statistics." Coconuts Today 4, No. 1: 117-153.

UCAP. 1987. Weekly Bulletin 22, No. 9 (March 5, 1987).

UNIDO. 1977. Guidelines for the Establishment and Operation of Vegetable Oil Factories. New York: United Nations Industrial Development Organization.

UNIDO. 1984. The Vegetable Oil and Fats Industry in Developing Vienna: United Nations Industrial Development Countries. New York: United Nations Industrial Development Organization, Sectoral Studies Series No 13, Vol. 1.

U.S. Bureau of Labor Statistics. 1987. Producer Price Indexes. Washington, D.C.: U.S. Department of Labor.

U.S. Department of State. 1986. Background Notes: Philippines, Washington, D.C.: Government Printing Office.

Valiente, A. et al. 1979. Coconut Socio-economic and Marketing Study. Quezon City: Ministry of Agriculture.

Woodroof, Jasper. 1979. Coconuts: Production, Processing, Products. Westport, CT: Avi Publishing Co.

Yu, Charlie. (Uniphil Technology Center, Inc.). 1987. Personal communication.