THE WORLD BANK

FAU 4

FAU-04

Agro-Industry Profiles

COCONUT

PROFILES IN THIS SERIES:

ABSTRACT

The objective of this Profile is to provide a technical review of the cocount processing industry. It explores the coconut industry from raw materials to primary processes performed on the coconut fruit, utilization of the fruit, and marketing aspects. It contains specifications on crop and processing yields, a glossary defining key words, and indicates useful references. It traces the processes of oil extraction (wet and dry milling), oil refining, coir production, copra production and desiccation. Storage, seasoning, drying and quality control are addressed as are some marketing aspects of copra, copra cake and meal, crude and refined coconut oil. Examples of investment and operating costs are presented in an Annex.

Coconut

CONTENTS

Coconut

DATA SHEET

Typical Yields

Planting density for coconut palms is 75 to 150 trees per hectare and each tree yields approximately 40 fruit per year. Typical oil content of copra is 63 to 68%.

Copra cake contains approximately 19 to 22% protein. Oil content of the cake varies between 0.5% (solvent extracted) and 17% (traditional methods).

Coconut oil belongs to the Lauric acid group and contains approximately 90% saturated acids.

35 to 45% of the fruit is husk; the percentage available for coir extraction declines with maturity.

Approximate Conversion Factors

5000 coconuts yield 1 metric ton copra.

8000 coconuts yield 1 metric ton of crude oil.

1000 coconuts yield 140 litres coconut water.

1000 coconuts yield 127 to 182 kg desiccated coconut.

1000 husks yield 130 kg coir fibre.

1 metric ton copra yields 610 kg oil and 370 kg copra cake.

INTRODUCTION

The coconut palm is characterized by the wide variety of uses which are made of all parts of the plant. However, the primary object of coconut cultivation is the fruit and this profile addresses only processing of the fruit. All four components of the fruit - the water, meat, shell and husk - can be used.

Coconut water, obtained mostly from immature nuts, is consumed as a beverage. Although many potential uses for the water have been identified, large-scale commercial applications have not been feasible, and disposal of the water can be a problem.

The white meat of the kernel can be consumed fresh, and is an important constituent of many national dishes.

Shredding and pressing the fresh meat produces coconut milk which can be consumed as a dairy substitute, or further boiled to produce oil. Alternatively the shredded meat can be dried to form desiccated coconut.

The most valuable part of the meat is its oil content (approximately 30%). Although the oil can be obtained directly from the fresh `wet' meat, it is usually extracted from dried meat - copra. An important by-product of oil extraction from copra is the cake which contains 19-22% protein and is used for animal feeds[1].

Although crude coconut oil can be consumed as such, refining is required for its major commercial uses: soap making, baking, confectionery, cooking oils and margarines.

The hard shell surrounding the kernel is used for fuel, and is popular for vessels, containers, ornaments and for other domestic purposes. Charcoal and certain grades of activated carbon can be produced for industrial use.

The fibres from the husk yield coir, which is widely used for cordage, mats, stuffing, nets and bags.

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1. See the Oil Crops Overview for general information on oils, fats, meak and cake.

The major processes are outlined in Flowchart 1, and consist of: oil extraction (milling), oil refining, coir production, copra production and desiccation.[2]

GLOSSARY

Coconut milk	Emulsion of oil, water and protein formed during pressing of fresh meat.
Coconut water	Liquid contained in the centre of the kernel.
Coir	Fibre extracted from the husk, depending on the length of the fibres they are classified as yarn, bristle or mattress.
Copra	Dried coconut kernel.
Dehusking	Removal of the husk from the nut.
Desiccating	Shredding and drying of fresh meat.
'Dry' milling process	Crushing of copra for oil extraction.
Paring	Removal of testa from kernel during desiccation.
Retting	Soaking of husks, first stage in production of coir.
Rubberizing	Coating of twisted crior yarn with latex, followed by drying and vulcanizing.
Testa	The brown skin on the exterior of the albumen or kernel flesh.
'Wet' milling process	Shredding and pressing of fresh meat for oil extraction.

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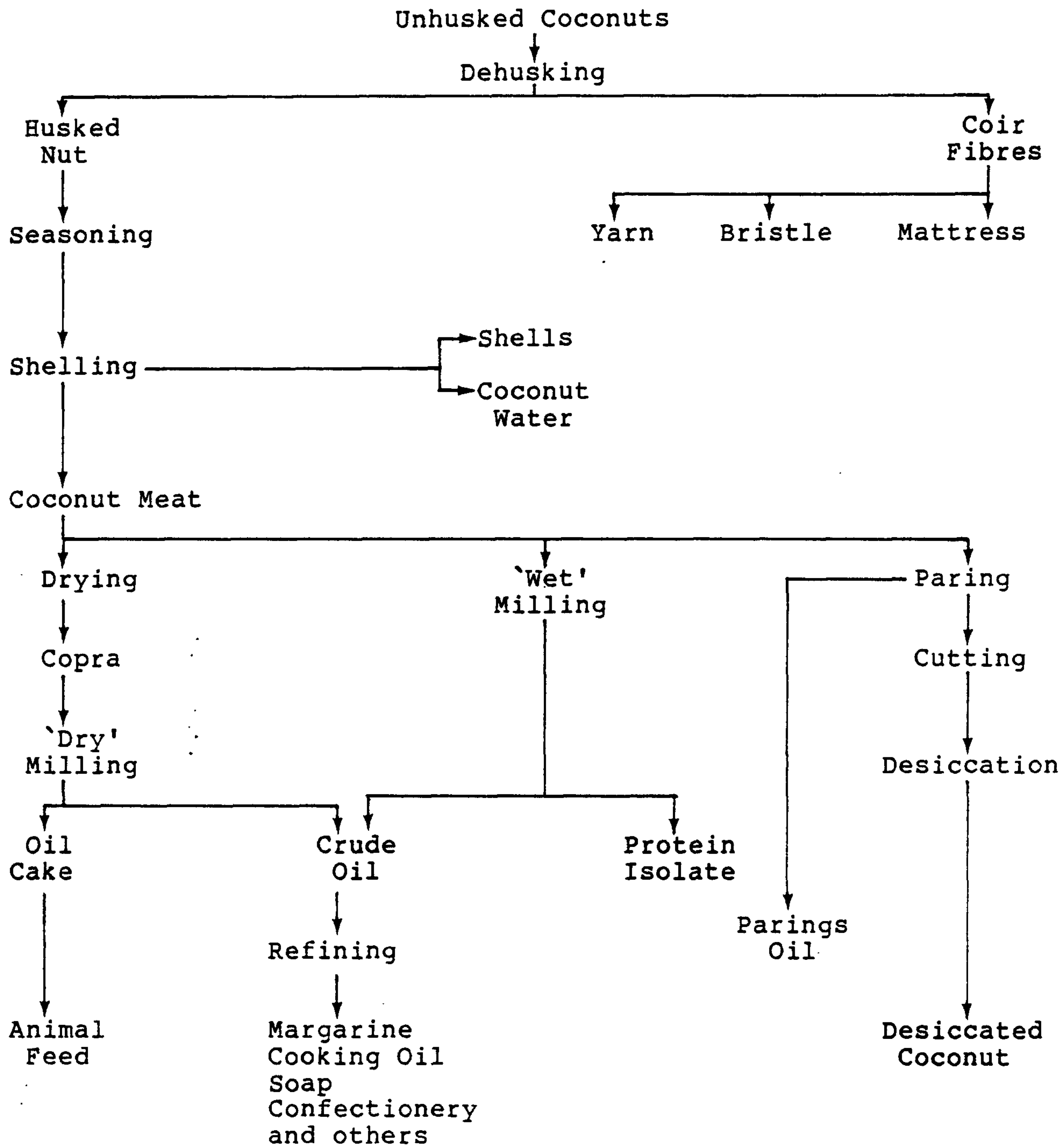
2. Since many coconut industries are based on the production of copra for export and subsequent processing, copra production is considered as a separate process.



Flowchart 1 : Coconut Processing - Overview

RAW MATERIALS

Coconut palms (Cocos nucifera) start to fruit in their 7th year and continue to bear fruit for more than 50 years. Typically, each tree produces about 40 nuts per year.

Coconut varieties produce nuts of different sizes, with different oil content, and with varying amounts of white kernel. Varietal selection therefore depends on primary end use.

There are two distinct types of coconuts: tall and dwarf varieties. The tall varieties are extensively cultivated, constituting an estimated 90% of all planted coconuts. They are comparatively hardy, late bearing and can live up to 80 or 90 years. The nuts mature within about 12 months of pollination. Dwarf varieties tend to have shorter lives. They yield heavily but irregularly for up to 40 years, producing a large number of small nuts each having a lower copra content than tall varieties. However, yields of copra per hectare are slightly superior to those of tall varieties due to the higher planting density achievable with smaller varieties. Ease of harvesting is also an advantage of dwarf varieties.

Since the mid 1970's hybrids of dwarf x tall crosses have been produced in rapidly increasing quantities for use as planting material. Such hybrids combine the precocity and high nut yield of dwarfs with the superior copra content of talls to greatly enhance overall yield potential. Tall x tall hybrids are also being developed.

Coconuts are traditionally cultivated as part of a mixed cropping pattern, and availability of adequate supplies of coconuts for processing is limited by the large proportion of total production (around 50%) consumed locally. In areas with large estates or plantations the proportion available for processing will be much higher.

Depending on their final use, coconuts need to be harvested at different stages of maturity. Oil extraction requires mature nuts (around 12 months old) which have the highest oil content. They should not be over-ripe, to avoid germination. The best nuts for coir production are under-ripe, harvested after 10-11 months.

Coconut palms bear fruit throughout the year but in most countries there are significant seasonal variations influenced by climatic factors. Production of up to 17% of the annual yield in a single month is not unusual.

Coconuts weigh around 1 to 2 kg each and, depending on the nut's maturity, the husk will comprise 35 to 45% of the total weight. Transport efficiency and costs are influenced by the location of the de-husking operation.

Coconuts are an important subsistence and small-holder crop. In India and Malaysia, for example, small-holders account for approximately 90% of total land under coconuts (Thampan, 1981). To ensure adequate supplies of raw material, an efficient system for procurement and collection from scattered sources is needed.

COPRA PRODUCTION

Introduction

Copra is the raw material used for commercial milling and extraction of coconut oil. In addition, high quality edible `ball copra' is consumed in India, and white copra is used to some extent in the confectionary trade.

The harvesting operation is critical to the subsequent quality and quantity of copra produced. When the coconuts are ripe (around 12 months old), their oil and kernel content is at its highest. Ideally, harvesting should be carried out as the epidermis is changing color from its immature hue (green/bronze/orange/yellow) to dull brown. Harvesting at 45 day intervals normally achieves the best trade off between ideal ripeness and plantation labor costs.

Depending on the labour situation, coconuts can be picked from the tree when ripe, or collected from the ground as they fall. However, fallen nuts have usually started to germinate and the yield of copra may be reduced by 6 to 7%. Also, unless ground conditions are good, many nuts may not be found.

The major stages of copra production are storage and seasoning, de-husking, shelling and drying.

Storage and Seasoning

In some areas it is common to store the harvested nuts before further processing. This may simply be a matter of assembling lots of sufficient size for sale and transport or it may be done to achieve various changes within the nuts which lead to higher oil content, higher copra yield, easier de-husking and shelling. Drawbacks include the risk of rodent infestation, germination and theft. Adequate ventilation and heat control can retard germination.

De-husking

In almost regions the husk is removed manually, usually by impaling the nut on a sharp spike. Twisting the impaled nut loosens the husk, leaving the kernel and hard shell intact. De-husking is usually conducted near the trees to minimize unnecessary transport costs.

Attempts have been made to mechanize the process, but with poor results.

In some regions, notably in the South Pacific, the nuts are not de-husked, they are simply chopped in half and the flesh gouged out.

Shelling

To dry the kernel, the shell is broken and the nut split in half. Coconut water should be collected through a drainage system to keep the work area dry, but disposal can be a problem.

Drying

This is the main aspect of copra production. The meat of newly split nuts contains approximately 50% moisture and it is prone to spoilage. To maximize oil extraction and improve keeping qualities the meat should be dried to a moisture content below 6% without delay after the nut has been split.

Halved nuts are usually partially dried before the kernel is extracted. In this manner the kernel contracts and can be removed from the shells with relative ease.

Drying of the separated kernel can be achieved by direct exposure to the sun and/or heat treatment from artificial sources. Sun drying alone is traditionally done by placing copra on wide meshed mobile trays. Protection from rain and insect damage is essential for copra drying in this manner which calls for 6 to 8 consecutive sunny days. In coconut growing regions this is quite rare and usually it is necessary to resort, at least in part, to artificial drying in kilns.

Kilns frequently incorporate sun drying by means of a sliding roof and rely on direct or indirect heating techniques. Ideally, open kiln drying ought to lower the moisture content of the kernel from the initial 50% to 35% in the first 24 hours. During the next 48 hours the moisture content should fall to about 20% and after a final 24 hour period to 5% - 6%. The speed at which copra dries is critical. Overheating causes `case hardening' which occurs at 77 degrees C initially, falling to 63 degrees C as the surface moisture is reduced.

Traditional direct heating systems normally consist of a raised grill platform for the copra above a firing chamber. Empty half shells are used as fuel and, when nested one within another to form a double row, make a slow burning fuse. Combustion gasses are carried through the copra layer by convection. The system is simple and efficient but there is the risk of smoke contamination of the copra as well as a danger of scorching and fire.

Indirect firing involves the use of a form of heat exchanger with some consequent loss of thermal efficiency. In its simplest form the kiln consists of oil drums welded together to make a flue underneath a copra platform. A furnace burning shell and husk is sited at one end of the kiln and the heat generated runs through the fire tube, or flue, to exhaust through a tall chimney at the opposite end. A high quality uncontaminated copra is produced.

Modern large scale industrial drying methods are of sealed bin design. Heating is by a shell burning heat exchanger or direct firing diesel burner. Hot air forced through bins in a reversible air flow pattern enables drying within 24 hours. The end product is very high quality `white edible copra' which commands a 50% premium over normal copra.

Quality Control

Good quality control during the production stages of copra is essential to the production of high quality oil and copra cake. Proper maturity is a prerequisite as immature nuts produce rubbery copra, and over-ripeness to the stage of germination results in serious loss of yield. Adequate ventilation is essential during storage.

Correct drying techniques are also critical. Dried copra ought to break easily with a sharp cracking sound, showing a good pearly white color inside. Excessive moisture in bagged copra makes it susceptible to damage from fungus and insects. Properly dried copra kept in a ventilated store will retain a free fatty acid content of less than 1% for months. Highly acidic copra of up to 8% F.F.A. can be the result of insufficient drying.

DRY MILLING

Dry milling is the standard process for coconut oil production. Compared to wet milling, processing techniques are simpler, oil yields are higher, and the raw material - copra - is a more stable form than the fresh meat required for wet processing.

Oil extraction from the copra is accomplished either through mechanical pressing, solvent extraction or by a combination of pre-pressing and solvent extraction. Details for each system are provided in the profile on oilseed processing.

Briefly, the processing stages involved are pre-treatment of the copra - drying, cleaning, crushing and cooking. Extraction by pressing or solvent follows. The pre-press solvent process is particularly suitable for copra processing, as the initial oil content of the raw materials is too high for efficient use of solvent extraction alone.

The end products of milling are crude oil and copra cake. High quality crude oil may be consumed without further processing. However, poor quality oil can result from inadequate drying or storage during copra production, and requires further refining. Copra cake is used as a protein supplement for ruminants.

WET MILLING

Introduction

'Wet' processes differ from other milling systems in that protein extraction from the flesh is an important objective. The protein content of fresh meat is 4 to 5%. Conventional dry processing of copra produces crude oil, and copra cake containing 19 to 22% protein, but in a form which is too fibrous for human consumption. In the wet process it is possible to isolate and use the protein for human consumption.

A further advantage of wet processing is reduction of the inherent loss of oil in copra milling. The drying process essential for extraction exposes the copra to spoilage and damage which impairs oil quality, and may raise refining losses through higher free fatty acid (FFA) content. Wet processing requires immediate processing of the fresh fruit, thus eliminating this storage and drying loss but at a cost in terms of convenience and access to adequate supplies of raw materials in the fresh form.

Processes

The principle of most modern wet processes is unchanged from the original `primitive' systems. An emulsion or 'milk' is obtained from pressed shredded meat and then broken down, usually by heating, to obtain oil and protein. Many variations of wet processing have been developed and details on the major systems are provided in an excellent survey by Grimwood (1975). However, this technology has not been applied extensively on a commercial scale.

In the typical wet process outlined in Flowchart 2 the shredded or ground meat has been pre-treated with the addition of solvent, alkaline solutions or by pressing. A series of centrifuges progressively separates the oil from the protein and any other solids. Heating, pasteurizing, filtering, distillation, homogenizing and creaming are other processes or stages which may be included.

A major technical problem has been the use of heat. Although maximum separation of the emulsion requires long boiling periods, prolonged heating may seriously damage the protein quality and discolour the oil. To overcome this problem, modern processes use centrifugal separators for oil and protein recovery thus reducing the necessary heating period. Use of centrifuges is standard for modern processes; however, there are differences at other stages, especially regarding pre-treatment of the emulsion to facilitate separation.

Assessment

Wet processes have been used on a relatively small scale, and often on a trial or experimental basis. The results of a TPI[3] study by Edmonds et al (1973) on the economics of the `wet' process are summarized by Keddie & Cleghorn (1980). Although raw material costs were the same for wet and dry processes, investment costs for wet processing were higher than those for conventional copra processing.

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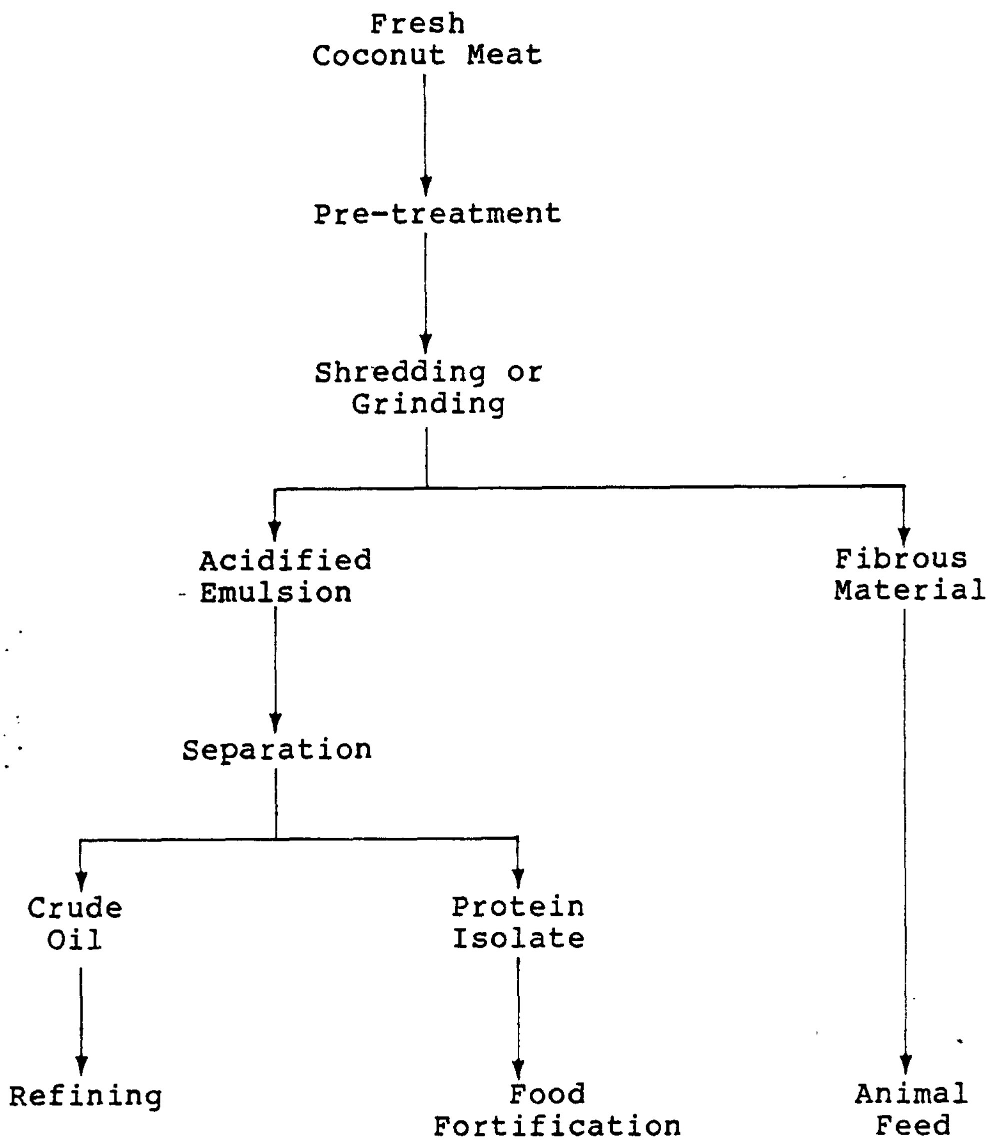
3. TPI (Tropical Products Institute) is now TDRI (Tropical Development & Research Institute).



Flowchart 2 : Wet Processing of Coconut

The advantages of the wet process were said to be: reduced wastage from raw materials spoilage, higher quality oil, and an edible protein by-product. However, results suggested that improved drying of copra reduces spoilage, that equally high quality oil can be produced from dry processes, and that the quantity of protein produced by the wet process was small and less marketable than copra cake.

Major disadvantages compared to conventional copra processing include the relative complexity of wet processing, and the lower yield of oil (around 10 to 15% less). This latter problem can be partially attributed to the initial grinding processes. Oil extraction can be improved if the meat is ground to subcellular dimensions. Details of two processes developed by the Tropical Products Institute, and Texas A & M University which attempt to solve this problem are provided by Grimwood (1975).

REFINING

Introduction

Although crude coconut oil can be consumed as such, it is often refined further, the object being to remove any gums, free fatty acids (FFA), flavours, odours, colours and other impurities from the oil.

The free fatty acid content of the crude oil is a major determinant of the subsequent refining losses. In general, multiplying the FFA by 1.4 will provide the total loss. 5% FFA in a metric ton of oil will yield 7% or 70 kg of soapstock. Although soapstock is a valuable by-product, reducing the oil loss through lower FFA content is usually preferred. The main cause of high FFA is improper treatment of the raw materials during storage, drying or milling.

Refining Systems

The principles of coconut oil refining are the same as those for other vegetable oils. Details on different systems and equipment can be found in the refining section of the oilseed profile. In brief, refining of crude coconut oil generally consists of three stages: neutralization, bleaching, and deodourizing. Degumming is not usually required for coconut oil since it contains few gums. Hydrogenation and winterization of the oil are optional further stages depending on the desired end products.

End Uses

The main uses for refined coconut oil are in soaps, margarines, shortenings, cooking oils, cosmetics and pharmaceuticals.

COIR PRODUCTION

Introduction

Although traditionally an important source of fibre, coir is no longer a major competitor and only about 8% of available husk is processed. Profit margins are modest even in countries with low labor costs.

There are three main types of fibre: 'yarn' is the longest and the most valuable; 'bristle' and 'mattress' fibres are shorter and are obtained together from the same husks.

The husk surrounding the hard shell and kernel constitutes 35 to 40% of the weight of mature coconuts. Large quantities of empty husks are a necessary by-product of copra production and coconut desiccation, and it is the fibre of these husks which is extracted to produce coir of bristle and mattress quality.

Production of high quality coir yarn requires immature nuts, therefore placing this activity in direct conflict with the requirements of the more lucrative copra and desiccation industries.

Processing Systems

All coir processes, while they differ according to the grade of fiber to be produced, consist of two essential operations: preparation and extraction of the fibres, and subsequent cleaning to remove the pith and other vegetable matter adhering to the fibres. Traditionally, coir production has been a laborious manual task but, especially with mattress and bristle fibres, some processes are now being mechanized.

Depending on the end uses of each fibre, the mattress and bristle fibres can be `twisted', `curled' or `rubberized'.

Traditional Processing

India is the major producer of yarn fibre by traditional methods. The better quality attributed to traditional methods is due to the short interval between harvesting and retting, together with the longer retting period (8 to 10 months).

The method of retting varies; the husks may be soaked in undisturbed coastal lagoons and backwaters or submerged in nets or other enclosures in brackish waters. Salt content of the water improves the fibre quality. Crushing the husks before retting shortens the soaking time needed. After retting, the softened husks are washed and squeezed to remove mud and odourous materials.

The husks are then beaten until the pith is separated from the fibre. Repeated beating, washing, drying and winnowing may be needed until the fibre is clean enough for spinning.

Either by hand, or using spinning wheels, the fibre is spun into yarn and the spun yarn twisted into hanks and graded.

Semi-mechanical Processing

This process developed from traditional processes, but in place of manual beating, `drums' are used to separate the fibre and pith.

The husks used are usually by-products from copra production or desiccation and are therefore from mature nuts. With the result that shorter mattress and bristle fibres are produced rather than yarn.

Retting can be performed in any area of stagnant water but most mills will have specially dug pits holding up to 200,000 husks. If the husks have been crushed and the water changed in the tanks, soaking is complete in 3 to 5 days (without crushing it takes 10 to 14 days).

Retted husks are held against rotating 'drums', usually in pairs with nails attached to revolving bars in a cage. These tear the shorter mattress fibres which pass down a chute, leaving the longer bristle fibres and pith in the hands of the operator.

The two kinds of fibre are treated differently. Bristle fibre is washed, dried, and 'hackled' or combed to remove pith and other vegetable matter. After grading, and depending on the final use, the hanks of fibre may be bleached or dyed, then baled. Wet mattress fibre is sifted to remove any remaining pith, dried, graded and baled.

Mechanized Processing

For more efficient production of mattress fibre, the `Downs Decorticator' was developed which reduces the time and labor requirements compared to those of other systems. Dry husks are fed into beater and defibering machines to produce a matted fibre in which with long bristles are broken up and mixed with the natural mattress lengths. The price of this product is only slightly higher than that of mattress fibre and operating efficiencies are offset by the higher capital cost of equipment. As a result, the process has not been widely adopted.

For further technical details on coir extraction, see Grimwood (1975) or Jarman & Jayasundera (1975).

DESICCATION

Introduction

Desiccated coconut is the dried, disintegrated white kernel of the nut processed for human consumption. There are strict hygene and quality requirements for the production and handling of this product.

Processing Systems

Manufacturing desiccated coconut is a relatively straightforward operation involving de-husking, shelling, testa removal (paring), washing, sterilization, disintegration, drying, grading and packaging of the coconuts.

Due to the dangers of contamination, it is desirable to mechanize as many stages of the process as possible. Mechanization of the de-husking, shelling and paring operations has met with little success, but all subsequent stages are now commonly mechanized.

Harvesting

The nuts to be desiccated should be mature, with a high oil content and a thick layer of kernel. These requirements can be met through good harvesting techniques, and growing of suitable varieties. (See Raw Materials, pg.4.)

Seasoning

In some cases seasoning is needed to ensure that the nut is sufficiently mature for processing. In addition to increasing the oil content of the nut, seasoning reduces moisture content and makes shelling easier as the kernel shrinks within the shell.

De-husking

The procedure is the same as that for copra production, whereby the nut is impaled on a spike and twisted to loosen the husk.

Shelling

Ensuring that the kernel is kept whole for the next operation is an important requirement of shelling. For this reason, manual shelling using small knives or hatchets is a skilled operation.

Paring

The testa is removed from the white kernel flesh. The parings are usually dried for storage, and subsequently boiled and milled to yield a second-grade oil.

Cutting and Washing

The kernels are sliced in half to remove the coconut water which is drained away. The water is usually discarded although it can be processed to obtain oil and other by-products.

The pieces of kernel are washed to remove any residual coconut water as well as impurities. An adequate supply of clean water is a critical factor in site location for desiccation plants.

Sterilization and Disintegration

The precise order in which these two operations are conducted varies between systems. The coconut is shredded or ground depending on the final products to be obtained. Sterilization is usually achieved by the application of live steam, or through immersion of the meat in boiling water.

Drying

Moisture content is reduced from around 55% to 3-5%, depending on the product requirements. Indirect drying is most common; with the temperature inside the drier at 75-80 degrees C, drying time is 45-50 minutes. The use of direct oil fired driers and a temperature of 120 degrees C inlet/80 degrees C outlet, reduces drying time to 25 minutes.

Grading and Packaging

After drying, the coconut is cooled and graded according to size through a series of sieves then packaged, normally in lined paper bags of 45-50 kg. Buyers usually rehydrate the product to 25% moisture and add sugar, salt and preservatives such as glycerine before drying to the 8-18% range in which desiccated coconut is usually sold to end users. Toasting or other operations to enhance flavor for particular product applications may also be performed before final sale.

Storage

Keeping qualities depend to a large extent on moisture content. Desiccated coconut can be stored in air-tight containers for many months in clean, dry and well-ventilated conditions away from exposure to direct sunlight.

MARKETING ASPECTS

Copra

In the past, much of the crushing was performed in the importing countries, with producer countries shipping their production in the form of copra. In recent years the emphasis has shifted and most producer countries now crush the bulk of their copra. In some areas where the supply of copra is limited and crushing uneconomic, it is still produced for export.

In terms of market requirements, the importance of correct drying and storage in the production of high quality copra has been emphasized. Buyers of copra require a reliable supply of good quality raw materials year-round.

Copra Cake and Meal

The main by-product of milling, copra cake or poonac, is a valuable source of protein for animal feed. It is also used as a fertilizer. Protein content of the cake is between 19-22% and the oil content varies with the extraction method. A major problem is the cake's propensity to absorb water and swell, particularly during transport and handling. Damp cake is prone to mould development.

Originally, copra cake was shipped in bags, but bulk shipping is now common.

Much of the demand for copra cake and meal comes from developed countries where it is an ingredient in compound feeds. Product substitution and feed formulation are discussed in the Animal Feeds Profile of this series.

Crude Coconut Oil

Coconut oil consists of about 90% saturated acids and the low levels of unsaturated fatty acids give it a high resistance to oxidation and subsequent rancidity. However, it is easily hydrolized and readily absorbs water which gives the oil a strong flavour.

With good handling and storage, crude oil, unlike refined oil, has good keeping qualities. It is this quality which allowed producing countries to mill their copra, and export crude oil to consuming countries for further refining. As consumer tastes and demands change in coconut-producing countries, however, more crude oil will be refined at source, rather than being exported.

Refined Coconut Oil

The poor keeping qualities of refined oil have traditionally dictated that refineries be located close to their consumers. Improved storage and handling technologies have made location somewhat less critical and increased domestic demands have also helped stimulate growth in refining in producer countries.

Refined oils are either fully refined or semi-refined (neutralized and bleached only). Practically all fully refined oil is used for edible purposes; semi-refined oil is often adequate for industrial uses.

As a member of the lauric acid group, coconut oil has some specialized uses, and direct substitution for these is confined largely to palm kernel oil. For certain inedible uses mineral oil-based synthetics directly compete, but within the edible oils market the natural lauric acid oils are relatively unchallenged by synthetic substitutes. In general, there is less substitution possible between fully refined oils than between crude oils.

Coir Fibres

Each of the three grades of fibre produced is aimed at different markets. The high quality yarn fibre is used for matting, carpets, ropes, and rugs. Bristle fiber is used for brushes, carpets, and, if rubberized it is used as stuffing in car seats, beds, carpet underlays, and upholstery. Mattress fibre is used for beds, upholstery, filtration pads, and as caulking material for boats.

The main competitors include sisal, animal fibres, and other natural fibres. Almost all commercially produced coir comes from India and Sri Lanka.

Shell

Coconut shell is a hard dense material of high calorific value. A significant proportion is consumed at source as fuel in copra drying and domestic cooking. When converted to charcoal the product is of very high quality. The yield of charcoal is about 30% of the weight of shells used and approximately 20,000 whole shells are required to produce a ton of charcoal. Further processing into activated carbon creates uses in solvent recovery, filtration, effluent treatment, and pharmaceutical purposes.

Clean shells, pulverised or ground to a fine powder, have application in mosquito coils, linoleum, thermoplastics, phenolic moulding powders, and as a filler in adhesive glues.

Desiccated Coconut

Desiccated coconut is produced in a variety of forms including threads, shreds, strips, chips and slices. The different cuts impart texture, while further sweetening, toasting or processing enhance the flavour.

Characteristics of good quality desiccated coconut may include; crispy, pleasant and fresh taste, snow-white colour, and low fatty acid content (less than 0.2%).

Desiccated coconut competes with dried fruit and nuts in the preparation of food products in five major market areas: the confectionery, bakery, frozen food, general food processing, and consumer products industries. Generally, imported desiccated coconut is rehydrated, tenderized, and sweetened before being distributed.

The coconut should not remain in the tropics for more than two months, and preferably for not more than one. Shipments to consumer countries should therefore be frequent; containers reduce contamination and prevent the coconut from acquiring odours from other cargo.

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ANNEX I:

EXAMPLES OF INVESTMENT AND OPERATING COSTS

Representative Investment and Operating Costs

COPRA OIL EXTRACTION

Establishment of a 25 tons per day copra oil extraction plant.

COUNTRY: Indonesia

NOTE: These data are representative only, and are unique to the time, country and circumstance of the identified investment. Their applicability to other situations may vary considerably.

ANNUAL FULL DEVELOPMENT PRODUCTION:

7500 tons of oil

FULL DEVELOPMENT CAPACITY UTILIZATION: not available

I. Investment Costs	US $ '000 Total Cost (1980 Prices)
Site Works	83.89
Buildings	
Office, Weighbridge, laboratory	33.49
Copra Store (800 m2)	102.07
Process Building (525 m2)	66.99
Pellet Store (400 m2)	51.04
Workshop (250 m2)	31.90
Other	112.44
Sub-Total Buildings	397.93
Foundations	39.87
Water Supply	59.01
Design & Supervision	385.96

Representative Investment and Operating Costs

NOTE: These data are representative only, and are unique to the time, country and circumstance of the identified investment. Their applicability to other situations may vary considerably.

	US $ '000 Total Cost (1980 Prices)
Investment Costs (cont'd)	
Machinery & Equipment	
Supplied by Press Manufacturers	
Copra Grinder	
Cooker/Press	
Screens	
Other	
Sub-Total	995.22
Other Machinery & Equipment	
Copra Conveyor	31.90
Storage Bin	52.63
Grinders & Accessories	60.61
Cookers & Accessories	31.90
Pelletisers & Accessories	65.39
Generators & Electrical Equipment	350.88
Boiler Plant	119.62
Weighbridge	57.42
Workshop Equipment	78.15
Other	92.12
Sub-Total	940.61
Sub-Total Machinery & Equipment	1935.82
Transport & Installation	423.60
Total Investment Costs	3326.09

Representative Investment and Operating Costs

NOTE: These data are representative only, and are unique to the time, country and circumstance of the identified investment. Their applicability to other situations may vary considerably.

II. Annual Operating Costs at Full Development (excluding raw materials)	US $ '000 Total Cost (1980 Prices)
Fixed Costs	
Depreciation	192.80
Administration & Overhead	23.03
Sub-Total Fixed costs	215.83
Variable Costs	
Chemicals	44.76
Labor	6.64
Utilities	98.58
Sub-Total Variable Costs	149.99
Total Operating Costs	365.82

DATA SOURCES: Investment Costs are adapted from the project file for the appraisal of the Nucleus Estates Smallholders V Project in Indonesia (Report No. 3342-IND. Operating Costs are adapted from the Commonwealth Secretariat's Case Studies on Industrial Processing of Primary Products, Vol. II.

NOTES:
1. Exchange rate - Rp 627 = US$ 1.00. Based on IMF's International Financial Statistics, June, 1985.
2. Breakdown of local/foreign exchange costs is not available.
3. Operating costs are based on per ton estimates for coconut oil extraction in Indonesia adjusted to 1980 values.
4. Operating costs based on 300 working days/annum.
5. Data are net of contingencies.

Representative Investment and Operating Costs

COPRA PROCESSING CENTERS

Establishment of a copra processing facility.

COUNTRY: Malaysia

NOTE: These data are representative only, and are unique to the time, country, and circumstance of the identified investment. Their applicability to other situations may vary considerably.

ANNUAL FULL DEVELOPMENT PRODUCTION:

420 tons of copra

PER CENT OF FULL CAPACITY UTILIZATION: 100.00%

I. Investment Costs	US $ '000 Total Cost (1978 prices)
Land	1.36
Clearing/Filling	4.52
Drying Yard	4.52
Kiln/Buildings	13.57
Roads/Fencing	4.07
Equipment	0.90
Total Investment Costs	28.96

Representative Investment and Operating Costs

NOTE: These data are representative only, and are unique to the time, country, and circumstance of the identified investment. Their applicability to other situations may vary considerably.

	US $ '000 Total Cost (1978 prices)
II. Full Development Annual Operating Costs (excluding raw materials)	
Fixed Costs	
Administration & Overheads	6.33
Communications	0.45
Sub-Total Fixed Costs	6.79
Variable Costs	
Hired labor	2.26
Utilities	0.27
Supplies & Services	1.09
Sub-Total Variable Costs	3.62
Total Operating Costs	10.41

DATA SOURCE: Adapted fromProject File, Malaysia Smallholder Coconut Development Project, Report No. 1906-MA, June 30, 1978.

NOTES:
1. Exchange rate - Malaysian $ 2.21 = US $ 1.00. Based on IMF's International Financial Statistics, June, 1985.
2. Full development is year 3 following project start-up.
3. Depreciation allowances are not included in cost estimates.
4. Data are net of contingencies.
5. Detailed breakdowns between local and foreign expenditures is not available.

Representative Investment and Operating Costs

COCONUT OIL MILL

Establishment of a copra crushing mill to produce crude oil and copra meal pellets.

COUNTRY: Western Samoa

NOTE: These data are intended as representative only and are unique to the time, country and circumstance of the identified investment. Their applicability to other situations may vary considerably.

ANNUAL FULL DEVELOPMENT PRODUCTION:

11,970 tons of oil
6,270 tons of pellets

PER CENT OF FULL CAPACITY UTILIZATION: not available

	US$ '000		
	Local	Foreign	Total
	(April,	1977	prices)
I. Investment Costs			
Site Development	55.00		55.00
Civil Works & Buildings	66.00	263.00	329.00
Machinery & Equipment			0.00
(full press mill)		1273.00	1273.00
Installation Costs		255.00	255.00
Pre-Operating & Start-Up			0.00
Expenses	63.00		63.00
Contractor Costs		153.00	153.00
Total Investment Costs	184.00	1944.00	2128.00

Representative Investment and Operating Costs

NOTE: These data are intended as representative only and are unique to the time, country and circumstance of the identified investment. Their applicability to other situations may vary considerably.

	US$ '000 Total Cost (April, 1977 prices)
II. Full Development Annual Operating Costs (excluding raw materials)	
Fixed Costs	
insurance	53.26
maintenance	48.06
depreciation	137.69
administrative	220.83
Sub-Total Fixed Costs	459.85
Variable Costs	
power	283.18
water	3.90
fuel	35.07
bags	16.89
supplies	51.96
labor	188.36
Sub-Total Variable Costs	579.35
Total Operating Costs	1039.20

DATA SOURCE: Adapted from Appraisal of the Coconut Oil Mill Project in Western Samoa (No. SAM: AP - 7) Asian Development Bank, November, 1977.

NOTES:
1. Exchange rate Western Samoa $ 1.00 = US $ 1.299.
2. Full development is year five after project start-up.
3. Data are net of contingencies.
4. Detailed foreign/local cost breakdown for operating costs is not available.

ANNEX II:

CONVERSION TABLES

WEIGHTS AND MEASURES

avoirdupois

Ton: short ton	20 short hundredweight, 2000 pounds; 0.907 metric tons;
long ton	20 long hundredweight, 2240 pounds; 1.016 metric tons.
Hundredweight	cwt;
short hundredweight	100 pounds, 0.05 short tons; 45.359 kilograms;
long hundred weight	112 pounds, 0.05 long tons; 50.802 kilograms.
Pound	lb or lb av; also #; 16 ounces, 7000 grains; 0.453 kilograms.
Ounce	oz or oz av; 16 drams, 437.5 grains; 28.349 grams.
Dram	dr or dr av; 27.343 grains, 0.0625 ounces; 1.771 grams.
Grain	gr; 0.036 drams, 0.002285 ounces; 0.0648 grams.

Troy

Pound	lb t; 12 ounces, 240 pennyweight, 5760 grains; 0.373 kilograms.
Ounce	oz t; 20 pennyweight, 480 grains; 31.103 grams.
Pennyweight	dwt also pwt; 24 grains, 0.05 ounces; 1.555 grams.
Grain	gr; 0.042 pennyweight, 0.002083 ounces; 0.0648 grams.

METRIC SYSTEM

Square kilometer	sq km or km^2; 1,000,000 square meters; 0.3861 square mile.
Hectare	ha; 10,000 square meters; 2.47 acres.
Hectoliter	hl; 100 liters; 3.53 cubic feet; 2.84 bushels;
Liter	l; 1 liter; 61.02 cubic inches; 0.908 quart (dry); 1.057 quarts (liquid).
Deciliter	dl; 0.10 liters; 6.1 cubic inchs; 0.18 pint (dry); 0.21 pint (liquid).
Centiliter	cl; 0.01 liters; 0.6 cubic inch; 0.338 fluidounce.
Metric ton	MT or t; 1,000,000 grams; 1.1 US tons.
Quintal	q; 100,000 grams; 220.46 US pounds.
Kilogram	kg; 1,000 grams; 2.2046 US pounds.
Gram	g or gm; 1 gram; 0.035 ounce.