COCONUT

Post-harvest Operations

INPhO - Post-harvest Compendium

Food and Agriculture Organization
of the United Nations

COCONUT: Post-harvest Operations

Organisation: Asian and Pacific Coconut Community (APCC) www.apcc.org.sg
Author: P.G.Punchihewa and R.N. Arancon
Edited by AGSI/FAO: Danilo Mejia (Technical), Beverly Lewis (Language & Style),
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1. Introduction

In beauty and utility no other tree can surpass the coconut tree. It is the most extensively grown nut in the world, the most important palm. It provides people basic needs such as food, drink, shelter, fuel, furniture, medicine, decorative materials and much more. They are a necessity and a luxury. It is the "heavenly tree", "tree of life", "tree of abundance" and "nature's supermarket."

1.1 Economic and Social Impact of Coconut

Total world coconut area in 1996 was estimated at 11 million hectares and around 93 percent is found in the Asian and Pacific region. The two biggest producers Indonesia and the Philippines have about 3.7 million ha and 3.1 million ha respectively. India is the third largest producer. In the South Pacific countries, Papua New Guinea is the leading producer. In Africa, Tanzania is the largest producer while in Latin America Brazil accounts for more than one half of the total coconut area of that region. (See Table 1.).

Table 1. WORLD: Area of Coconut 1992-1996 (In 1000 Ha)

C o u n t r y	1992	1993	1994	1995	1996
A. Asian and Pacific	10261	10244	10427	10555	10642
F.S. Micronesia	17	17	17	17	17
Fiji	65	65	65	64	65
India	1529	1538	1635	1714	1796
Indonesia	3599	3636	3681	3724	3745
Malaysia	315	310	305	290	280
Papua New Guinea	260	260	260	260	260
Philippines	3077	3075	3083	3064	3093
Solomon Islands	59	59	59	59	59
Sri Lanka	419	419	419	419	419
Thailand	389	336	397	412	377
Vanuatu	96	96	96	96	96
Vietnam	220	215	186	19	190
Western Samoa	46	50	55	75	75
Palau	14	14	14	14	14
Bangladesh	31	31	31	32	29
Myanmar	29	30	31	32	33
French Polynesia	50	50	50	50	50
Kiribati	27	25	25	25	26
Others	19	18	18	18	18
B. Africa	444	446	466	460	460
Benin	12	12	12	12	12
Comoros	17	17	18	18	18
Ghana	28	30	46	40	40
Ivory Coast	33	33	32	32	32
Madagascar	33	33	33	33	33

C o u n t r y	1992	1993	1994	1995	1996
Tanzania	305	305	310	310	310
Others	16	16	15	15	15
C. America	484	448	456	459	476
Brazil	236	228	232	238	258
Mexico	165	141	143	139	135
Jamaica	35	35	35	35	35
Venezuela	23	22	23	23	23
Others	25	22	23	24	25
T o t a l	11189	11138	11349	11474	11578

Source: Statistical Year Book 1996, Asian and Pacific Coconut Community (APCC)

Table 2: World Production of Coconuts (Measured in Nut Equivalent) 1992-1996 (1000 nuts)

C o u n t r y	1992	1993	1994	1995	1996
A. Asia and Pacific	42113805	43671709	45462211	48295884	47934625
F.S. Micronesia	40000	40000	40000	40000	40000
Fiji	195000	198000	196200	196040	196400
India	10080000	11241000	11975000	13300000	13968000
Indonesia	12376000	13030000	13245000	13521000	13595000
Malaysia	883000	800000	787000	748000	722000
Papua New Guinea	980000	1058000	840000	869000	960000
Philippines	11405000	11328000	11207000	12183000	11935000
Solomon Islands	262000	267000	272000	280000	287600
Sri Lanka	2296000	2164000	2622000	2755000	2546000
Thailand	1103000	1128000	1849000	1898000	1130000
Vanuatu	327000	317000	317000	317000	346000
Vietnam	1010000	1000000	978000	1054000	1065000
Western Samoa	122000	144000	159000	160000	160000
Palau	70000	70000	70000	70000	70000
Others	964805	886709	905011	904844	9136
B. Africa	2129145	2230674	2181004	2196295	2193000
C. America	3352218	3097368	3487416	3522878	3469929
T o t a l	47595168	48999750	51130631	54015056	53597554

Source: Statistical Yearbook 1966, Asian and Pacific Coconut Community (APCC)

The average annual production of coconut during 1992-1996 was estimated to be 50 billion nuts, or 10 million metric tons of copra equivalents. (APCC 1996, Table 2).

Of the world production of coconut, more than 50 percent is processed into copra. While a small portion is converted into desiccated coconut and other edible kernel products, the rest is consumed as fresh nuts. The coconut palm also provides a series of by-products such as fibre, charcoal, handicrafts, vinegar, alcohol, sugar, furniture, roofing, fuel among others, which provide an additional source of income. Diversified local uses of the coconut palm number over 200. (See Figures 1 and 2).

Figure 1 - Potential Products from the Coconut Palm

T H E C O C O N U T P A L M

TRUNK FRUIT INFLORESCENCE FROND

FUEL LEAF SPINE
NUT HUSK SYRUP

TIMBER CHARCOAL
FIBRE MATTING FUEL

WATER FLESH SHELL FUEL BEVERAGE
DISTILLATION

PRODUCTS

BAVERAGE POWDER
FILLER DUST SUGAR

COOKING Fresh Dry
MILK Process Process

FOOD Peel CHARCOAL COIR

BRIQUETTES
ACTIVATED

WHITE FLESH TESTA CARBON SOIL CONDITIONER

DRY COPRA

Aqueous Dry HARDBOARD
Process Process STOCK ROOFING

FEED

Ultra-fine Shred Gasification
Shredding Extraction

DESICCATED

COCONUT PRODUCER GAS HEAT
Separation

Synthesis
ELECTRICITY

EDIBLE CREAM
MEAL METHANOL or

EDIBLE CRUDE AMONIA
NATURAL OIL BRISTLE FIBRE YARN

dry OIL STOCK

FEED
refine

DRY FOOD
PRODUCTS BLAND INDUSTRIAL OIL BRUSHES MATTRESSES TWINE

COOKING OIL

refine BROOMS
RUBBERIZED ROPE
COIR

DAIRY MILK Process
SUBSTITUTE COCO CHEMICALS CONCRETE

SOAP
REINFORCING

VEHICLE/

AIRCRAFT SEATS
MILK YOGURT CHEESE ICE CREAM ETC
POWDER

Products are expressed in upper case and processes in lower-case letters.
Source: Proceedings of XXXIII COCOTECH Report 1991, APCC

Figure 2. Coconut Tree of Life - Its Parts and end

1.2 World Trade

A wide range of coconut products are internationally traded. There are more than 50 unprocessed, semiprocessed or processed coconut products entering the international markets in small and big quantities. Aside from copra and coconut oil, other exports which have a significant volume are desiccated coconut, copra meal, cocochemicals (fatty acids, fatty alcohol, methyl ether), shell charcoal and activated carbon, fibre products, coconut cream, milk, powder and nata de coco.

Although global production continues to increase, the growth rate of domestic use was faster therefore reducing the exportable supply of kernel products to about one third of the production. However there has been a sizeable increase in the export of non-traditional products in recent years. Both copra and coconut oil are traded internationally. In the past, the main export was copra.

In the 1960s over 1 million tons of copra was traded world-wide per annum. The volume declined to about 900000 tons a year in the 1970s further declining to an annual average of 350000 tons in the 1980s. This immense drop occurred when the producing countries established domestic copra processing plants in response to their desire to obtain more value-added products. In 1994 copra exports further dropped to 234874 tons with Papua New Guinea at 53767 tons followed by Indonesia, Vanuatu, Philippines, Solomon Islands and Malaysia with exports below 40000 tons each. The downtrend in copra exports is likely to continue.

In contrast, coconut oil exports increased marketedly. World trade in coconut oil during the period 1964-1968 averaged only 506000 tons a year. This rose by 75 percent during the next decade to reach an average volume of 888000 tons. The market further improved to an average of 1.2 million tons in 1980s and 1.5 million tons in 1990-1994. 1995 was a peak year for coconut oil when exports rose to 1.8 million tons. The world annual tonnage of coconut oil and copra exported for 1990-1994 averaged 1.6 million tons of oil with about 55 percent from the Philippines. Coconut oil is imported by 100 countries. The United States of America and Western European countries absorbed about 70 percent of total imports.

1.3 Primary Products

The main coconut product, copra (dried kernel), and its derivatives coconut oil, copra cake, plus desiccated coconut represent a major source of foreign exchange. For several small nations, especially in the Pacific, copra is the principal source of foreign exchange.

Coconut oil is the leading commercial product which contributes nearly 7 percent of the total supplies of vegetable oils in the world. The world's production of coconut oil reached 3.1 million tons in 1996.

Traditionally, the coconut is dried to produce copra and the oil is then obtained from the copra by expression or prepress solvent extraction methods. The residual product after the oil extraction coconut meal contains 18-25 percent protein, but is too fibrous for use in monogastric diets. Consequently its main use is ruminant feeding.

Desiccated coconut is the dried, white, particulate or shredded food product manufactured from freshly peeled coconut kernels. The world production of desiccated coconut is around 200,000 mt a year, the bulk of which is exported and is the second next most significant coconut product in global trade. In 1996 the total volume of desiccated coconut imported was 174,000 mt tons mainly purchased by Europe and the United States.

Coconut Processing

Though coconut can be processed into many products, the next part focuses on the processing of coconut oil, highlighting the dry-process of coconut oil extraction and two improved coconut oil extraction technologies which have proven to be adaptable at the village level, namely: a) The Hot-Oil Immersion Drying Technology; and b) The Ram Press Coconut Oil Extraction Technology. These technologies were selected as the most practical. Though their viability is site-specific, women and members of the farming family may run the technology.

Coconut Oil Processing - The Dry Process

Coconut oil is one of the main traditional products derived from the meat or kernel. It is a mixture of chemical compounds called glycerides containing fatty acids and glycerol. The different fatty acids present in coconut range from C6-C18 carbon atom chains.

Coconut oil processing methods or technologies are classified into two (2) major types: the dry and the wet processes. The oil extraction technology which starts with copra as the raw material is termed as the dry process, while the method that uses fresh coconuts as starting material is generally called the wet process.

Dry processing of meat for oil production involves the conversion of coconut meat into copra prior to expelling and refining. This process is however done off-farm, in an oil mill. From the farm, the copra goes through a series of traders. Storage in warehouses range from two weeks to two months. At the mill, the copra undergoes the following steps, (Figure 12):

1) Cleaning: Copra is transferred from the warehouse to a mill by a series of floor conveyors, rotor-lift and overhead conveyors. Copra is cleaned of metals, dirt and other foreign matter manually by picking or through the use of shaking or revolving screens, magnetic separators and other similar devices;

2) Crushing: Copra is broken into fine particle sizes of about 1/16" to 1/8" by high speed vertical hammer mills to facilitate oil extraction;

3) Cooking/Conditioning: The crushed copra that has about 5-6 percent moisture is passed through a steam-heated cooker. This brings the temperature of the copra to the conditioning temperature of about 104^{o}C (220^{o}F). At the conditioner, the copra is maintained at about 104-110^{o}C (220-230^{o}F) for about 30 minutes to insure uniform heat penetration before oil extraction. Moderately high temperature facilitates the expelling action. Oil is able to flow out more easily due to decrease in viscosity proteins and other substances present in the copra. Heating dries and shrinks these substances. Moisture content of copra is about 3 percent when it leaves the conditioner.

4) Oil extraction: In the expeller, the milled copra is subjected to high-pressure oil extraction, first by a vertical screw, and finally by a horizontal screw. To control the temperature during extraction, the main shaft is provided with water-cooling and cooled oil is sprayed over the screw cage bars. The temperature of the oil should be kept at about 93-102^{o}C (200-215^{o}F) to produce light coloured oil and effect good extraction.

5) Screening: The oil extracted in the expeller flows into the screening tanks to remove the entrained foots from the oil. The foots settle at the bottom and are continuously scooped-out by a series of chain-mounted scrapers which lift the foots to the screen on top of the tank. While travelling across the screen, oil is drained out of the foots. The filtered oil flows into a surge tank from where it is finally pumped to the coconut oil storage tank.

6) Filtration: The oil is passed through a plate and frame filter press to further remove the solids in the oil. Two filter presses are provided - one on duty while the other is being cleaned and dressed. Maximum filtering pressures reach about 60 psi. The filtered oil flows into a surge tank from where it is finally pumped to the coconut oil storage tank.

Coconut oil produced from good quality copra is clear, low in fatty acid and has good coconut aroma. However crude coconut oil from bad quality copra is dark; turbid; high in free fatty acids (FFA), phosphatides and gums; has an unpleasant odour. To render this oil edible, it has to undergo a refining process. Typically, 5 percent of the weight of the crude oil is lost in refining but the loss can be as high as 7.5 percent.

Figure 12: Dry Process of Coconut Oil Manufacture

NaOH-_ _ Soapstock

Filtered crude oil

Crude coconut oil

suspended solids

copra cake

Refining consists of neutralisation, bleaching and deodorising. Neutralisation reduces the FFA to improve the taste and appearance of the oil. It is done by reacting sodium hydroxide with free fatty acid to form an oil-insoluble precipitate called soapstock.

The amount of sodium hydroxide required to neutralise is 1.418 kg NaOH per 1 percent FFA content per ton of crude coconut oil. In actual practice, it is reported that 10 percent excess is added to ensure complete neutralisation. This amounts to 1.50 kg NaOH per ton of crude coconut oil per 1 percent FFA.

The soapstock is then removed once it settles out. This is either converted into either acid oil by treatment with sulphuric acid or into soap by complete saponification.

Phosphotides and gums are removed by physical refining in which the first stage involves treating the oil with phosphoric acid. These are then separated from the oil either by centrifugation or decantation.

Bleaching takes out most of the dissolved or colloidal pigments responsible for the colour of crude oil. Either activated carbon or bleaching earth such as bentonite (1 to 2 percent) or a combination of both are added to neutralised the oil under vacuum while heating it to 95-100^{o}C. Afterwards, the bleaching agents are removed by passing the oil through a filter press.

Deodorisation removes volatile odours and flavours as well as peroxides that affect the stability of the oil. It is done by heating the oil to a temperature between 150-250^{o}C and contacting with live steam under vacuum conditions (29 psig pressure).

Coconut Oil Extraction: The Hot Oil Drying Technology (HOID)

The Hot Oil Immersion Drying (HOID) technology or the `fry-dry' process is a method of extracting coconut oil from fresh coconut meat (wet process). The process involves grating and then drying the freshly cut coconut kernel by immersing it in hot oil. The dried residue is subsequently removed from the hot oil, drained and passed through a screw press where the oil is extracted under pressure leaving a dry cake. (See Figure 13).

Figure 13. Process Flow of the Hot-Oil Drying Technology (HOID) of Extracting Coconut Oil

to be sold

HOID or `fry-dry' process is indigenous to West and North Sumatra, North Slaws in Indonesia and is currently practised all over the country. It was reported that a few areas in the Philippines have used the technology but not many are fully knowledgeable of its application. It is believed that there are good prospects and a wider scope for the introduction and application of the HOID technology not only in other parts of Indonesia but also in many areas in Asia and the Pacific, especially in medium and large scale operations.

The HOID technology is an alternative method of producing coconut oil. The oil is generally of a better quality and preferred by certain segments of the population, especially in Indonesia, because of its distinctive coconut flavour. The HOID oil can be used directly as cooking oil, without chemical refining. In certain parts of Indonesia, HOID oil is sold at prices higher than that of refined palm oil.

The method of HOID oil production involves the following steps:

1) The fresh coconut meat is delivered to the processing plant where it is inspected, washed and cut into pieces with a hammer mill or a grater.

2) The grated kernel is then fried in the pan of hot coconut oil at approximately 120^{o}C for 20-45 minutes depending on the oil temperature and ratio of fresh meat to coconut oil used. Care must be exercised not to add too much meat at once during the frying because the immersion of the cut coconut kernel results in a rapid evolution of steam which can result in oil spillage. Stirring of the grated coconut is occasionally done during the frying. The drying process is completed when there is no more steam produced, the coconut meat becomes yellowish to brown and the temperature of the coconut oil in the pan increases;

3) The fried particles are then taken out of the oil by means of perforated spoon affixed to the end of a long wooden handle. The meat is then dumped in a filter box and the oil is allowed to drain through a meshed plate at the base of the container.

4) The drained, cooked brown coconut particles, rich in coconut oil, are then fed to the hopper whence it is fed to the screw press. The expelled oil is passed through a mesh plate and settled in a tank before it is pumped or poured into the main settling tank.

5) The oil is then clarified by settling the oil in the tank. Sometimes a filter press is used. Once clarified, the oil can be sold directly in the market as cooking oil without further chemical refining.

The main equipment used in a small HOID processing plant are as follows: a) hammer mill or grater - this is used to cut the fresh coconut kernels. In some areas in Indonesia, the kernel is grated; b) drying pans-either circular or rectangular in shape. These pans are equipped with wooden stirrers and spoons for removing out the dried meat manually, c) furnace - is used to heat the pans by burning the wood, coconut shell or husk in the combustion chamber; d) screw press - this is used to extract oil from cooked, brown coconut meat; e) filter press or setting tank; and f) a draining tank and other handling equipment such as scooper, tray, metal and rattan baskets.

The viability of the process is most sensitive to the price of the raw material, price of oil and the oil yield. Thus, it is important that the plant must be designed and operated to minimise oil losses and maximise returns from efficient operation of the whole system. The viability of the process is also dependent on the site.

Ram Press Coconut Oil Extraction

Ram press coconut oil extraction is a method of expelling oil from dried coconut either in the form of dried fresh coconut gratings, copra or dried residue from aqueous coconut processes.

The ram press also called the Bielenberg press was developed by the Appropriate Technology International, a Washington based NGO, in 1985 through its Village Oil Press Project in Tanzania. It is manually operated, low-cost piece of equipment which was originally designed to be used by smallholder farmers to process soft-shelled sunflower seed to obtain scarce cooking oil. The original design of the Ram Press was arduous to use and took two men to operate.

Recently, the Natural Resources Institute (NRI) of the UK has carried out some work on improving small scale coconut oil extraction methods using the participatory approach, particularly involving women in the rural areas in Asia, the Pacific and Africa. One of the design advancements of the Ram Press is a version that is smaller and easily operated by a woman.

The newly designed Ram Press has a long, pivoted lever which moves a piston backwards and forwards inside a cylindrical cage constructed from metal bars spaced to allow the passage of oil. At the end of the piston's stroke an entry port from the feed hopper is opened so that the oilseed or the squeezed coconut gratings (called chicha in Tanzania) can enter the cage. When the piston is moved forward, the entry port is closed and the chicha is compressed in the cage. (See Figure 14, 15 and 16).

Figure 14: Villager Using the Traditional Coconut Grater in Tanzania

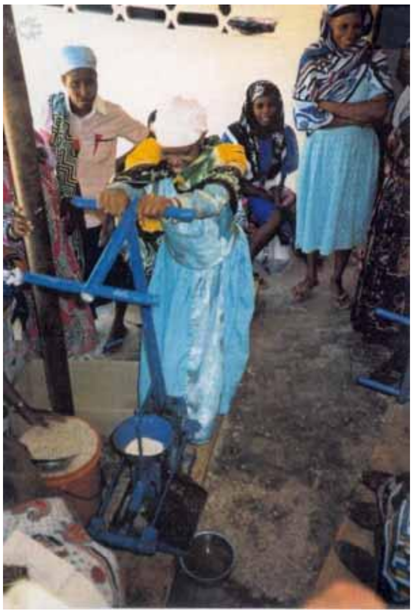

Figure 16: Ram Press Operated by Women in Zanzibar


Figure 15: Rotary Coconut Grater

The compressed chichi is pushed through a circular gap at the end of the cage. The width of this gap, which can be varied using an adjustable choke, controls the operating pressure of the press. The lever mechanism of the press is such that it can operate pressures greater than those obtained in most manually-operated presses, and as high as those in small-scale expellers. While the Ram Press has a low seed throughput, it has the advantage of continuous operation.

Laboratory and field trials conducted by the NRI in Tanzania indicated that the Ram Press was suitable for pressing sundried squeezed coconut gratings or chicha. The oil extraction efficiency achieved was 60-70 percent. Although more arduous to use when processing chicha than when processing sunflower seed, women users in the villages of Zanzibar found that the ram press is easy to operate, especially when several changes in operation were made.

Desiccated Coconut

Desiccated coconut is the dehydrated, shredded white kernel of the coconut. It is produced from fully ripe coconut kernel under strict hygienic conditions for human consumption. It is used both in household foods and processed foods particularly in ready-to-cook mixes and in packaged and canned foods. In the bakery and confectionery industries desiccated coconut is a preferred product. Nutritionally desiccated coconut is not different from fresh coconut kernel. It retains all the characteristic features of the wet kernel including the original nutrients. Good desiccated coconut is crisp, snow white in colour with a sweet, pleasant and fresh taste of the wet kernel.

The production of desiccated coconut involves dehiscing of fully matured coconut. This involves detailing without breaking the kernel, removing the brown test and slicing the pared kernel into two halves to release the nut water. Next comes washing and sterilising the kernel pieces either by passing them through boiling water or subjecting the pieces to live steam. Stabilising the sterilised kernel pieces is done by immersion in a solution of sulphur dioxide. Finally the kernel is disintegrated or shredded into standard or fancy cuts. The final stage the kernel is dried, cooled, graded and packaged in moisture and odour proof containers. In the desiccating process the wet kernel is shredded into nine different cuts. These cuts are grouped under three broad categories such as granular cuts, shred cuts and speciality cuts. The cuts are further processed at the destinations to satisfy specified end use requirements. The more common products so produced are (1) sweetened coconut (2) toasted coconut (3) coloured coconut and (4) creamed coconut. The proximate composition of selected types of desiccated coconut is given in Table 7.

Table 7: Proximate Composition (in percent) of Selected Types of Desiccated Coconut

Component	Desiccated	Sweetened	Toasted
Moisture	2.50	11.50	0.50
Fat	66.00	39.00	46.50
Non-fat solids	31.50	20.00	22.50
Added sugars	-	27.00	30.00
Propylene glycol	-	2.00	-
Salt	-	0.50	0.50

Source: Franklin Baker (1971)

1.4 Secondary and derived product

In major coconut producing countries, several products and by-products are processed for export. They are coconut fibre: coir and coir products, mats, mattings, brushes, brooms, rubberized coir mattresses; shell products: charcoal, activated carbon; coconut-based food products: coconut milk, cream, nata de coco, coconut jam, young tender coconut. For coconut-based oleochemicals including fatty alcohol, fatty acids, methyl esters, tertiry amines, alkanolamides and glycerine there has been a growing demand in the world market

Today, technologies exist for many other value-added products from the coconut tree, its fruit as well as the wastes generated. These technologies are not centred in any one country but are scattered across the major coconut growing regions.

Coconut food processing technologies that are adaptable by individuals or groups of coconut farmers will be featured here. These coconut-based technologies require very simple locally available materials, and their operation is quite easy to follow. The coconut-based products that are derived from these technologies may be consumed by the farming family or sold in the domestic market. Thus, adding value to the coconut, and enabling the farming family to earn additional income. These technologies include a) Coconut Vinegar Making; b) Moulded Coconut Sugar; c) Coconut Jam; and d) Nata de coco; e) Soap making; f) Coconut Shell Charcoal Making; and g) Coconut Fibre Products.

Coconut Water-Vinegar

Coconut water vinegar is a natural product resulting from the alcoholic and acetos fermentation of sugar-enriched coconut water. It contains 3-4 percent acetic acid and is used as an indispensable commodity in any household.

Vinegar derived from fermenting coconut water can be produced either on a commercial scale or as a village cottage industry. As a non-synthetic food product, coco water vinegar is widely preferred as table seasoning, or as ingredient in food processing.

Cocoa water vinegar is processed by allowing filtered coconut water, mixed with other substances, to undergo fermentation and acetification at ambient temperature (28-32^oC). The first step of the process is done by straining the coconut water through filter cloth. The sugar content of coco water is then adjusted to 15 degrees Brix (162 grams per liter) by adding refined sugar into it. The mixture is pasteurised by heating to boiling point. The boiled mixture is then cooled and inoculated with the active dry yeast at one-half gram per litre. The mixture is then allowed to undergo alcoholic fermentation for five to seven days. After the fermentation process, alcoholic coconut water is then transferred to another container with a faucet at its bottom. Mother vinegar or a starter culture is then added to about 1/4 its volume. The container is only filled up to 3/4 its capacity to provide headspace for effective acetic acid fermentation. The mixture is then stirred thoroughly, covered with clean cloth and allowed to undergo acetification for seven days.

The coco water vinegar is harvested by opening the faucet or by siphoning. The amount of vinegar harvested is equivalent to the amount of alcoholic coconut water added. The remaining vinegar will then serve as the starter for the next batch of alcoholic coconut water acidification. Since the process involves fermentation care must be taken to ensure that all fermentation containers are either made of plastic or stainless steel.

The process produces a natural product, which is highly acceptable, based on flavour, aroma and general acceptability. It contains 4.0 percent acetic acid, which conforms to the Food and Drug Administration requirements.

The technology is simple, economic and an accelerated method of coconut water vinegar production. It can be easily adopted in the rural areas since no sophisticated equipment is needed and very little capital investment is required.

The utilisation of coconut water which is considered a waste material in copra making or in desiccated coconut factories will certainly give an added income to the rural families in the coconut farming communities. It will provide productive use of the time and employment to the women in the coconut countryside.

Toddy Vinegar

When the coconut inflorescence is tapped, a very sweet juice or sap exudes from it. This is called coconut toddy in Malaysia, Sri Lanka, India and other countries. The coconut toddy contains as high as 16 percent sucrose and can be had throughout the year.

A characteristic of coconut sap is its spontaneous and rapid fermentation. No yeast is needed since there is a ready source of very active "wild" yeast in the environment. The coconut sap starts alcoholic fermentation right away and becomes completely fermented within a day.

Fresh coconut toddy can be used as a beverage. However, it becomes unpalatable if allowed to ferment for more than 24 hours. After this period, acetic fermentation converts the alcohol into vinegar. In the traditional method of vinegar production, toddy is allowed to ferment in large acetifying vats for 10 to 14 weeks. When the vinegar reaches the maximum strength of about 4 to 7 percent acetic acid, the clear supernatant liquid or vinegar is then transferred to closed casks for ageing up to six months. The aged vinegar is then bottled for household or commercial purposes.

Alcoholic Beverages from Coconut Sap

Sweet toddy or fresh sap undergoes spontaneous fermentation producing a common alcoholic drink `fermented toddy'. The toddy becomes stale when the fermentation exceeds 24 hours. Normally, the toddy is consumed within 12 hours after the sap is collected. The nutritional value of toddy for thiamine and riboflavin resides mainly in the yeast-free fluid portion. Toddy also contains small amounts of protein, fat and other nutrients.

Fermented toddy on distillation yields a strong alcoholic drink known as arrack or lambanog. (See Figure 17). The range of recovery is 15-18 per cent of the original toddy. Normally, sweet toddy is allowed to undergo fermentation in loosely covered wooden or plastic container for 3-5 days before it is distilled. Reports revealed that analysed, samples of arrack collected from several location had average value of total soluble solids of (^{o}Brix) 13.52, a pH of 3.92 and alcohol content of 42.65 (Vol. percent).

Figure 17: Arrack and Lambanog

Home-Made Moulded Coconut Sugar

Moulded coconut sugar is edible sugar made from fresh coconut sap. Produced by small-scale cottage industries, moulded coconut sugar is used for edible purposes essentially as a sweetening agent in many traditional food preparations and food products especially in Indonesia. The concentration of total sugars in moulded coconut sugar is 80 percent total soluble solids. (See Figure 18).

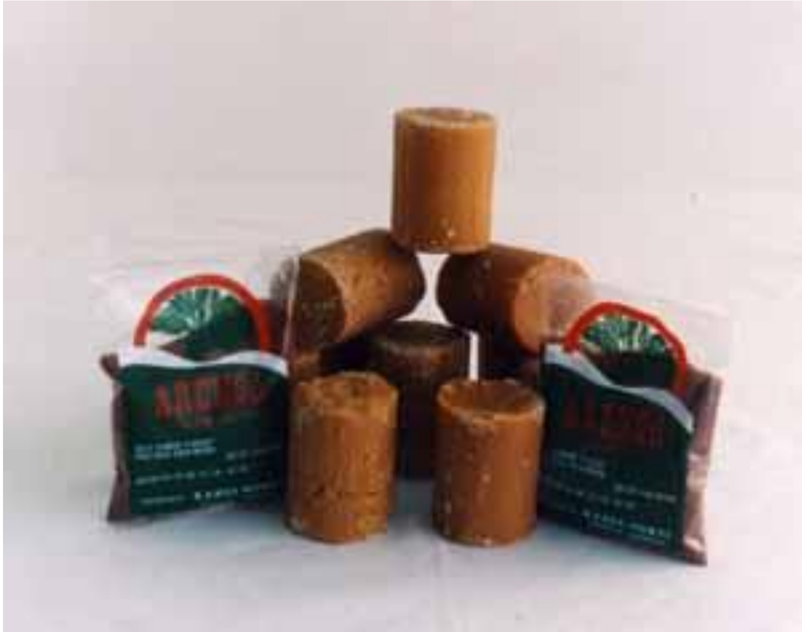

Figure 18: Moulded coconut sugar

The process of producing moulded coconut sugar starts from tapping or collection of coconut sap. But before this is done, the collection vessels are first washed with clean water, followed with hot water and then dried. Alternatively, the clean vessels are smoked using firewood for 10-15 minutes. The treatments are used to reduce microbial loads of vessels.

To prevent spoilage of sap during tapping, the collection vessels are added with tablespoon in the form of paste, a few pieces of mangosteen bark or other natural preservatives such as special varieties of leaves. Once treated, the collection vessels are then ready to be used for tapping the coconut sap.

Collection of coconut sap from the palm is done twice a day at 6 to 7 in the morning and at 4 to 5 in the evening. Although it is not a common practice by home processors, it is desired that the collected sap be tested for acidity using a pH indicator paper. This is because the fermented or spoiled coconut palm sap is no longer suitable for brown sugar manufacture.

The collected coconut sap is then filtered through a muslin cloth to remove insects, ants and other contamination. It is then transferred into a cooking vessel.

The next step involves evaporation of water from the sap to increase the concentration of the sap. Thus, the filtered sap is boiled in a cooking vessel at a temperature of 100-110^{o}C for 3 hours. The material will then turn into a thick liquid. During boiling, foam will be formed. This should be discarded from the vessel. A few drops of cooking oil or grated coconut are added to the mash to prevent excessive foam formation.

The mash is heated for another one hour with occasional stirring. To avoid caramelisation of sugars, heating should be done slowly. When the mash has become very thick and suitable for moulding, the cooking vessel is lifted from the stove and cooled to 60^{o}C. The cooled mash is then poured into clean halves coconut shell or bamboo vessels for cooling and setting.

Home-Made Coconut Jam

Referred to as coconut caramel spread (siamu popo) by some South Pacific countries, especially in Samoa, coco jam is actually coconut milk cooked in brown sugar and glucose. Coco jam is the `butter' in many coconut producing countries and it is commonly taken as a spread, biscuit sandwich, pancake syrup, sponge cake filling, doughnut spread, ice cream topping, fruit dessert topping and as marinade syrup for meat. (See Figure 19). The concentration of total sugars in coconut jam is 75-76 percent total soluble solids.

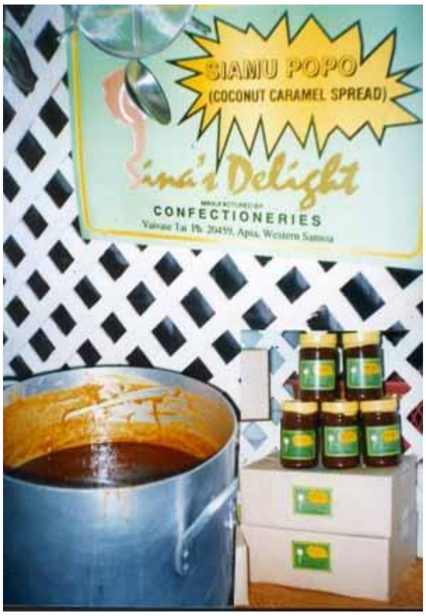

Figure 19: Coconut caramel spread (siamu popo)

To produce good quality coconut caramel spread, one starts with choosing 100 fully matured coconuts which are devoid of cracks or any damage. The selected nuts are dehusked, cut into halves and grated immediately. Freshly grated coconut meat has the characteristic coconut smell and must not have any off odour. It is also important that all containers used are thoroughly clean and the working place completely sanitary.

Once the grated coconut is ready, (33.3 kg) coconut milk may then be extracted by adding water in the proportion of 1 part grated coconut to 0.5 part water (if pressing to be done manually). However, no water is needed if pressing is done mechanically.

Strain or filter the coconut milk through cheesecloth to remove any solid particle or foreign matter from the milk. Weigh the coconut milk (12 kg) and determine the amount of brown sugar (2.13 kg) and glucose (1.06 kg) needed. Mix the sugar the glucose with one-half of the total volume of the coconut milk and boil slowly to dissolve the brown sugar and the glucose. Stir continuously for about 10 minutes and maintain the cooking temperature at about 78-80 degrees C.

Add the remaining half of the coconut milk extract when almost thick and boil for another 35 minutes until the temperature reaches to 100-102 degrees C. Stir the mixture frequently or almost continuously to prevent burning continue to boil until done. The end point is reached when a drop of the mixture forms a soft ball in cold water. Strain the cooked mixture through a clean wire mesh and pack while hot. Packing is best done using clean and sterilised bottles for longer shelf life. Cool the bottles, label and seal.

Nata-de-Coco Production

Nata de Coco is a white, gelatinous food product obtained from the action of micro- organism Acetobacter xylinum on coconut water or coconut milk mixed with water, sugar and acetic acid. Quality nata is smooth, clear and chewy. It is sweetened by boiling it in sugar-water solution.

Nata de Coco is popular primarily for its food uses. It can be sweetened as desserts or candies. It is an excellent ingredient for sweet fruit salads, pickles, fruit cocktails, drinks, ice cream, sherbets and other recipes. Nata de coco also has some industrial uses.

The process flow in the production of nata de coco is:

1. Preparation of ingredients - Measure all ingredients in the formulation, properly from the 28 litres of tap water, get approximately 3 litres for dissolving sugar and 2 litres for extracting the coconut milk from the freshly grated coconut meat.

2. Milk extraction: Place the coconut meat in the basin and add half of the water set aside for extraction. Mix thoroughly and squeeze grated meat in water. Filter through a piece of cheesecloth. Repeat extraction using the remaining water and filter. Add second extract to the first.

3. Filtration of dissolved sugar: Filter dissolved sugar to remove impurities that might have entered accidentally into the sugar in stock.

4. Mixing: To the remaining 23 litres of water, add the extracted coconut milk, dissolved sugar, glacial acetic acid and mother liquor. Stir thoroughly with a wooden ladle to get a homogenous mixture. Set aside a small portion as mother liquor for the next mixing.

5. Filling: Distribute the rest of the mixture into nata moulders at a level of approximately 3 centimetres high.

6. Fermentation: Arrange the nata moulders in the nata fermentation room. Cover with newspapers or similar materials. To maximise space, nata moulders can be placed one on top of the other to obtain several layers. Fermentation is completed after 8-10 days, depending on environmental conditions. Optimum temperature for nata production is between 23-32^{o}C.

7. Harvesting: Harvest by separating nata from the spent liquor.

8. Scraping: Clean nata by scraping the cream and the thin, white layer at the bottom part using a blunt piece of plastic or bamboo.

9. Soaking: Place clean nata in a plastic container and keep immersed in water.

10. Syrup of Nata de Coco: To cook nata de coco in syrup, cut clean nata into cubes approximately 1 cm3 or according to the customer specifications. Soak the nata for one or more days in several changes of water to remove the sour taste and smell. Drain the nata and boil in water for 5 to 10 minutes. Check if acid is totally removed.

Add sugar equal to the weight of drained nata. Mix thoroughly and set aside overnight. The next day, stir the mixture to disperse any undissolved sugar. Add a small amount of water. Heat the mixture to boiling point, stirring occasionally. Add flavouring, if desired. Set aside overnight and repeat the heating process until the nata is fully penetrated with sugar as evidenced by the clear and crystalline appearance of the sweetened nata.

Pack the sweetened nata 2/3 full into sterilised preserving jars. Add syrup leaving a 1/4 inch air space. Cover jar immediately with PVC lined caps. Sterilised bottled nata by immersing in boiling water for 30 minutes.

Remove bottled nata and tighten the caps. Cool the jars in inverted position to further sterilise the caps and check for leakage. Wash cooled jars and wipe them thoroughly, place plastic seal and label. Store in cool dry place.

Soap Making

Mixing oil with a solution of caustic soda in water makes soap. When the caustic soda is mixed with oil, a chemical reaction occurs and all the component fatty acids of the oil are changed into sodium salts, known familiarly as "soap".

The oil, caustic soda and water used to make the soap have to be mixed together in correct proportions to ensure that the finished soap contains no excess alkaline which would cause a burning reaction on the skin. The oils used for soap making fall into two categories. In the first category are oils that are obtained from the kernels of different types of palms. The most commonly known oils in this category are coconut oil and palm kernel oil. They are known are "lauric oils" because lauric acid is the major fatty acid that they contain. These fats make hard soap which produces fast foaming lather.

To make soap by the cold process follow the following steps. Weigh one kilo of NaOH and two kilos of water, and pour the NaOH flakes in water and stir constantly until dissolved. Avoid inhaling the vapour over the solution as the mixture will become very hot and. Set aside for cooling to a temperature of about 96^{o}F.

Prepare six kilos of coconut oil and slowly pour this into the caustic soda solution, while constantly stirring the mixture in one direction. The mixture is kept stirred until it thickens to a desired consistency, approximately after 40 minutes to 1.75 hours. Add any desired colour or essence. Stir and immediately pour into moulders and leave for about 24 hours for saponification.

Cut into desired sizes and dry or age for at least one week to complete the chemical reaction. Wrap if required and use the soap only after one week of ageing.

Coconut Shell Charcoal Making

Charcoal making is based on the principle that coconut shell, wood and other carbonaceous materials can be converted into charcoal by incomplete burning. Limiting the amount of air used during the burning process produces incomplete burning. Thus, the quantity and quality of charcoal depend largely on how well the amount of air is regulated in the charcoal chamber.

Charcoal making started with simple methods such as those employed in the backyard to make charcoal for household use. As demand increased, more sophisticated methods were developed to produce charcoal in commercial scale. Today, small backyard and commercial kilns are being used.

The two types of kiln used in charcoal making are the primitive or modified pit and the drum.

Primitive or modified pit - A simple pit is dug in the ground just enough to accommodate the desired number of coconut shells to be made into charcoal. The process mainly involves simple drying of coconut shells arranged in the hole and burned. Some farmers cover the pit from time to time while the shells burn. To control the fire, sprinkle the flame with enough water so as to put the fire totally out. The charcoal produced out of the modified pit method is suitable only for household use due to its poor quality.

-Drum - A 55-gal drum open on one end, and punched with four holes at the bottom is used in this method. This is then raised from the ground by two pipes to allow air entry through the holes. As a starter, remove the cover from the drum, place and burn a shovel full of shells on it. When already burning strongly, throw the shells into the drum. Throw in just enough fresh shells to put the flames but not the fire. Feed shells continuously at the top to assure that they will not burn fiercely. Slow burning gives the highest charcoal yield and the least ash. When burning reaches the top pile of shells, cover the drum with banana stalks or wet sack plastered with sand or mud. Never allow sand or mud to get inside the drum. The charcoal-filled drum should be left to cool overnight. It takes about for hours of shell burning to fill one drum. When properly attended to, one drum can yield 75-90 kg charcoal. Generally, it takes 3 tons of shells to make 1 ton of charcoal.

Uses of Coconut Shell Charcoal Activated Carbon:

Activated carbon from coconut shell charcoal is a manufactured carbonaceous material having a porous structure and a large internal surface area. It can absorb a wide variety of substances. Activated carbon particles are capable of attracting molecules to their internal surface area and are therefore called adsorbents.

The main characteristic of activated carbon is the extent of their internal pores. Among other products with internal pores used as adsorbents on a commercial scale are silica gel, zeolites, alumina and molecular sieves. The main difference between these adsorbents and activated carbon is the ability of activated carbon to adsorb an extremely wide spectrum of adsorbates. This is because activated carbon has different types and/or sizes of pores.

Generally, coconut shell charcoal-based activated carbon is microporous and depending on the size of the pores predominant, it will exhibit affinities for molecules of different sizes. Activated carbon is used for a wide array of purposes which include water, air and food purification; solvent recovery, pharmaceutical industry and catalyst support. The examples of use of coconut shell charcoal activated carbon in air purification are their uses in gas masks, cooker hoods and other filters.

Other uses of coconut shells

Coconut shell is exploited in small-scale industries, e.g. manufacture of novelties. It has been in demand when ground into a "flour" for mosquito coils (insect repellent) and as filler for articles made of synthetic resin-plastics. With the present shortage of fuels, the shell itself and the charcoal made from it are gradually taking the place of liquefied petroleum gas (LPG) for home cooking.

Coconut Fibre Products

Coconut husk is the raw material for the coir industry. (See Figure 20A). The coir fibre is extracted either by natural retting (microbiological process) or mechanical means.

Figure 20a: Mechanical extraction of the coconut husk

Roughly 10 percent of the global annual production of coconut husks is used to extract coir fibre resulting in 480,000 M.T. of coir approximately. An average of 100,000 tons of this total production (21 percent) enters into the world trade. Majority of exports take the form of fibre that is then processed in consuming countries. Coir product exports take the form mainly of mats, matting, brushes and a very small quantity of needled felt and rubberised coir.

Extraction Process of Coconut Fibre

There are two distinct varieties of coir fibre, white fibre and brown fibre. The fibre extracted from green coconut husk by the natural retting process is known as "white fibre" whereas fibre extracted mechanically from dry coconut husk is "brown fibre".

Retting of coconut husk for the production of white fibre is biological process which softens the husks paving way for easy extraction of fibre manually by beating with wooden mallets. (See Figure 21). It is normally done in the saline back waters that are bestowed with a gentle natural tidal action. There are three process of retting: Net retting, Pit retting and Stake retting. In the areas where very good quality fibre is produced, Net retting is practised. In this process, the husks are filled inside a net made out of coir yarn and toyed to the retting field. The bundles are then weighed down using mud. Stake retting is practised where there is a heavy current and fear of husks being washed off. In this method, husks are filled in the enclosures made out of bamboo stakes and covered with mud. In Pit retting, the bottom of the pits are covered with mud and sides with plated coconut leaves or coir yarn nets. The entire pit or nets are filled with fully matured green husk. The bundles are piled appropriately in such a manner and they are not disrupted and left for a period varying from 4-12 months. After about 4 weeks of soaking the water gets warm up, becomes cloudy and yellowish white covering is formed on the surface. Exhale of gas bubbles is observed with the smell of hydrogen sulphide which subsides after a period of approximately 4 months. The retted husks are taken out from the soaking pits and beaten manually by wooden mallets to separate the fibre from the embedded pith. The extracted fibre is cleaned properly and dried under shade for further processing. (See Figure 22). The fibre is graded in accordance with its colour, length of fibre and other factors. Women of coconut farming families are greatly involved in these activities.

Figure 21: Manual extraction of coco fibre by beating with wooden malletsk

Figure 22: Flow Chart of Processing in the Production of Coir

Coconut Palm

Plucking of Coconut

Dehusking

Green Husks Dry Husk

Natural Retting Crushing

Manual Extraction Soaking
of White Fibre
Mechanical Extraction
Spinning of Different
Types of Yarn/Rope Decortation Defibering

Decorticated Bristle Mattress
Weaving Coir Mats, Fibre Fibre Fibre
Mattings, Carpets, Ropes

Curled Coir Curled Coir
Rubberised Coir
Needled Felt

1.5 Requirements for Export and Quality Assurance

Export of coconut oil and copra are governed by the standards of the National Institute of Oilseed Production (NIOP), the Federation of Oilseed, Fats and Oils (FOSFA) and the Asean Vegetable Oil Club (AVOC). For aqueous coconut products, the Asian and Pacific Coconut Community (APCC) formulated a set of standards which its member countries have accepted as reference material. Trade in other products are conducted on terms mutually agreed by buyer and seller. Export of copra and copra meal to EU is governed by the regulations formulated in 1991 which set the limit for aflatoxin.

Copra Classification Standards

The oil content, the colour and appearance, and the moisture content are variable. These characteristics are demonstrated in the grades and standards used for copra.

In the Philippines there are four recognised classes of copra designated A, B, C and D. The classification is based on the method of drying. Under each class are seven grades, from 1 to 7, based on moisture content. The classes are given in Table 3 and the grades in Table 4. These tables show the 3 types of copra drying in existence: sun drying, smoked tapahan drying and hot air drying. It is also indicates among the grades, as high as 22 percent moisture content (Corriente) is traded. The best grade copra contains no more than 6 percent moisture.

Table 3: Quality Standard for Copra in the Philippines: Classes of Copra (Based on Method of Drying and Appearance)

Class	Name/Designation	Requirement (Appearance)
A.	Hot air, kiln or mechanically dried	Clean, whitish or pale; free of smoke, moulds and dirt
B.	Sun dried	Dull white; low in dirt, mould and decay; free of smoke
C.	Smoked or tapahan	Tinged with soot; low in mould, dirt a decay; not unduly charred or burned
D.	Mixed	Low in mould, dirt, soot and decay

It must be noted however, that trading of copra is essentially based on moisture content. In the Philippines where roughly 90-95 percent of total production is sold to the village trader, copra with 20-25 percent moisture content are bought at a discounted price. This is referred to as the "pasa system" of copra buying where a discount on the copra price is based on moisture. Thus, copra is classified according to its moisture content even at the first point of sale. (See Table 4). Since moisture meters are not readily available in the villages, moisture content determination is done visually or by cracking or splitting the copra by hand and feeling. Experienced and highly skilled copra buyers do this.

Table 4: Grades of Copra Used in the Philippines (Based on Moisture Content)

Grade	Name/Designation	Moisture Content	Requirements
1	Resecada Bodega	6.0 percent	Free from noticeable mixture of copra from unripened nuts
2	Resecada	7.5 percent	Free from noticeable mixture of foreign materials
3	Semi-Resecada	9.0 percent	Free from noticeable mixture of foreign matter
4	Buen Corriente Mejorado	12.0 percent	Reasonably free of vermin
5	Buen Corriente	15.0 percent	Reasonably free of weevils and other insects
6	Corriente Mejorado	20.0 percent	No objectionable odour or putrefaction
7	Corriente	22.0 percent	No objectionable odour or putrefaction

In India standard contract terms for milling copra were specified in as early as 1949. Since then, these form the basis of transactions in the domestic market. The terms apply to sundried and smoke dried copra, but the smoked copra cannot be tendered against a contract for sundried copra. The following are the details of contract terms for milling copra.

Table 5. Contract Terms for Trading Copra in India
Based on Moisture Content and Appearance

1. Moisture	Basis 6 percent	- with mutual allowance
	Below 6 to 5 percent	-allowance to seller equal to 1.5 times less moisture
	Below 5 percent	-allowance to seller at the rate of 1.25 percent for every 1 percent less of moisture
	Over 6 to 8 percent	-rebate to buyer equal to 1.25 times the excess
	Over 10 percent	-rejection at buyer's option
2. Dirt and Foreign Matter	Basis 0.5 percent	- with mutual allowance
	Below 0.5 percent	- proportionate allowance to seller
	Over 0.5 to 2.0 percent	- rebate to buyer equal to 1.25 times the excess
	Over 2.0 percent	- rejection at buyer's option
3. Mouldy	5 percent free	

In Papua New Guinea (PNG), copra intended for export is classified into the following grades (See Table 6.).

Table 6: Copra Classification in Papua New Guinea

Grade	General Appearance
A. (Hot-Air Dried Copra)	Clean; of good colour; free from smoke, excess mould or insect infestation, charred pieces or foreign matter; free from an unreasonable admixture of copra from germinated nuts; not exceeding 6 percent moisture content (MC) ; not exceeding 3 percent free fatty acid (FFA) content.
C. (Smoke Dried Copra)	Clean and of uniform colour, not burned or tarry; free from excess mould or insect infestation, charred pieces or foreign matter; free from an unreasonable admixture of copra from germinated nuts; not exceeding 6 percent MC; not exceeding 3 percent FFA.
D. (Mixed Copra)	Copra of exportable quality which cannot be reconditioned to a higher grade; not exceeding 7 percent MC and not exceeding 4 percent FFA.

2. Post-Production Operations

Bearing coconut palms produce nuts throughout the year, although yields may vary with the season. A normal-bearing, adult palm produces at least one matured ready-to-harvest bunch of coconuts every month. Depending on the variety, the number of nuts per bunch can vary from 5 to 15. The theoretical number of bunches per palm that can be harvested annually is about 14 from tall coconut varieties and 16 from the dwarf species.

2.1 Pre-Harvest Operations

It usually takes 12 months for a nut to mature from pollination to harvest. Husk colour is the best indicator of coconut maturity. To attain good quality products, it is advisable that coconuts be harvested at the right maturity. Thus, only nuts that are partially or completely brown should be harvested. Nuts harvested at the tenth month or colour-break stage, should be stored or seasoned for some time to increase copra and oil yield.

To obtain maximum copra and oil recovery, nuts must be harvested when fully ripe. At this age of maturity, the estimated age is from 11 to 12 months. Although this stage is ideal for copra-production, in practice, green and immature nuts (about ten months old) are sometimes included during harvest especially as harvesters are paid on a per nut basis in certain countries.

Immature nuts when converted into copra will produce rubbery copra with low oil recovery. Rubbery copra is also susceptible to insect and mould attack due to its high moisture content. Immature nuts should therefore be segregated for seasoning for about two to four weeks. Seasoning is done under a shed, preferably with a concrete or wooden floor.

2.2 Harvesting

In practice, the harvesting cycle varies from 45 to 60 or 90-day periods. However, considering the hired labour cost, the recommended harvesting cycle is every 45 days for practical and economic reasons. Two to three bunches of coconuts could be harvested from each palm if this cycle is followed. This harvesting cycle has been found to yield a good number of mature nuts with high copra and oil recovery.

2.2.1 Methods of Harvesting

The methods of harvesting coconuts vary among countries or even among provinces within the same country. Producers from certain countries, especially in the Pacific, do not harvest their coconuts. Mature nuts are just left to fall on the ground and gathered by the farmer or the members of the farming family at regular intervals.

There are two common methods of harvesting coconuts. These are the pole and the climbing method. A third method is only practised in Thailand, Malaysia and Indonesia. This procedure involves harvesting of mature coconuts using of trained monkeys.

The pole method of harvesting is common in many countries in the region. In this case a harvesting scythe attached to the end of a long bamboo pole is used. (See Figure 3).

Figure 3: Climbing Method of Harvesting Products Coconut

The palm-climbing device is useful and advantageous for harvesting operations in places where traditional palm climbers are not available. (See Figure 4). The device is more efficient than manual climbing. With its use around 80 trees are harvested a day. There is also no risk of falling from the tree. In research stations and seed farms, the gadget could be useful for breeding purposes.

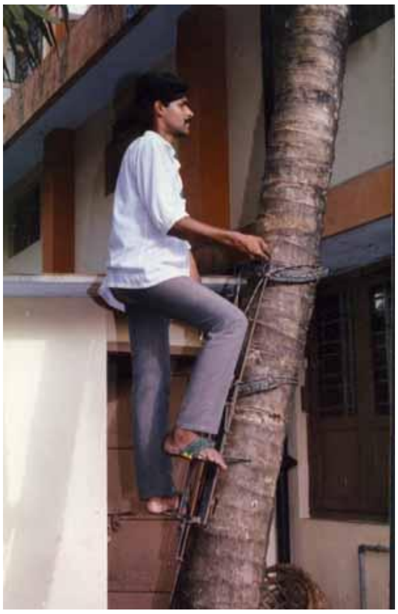

Figure 4: Palm Climbing Device in India

Although both the pole and the climbing method of harvesting require considerable experience and skill to be performed safely and efficiently, each has its own advantages and disadvantages. Harvesting using bamboo poles is generally faster, more efficient, less tedious, and less dangerous when compared with climbing. With bamboo poles, a harvester could also harvest more nuts per unit of time from more trees. On the other hand, the advantage of harvesting by climbing is that the climber/harvester could clean and inspect the crown of the palm for pest and disease attack. However, the cuts made to construct steps in the trunk in certain countries to facilitate climbing make the trees less suitable for timber purposes and fractures serve as entry points for pests.

Harvesting coconuts by using trained monkeys is considered efficient and cost-effective especially in areas where labour has become scarce.

Coconut Dehusking and Splitting

After harvesting, the succeeding operations are collection of the nuts, ripening, and dehusking. Harvested nuts are usually gathered together on a single layer on the ground. If the soil is moist, there is always the tendency for the nuts to germinate. Hence, nuts are not allowed on the damp ground for a long time, but are moved to a drier place. As mentioned earlier, the nuts are kept for about a month to ripen on the ground. This practice promotes desirable changes in the greener or somewhat less mature nuts: the coconut meat is said to grow thicker and harder thus producing a better quality copra if copra is desired, or a more suitable material for desiccated coconut production. Immature nuts tend to produce rubbery copra. Producers claim that seasoning or storage of 10-11 month old green nuts for one month or so improves the coconut kernel. This reduces the tendency to produce rubbery copra. Also dehusking is easier.

Coconuts in the husk are very bulky. They are dehusked first before being transported in trucks or carts.

Dehusking is a manual procedure. The principal part of the dehusker is a sharp-pointed shard of steel (a part of the native plow) positioned vertically with the point up and the broader part firmly placed on the ground. The farmer-operator impales the coconut on the sharp point with a strong determined downward movement. A few impaling strokes loosen the husk, making it come off (usually) in one piece. (See Figure 5). Impaling requires accuracy and nerve. Hence it has been difficult to get dehuskers in countries that are still trying to set up coconut plantations.

Figure 5: Coconut Dehusking Tool

Since dehusked coconut is an important article of commerce locally, husking therefore becomes mandatory. The coconut husks are left with the farmer. In the places where there is a coir fibre industry, the husks may be sold to this industry. Most often the husks are not sold but are used as fuel for drying copra. If little or no copra is made, there is an accumulation of coconut husks.

Since the coconut meat is found well inside the nut and is firmly attached to the shell, certain steps are necessary before drying the coconut kernel.

Nut Splitting

After the coconut is dehusked, the hard but brittle shell is exposed and can be split open into two halves using a machete. The coconut water is drained off leaving the cups ready for the drying stage. The meat is still attached to the shell. During the drying process, the meat shrinks and is easily detached or scooped out from the shell. These cups of coconut meat are then dried further.

Some farmers also practice nut splitting using a heavy machete even without dehusking the coconut. After nut splitting, the water is allowed to drain off. With meat still attached to the shell and the shell to the husk, the halved nuts are dried under direct sunlight. During the drying process the meat becomes detached or is scooped out from the shell with a scooping knife. The cups of meat are then further dried into copra.

2.3 Copra Processing

Copra is produced after drying the coconut kernel. Copra and the coconut oil as well as the cake derived from it are a major source of foreign exchange for many coconut growing countries in Asia, the Pacific, and Africa.

The quality of copra and copra cake is influenced by the method and the manner of drying the coconut kernel. Improperly dried copra gives rise to certain moulds, the most harmful of which is the yellow green mould called *Aspergillus flavus* and other aflatoxin related moulds. Aflatoxin is harmful both for man and animals.

It is therefore extremely important that the coconut kernel be properly dried to prevent the attack of aflatoxin related moulds. Processing of mature nuts to copra has several problems. Improper processing results in low oil yield and incidence of aflatoxin. Proper post-harvest practices, as well as proper drying and storage can increase the oil yield to about 20 percent. Proper drying of coconut results in copra with lower moisture content and lower incidence of aflatoxin.

Copra is mainly produced by small coconut holders using sun drying or smoke-kiln methods. Hot-air dryers are also used to a limited extent.

Copra making involves different steps between harvesting and marketing of the produce. Of these, drying the coconut kernel or reducing its moisture content from 50 percent to 6 percent most influences the quality of the product.

The following are ten guidelines for producing aflatoxin-free copra:

1) Harvest only fully matured (brown) nuts. These are the 12-month old or older nuts;

2) Do not pay the harvester for immature (green) nuts; instead penalise them for picking green nuts;

3) For producers selling husked nuts to desiccated coconut factories, segregate the "fouls" for processing into copra. Never mix the "regular copra" with the copra from "foul" nuts. They tend to have high mould growth;

4) When preparing copra, split the nuts and expose the meat only when certain that drying can start immediately or within four hours from splitting (exposure) to prevent mould formation. When there is the threat of bad weather, defer nut splitting;

5) If the weather suddenly turns bad during the sun-drying period and is expected to remain so for some time, use of mould inhibitors is recommended;

6) For producers practising sun drying, maintain cleanliness in the drying area. Clean pavement or floors before spreading fresh coconut meat. Make sure that soil and other extraneous matters are not mixed with the meat. Plastic sheeting may be used under the coconut meat to avoid direct contact with the ground;

7) Have on hand a portable cover (plastic sheeting) to protect coconut meat from rain and dew. These are shaped like roofing (inverted Vs) to allow aeration. On extended downpours, heat and dry the copra within 24 hours;

8) Continuous sun drying for four to five days (in good sunlight) shall achieve 6 percent moisture content;

9) For producers using smoke, kiln dryers, and other types of dryers, a drying temperature of $35^{o}C$ to $50^{o}C$ should be maintained for the first 16 hours of drying followed by $50^{o}C$ during the next phase until a final moisture content of 6 percent if reached. It is important that drying should begin four hours after the nuts are split to prevent mould contamination;

10) Pressing the copra between the thumb and forefinger, the thumb against the whitemeat is a quick test for 6 percent moisture content. If the copra kernel (white portion) does not stick to the thumb, and readily drops when released, the 6 percent (approximately) moisture level has been achieved.

2.4 Drying

There are several methods and practices in drying the coconut kernel or in making copra. The methods vary from that which is considered primitive and traditional to one that adheres to certain scientific principles of drying.

The three common methods of drying are: a) sun drying or solar drying; b) kiln drying which is either direct on semi-direct drying; and c) indirect drying using hot-air dryers.

2.4.1 Sun Drying

Where weather conditions permit, sun drying can produce good quality copra. This method is used only during the dry season and when drying only small quantities of nuts. (See Figures 6 and 7).

Figure 6: Sun Drying Copra

Figure 7: Coconut Dehusking Tool

Since sundrying requires no expenses for fuel, the overall drying cost is considerably cheap compared to other copra drying methods using fuel-fed dryers. Fuel saved could mean possible additional farm income when sold or transformed into high value products like coconut shell charcoal, activated carbon, coir, etc., leading to the maximum utilisation of farm resources. Because the dryer is capable of producing clean, white and edible copra, copra produced should command a premium price. Moreover, its adoption could promote a high degree of consciousness in the production of superior quality export products.

2.4.2 Kiln Drying

There are two types of smoke dryers commonly used by coconut farmers, namely: the direct and semidirect types. Primarily, both types have the same heating principle but differ only in design and manner of firing or charging fuel. The direct dryer is designed in such a way that the fire bed is directly located below the copra bed.

On the other hand, the design of semidirect dryer is superior to the direct type. The hearth where fuel charging/feeding is done is located on one side of the dryer, connected to the drying bed by a tunnelike flue.

Direct Smoke Copra Dryer

The direct smoke dryer is a commonly used by coconut farmers in many coconut producing countries in the world. The smoke dryer has a grill-platform usually of split bamboo which constitutes the drying area. Halved nuts in the shell are placed on this grill. Underneath the platform is a fire hearth where coconut shells and husks are burned slowly to provide the heat for vaporising the water from the coconut meat. Generally, there is no chimney. (See Figure 8). The coconut meat shrinks upon drying and may be removed or scooped out from the shell. The meat is then further dried in the smoked dryer.

Figure 8: Direct Smoke Copra Dryer

The basic features which make the direct smoke dryer preferred by farmers are the high thermal efficiency of the dryer (the coconut meat is directly heated), the low cost of construction (the component parts are available on the farm), the simplicity of the design and the low cost of fuel. However, copra produced from this dryer are usually dark, sooty with smoke and at times scorched. Since the fuel is burned inside a pit underneath the drying bed, the dryer has to be attended when it is in operation to prevent the dryer from burning.

Semi-Direct Copra Dryer

It is a simple structural design, cheap and easy to build. The dryer has a combustion pit located about 3 feet away from the drying bed. The hot combustion product is channelled to the drying bed via an underground tunnel. The dimension of the excavation pit is 6 feet in width, 12 feet in length and a depth of 4 feet. The pit floor of the firing chamber is slightly inclined upward toward the end portion, which is designed to direct the flow of heated air. Dry coconut husks are used for fuel. It has a capacity of 2,000 nuts which are dried after 20 to 25 drying hours with resultant moisture of 6 percent. (See Figure 9).

Figure 9: Semi-Direct Smoke Copra Dryer

Due to the ease of structural design and operation, needing only inexpensive and locally available construction materials, this dryer is deemed to be socially adaptable and economically ideal for small coconut farmers. Since the total construction cost is within the reach of small coconut farmers with minimal fuel costs , the over-all production cost per kilo of copra would be much cheaper. Reflecting that fuel consumption per batch is approximately 50 percent of nut capacity, the savings per coconut husk (50 percent) plus coconut shell has a higher commercial value. This would mean additional financial benefits for the coconut farmers.

2.4.3. Copra Drying Using Hot-Air Dryers

In drying copra using hot-air dryers, the coconut meat is dried by means of uncontaminated hot air that passes through the copra bed. Since the smoke does not come in contact with the kernel, the copra produced is clean and white. If properly done, copra-drying using hot-air dryers produces good quality copra with 6 percent moisture content.

There are quite a few hot-air dryer designs. The common ones are a) The Modified Kukum Hot-Air Dryer and b) The Cocopugon or the Brick Hot Air Dryer.

The Modified Kukum Dryer

The Modified Kukum Dryer is an indirect natural draught dryer measuring 1.83 m in width, 3.66 m in length and 2.13 m in height. About 2000 nuts (average size) can be accommodated (volume of drying bed: 2.8 m3). Its heat exchange is made up of three standard oil drums welded together with five semi-circular baffles installed alternately inside the drums at distance of 0.46 m. The furnace measures three feet in length and two feet in width and is made of steel plastered with 6 cm thick cement-ash mixture inside. The furnace is provided with a slanting grate and door to regulate air entry. A butterfly valve is also provided at the chimney to control the temperature. (See Figure 10).

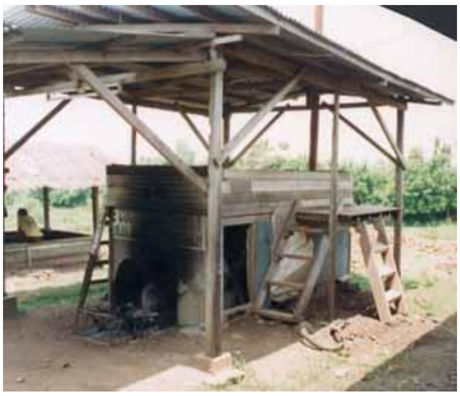

Figure 10: Modified Kukum Hot Air Copra Dryer

About 30 hours are needed to dry one batch to 6 percent moisture content. Based on a 10 hours operation time per day, drying takes three days. About 8.7 minutes are needed to produce one kilo copra with the modified Kukum dryer.The Modified Kukum dryer produces good quality copra. However, maintenance and repair costs are the high. The metal parts of the dryer, which start to corrode as soon as the dryer is being constructed.

Frequent use of the dryer will reduce corrosion, but never stop it. Since copra is a low price product, the use of stainless steel or even the application of primer is not economical. The exposure to high temperatures, aggressive fumes and water induce corrosion of the metal dryer components.

Cocopugon Hot-Air Brick Copra Dryer

The Cocopugon is a further improvement of the modified Kukum Dryer. Instead of using metal drums as the heat exchanger common in Kukum Dryers, the Cocopugon uses bricks. Bricks are known for their high strength, durability and dimensional stability.

The proportions of the Cocopugon are 260 cm in width, 360 cm in length and 200 cm in height. Standard fire bricks and 2.5" crown bricks are used for the chimney and the heat exchanger, respectively. The dryer can accommodate 2,000 average sized nuts per batch (volume of drying bed: 3.33 m3). To facilitate ease of loading and unloading, the right side of the drying bed wall is removable. A one step stair and platform is also provided on the same location. (See Figure 11).

Figure 11: Cocopugon Hot-Air Brick Copra Dryer

Unlike dryers with metal heat exchangers, this dryer needs to be preheated. Firing should be done first before loading the split nuts. The burner can accommodate about 200 to 300 husks. Refuelling has to be done every 3 to 5 hours. The heat stored in the bricks will be released slowly after the last firing on the first drying day, such that drying will continue for several hours without adding fuel (husks). After a preheating time of 3.5 hours and a loading time of two hours, the average temperature in the bottom layer is 66.3ºC.

The burner then has to be fed five to seven times for the whole drying period. Formerly, this could only be accomplished in one day at a feeding interval of about three to four hours assuming a constant fuel feed rate. Unloading could be done after the dryer has cooled down on the second day. If operated on a two days schedule, five firings are needed on the first day and another two to three firings on the second day. Unloading will be done the next morning to utilise the heat stored in the bricks. If the baffle in the chimney is closed during nighttime, embers can still be found inside the burner on the following morning making it easy to continue firing. The temperature curve for the burner has several small peaks indicating the maximum temperature per feeding interval. The effect on the drying bed temperature is minimal, thus having an almost constant drying temperature. Even if the burner is fully loaded, the resulting temperature in the drying bed does not exceed 90 to 95ºC, thus eliminating the risk of producing scorched copra.

Since the heat exchanger or the burner covers almost the whole area inside the dryer body, the temperature distribution is very uniform. The difference in temperature between the highest and lowest value is less than 5º Kelvin. A standard deviation of 3º Kelvin indicates a very constant temperature.

During operation, the dryer operator spends two hours per batch at the dryer, meaning the labour requirements are cut down by more than 50 percent to 4.1 minutes per kilogram copra compared with the modified Kukum dryer. The farmer can therefore leave the dryer in between fuel feedings and use his time for other activities.

3. Overall Losses

Lack of awareness and actual skills on coconut post-harvest technologies have caused significant losses starting from the harvesting of the nuts, seasoning, drying and storage. While wastage and losses occur at different stages, the copra drying stage or the efficiency of the drying process at the farm level is the most critical stage as this affects subsequent losses in terms of product quality and reduced prices.

Harvesting of immature nuts causes the production of rubbery copra with high moisture content. If one allows the nuts to fall naturally, without harvesting or picking the nuts from the tree, the losses due to over-ripe nuts or germinated nuts are likely to occur. This could be as high as 10 percent of the total harvest especially with varieties that are early germinating. As the growing embryo utilises the stored food in the endosperm, the copra produced from germinated nuts would be thinner, lighter and with lower oil content. Losses due to pilferage and losses due to nuts that are hidden or covered by thick weeds or shrubs could also range from 5 to 10 percent of the total harvest if one does not regularly harvest his coconuts. To avoid these losses, it is recommended that the 45-day cycle of coconut harvesting be adopted. Seasoning of unripe nuts for 2-4 weeks should also be practised. Farm sanitation, e.g. weeding of thick shrubs and grasses in the spaces between coconut palms is highly recommended to prevent losses due to uncollected nuts.

As mentioned earlier, major post harvest losses are caused by improper drying of copra as a result of a lack of know-how on the proper drying technology and the lack of incentives to adopt the recommended copra dryers and the appropriate copra drying methods. Improperly dried copra or copra with high moisture content are prone to aflatoxin contamination.

Coconut researchers have also identified beetles, cockroach, a moth and an earwig to be associated with deteriorating copra and copra cake. Studies reveal that after one year of storage, copra weight loss due to pests be as high as 5 to 10 percent. Spraying of suitable insecticides may be done but this is not practised due to its prohibitive cost. Sanitary practices in the copra warehouse are the best recommended alternative to control these pests. Generally, these pests are considered a minor problem when compared to the attack of aflatoxin-related moulds or fungi.

Other factors cited to contribute to copra/copra cake deterioration are presence of wet or improperly dried copra, rubbery copra, delays in transport, long storage period, and unsanitary conditions in the farms and warehouse. Long storage time also favours the breeding of copra pests or the proliferation of aflatoxin related moulds.

4. Economic and Social Considerations

Coconut is a subsistent crop which has provided the basic needs of a number of countries in the tropics for centuries. With the use of coconut oil in the production of soap and margarine in Europe in the 19^{th} century, it was converted into a commercial crop. In the beginning of 20^{th} century copra was the king among the oil seeds. In East Indies it was known as green gold.

However the period after the Second World War saw the substitution of vegetable oils and oleochemicals for coconut oil in international trade. The increase in the output of coconut was marginal. Price of coconut oil fluctuated heavily due to frequent short supply situations. A campaign against coconut oil alleging that it causes cardiovascular diseases aggravated the situation.

With the depressed price of coconut oil, coconut-producing countries have now moved from traditional products to the processing of value added products. Consequently, recent years have seen coconut oil being further processed to produce coco-chemicals. Export of coconut shell charcoal and activated carbon is on the increase though in small quantities; products like coconut cream, nata de coco, fibre dust, coconut powder, coconut water, geo-textiles are finding their way into the international market.

Another interesting feature that is becoming evident increasingly is the shift of the foreign markets from the traditional base to new areas. The newly industrialised countries in the East as Taiwan, South Korea are fast emerging as key importers of coconut products.

The medical and other evidence that came to light in the last few years in defence of coconut oil has cleared the misconception and misinformation about it.

Coconut products are also drawing attention as environmentally friendly. Research carried out has proved the adaptability of coconut oil as biodiesel. Coir is an excellent natural fibre which is strong, durable and biodegradable. Coir geotextiles are now becoming popular and is being used increasingly for erosion control particularly where land, bank reinforcements is required as well as for landscaping. Coconut shell which is a major by product of coconut industry finds important uses in daily life in place of non-biodegradable plastic containers. Activated carbon produced out of cocoshell charcoal is used for water purification, air purification and food purification. Fibre dust briquettes have found a place as a soil reconditioner and a suitable nutrient for landscaping and an ideal ready made potting mixture. Coco peat a hundred per cent renewable resource is now replacing bog peat, depletion of which environmentalist feel would destroy land forms, habitat of some unique fauna and flora in the U.K. Coconut water is a safe drink in the world unadulterated and untouched by human hands. Cocowood is a renewable resource and an answer to depleting forests reserves. Coco shell, husk, trunk, coir dust, fronds are energy sources.

Coconut is a smallholder crop and millions of rural people depend on it for survival. Its development particularly in post harvest activities could be the base for rural development in the coconut producing countries.

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6. Annex

6.1 List of Tables

6.2 List of Figures