Processing Manual for Virgin Coconut Oil, its Products and By-products for Pacific Island Countries and Territories

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Processing Manual for Virgin Coconut Oil, its Products and By-products for Pacific Island Countries and Territories

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PREFACE

Virgin coconut oil (VCO) is the purest form of coconut oil. Introduced onto the world market at the end of the 20th century, it is one of the highest value products derived from the fresh coconut. From a much maligned substance in the 1970s and 1980s — the American Soybean Association claimed that coconut oil caused heart disease and atherosclerosis — this high quality version has resurrected the reputation of coconut oil and made a dramatic turn-around in the world market as a functional food that not only nourishes but also heals. Because of its multi-functional uses and the way it can be produced at different production levels, VCO has been generating a lot of interest in coconut-producing countries as well as importing countries. VCO production offers an opportunity to coconut farmers to improve their income with this alternative to low value copra production.

In February 2006, the Food and Agriculture Organization Regional Office for Asia and the Pacific (FAORAP) published the manual *Virgin coconut oil production manual for micro and village scale processing*. This is a ready reference that discusses key aspects of the production of good quality VCO. One of the major concerns with producing VCO on a home, micro and village scale of operation is achieving a product with consistently good quality that will meet international standards and always be fit for human consumption. The FAO manual addresses these concerns and documents the VCO processing technologies developed in the Philippines, as well as the results of programmes initiated by FAORAP in promoting and improving the VCO industry in Thailand. The manual was prepared by Ms Divina D. Bawalan, previously a senior science research specialist with the Philippine Coconut Authority, and Mr Keith R. Chapman, formerly an industrial crops officer at FAO's Asia-Pacific office.

In the course of conducting VCO training courses in Pacific Island countries and territories (PICTs) since 2006, Ms Bawalan discovered that one of the simplest micro/home scale VCO processing technologies, which was developed in the Philippines and documented in the FAO VCO manual, does not actually work well in the Pacific region. This may be due to the differences in coconut variety, coconut harvesting procedures and other factors. Hence, for every training course in a Pacific country, modifications to the natural fermentation process were made, adapting it to the particular conditions of each country.

In 2009, a roundtable meeting was held in Nadi, Fiji, to discuss the state of the art of coconut processing and the market prospects of coconut products in Pacific countries. The meeting was organised by the Secretariat of the Pacific Community (SPC) and the Asian and Pacific Coconut Community (APCC). It highlighted the need for PICTs to focus on the production of high value coconut products. Consequently, SPC's Land Resources Division (LRD) deemed it necessary to develop this *Processing manual for virgin coconut oil, its products and by-products for Pacific Island countries and territories* which is appropriate for the conditions in the Pacific region. The preparation of this manual meets with LRD's mandate to improve the food and nutritional security of the Pacific community. Funding for the preparation of the manual was provided under LRD's EU-funded (European Development Fund 9) project on Facilitating Agricultural Commodity Trade (FACT) in the Pacific Islands.

Aside from presenting VCO processing technologies specifically applicable to the PICTs, the manual covers technology options for the processing of coconut shell, water from matured coconut and coconut milk residue, which are the by-products generated in VCO processing. It also includes the processing of VCO-based downstream products such as herbal soap, aromatherapy oils and herbal ointments using aromatic plants available in PICTs. In essence, this manual is an expanded and more focused version of the *Virgin coconut oil production manual for micro and village scale processing* by Bawalan and Chapman published by FAORAP in 2006. Permission C017/2010 from FAO HQ (Publishing Policy and Support Branch) to use/reproduce some figures, information and sections from the FAO manual to complete the Pacific VCO Manual is gratefully acknowledged.

Similar to the goal of the FAO VCO processing manual, this manual is intended as a primary source of practical knowledge on the proper handling and processing of fresh coconuts to ensure that VCO and its by-products will be produced to meet and possibly exceed international standards. Further, it is envisioned that the manual will lead to a better understanding of coconut oil and its quality parameters so that VCO processors can easily respond to the queries of their buyers. In the preparation of the manual, images from different PICTs which were collected during the conduct of training courses are used to illustrate key points.

ACRONYMS AND ABBREVIATIONS

APCC	Asian and Pacific Coconut Community
BAFPS	Bureau of Agricultural and Fisheries Product Standard
CFL	Compact fluorescent lamp
DC/DCN	Desiccated coconut
DME	Direct micro expelling
EU	European Union
FACT	Facilitating Agricultural Commodity Trade
FAO	Food and Agriculture Organization (United Nations)
FAORAP	FAO Regional Office for Asia and the Pacific
FFA	Free fatty acid
FNRI	Food and Nutrition Research Institute
GLC	Gas liquid chromatography
GMP	Good manufacturing practice
HACCP	Hazard analysis critical control points
kg	Kilogram
LRD	Land Resources Division (SPC)
LTO	License to operate
MC	Moisture content
MCFA	Medium chain fatty acid
NRI	Natural Resources Institute
PAH	Polycyclic aromatic hydrocarbon
PCA	Philippine Coconut Authority
PDD	Product Development Department
PICTs	Pacific Island countries and territories
PNS	Philippine National Standard
psi	Pounds per square inch
RBD	Refined, bleached and deodorised
RP	Republic of the Philippines
SPC	Secretariat of the Pacific Community
SSOP	Sanitation standard operating procedures
UK	United Kingdom
UCAP	United Coconut Association of the Philippines
UHT	Ultra high temperature
USD	United States dollar
VCO	Virgin coconut oil

Chapter 1
Coconuts and Pacific Island countries and territories

1.1 Characteristics of Pacific Island countries and territories

The main geographic characteristics of Pacific Island countries and territories (PICTs) are their small land masses, distance from world markets and dispersal over wide areas of ocean or archipelagic formations (Hazelman 1996). Twenty-two countries and territories, comprising some 7500 islands, are spread over 30 million square kilometres (Tevi 1997), of which 98% is ocean. Of the 7500 islands, only 500 are inhabited (Bird 2002) (Figure 1).

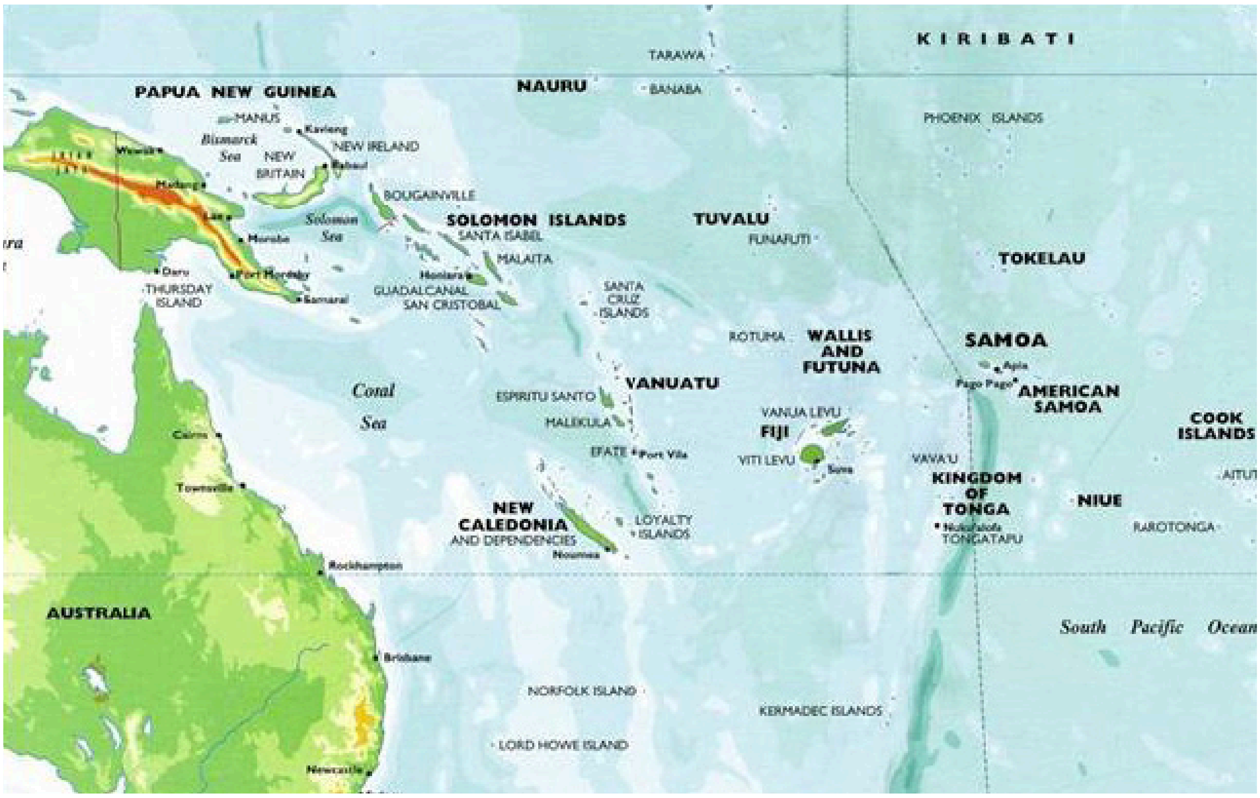


Figure 1. Map of the Pacific region

Source: Secretariat of the Pacific Regional Environment Programme (SPREP)

The Pacific region is divided into the three sub-regions of Melanesia, Polynesia and Micronesia, based on ethnic, linguistic and cultural differences. Tevi (1997) mentions the following geographical characteristics of the sub-regions:

> The Melanesian countries of Papua New Guinea, the Solomon Islands, Vanuatu, Fiji and New Caledonia comprise large, mountainous and mainly volcanic islands. They are endowed with considerable natural resources: fertile soils, large forests, mineral deposits and rich ocean resources. Micronesia and Polynesia are characterised by much smaller island countries. Most are small atolls with poor soil, with elevations usually between one and two metres (Kiribati and Tuvalu); there are some islands of volcanic origin with more fertile lands (Samoa and Tonga). Natural resources are mostly limited to the ocean; the seas of Micronesia and Polynesia are generally rich in living resources, and reported to have significant prospects for exploitable non-living resources (petroleum, natural gas, minerals).

1.2 The coconut industry in the Pacific region

The most widespread crop in PICTs is the coconut *(Cocos nucifera linn.)* inasmuch as the palm grows even in the infertile soil of the atoll countries. Coconuts have been part of the everyday life of Pacific Islanders for thousands of years. Coconut milk extracted from the grated fresh coconut kernel is an indispensable ingredient in traditional meals. Home-made coconut oil is used for cooking and for hair and skin conditioning. In Rarotonga, Cook Islands, slices of fresh mature coconut kernel are served with fruit after every meal.

The coconut's uniqueness and vital importance among Pacific crops is evidenced by the long history of usage and the numerous studies that characterise and define the composition of the different components of the tree and its fruit. It has been demonstrated that every part of the coconut tree and its fruit can be used or converted into valuable products. If properly utilised, the coconut has the highest economic value among the various palm trees (Bawalan 2003). This is the reason the coconut is often referred to as the tree of life, or the king of tropical flora or the tree of abundance.

While the coconut industry has lost much of its significance in the economies of PICTs in recent years, coconuts remain one of the major sources of livelihood, especially for people living on the outer islands who have to rely on the resources of their island because of the distance to urban centres and high inter-island transport costs.

With the exception of Papua New Guinea, the majority of PICTs have land areas less than 1000 square kilometres (Table 1). Correspondingly, coconut areas and production in these countries are miniscule compared to the Philippines and Indonesia (Table 2).

Table 1. Profile of Pacific Island countries and territories

Country	2010 Mid-year population estimate	Land area Sq. kilometres
American Samoa	65,896	199
Commonwealth of the Northern Marianas	63,072	457
Cook Islands	15,708	237
Federated States of Micronesia	111,364	701
Fiji Islands	847,793	18,273
French Polynesia	268,767	3,521
Guam	187,140	541
Republic of Kiribati	1000,835	811
Nauru	9,976	21
New Caledonia	254,525	18,576
Niue	1,479	259
Palau	20,518	444
Papua New Guinea	6,744,955	462,840
Pitcairn Islands	54	5
Republic of the Marshall Islands	54,439	181
Samoa	183,123	2,785
Solomon Islands	549,574	30,407
Tokelau	1,165	12
Tonga	103,365	650
Tuvalu	11,149	26
Vanuatu	245,036	12,281
Wallis and Futuna	13,256	142

Source: Secretariat of the Pacific Community 2010

Table 2. Coconut area and production in Asian and Pacific Coconut Community member countries

Country	Coconut area (hectares)	Coconut production	
		Million nuts	Copra equivalent (tonnes)
Federated States of Micronesia	17,000	40	7,000
Fiji Islands	60,000	150	25,000
India	1,903,000	14,744	2,100.000
Indonesia	3,799,000	16,235	3,247,000
Kiribati	29,000	131	26,000
Malaysia	115,000	390	78,000
Marshall Islands	8,000	27.5	6,000
Papua New Guinea	221,000	1,101	132,000
Philippines	3,380,000	12,573	2,399,000
Samoa	93,000	180	60,000
Solomon Islands	59,000	100	20,000
Sri Lanka	395,000	2,909	556,000
Thailand	247,000	1,186	356,000
Vanuatu	96,000	308	61,000
Vietnam	141,000	760.08	169,000

Source: www.apccsec.org

1.2.1 Coconut harvesting, collection and husking practices in PICTs

Generally speaking, harvesting of nuts in the strictest sense of the word is not practised in any PICTs. In coconut-producing countries in Asia, the nuts are plucked by means of a long pole or by climbing, whereas in PICTs, the mature nuts are allowed to fall to the ground. They are collected only when the coconut farmer or the estate worker wants to cut the raw kernel (also known as green copra) from the nut for subsequent sale or processing into copra.

The Pacific Island style of harvesting consists of walking through the coconut grove, picking up the nuts, putting them in a sack or basket made of coconut leaves (Figure 2) and carting them to a central place for cutting. In some areas in Fiji, horses or cattle-drawn improvised carts (Figure 3) are used to bring the whole nuts to the area where the copra dryer is located and copra cutting is done (Bawalan 2008).

Source: www.spc.int

Figure 2. Basket made of coconut leaves for carrying coconuts.

Figure 3. Cattle-drawn improvised carts for transporting coconuts in Fiji

The Pacific style of harvesting, or the natural fall method, while relatively cheap, has two disadvantages:

1. A lot of nuts are left on the ground, as the nut collector usually stays on existing tracks, especially in areas of rough terrain and heavy undergrowth.

2. Frequent collection is required to prevent germination of nuts on the ground and on the tree (the Rennell Island Tall Palms of Solomon Islands have been observed to germinate while still intact on the palm). Germination causes a reduction in the quantity and quality of fresh kernel, dried coconut flesh or copra and the resulting oil. During the rainy season, germination of nuts on the ground is aggravated and heavy losses are incurred.

These harvesting practices restrict the type of coconut food products that can be commercially produced in PICTs, since specific food products require specific levels of maturity of the nuts to obtain the expected high quality.

Most coconuts produced in PICTs are not husked; they are just cut into halves and the fresh kernel is cut out of the shell for drying into copra or for selling to traders who convert it into copra. In PICTs, husking of coconuts is done only for nuts earmarked for the following purposes:

- delivery to processing plants using fresh coconuts as starting material for VCO and coconut cream;
- delivery to markets that sell husked coconuts;
- home use for grating and extracting coconut milk as an ingredient in traditional Pacific dishes and for making coconut oil for cooking and other purposes.

On-farm husking of the nuts earmarked for these purposes is done to reduce the bulk and weight of the nuts when they are transported to specific destinations. Husking is done manually, using a round metal bar with sharpened tip anchored in the ground (Figure 4). Otherwise, the whole nuts are split with an axe (Figure 5) and the coconut kernel is taken out with a knife (Figure 6) or other tool.

Figure 4. Husking tool and husking operation in Fiji

Figure 5. Splitting of whole coconuts with an axe

Figure 6. Cutting green copra

1.2.2 Coconut processing in the Pacific region

The coconut industry in the Pacific region is primarily based on copra. Smallholders and estate plantation owners derive income from coconuts by selling copra, green or dried. Copra is generally produced by drying the kernel in various types of hot air dryer (Figure 7). In some areas, split whole coconuts are sun-dried. Since copra is a low value product and prices in the world market fluctuate, the income obtained by farmers is marginal. This could be the reason for the coconut industry in PICTs losing much of its economic significance.

Figure 7. Hot air copra dryers in Fiji

Several PICTs, including Fiji, Kiribati, Marshall Islands, Papua New Guinea, Samoa and Vanuatu, have established oil mills to add value to their copra. However, unless the copra-derived coconut oil produced is used domestically, the value-added by the oil milling is negated due to the high cost of exporting the oil.

It should be noted that PICTs will never be able to compete with big coconut producers in Asia on price alone. The distance of PICTs to major coconut product trading centres and their small volume of production severely limit the type of coconut products that can be economically produced for export. Hence, PICTs should focus on high value coconut products that can be produced on micro and village scales of operation and those that can be utilised and marketed domestically and/or easily exported to the nearby markets of Australia and New Zealand.

Marshall Islands and Vanuatu are the leaders among PICTs in the utilisation of coconut oil for fuel, where filtered coconut oil is blended with diesel or kerosene. Fiji and Samoa lead the group in terms of the largest number of coconut-based products. Hoff (2008) reported that in Samoa, copra, coconut oil, canned coconut cream, virgin coconut oil, handicrafts from coconut shell, and furniture and novelty items from coconut wood are being produced. He also mentioned that both mature and young coconuts are sold in many places in Samoa with the greatest concentration of sales at Fugalei Market in Apia. Aside from producing copra, crude coconut oil and VCO, Fiji is now known for the downstream processing of high quality coconut oil and VCO into specialty soaps and skin care products (e.g. lotions, creams and scented body oils). In addition, Pacific Green, a company which has become synonymous with high quality coconut wood furniture, is also based in Fiji.

With the development of a niche market for VCO (Figure 8) and its increasing popularity in developed countries, several Pacific countries — Fiji, Marshall Islands, Papua New Guinea, Samoa, Solomon Islands and Tonga — have now gone into VCO production. This is mostly done by small-scale producers in villages.

Figure 8. Virgin coconut oil

At present, VCO production in PICTs is still very small in volume. A major concern in producing VCO on a micro- and village-scale is achieving consistently high quality oil that conforms to international standards. This manual provides detailed guidelines, from harvesting to product packaging and storage, on how to achieve this standard.

1.3 Socio-economic significance of VCO processing in PICTs

The advent of VCO in the world market offers an opportunity for PICTs to convert their coconuts into high value products. VCO can be produced economically on micro- or village-scale operation and VCO processing is appropriate, given the available coconut supply in PICTs, and well suited to the harvesting practice in PICTs, since the process requires fully mature nuts. Under normal circumstances, coconuts fall naturally from the tree at full maturity.

Among the plant-derived vegetable, seed and nut oils, VCO is considered unique in the sense that it is the only oil with multi-functional uses: It is the only oil which one can eat as a food supplement or functional food, use for cooking, apply to the hair and skin as a moisturiser and conditioner, and use as a major ingredient in skin care products or as carrier oil in aromatherapy and massage oils. Moreover, it can be used in applications in which the copra-derived refined, bleached and deodorised (RBD) oil is traditionally used, e.g. as a substitute for expensive butterfat in filled milk, filled cheese and ice cream or to provide the lubricating action in dressings or the leavening effect in baked items.

The VCO-based products industry (e.g. skin and hair care products) is growing. Under these conditions, VCO will not lack for prospective markets. To expand VCO production, what is needed in PICTs is a concerted effort in technology transfer, access to reliable equipment suppliers, market promotion and a strong trader/exporter base that can aggregate the VCO produced by village producers and export in bulk.

As mentioned previously, VCO is a high value product. Based on export data for the Philippines, the average bulk price of VCO is about five times higher than the average price of copra-derived coconut oil (CNO) in the world market. Records show that the average Philippine export price (2003–2008) of CNO is USD 696 per tonne, while the average export price (2003–2008) for VCO was USD 3231 per tonne. The Philippine export performance for copra-derived coconut oil and VCO can be used as a benchmark for the world market price of these commodities because the Philippines is the biggest producer and supplier of both products.

Philippine Coconut Authority (PCA) statistics show that, as of 2008, VCO produced in the Philippines is exported to 38 countries, with the USA being the biggest importer, accounting for 62.5% of the total volume exported, followed by Canada at 27.3%. The use of VCO as functional food is common in the Philippines and it can now be readily bought from drug stores and supermarkets, packaged in 250 and 500 ml bottles. Since 2005, a big herbal company has been selling VCO with added flavours (banana, jackfruit and corn) to make it more palatable. It should also be noted that one of the first companies that marketed VCO through the Internet since 2000 is Mt Banahaw Health Foods Corporation under the brand name Tropical Traditions. This company (now based in the United States) is also credited with being the one that started the VCO industry in the Philippines. Its VCO production and marketing scheme, in which VCO is produced by coconut farmers at home while quality assurance, aggregation and marketing are handled by the company, can be adapted in PICTs.

As demonstrated in Samoa, organically produced VCO attracts high-end international buyers who are willing to pay a high price for the product. However, the VCO producer should also consider the fact that organic certification is an investment in itself (see Section 3.6.2 for more details). A word of caution — in making price projections for VCO, one should take note of the law of supply and demand, i.e. the more suppliers, the higher the competition and the lower the price. When the Philippines first exported VCO to the USA in 2001, the only exporter at that time received USD 11,006 per tonne (or USD 11.01/kg). When more producers entered the market, the price tapered down to the current levels of USD 3200 per tonne (or USD 3.20/kg).

Chapter 2
Understanding coconut oil and its quality parameters

2.1 Characteristics of coconut oil

In its purest form, coconut oil is clear (like clean water), with a distinct coconut flavour and aroma and no rancid smell, even without undergoing chemical refining and deodorisation processes. It was only in the late 1990s that the clear version of coconut oil (otherwise known as virgin coconut oil) became known in the market. The coconut oil which has been traditionally produced and traded since the later part of the 19th century is yellow in colour.

The degree of saturation and the length of the carbon chain of the fatty acids in any fat or oil help to determine its properties, corresponding uses and effects on human health. The outstanding characteristic of coconut oil compared to other fats and oils is its high content of medium chain fatty acids (MCFAs) with carbon chain lengths ranging from 8–12 (see Annex 1 for a detailed explanation of fatty acids). Several studies on coconut oil have indicated that MCFAs have antibiotic and other beneficial properties for human health. In the digestive system, the MCFAs in coconut oil are rapidly absorbed, carried by the portal vein to the liver and then oxidised, thereby producing energy very rapidly (Dayrit 2005). This makes coconut oil and its derivatives suitable as diet components for convalescing patients and premature infants. Dietary supplements containing MCFAs and their monoglycerides (e.g. monolaurin) are now marketed in health food stores. About 64% of coconut oil consists of MCFAs, with lauric fatty acid (C_{12}) in the largest proportion, ranging from 45–56% depending on the coconut variety. The comparative fatty acid profile of common fats and oils is shown in Table 3.

Table 3. Comparative fatty acid profile of common fats and oils

	Coconut oil	Palm oil	Soybean oil	Corn oil	Butter
A. Saturated	**%**	**%**	**%**	**%**	**%**
C4:0	-	-	-	-	3.0
C6:0 Caproic	0.5	-	-	-	1.0
C8:0 Caprylic	7.8	-	-	-	1.0
C10:0 Capric	6.7	-	-	-	3.0
C12:0 Lauric	47.5	-	-	-	4.0
C14:0 Myristic	18.1	1.1	-	-	12.0
C16:0 Palmitic	8.8	44.0	11.0	11.5	29.0
C18:0 Stearic	2.6	4.5	4.0	2.2	11.0
C20:0 Arachidic	0.10	-	-	-	5.0
B. Unsaturated	**%**	**%**	**%**	**%**	**%**
C16:1 Palmitoleic	-	0.1	-	-	4.0
C18:1 Oleic	6.2	39.2	25.0	26.6	25.0
C18:2 Linoleic	1.6	10.1	51.0	58.7	2.0
C18:3 Linolenic	-	0.4	9.0	0.8	-
Others	-	0.4	-	-	-
% Saturated	92.1	49.6	15.0	13.7	69.0
% Unsaturated	7.9	50.4	85.0	86.3	31.0

Source: Arranza 2001

The most significant physical property of coconut oil is that, unlike most fats, it does not exhibit gradual softening with increasing temperature but passes rather abruptly from a brittle solid to a liquid within a narrow temperature range. Coconut oil is liquid at temperatures of 27°C or higher and is solid at 22°C or lower, when it is similar to the consistency of cocoa butter.

Coconut oil that does not rapidly solidify when placed in the refrigerator is not pure, and presumably has been mixed with other oil or other substances.

2.2 Types of edible coconut oil

At present, there are two types of edible coconut oil available in the commercial market: refined, bleached and deodorised (RBD) coconut oil and virgin coconut oil (VCO).

Refined, bleached and deodorised coconut oil

RBD coconut oil (Figure 9) is derived from copra, the dried coconut kernel that is processed either by sun drying, smoke drying or hot air drying. The crude coconut oil is subjected to chemical refining, bleaching and deodorisation processes to make it fit for human consumption. (Please refer to Annex 2 for a description of the processing of RBD coconut oil.)

RBD coconut oil is yellow in colour, odourless and tasteless, and does not contain any Vitamin E since this is removed during the chemical processes. RBD coconut oil is generally used as a cooking oil in the Philippines.

Figure 9. Refined, bleached and deodorised coconut oil

Virgin coconut oil

The Philippine National Standard for VCO (PNS/BAFPS 22:2007/ ICS 67.200.10) officially defines VCO as:

> … an oil obtained from the fresh, mature kernel of the coconut by mechanical or natural means, with or without the use of heat, without undergoing chemical refining, bleaching or deodorizing, and which does not lead to the alteration of the nature of the oil. Virgin coconut oil is an oil which is suitable for consumption without the need for further processing.

VCO is the purest form of coconut oil. It is clear/colourless, contains natural Vitamin E and has not undergone atmospheric and hydrolytic oxidation as attested by its low peroxide value and low free fatty acid content. It has a mild to intense fresh coconut aroma. The intensity of the scent depends on the process used in its production.

RBD and VCO coconut oil have the same physical and chemical characteristics but have different sensory attributes and prices.

2.3 Multifunctional uses of coconut oil

As an edible oil, coconut oil is used for frying and cooking because of its good resistance to rancidity development (Bawalan and Chapman 2006). It is also used as a substitute for expensive butterfat in filled milk, filled cheese (reconstituted milk/cheese) and ice cream to make these products more affordable without altering their palatability. When hydrogenated, coconut oil is used as margarine, shortening and baking fat. Other edible applications are as follows:

- a source of fat in infant formulas and baby foods because it can be easily absorbed and digested;
- a spray oil for crackers, cookies and cereals to enhance flavour, increase shelf-life and impart a glossy appearance;
- an ingredient in confectionary.

The Spectrum of Coconut Products (PCA undated) states that in food preparations and in diet, coconut oil performs the following functions:

- It serves as an important source of energy in the diet.
- It supplies specific nutritional requirements.
- It provides the lubricating action in dressings and the leavening effect in baked items.
- It acts as a carrier and protective agent for fat-soluble vitamins.
- It contributes to palatability and enhances the flavour of food.

The major inedible use of coconut oil is as a raw material for (a) the manufacture of laundry and bath soaps, (b) coconut chemicals for the production of biodegradable detergents, shampoos, shower gels and other cleaning agents, (c) cosmetics and toiletries, (d) foam boosting of non-coconut oil-based soaps, and (e) the production of synthetic resins and plasticisers for plastic (Bawalan and Chapman 2006).

Among vegetable, seed and nut oils, VCO is considered unique in that it is the only oil that is multi-functional. It has more uses than RBD coconut oil; can be utilised in all applications where crude, cochin and RBD coconut oil are traditionally used; and is a much better alternative if it can be made available in large quantities at an affordable price.

The current emerging major uses of VCO are:

- a hair and skin conditioner
- an oil base for various cosmetic and skin care products
- a carrier oil for aromatherapy and massage oils
- a nutraceutical and functional food.

2.4 VCO as a versatile product

VCO is a unique and versatile coconut product for the reasons given below.

a) It has multi-functional uses as discussed above, thereby providing flexibility in marketing.

b) Technologies are available for it to be processed at different scales of operation.

- VCO can be produced at home even without any specialised equipment or it can be produced in large-scale commercial plant operations.

a) Other functional food products can be processed together with it, depending on the type of technology applied, thereby maximising the utilisation of coconut kernel and increasing the economic viability of the operation.

- For the dry process of VCO manufacture, high dietary fibre coconut flour can be produced as a co-product. For the wet process (coconut milk route), low fat desiccated coconut (DCN) or another type of VCO and coconut flour can be produced as co-products.

b) With minimal additional investment, VCO production can easily be integrated with an existing coconut milk or desiccated coconut processing plant.

- Production of VCO can be integrated with an existing DCN plant with just the addition of a high pressure expeller and filter press. It can also be integrated with an existing coconut milk plant with the addition of fermentation equipment (modified natural fermentation process) or the addition of a three phase centrifuge (centrifuge process).

c) Lower quality VCO can still be used for processing other downstream products such as bath soaps and massage oils, thereby preventing any waste.

d) It is one of the highest valued coconut products in the world market.

2.5 Health benefits of VCO

Virgin coconut oil is considered a nutraceutical, i.e. a substance that nourishes and also protects and heals. Studies have suggested the following.

- The medium chain (C_8–C_{12}) fats in coconut oil are similar in structure to the fats in mother's milk that gives babies immunity from disease and have similar effects (Kabara 2000).
- Coconut oil possesses anti-inflammatory, anti-microbial and antioxidant properties that work together to protect the arteries from atherosclerosis and the heart from cardiovascular disease (Fife 2004).
- It is cholesterol-free, trans-fat free and heart-healthy (Verallo-Rowell 2005).
- It boosts the immune system (Dayrit 2005).
- It protects against heart disease by increasing high density lipoprotein which collects the excess or unused cholesterol in the body for excretion in the liver (Blackburn et al. 1989 cited in Dayrit 2005).
- Monolaurin, which is formed by the body when coconut oil is ingested, provides protection against infectious diseases caused by lipid-coated microorganisms (Kabara 2000). Diseases caused by such pathogens are not ordinarily cured by known antibiotics.
- It is digested easily without the need for bile and goes direct to the liver for conversion into energy (Dayrit 2005).
- It stimulates metabolism, boosts energy and prevents deposition of fats, thereby helping to prevent obesity (Dayrit 2003).
- It improves the nutritional value of food by increasing the absorption of vitamins, minerals and amino acids (Fife 2004).
- It inhibits the action of cancer-forming substances (Lim-Syliangco 1987).

For further information on the health benefits of coconut oil and frequently asked questions about VCO, please refer to Annex 3.

2.6 Quality standards of virgin coconut oil

Quality assurance in the context of any industry should be viewed from two perspectives. One is the need to ensure that the product produced by any processor conforms to a set of domestically and internationally accepted product standards. This is particularly critical in VCO processing, inasmuch as it is now developing into an important source of foreign exchange for coconut-producing countries. The market for VCO, whether local or international, should be protected and sustained by ensuring that only VCO with the highest quality is produced and traded.

From the other perspective, quality assurance needs to be strictly implemented to protect consumers and assure them that the VCO that they are buying is of the highest quality. At present, VCO is bought for use as a food supplement or nutraceutical because of the growing number of its beneficial effects on human health, as attested to by the medical literature. In this case, the quality of the product is of paramount importance since the product is being taken internally without being cooked or heated (which would further sterilise the product).

In addition, VCO is in growing demand as a base oil for hypoallergenic skin care products, which also require good quality. Annex 4 has details of the revised Philippine National Standard for VCO (PNS/BAFPS 22:2007/ICS 67.200.10) and the Asian and Pacific Coconut Community (APCC) standard for VCO.

Standards cover many aspects of VCO: the identity characteristics (fatty acid composition), quality characteristics (colour, odour and taste, free fatty acid and moisture contents, peroxide value), allowable contaminants, hygiene, packaging, labelling and methods of sampling and analysis. Please refer to the Glossary for the definition of free fatty acid, moisture content and peroxide value.

As a general rule, VCO production samples should be regularly analysed in a laboratory to determine its actual quality. However, as a first step in determining the quality of VCO, small scale VCO processors who cannot afford to set-up their own quality control laboratory or to send samples regularly to analytical laboratories should do sensory evaluation by testing the colour, odour and taste of the VCO.

Colour is the first characteristic that distinguishes virgin coconut oil from any other type of plant-derived oil (vegetable or oilseed). The colour of VCO also indicates that it has been processed at the right temperature and with strict quality control in handling the fresh coconut. For the coconut oil to be categorised as virgin, its colour should be water-clear. The colour of virgin coconut oil can be visually determined by putting a 250 ml sample in a clear glass bottle and looking at it against a white background.

The **odour** and **taste** of VCO is sweet coconut, no rancid smell, no 'off' flavour and no sour taste. A simple test to determine the odour and taste of VCO is done by heating a sample in a water bath to a temperature of about 50°C, putting a teaspoon of warm VCO on the tongue, then inhaling air through the mouth and exhaling through the nose.

In addition, VCO should not cause any itchiness in the throat when ingested, since this is an indication that the free fatty acid content is already higher than the prescribed standard.

Chapter 3
VCO production technologies

VCO production is composed of three basic stages, namely, pre-processing, processing and post processing. The VCO processor either at the plant or at home should adhere strictly to a set of guidelines or good manufacturing practices (GMPs) and quality control procedures (as may be required) in each of these stages to ensure the production of high quality VCO. These are discussed in detail, together with sanitation standard operating procedures in Chapter 4.

3.1 Pre-processing stage

The pre-processing stage covers all necessary steps before the fresh coconut is actually opened for conversion into VCO. These steps include on-farm activities (harvesting, collection and husking of nuts), transport from the farm to the VCO processing site (factory or home), storage, and selection for daily processing.

General farm practices for harvesting, collection and husking of coconuts in PICTs are described in detail in Section 1.2.1. GMPs for harvesting, husking, transport of husked nuts, storage and the required quality control for selection of nuts at the farm, at the processing plant and at the storage area prior to processing are discussed in detail in Chapter 4 Section 4.1.

3.2 Processing stage

The processing stage covers all the necessary steps from the opening of the fresh coconuts to the recovery of VCO. The processing steps that are employed depend on the type of VCO processing technology that is selected.

There are nine existing VCO processing technologies which VCO producers can adopt and/or adapt. VCO production starts with the fresh kernel which is subjected to a series of processing steps specified in a particular technology. The choice of the technology depends on the scale of operation, the degree of mechanisation that is desired, the amount of investment available and, most importantly, the demands of the prospective buyer(s).

VCO processing technologies can be generally categorised into **fresh-dry processes** and **fresh-wet processes**.

Fresh-dry is the general term given to VCO processing technologies in which VCO is obtained directly from fresh coconut kernels. All these processes require drying of fresh kernels in comminuted form (grated, shredded, ground, milled) before extracting the VCO. Process technologies under the fresh-dry category can be seen schematically in Figure 10.

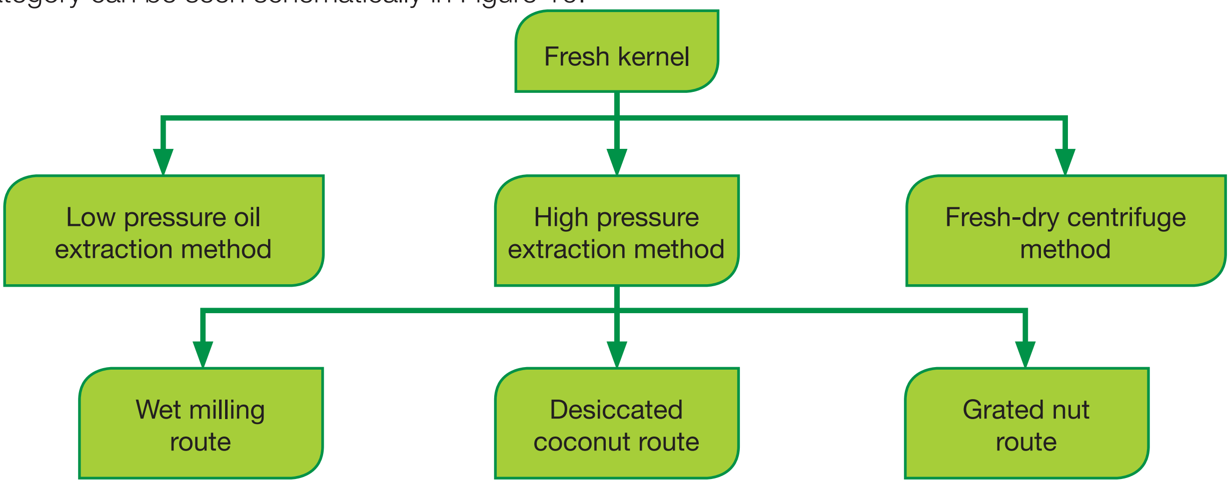


Figure 10. Schematic diagram of VCO process technologies under the fresh-dry process

One of the major constraints against upscaling VCO production in PICTs using the fresh-dry process is the lack of an appropriate mechanical dryer for the coconut kernel. The direct micro expelling (DME) dryer design that is currently being used is too labour-intensive but VCO producers in PICTs use it for lack of anything else. Most of the available mechanical coconut dryers that are being used in other coconut-producing countries, including the Philippines, India and Sri Lanka, have high processing capacities (150–800 kg dried kernel/hour) which is well beyond the capacity that can usually be supplied under existing coconut production in PICTs.

Fresh-wet is the general term given to VCO processing technologies in which VCO is recovered from coconut milk by various means after it has been extracted from freshly comminuted coconut kernel. VCO processing technologies under the fresh-wet category are shown schematically in Figure 11.

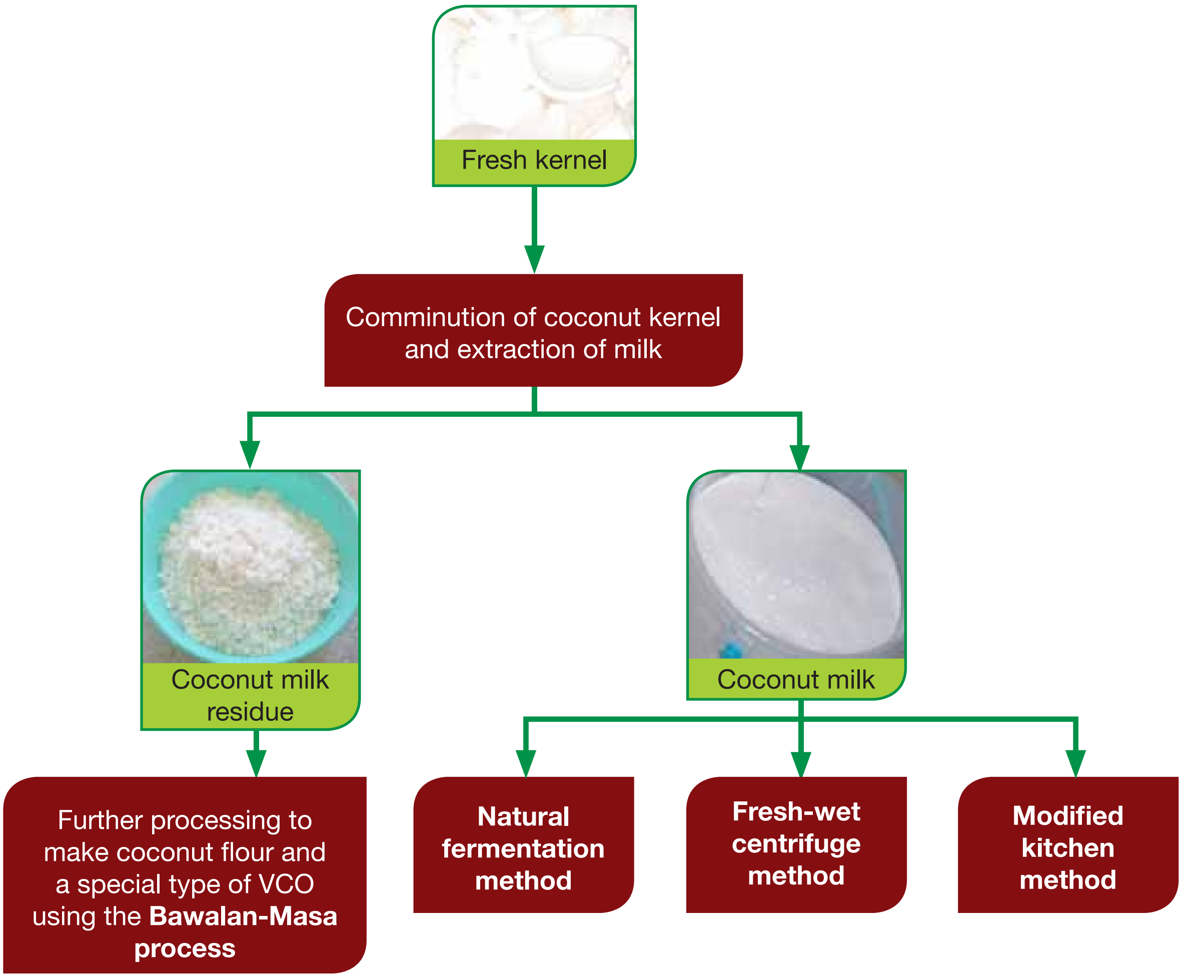


Figure 11. Schematic diagram of VCO process technologies under the fresh-wet process

3.2.1 Fresh-dry VCO processing technologies

As can be seen in Figure 10, the fresh-dry process can be classified into the low pressure oil extraction method, the high pressure expeller method and the fresh-dry centrifuge method. These are described in the following sections.

3.2.1.1 The fresh-dry low pressure oil extraction method

The fresh-dry low pressure oil extraction method is also called intermediate moisture content method by researchers from the Natural Resources Institute (NRI) of the UK, which developed and introduced the technology to the Philippines and several countries in Africa. It works on the principle that oil from seeds or nuts can be extracted using low pressure (about 460 psi) provided that the moisture content of the material is within the range of 10–13%. The traditional process of extracting plant-based oil is through the use of high pressure expellers (above 1600 psi), generally at a feed moisture content of 3–4%.

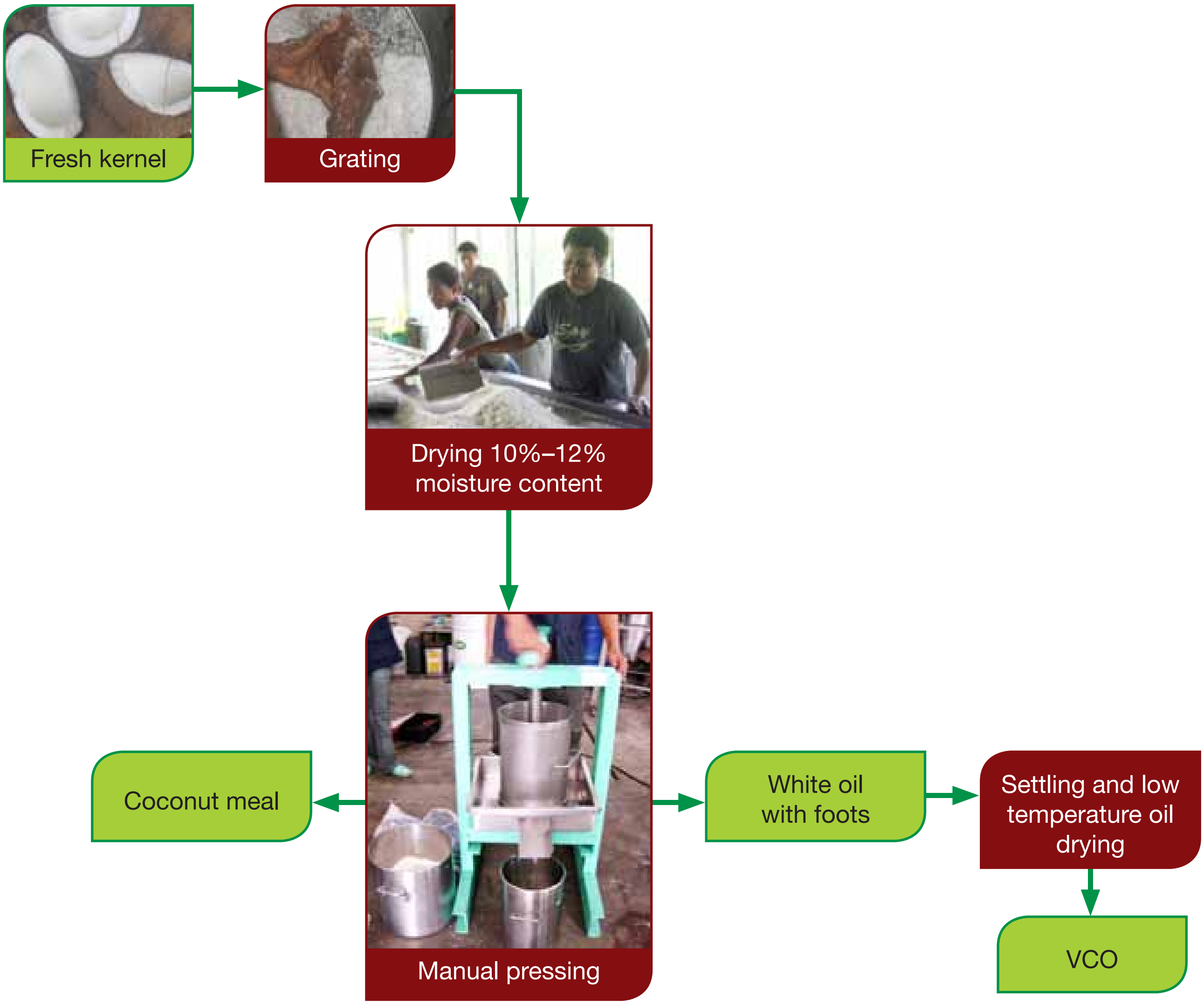


Figure 12. The fresh-dry low pressure oil extraction method

The low pressure oil extraction method (Figure 12) for coconut oil developed at NRI involves splitting the nut, grating the meat into fine particles, drying it to a moisture content of about 10–12% and extracting the oil using an NRI-developed, manually operated, vertical screw-type press known as a bridge press (Figure 13).

Figure 13. Bridge press developed by the Natural Resources Institute, United Kingdom

The grated kernel is dried either by solar drying (not sun drying) or by indirect hot air drying. The dried grated meat is placed in bags made of cheese cloth prior to oil extraction in the bridge press. This is to make it easier to remove the residue and to reduce the amount of fine kernel particles that are entrained in the oil, since cheese cloth also acts as filter medium.

The direct micro expelling process developed by Dr Dan Etherington of Australia works on the same principle. However, it differs in the type of manually operated press being used for oil extraction and the manner in which the grated coconut meat is dried prior to oil extraction.

3.2.1.1a The fresh-dry direct micro expelling process

VCO processing technology as practised in PICTs is synonymous with the direct micro expelling (DME) process developed by Dr Dan Etherington of Australia. The DME process and equipment were first introduced in Fiji in 1998 with the setting up of the processing facility in Nadi Village, Cakaudrove Province, Vanua Levu (Bawalan 2008). Small scale VCO production using the DME process is now being done in Fiji, Federated States of Micronesia, Papua New Guinea, Solomon Islands and Samoa.

The DME technology and equipment is supplied by Kokonut Pacific Pty. Ltd. A standard set consists of the robust rack and pinion SAM™ press with its interchangeable stainless steel cylinders and pistons; two electric graters; tools for collection, measurement and cleaning; and the trainer's manual (www.kokonutpacific.com.au). Part of the system is a DME-designed coconut shell-fired, flat-bed, conduction-type dryer which is constructed on site. This set of equipment can process about 300 nuts each eight-hour day. As mentioned previously, the DME process works on the same principle as the low pressure oil extraction method.

The DME process described below is the standard process with a few modifications to address the need for higher processing capacity and to suit the Pacific context.

Splitting of the coconuts – pre-selected fully mature, husked coconuts without cracks, spongy haustorium (or vara), or germinating root/shoot are split into half cups ready for grating.

Grating – the fresh coconut kernel is comminuted into fine particles and removed from the shell through the use of motorised DME grater (Figure 14) or other types of grater (Figure 15) which are now also used by processors in Fiji.

Figure 14. Motorised DME grater

Figure 15. Other types of coconut grater being used by VCO processors in Fiji

Drying – the freshly grated coconut kernel is dried to a moisture content of about 10–11% using a DME-designed coconut shell-fired flat-bed conduction-type dryer (Figure 16). This is done by spreading batches of 12 kg of grated kernel thinly on the surface of the dryer. In the standard DME process, batches of 3–3.5 kgs of grated kernel are dried. The loaded kernel is regularly turned by two people positioned on either side of the dryer.

GMP 4.2.3.1

These arrows direct you to the good manufacturing practice for this process.

Figure 16. Drying of grated kernel in a standard DME flat bed direct contact type dryer

The moisture content of the dried kernel is usually determined by feel and greatly depends on the skill of the operator doing the drying process and preparing the grated kernel prior to extraction. This is the major reason why batches of VCO produced using the DME process have variable quality. A suggested science-based procedure to indicate if the grated meat is at the right moisture content level is discussed in Annex 5.

Drying is the most critical part in the DME process for the following reasons:

- If the kernel is not turned by highly skilled dryer operators, it may get scorched or burned and produce yellow oil, which can no longer be classed as VCO.
- The right moisture content (10–11%) of grated kernel is needed prior to its transfer to the cylinder for oil extraction. If the moisture content is too low, then no oil will be extracted. If the moisture content is too high, then the oil that comes out of the press is mixed with coconut milk (i.e. it is cloudy). Residual moisture in the oil will shorten its shelf-life.

Loading into cylinder – When the grated kernel is dried to the right moisture content (10–11%) and at the right temperature (about 70°C), it is loaded into the DME cylinder through a built-in hopper located on one side of the front end of the dryer (Figure 17). Kokonut Pacific recommends the use of a cylinder that is already hot (by putting it in the sun before being loaded). It should be noted that the feed hopper is absent in the modified DME process.

Figure 17. Loading of dried grated kernel in the DME cylinder through a built-in feed hopper.

Oil extraction – the DME cylinder with the dried grated kernel and piston on top is then positioned in the DME press and the lever mechanism pushed down to compress the loaded grated kernel in the tube and subsequently release/extract the oil (Figure 18). After the pressing is done, the spent grated coconut kernel is pushed out of the tube.

Figure 18. Low pressure oil extraction using a DME press

Figure 19. New Zealand Press

GMP 4.2.3.2
GMP 4.2.3.4

Settling – The oil coming out of the DME press has entrained fine particles of dried kernel. These are removed by allowing the oil to clarify by letting it stand for at least two weeks.

Alternatively, and currently replacing the DME press for a higher VCO production capacity is the fabricated press (Aquarius or Axis Olive oil press) from New Zealand (Figure 19), which is a combination of a manually operated vertical screw and a hydraulic jack type pressing system.

The major advantage of the DME process is that VCO can be produced within four hours from start to finish, thereby guaranteeing a very fresh product. On the other hand, it needs relatively high investment for equipment and a plant building for a small processing capacity of about 300 nuts per eight-hour day. Likewise, without any motorised filtering device, a minimum of two weeks must pass after oil extraction before the clarified VCO can be used or sold. In economic terms, this means working capital is tied-up and the producer needs a building with enough room to store the oil during gravity settling.

VCO produced using the low pressure oil extraction process is less viscous than VCO produced from the high pressure oil expeller process. It can be inferred that not all natural gums in the coconut kernel are extracted with the oil, since oil extraction is done at low pressure. The coconut aroma is also less intense.

3.2.1.2 The fresh-dry high pressure expeller methods

GMP 4.2.3.3

For a VCO processing capacity of 3,000 or more nuts a day, the high pressure expeller method under the fresh-dry process is appropriate. This method requires the use of mechanical dryers and high pressure expellers with water-cooled wormshafts. If the high pressure expeller method for VCO production is adopted in PICTs, it is advisable to use the wet-milling route because this has the highest oil extraction efficiency and not much major equipment is needed.

VCO produced from the high pressure expeller process contains all the natural gums present in the fresh kernel, so it is viscous and feels a little greasy to the skin. It has a moderately intense coconut aroma and is normally used as a base oil in specialty soaps and as an ingredient in hypoallergenic cosmetics and skin care products.

The VCO obtained after extraction has entrained very fine particles of dried kernel (generally referred to as ‘foots’) which are normally removed through the use of a motorised plate and frame filter press. It takes a minimum of two weeks to clarify the oil if gravity settling is used.

Full-protein, medium-fat coconut flakes are obtained as a co-product in the high pressure expeller method. If the preparation of the fresh kernel and subsequent oil extraction is done under very strict sanitary conditions and in accordance with the GMPs of VCO processing (please refer to Chapter 4), the coconut flakes can be further ground to produce coconut flour.

An expeller press for VCO production is designed in such a way that the temperature inside does not rise beyond 90°C. If it does so, the oil produced will have a pale yellow colour that disqualifies it from being labelled ‘virgin’. The press has a screw that moves the ground, dried coconut kernel continuously to the discharge end of the expeller and forces it to enter a very narrow clearance called a choke. In so doing, high pressure is created to compress the material and subsequently release the oil. The extracted oil flows down through slats in a barrel cage surrounding the screw or worm shaft. The defatted material forms into a hardened cake in which the thickness is defined by the adjustments made on the choke.

The high pressure expeller method of VCO production can be subdivided according to how the fresh coconut kernel is prepared before drying:

- the **wet milling route** (grinding), described in detail below
- the **desiccated coconut route** (shelling, paring, washing, grinding, blanching)
- the **grated nut route** (grating)

After drying, the same extraction process is followed, using the same operating conditions as well as the same post-processing of the oil (Figure 20).

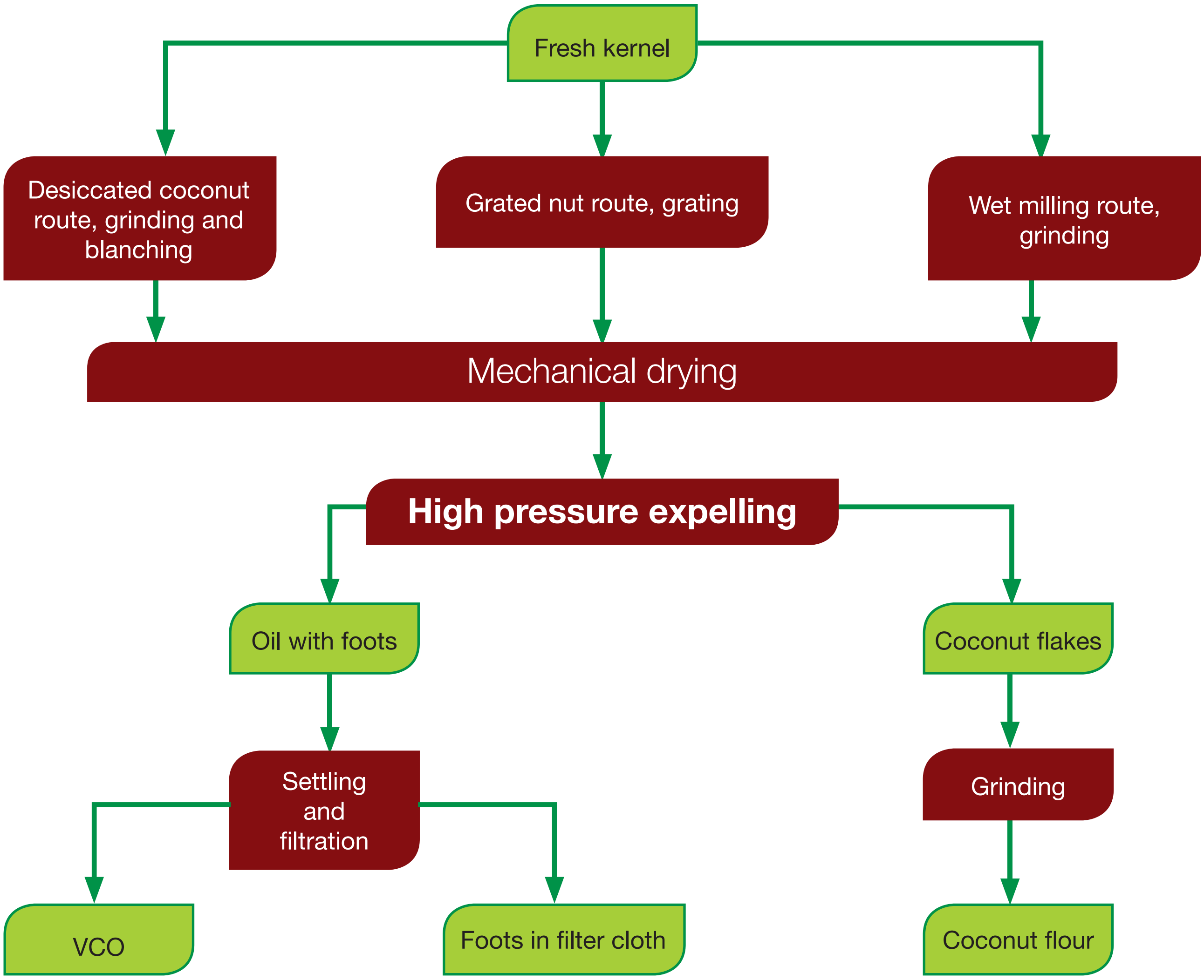


Figure 20. The fresh-dry high pressure expelling process

3.2.1.2a The fresh-dry high pressure expeller method, wet milling route

This technology involves the following process steps:

Shelling – involves the removal of the brown shell from the husked nut in order to free the fresh kernel. This is done either by the use of a manual shelling tool or a shelling machine (Figure 21). The fresh kernel can also be separated from the shell, much like the way green copra is usually cut in PICTs.

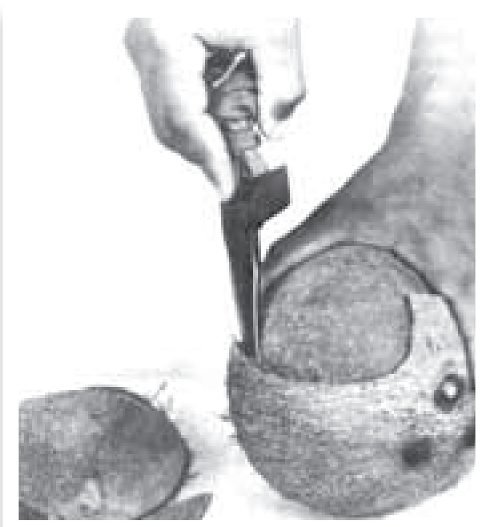


Figure 21. Motorised shelling (left) and manual shelling (right)

Source: Hagenmaier (1980)

Cutting – Cut the shelled fresh kernel either manually with a knife or a manufactured cutter to remove coconut water and reduce to a size appropriate for feeding into the grinder. This step is no longer necessary if the fresh kernel is removed from the shell like green copra.

Grinding or wet milling – Granulate the fresh kernel to about 3 mm particle size using a grinder or knife mill.

Drying – The ground or milled fresh coconut kernel is dried to a moisture content of 3–4% at temperatures of 70–75°C using an indirect, hot air dryer (e.g. tray type or conveyor). See Annex 6 for details of the different types of dryers.

Oil extraction – The dried kernel is fed to the high pressure expeller with a built-in cooling system immediately after drying. Extracting the oil while the feed material is still hot allows the oil to flow freely, thereby increasing product yield.

GMP 4.2.3.3

Settling of the oil – The oil is allowed to settle by gravity for a minimum of seven days, preferably in a tank with a conical bottom, to give sufficient time for the entrained foots to settle at the bottom. Commercial oil milling plants have built-in settling tanks fitted with a moveable screen and mechanical scrapers to continuously remove the foots before the oil is passed through the motorised plate and frame filter press. However, the processing capacity of this type of equipment is generally too big for application in a village scale operation.

Typically, oil extracted by a well-designed high pressure expeller already has very low moisture content, so there is no need to subject the oil to an oil drying step. However, it entrains a higher percentage of foots — about 10–5% of the weight of the oil expelled.

Filtration of the oil – After settling, filtration of the oil is done using motorised filtering devices to remove the remaining entrained foots which were not removed during settling. Refer to Annex 6 for information on filtration equipment.

The standard equipment used for filtration in commercial oil milling plants is the motorised plate and frame filter press to ensure that all foots are removed. When filtration is done using gravity filters, there may still be foots settling at the bottom of the container after a long period. In these cases, decant and transfer the oil to another container and let stand for another seven days.

Given a properly designed expeller and the correct operating conditions, the highest oil extraction efficiency is obtained from the high pressure expeller method, especially if the fresh coconut kernel is milled and dried without removing the testa, or brown skin of the kernel (Bawalan and Chapman 2006). Most VCO processors remove the testa because there is a general belief that it causes discolouration of the oil. However, this is not the case, as proven by various production trial runs conducted by the author at the PCA Davao Research Center since 1990. As long as the fresh kernel is properly handled and processed under the right operating conditions, the oil is water-clear, even when the testa is not removed. It should be noted that testa should be removed if coconut flour is intended to be produced as a coproduct with VCO.

3.2.1.2b The fresh-dry high pressure expeller method, DCN route

Processing of the fresh coconuts prior to oil extraction under the DCN route has the following steps.

Shelling – This is the same step as described in the wet milling route. However, the manner in which green copra is taken from the shell is not applicable here.

Paring – This involves the removal of the brown testa covering the white meat. It is done either manually using a double-bladed knife or by using a paring machine (Figure 22). The process is like peeling potatoes. The paring knife is calibrated so that little or no white meat is shaved off. The use of paring machines still requires follow-up manual paring because not all the brown skin is removed.

Figure 22. Manual paring (left) and paring machine (right)

Cutting – The order in which this step is done depends on the method of paring. If the paring is done manually, then cutting is done after paring (i.e. manual paring of shelled nuts is done while the coconut water is still inside the intact nut). If paring is done using a machine, then cutting and removal of coconut water is done after shelling.

Figure 23. Washing of pared fresh coconut kernel

Washing – The white coconut kernel is thoroughly washed in washing tanks fitted with several spray nozzles using fresh water chlorinated to about 3 ppm active chlorine (3 mg/l) (Figure 23).

Grinding – The white coconut kernel is ground between a stationary and a rotating disk with a distinct configuration of sharp edges in a grinding machine. This is fitted with attachments that can produce a desired particle size and feeding screws that ensure a fairly even particle size.

Drying – The ground white coconut kernel is dried to a moisture content of 2.5–3% using a conveyor type hot air dryer where the ground material is subjected to three diminishing temperature levels (100°C, 85°C, 65°C) as it passes through the dryer from beginning to end. Air heating is done either by steam or through a heat exchanger attached to a coconut shell-fired or gas-fired burner.

Oil extraction, settling and filtration are exactly the same as described in the wet milling route. The desiccated coconut (DCN) process is particularly useful to producers as DCN that does not pass the stringent quality standard for colour or microbial content can still be converted into high value virgin coconut oil and coconut flour (if the DCN fails the standard for colour) or an aflatoxin-free high grade animal feed (if the DCN fails the standard for microbial content).

3.2.1.2c The fresh-dry high pressure expeller method, grated nut route

Processing of fresh coconuts prior to oil extraction under the grated nut route has the following steps:

Splitting and grating – This is exactly the same as described in the DME process.

Drying – This is exactly the same as described in the wet milling route.

Oil extraction, settling and filtration are exactly the same as described in the wet milling route.

3.2.1.3 The Fresh-dry centrifuge method

This is the newest VCO processing technology being promoted by the Integrated Food Processing Machinery Pte Ltd of Singapore. The novel idea in this process is the use of a micro-pulveriser to convert dried, finely ground coconut kernel into a paste-like consistency. The high oil content of the dried kernel is the reason it is turned into a paste when micro-pulverised. The coconut paste is then passed through a two-phase (solid-liquid) centrifuge to recover the VCO. The resulting residue (slurry) is a by-product of the process and can be reconstituted with hot water into a healthy, high-fibre, low-fat coconut milk.

The process involves the preparation of kernels much like the process involved in desiccated coconut production (refer to Section 3.2.1.2b), then micro-pulverisation and centrifugation (Figure 24).

Micro pulverised DCN is another high value coconut product in itself. It is called creamed coconut in the world market and is used for making coconut-based confectionaries and candies.

The VCO produced by the fresh-dry centrifuge process is ready to use immediately after recovery from the centrifuge. It has a very intense, fresh coconut aroma, is viscous and feels greasy on the skin. It is suitable for use as a functional food.

Among the VCO processing technologies, the fresh-dry centrifuge process has the highest energy input. Micro-pulverisation of the dried material with high oil content (about 67%) is a difficult process and requires high electric power input. Based on the author's experience, grinding coconut flakes with an oil content of just 8–12% to convert into coconut flour at 100 mesh particle size requires special process conditions and a 7.5 HP motor. In micro-pulverisation, the particle size of ground dried kernel is reduced to 5–10 microns.

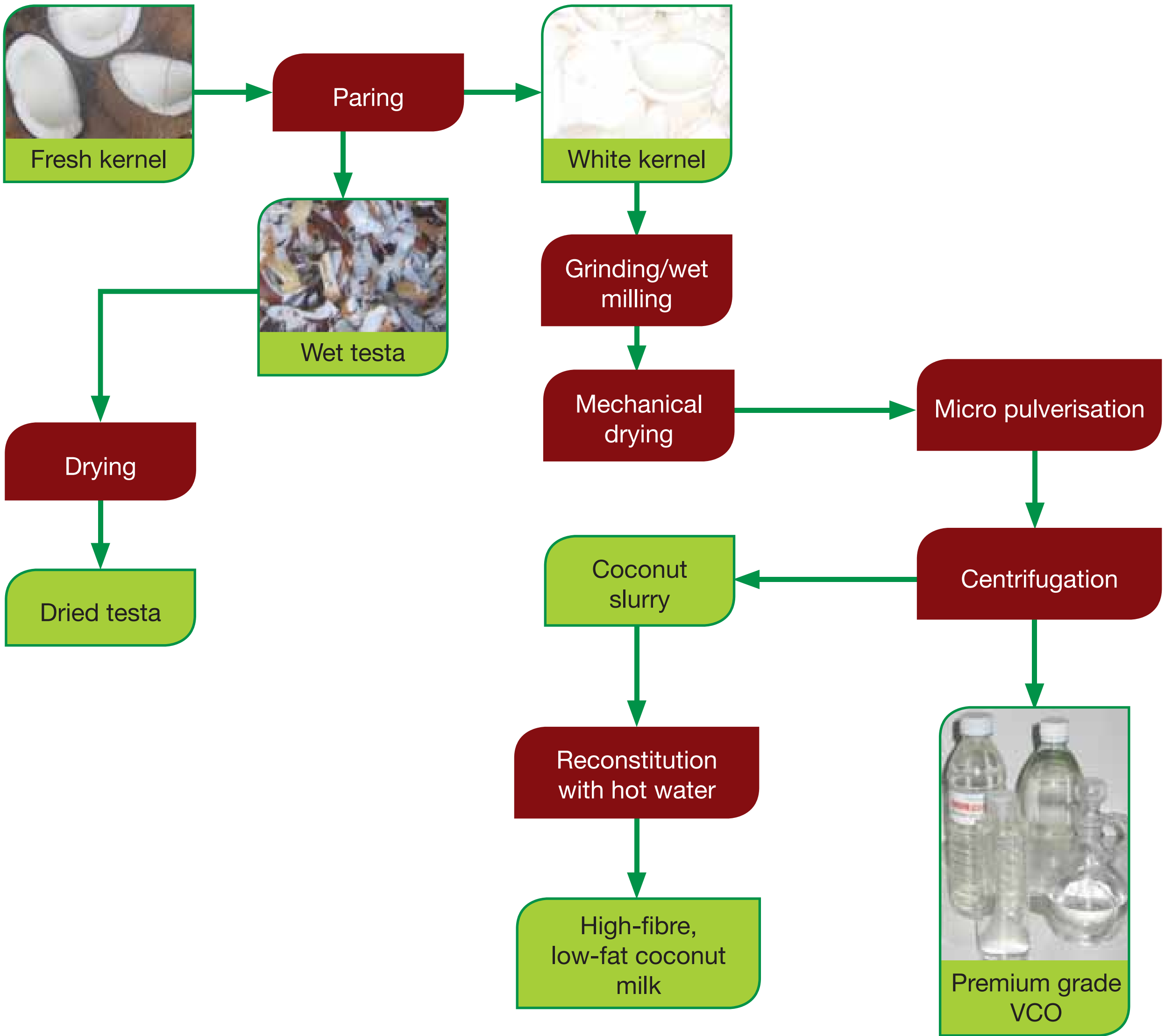


Figure 24. The fresh-dry centrifuge process

3.2.2 Fresh-wet VCO processing technologies

GMP 4.2.4

Coconut milk is an emulsion of oil in water bonded by protein. To separate the oil from the water, the protein bond has to be broken, either by heating or by the use of natural enzymes or a high centrifugal force. This is the basis for the development of VCO processing technologies under the fresh-wet process.

Fresh-wet is the general term given to VCO processing technologies in which VCO is recovered from coconut milk, the milky fluid obtained when freshly comminuted coconut kernel is pressed, either by manual or mechanical means with or without the addition of water. The yield and quality of coconut milk obtained from a batch of fresh coconuts depends on the coconut variety, the maturity of the nut, the particle size of the kernel, the kernel temperature prior to extraction, the ratio of water to comminuted kernel (if water is added) and the extraction pressure. Generally, moisture content ranges from 47–56% while oil/fat is 27–40% (Banzon, Gonzales and Leon 1990).

In a micro or village scale operation, the coconuts are split, the kernels are grated and the milk is extracted either manually or using a manually operated milk press (hydraulic or vertical screw-type) or a motorised hydraulic or horizontal screw-type milk extractor. The type of coconut milk extraction method depends on the scale of operation. Likewise, the number of milk extractions done and the type of hydrating liquid to be used (tap or purified water or coconut water) depends on the preference of the processor and the type of equipment used for milk extraction.

After the milk has been extracted, a solid residue is left, amounting to 25–50% of the weight of the fresh coconut kernel on a wet basis, depending on the extraction process. Please refer to Section 6.3.1 for options on how to utilise this residue.

VCO produced from the fresh-wet process is very light in texture, much like mineral oil, and is easily absorbed by the skin. This is actually the major advantage of VCO produced from the fresh-wet process over VCO produced from the fresh-dry process. The natural gums in fresh coconut kernel go with the coconut milk when it is extracted. However, these gums are automatically removed when VCO is recovered from coconut milk by other methods.

VCO produced by the fresh-wet process can be clarified by a very simple filtration process because the particles of coagulated protein or curd are relatively large and floating on the surface of the oil.

There are three methods for the production of VCO under the fresh-wet process (Figure 11), the modified kitchen method, the modified natural fermentation method and the fresh-wet centrifuge method. These are described in the next sections.

3.2.2.1 The modified kitchen method

GMP 4.2.4.2a

This VCO processing technology is generally referred to as the modified kitchen method as it is very similar to the traditional way of making coconut oil at home, a common practice in PICTs. The basic difference is in controlling the heat to prevent the coconut oil from turning yellow. The process (Figure 25) involves gradually heating the coconut milk mixture (first and second extract) until all the water has been evaporated to produce the virgin coconut oil and proteinaceous residue (called *sinusinu* in Fijian).

After grating the fresh kernels, the milk is extracted by either the manual method or by using a hydraulic jack and manually operated milk press.

- Manual method. Mash the grated kernel thoroughly to facilitate the flow of the milk. Then place it in a clean cheesecloth bag and squeeze tightly (Figure 26) to extract the milk.

  Second milk extraction – A second milk extraction is recommended only if manual extraction is used. It is an optional step and is done to increase the amount of coconut milk recovered from the grated kernel. Add hot water to the coconut milk residue obtained after the first milk extraction in a 2:1 ratio, i.e. for every two cups of residue, add one cup of hot water. Mix thoroughly. Place it in a cheesecloth bag and squeeze tightly.

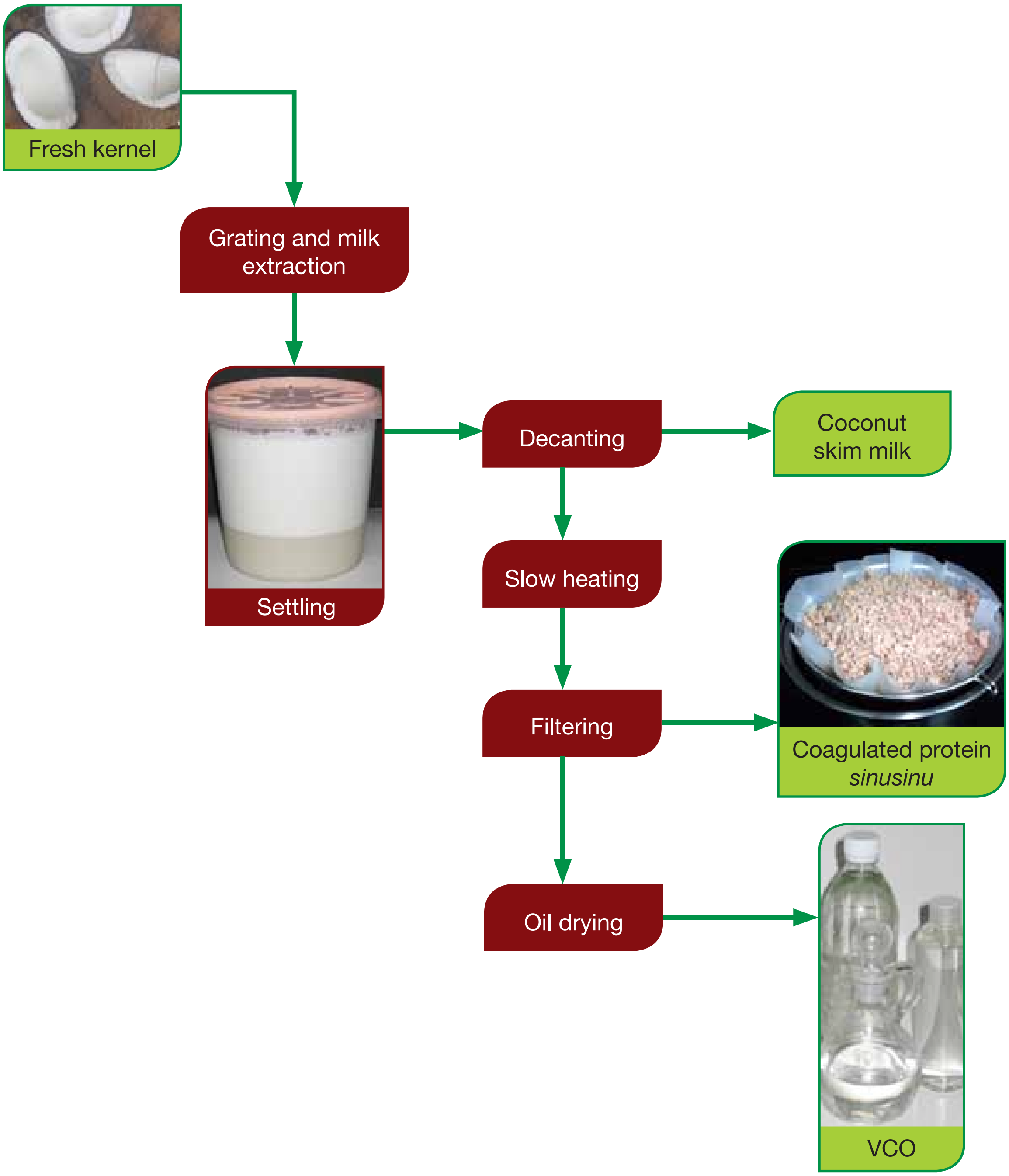


Figure 25. The modified kitchen method

Figure 26. Hand squeezing of coconut milk using a cheese cloth

- Hydraulic jack method. Place the grated kernel in a white net bag (Figure 27), position the bag at the centre of a manually operated hydraulic jack type press and extract the coconut milk in accordance with the jack's operating procedure.

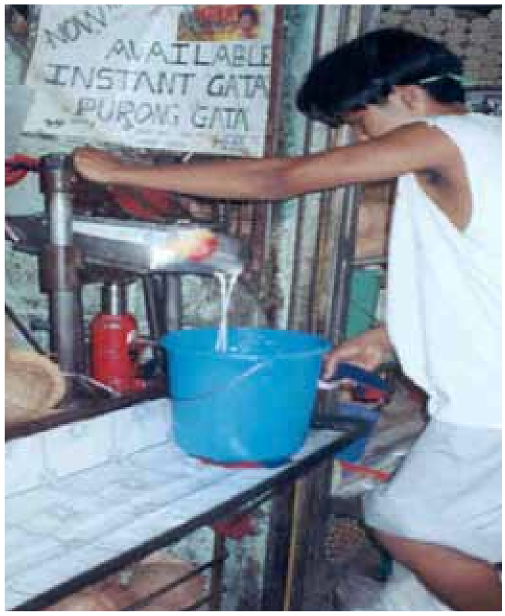


Figure 27. Extraction of coconut milk using a hydraulic jack

Source: PCA Product Development Department

The coconut milk is subjected to the steps described below to recover the VCO.

Settling of the coconut milk – This process step is actually optional. The coconut milk can be heated immediately without settling. However, it is preferable to allow the coconut milk to stand for at least two hours for the following reasons:

- Settling for at least two hours separates the coconut milk into cream (oily phase) and skim milk (watery phase) (Figure 28). The heating time to recover the VCO will be considerably reduced by just heating the coconut cream and discarding the skim milk, as this step will considerably reduce the amount of water in the coconut milk.
- Coconut skim milk can be used as a nutritious beverage if settling is done in the refrigerator or ice box for a maximum of two hours. (Refer to Section 6.4 for the nutritional value and more information on coconut skim milk.) Settling beyond two hours, even in the refrigerator, will make the skim milk sour and unsuitable for human consumption.

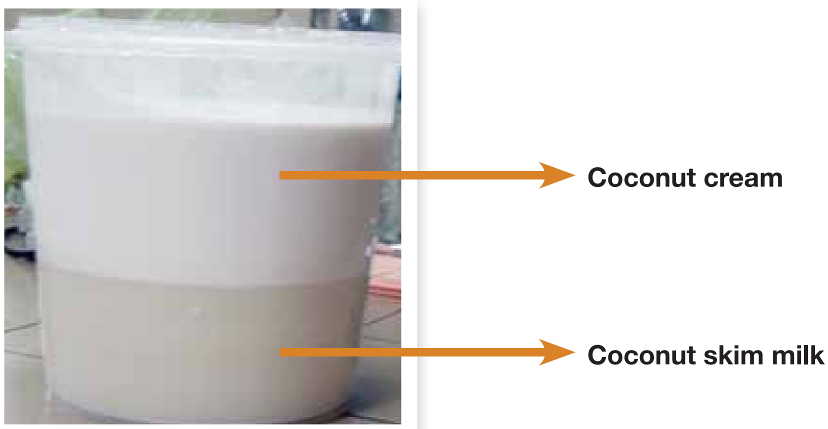


Figure 28. Separated coconut cream and skim milk

Separation of coconut cream and coconut skim milk – Separate the cream (oily phase) from the skim milk (watery phase) by scooping the cream from the top.

Heating the coconut cream – Place the coconut cream in a wok and heat it to coagulate the protein, evaporate the residual water and release the oil. For the first hour of heating, the temperature can be allowed to reach 90°C (stove setting between medium and high). For the rest of the time, when the protein starts to coagulate, the temperature should not exceed 80°C (stove setting at medium). Reduce the stove setting to low when the oil starts to separate from the coagulated protein (Figure 29). Stir the coconut cream during this heating process to disperse the heat constantly.

Figure 29. Separation of oil from the coagulated protein during heating of coconut cream

Remove the oil from the wok by scooping it out as soon as enough has separated from the coagulated protein. Do not allow the *sinusinu* to turn brown as this will cause the oil to turn yellow.

Separation of oil and *sinusinu* – Separate the oil from the *sinusinu* by pouring the mixture through a stainless steel strainer with fine mesh or a muslin cloth placed over a stainless steel pot (Figure 30). Set aside the *sinusinu* for use as a topping for rice cakes or as an extender to meat-based food recipes, making the meal cheaper without reducing its nutritional value (e.g. mix it with minced beef or pork for meat balls). *Note: the* sinusinu *should only be used for food if it is obtained from coconut milk which is directly heated after extraction or when settling time to separate the cream with coconut skim milk prior to heating does not exceed three hours. If the settling time exceeds three hours, the* sinusinu *tastes sour and is no longer palatable.*

Figure 30. Separation of VCO and sinusinu

GMP 4.2.4.3

Filtration of oil – filtration of the VCO is done to clarify it. Filter the oil which was scooped up from the wok during the heating process and the oil that separated when the oil-*sinusinu* mixture was strained. One way of filtering is to put a sterilised cotton swab (like those used in hospitals) in the hole of a big funnel (Figure 31), pour the oil over it and allow the oil to trickle through. Absorbed oil in sterilised cotton balls can be recovered by squeezing and mixing with second grade VCO for further processing. (The use of tissue paper is not recommended because of the possible presence of chemicals, e.g. bleaching agents.) For bigger scales of operation, a manufactured pressure filter with a filter cloth is recommended to increase the filtration rate.

Filtration is quite simple because the coagulated protein particles are just adhering or floating on the surface of the oil.

Figure 31. Simple filtration of VCO

Oil drying is the removal of moisture that might still be entrained in the oil after extraction. Please refer to Section 3.3 (post-processing stage) for oil drying techniques.

It should be noted that there is no clear indication when the heating step in the modified kitchen method should be stopped or when the residual moisture content is removed. Hence, an oil drying step is necessary to ensure that the residual moisture content is reduced to the lowest level possible (0.1% or below) in order to prolong the shelf-life of the oil.

3.2.2.2 The fresh-wet modified natural fermentation method

This technology was introduced by the author in several countries in the Pacific through a series of training courses that began in 2006 and were funded by the APCC and SPC – EU FACT Project (Figure 32). It is now the most common VCO processing technology being used by homescale VCO producers in Fiji.

Figure 32. Participants at the training courses on VCO processing and related matters held at SPC's Community Education Training Centre, Narere, Fiji. The author, Dr Lex Thomson and Mr Tevita Kete of SPC-EU FACT Project can be seen in the picture on the right.

If properly diluted coconut milk is allowed to stand under favourable conditions for several hours, the oil naturally separates from the water and protein that binds them together as coconut milk emulsion. This process is termed fermentation, although no fermenting substance is actually added. It is believed that natural enzymes in coconut may be acting as the fermentation medium. In the traditional natural fermentation method, settling and subsequent fermentation of coconut milk lasts for 36–48 hours. However, laboratory analysis of coconut oil produced using this process shows that the free fatty acid (FFA) content ranges from 0.33–0.38%. This already exceeds the prescribed standard of a maximum of 0.1% FFA. Likewise, in certain cases, the coconut oil produced is already pale yellow in colour. Hence, the process in which the settling period/fermentation time is controlled up to a maximum of 16 hours is termed the 'modified natural fermentation process' (Figure 33).

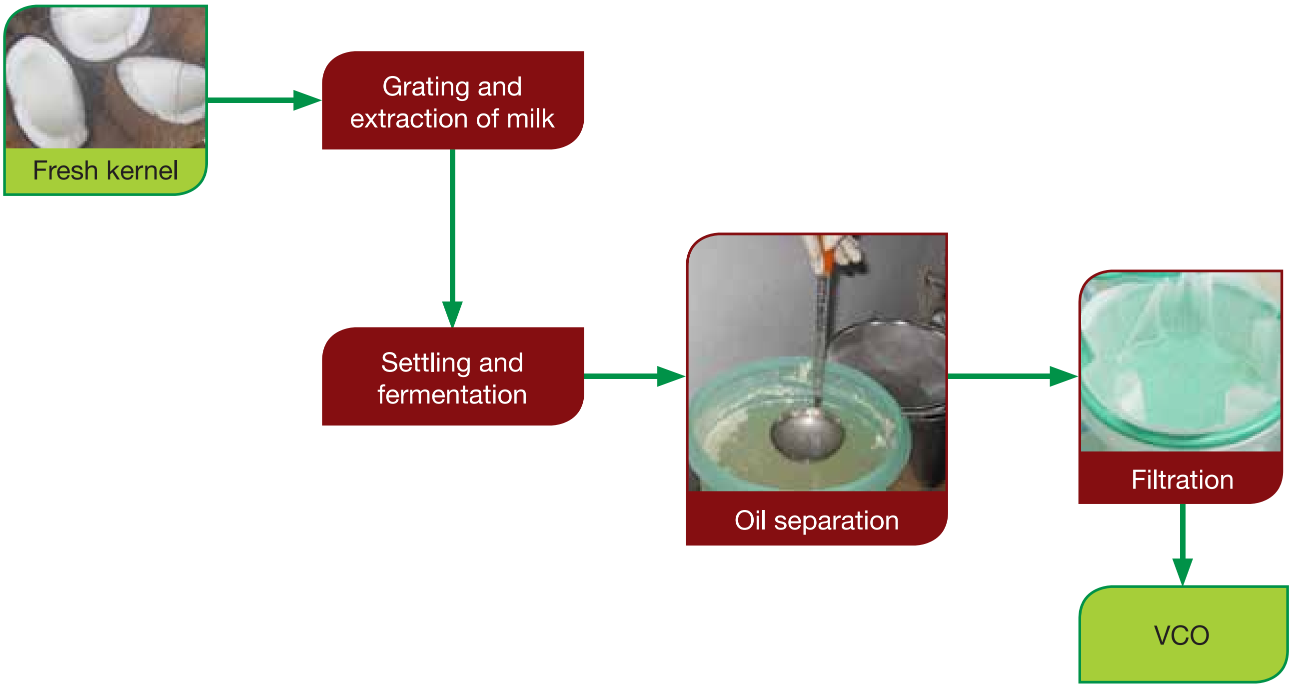


Figure 33. The modified natural fermentation method

This technology requires very little investment, modest labour and low energy inputs. VCO can be easily produced at home with this method, using a manual coconut grater and kitchen utensils.

The heart of the method is the preparation of coconut milk and the right temperature that will promote overnight separation of the milk into different layers of gum, water, proteinaceous curd and oil.

The modified natural fermentation process is very sensitive to the maturity and the freshness of the coconuts. Fully mature coconuts should be processed within three days from the time of harvesting to ensure that the oil separates naturally from the coconut milk after 16 hours. Immature nuts contain a higher percentage of protein, which makes the protein bond in coconut milk more difficult to break to release the oil. Likewise, the longer the coconuts are stored, the higher the risk of spoilage and contamination.

Splitting and grating – This is the same process as described in the modified kitchen method.

An alternative to splitting and grating is to manually remove the shell and feed the kernel into a Thai coconut shredding machine (Figure 34) or a Malaysian grinding machine.

Milk extraction – After grating or shredding the fresh kernels, the milk is extracted by either the manual method or by using a hydraulic jack and manually operated milk press or by a motorised screw milk press (for larger scale of operation).

- Manual method. The grated kernel is thoroughly mashed to facilitate the flow of the milk. Place the mashed grated coconut kernel in a clean cheesecloth bag and squeeze tightly (Figure 26) to extract the milk.

Figure 34. Thai coconut shredding machine

- Hydraulic jack method. Place the grated kernel in a white net bag (Figure 27), position the bag at the centre of a manually operated hydraulic jack type press and extract the coconut milk in accordance with the jack's operating procedure.

- Motorised screw type milk press. Feed the grated or shredded fresh coconut kernel evenly into the feed hopper of the machine.

Second milk extraction – A second milk extraction is recommended only if manual extraction is used. It is an optional step and is done to increase the amount of coconut milk recovered from the grated kernel. Add hot water to the coconut milk residue obtained after the first milk extraction in a 2:1 ratio, i.e. for every two cups of residue, add one cup of hot water. Mix thoroughly. Place the mixture in a cheesecloth bag and squeeze tightly. Add this milk extraction to the first and stir for about ten minutes.

Dilution of coconut milk – Dilution of coconut milk with potable water (or coconut water as described below) is necessary to facilitate the removal of natural gums which interfere with the natural separation of VCO. These gums, which are inherent in the fresh kernel, go with the coconut milk when it is extracted. Add water, following the recommendations below and stir for about 15 minutes.

- The dilution ratio for coconut milk:water is 1:1 that is, for every cup of coconut milk, add one cup of water. (In Kiribati more water is needed because coconuts there have more gum; the dilution ratio should be one cup milk:two cups of water.)

- For plucked or newly fallen coconuts, water at a temperature between 27° and 30°C) can be used. If using coconuts from the market (and therefore not knowing how long ago they fell or were picked) the diluting water should be heated to a temperature of about 50°–60°C.

Coconut water can be used as a substitute for water but filtration must be followed immediately by storage in a refrigerator. Using sterilised (boiled) coconut water delays the natural separation of VCO from the other components of coconut milk, such that complete separation of the oil is achieved only after 40 hours of settling. This was found out during the training course in Fiji in October 2009.

Settling/fermentation – allow the coconut milk mixture to stand for 12–16 hours in a place where the temperature can be maintained at 35°–40°C to produce premium grade VCO (Figure 35).

GMP 4.2.4.2b

For home scale production of VCO (50 nuts per batch), the following methods can be used to achieve the temperature that will promote efficient fermentation.

a. In places where there is no electric power or where electricity is available for only a few hours at night, pour boiling water into a metal pot, put the lid on it and place it next to the container of coconut milk in a kitchen cabinet or, if available, a styrofoam box (normally used for transporting fish with ice) because of its insulating property.

b. In places where electricity is available, use a tall carton and hang a 20 watt incandescent bulb (not CFL) over the container of coconut milk.

For VCO production from more than 50 nuts per batch, the use of a fermentation cabinet is recommended (Annex 6).

Figure 35. Gravity settling of coconut milk to separate cream and skim milk

When proper operating conditions and sanitary precautions are strictly followed, five distinct layers can be seen in the fermenting container after 16 hours (Figure 36). The bottom layer is gummy material. The next layer up is the watery portion which is actually fermented skim milk. The skim milk recovered here is not fit for human consumption and must be properly discarded. Above the layer of skim milk is a solid layer composed of spent fermented curd and above this is the separated oil for recovery as VCO. At the top is another layer of fermented curd. The fermented curd, especially the topmost layer, contains a lot of oil. Premium grade VCO is harvested when the colour of this curd is light cream. It should not be allowed to turn brown prior to recovery.

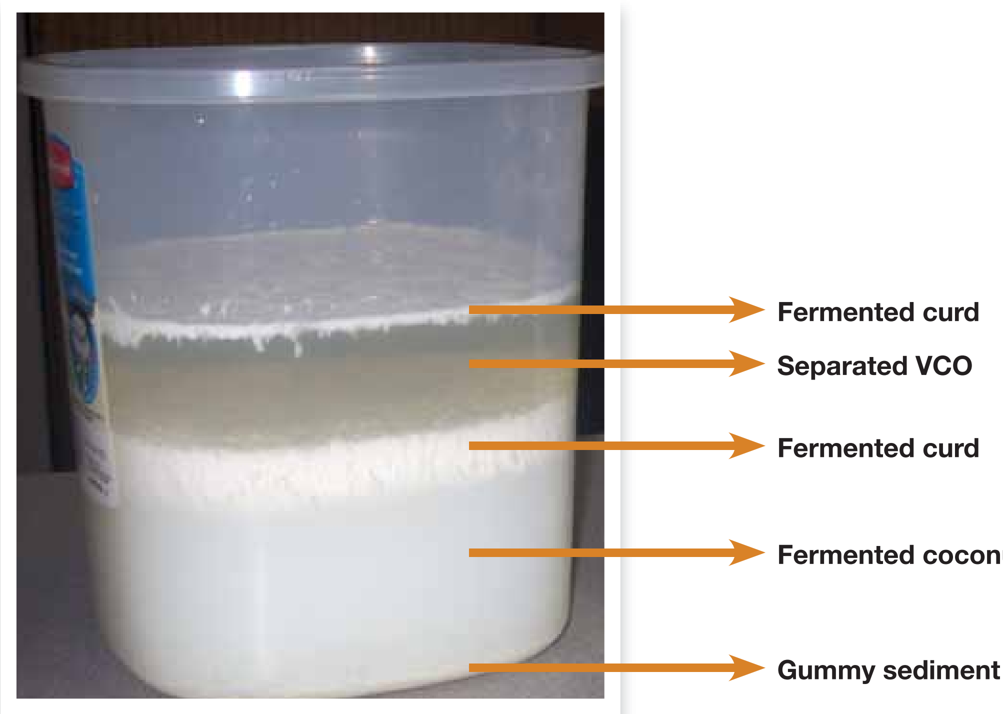


Figure 36. Layers after fermentation of coconut milk

Source: Bawalan and Chapman (2006)

Oil recovery – Remove the top layer of fermented curd and scoop out the separated oil (Figure 37). Take care not to disrupt the layers of oil, fermented curd and fermented skim milk. Collect the fermented curd in a container and set it aside.

Filtration of oil – Filtration of the VCO is done to clarify it.

One way of filtering is to put a sterilised cotton swab (like those used in hospitals) in the hole of a big funnel or an improvised funnel (Figure 31), pour the oil over it and allow the oil to trickle through. Absorbed oil in sterilised cotton balls can be recovered by squeezing and mixing with second grade VCO for further processing. (The use of tissue paper is not recommended because of the possible presence of chemicals, e.g. bleaching agents.) For bigger scales of operation, a manufactured pressure filter with a filter cloth is recommended to increase the filtration rate.

Figure 37. Manual recovery of VCO

Recovery of second grade VCO – The fermented curd that is collected in a separate container during the recovery of premium grade VCO is allowed to stand/ferment for a further 24 hours to recover second grade VCO (Figure 38).

Figure 38. Recovery of second grade VCO

The recovered second grade VCO is filtered separately from the premium grade. Please refer to Section 7.5 for ways of utilising second grade VCO.

In the Philippines, 6.5 litres of premium grade VCO and about 1 litre of second grade VCO are recovered per 80 husked coconuts.

Ageing – VCO obtained from the modified natural fermentation process develops a sour smell if operating conditions and fermentation time are not controlled properly. Ageing of VCO is an additional process done in the Philippines to ensure the removal of any faint sour smell. Please refer to Section 3.3.2 for the procedure on ageing.

3.2.2.3 The fresh-wet centrifuge method

There are different versions of the centrifuge method under the fresh-wet process. Process steps, supporting equipment and investment costs vary, depending on the type of centrifuge being used, i.e. the two-phase (liquid-liquid) or three-phase (liquid-liquid-solid) type.

3.2.2.3a The two phase (liquid-liquid) centrifuge process

There are variations of the two-phase (liquid-liquid) centrifuge method depending on how the VCO is recovered from the cream after the separation of the skim milk using the centrifuge. Some of the reported processes are the following:

Process 1: The cream is subjected to vacuum evaporation to remove water and coagulate the protein. The oil is then passed through a pressure filter to get clarified VCO and then vacuum-dried.

Process 2: The cream is frozen, then heated in a double boiler and filtered to remove the coagulated protein. The oil is passed through the centrifuge to remove the remaining water and then vacuum-dried.

Process 3: The cream is heated at a controlled temperature to coagulate the protein and remove the water. Then the mixture is passed through a pressure filter. The oil is then vacuum-dried.

Figure 39 shows the steps of the two-phase centrifuge.

Preparation of the coconut kernel prior to milk extraction is the same as the process used in the fresh-dry high pressure expeller method, DCN route, i.e. shelling, paring, cutting, washing and grinding. Please refer to Section 3.2.1.2b for details.

Extraction of coconut milk – Coconut milk is extracted from the freshly comminuted (pared) kernel by means of a motorised screw-type coconut milk press.

Filtration of coconut milk – Stainless steel strainers with fine mesh are used to remove all adhering solid particles. If not removed, these particles will cause clogging in the centrifuge.

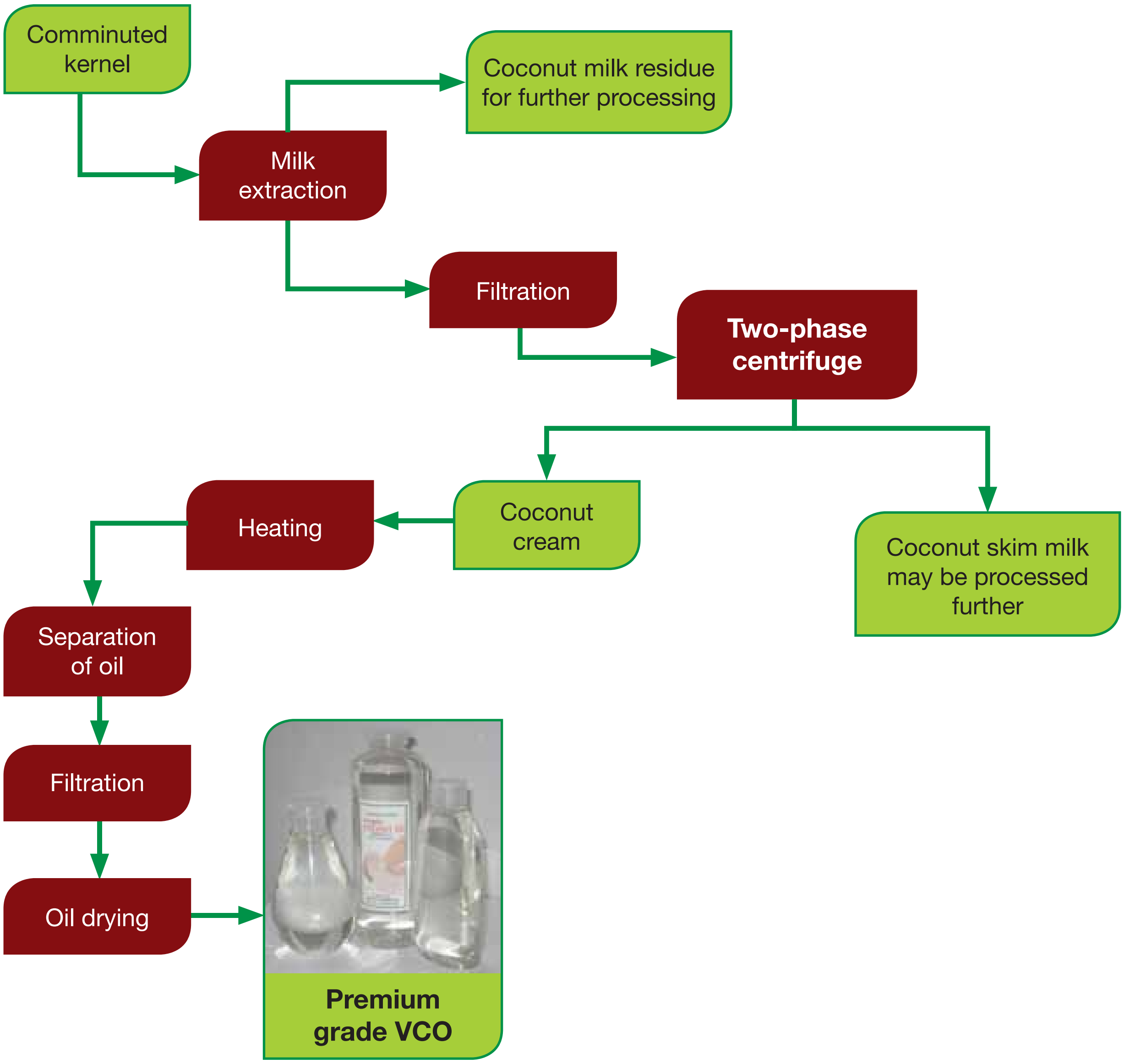


Figure 39. The fresh-wet two-phase centrifuge method

Separation of cream from the skim milk (Figure 40) – The coconut milk is passed through the liquid-liquid centrifuge to separate the coconut cream (oily phase) from the skim milk (watery phase).

Heating – The cream is heated using controlled temperature to coagulate the protein

Filtration – The oil is passed through pressure filter to separate the coagulated protein

Oil drying – The VCO produced is dried under vacuum to remove the residual moisture that is entrained in the oil.

In terms of oil recovery, this process has the lowest among the VCO processing technologies because, aside from the oil retained in the residue when the coconut milk is extracted, some losses are also incurred when the coconut cream is separated from the skim milk in the centrifuge.

Figure 40. Centrifugal separation of coconut cream and skim milk

3.2.2.3b The three-phase centrifuge

The three-phase (liquid-liquid-solid) centrifuge process (Figure 41) is much simpler than the two-phase centrifuge process. Filtered coconut milk is passed through a three-phase centrifuge system (Figure 42) where the oil is separated from the other components of coconut milk by means of a centrifugal force of 10,000 rpm.

The coconut milk is fed to the centrifuge with hot water. When the oil coming out of the centrifuge is still cloudy, it is fed in, again with hot water, for a second pass. The oil is then passed through a micro filter to remove the fine, solid particles, and dried, using a vacuum dryer, to recover the VCO.

Preparation of the coconut kernel prior to milk extraction is the same as the process used in the fresh-dry high pressure expeller method, DCN route, i.e. shelling, paring, cutting, washing and grinding. Please refer to Section 3.2.1.2b for details. Extraction and filtration of coconut milk is the same as described in the two-phase (liquid-liquid) centrifuge method.

Scales of operation for the three-phase (liquid-liquid-solid) centrifuge process are relatively large because of the high investment cost. The smallest three-phase centrifuge being used in the industry has a process capacity of 800 litres per hour (equivalent to about 3500 nuts/hour). The viability of VCO production using the centrifuge process can be improved if the coconut milk residue is processed further to make coconut flour and another type of premium grade VCO.

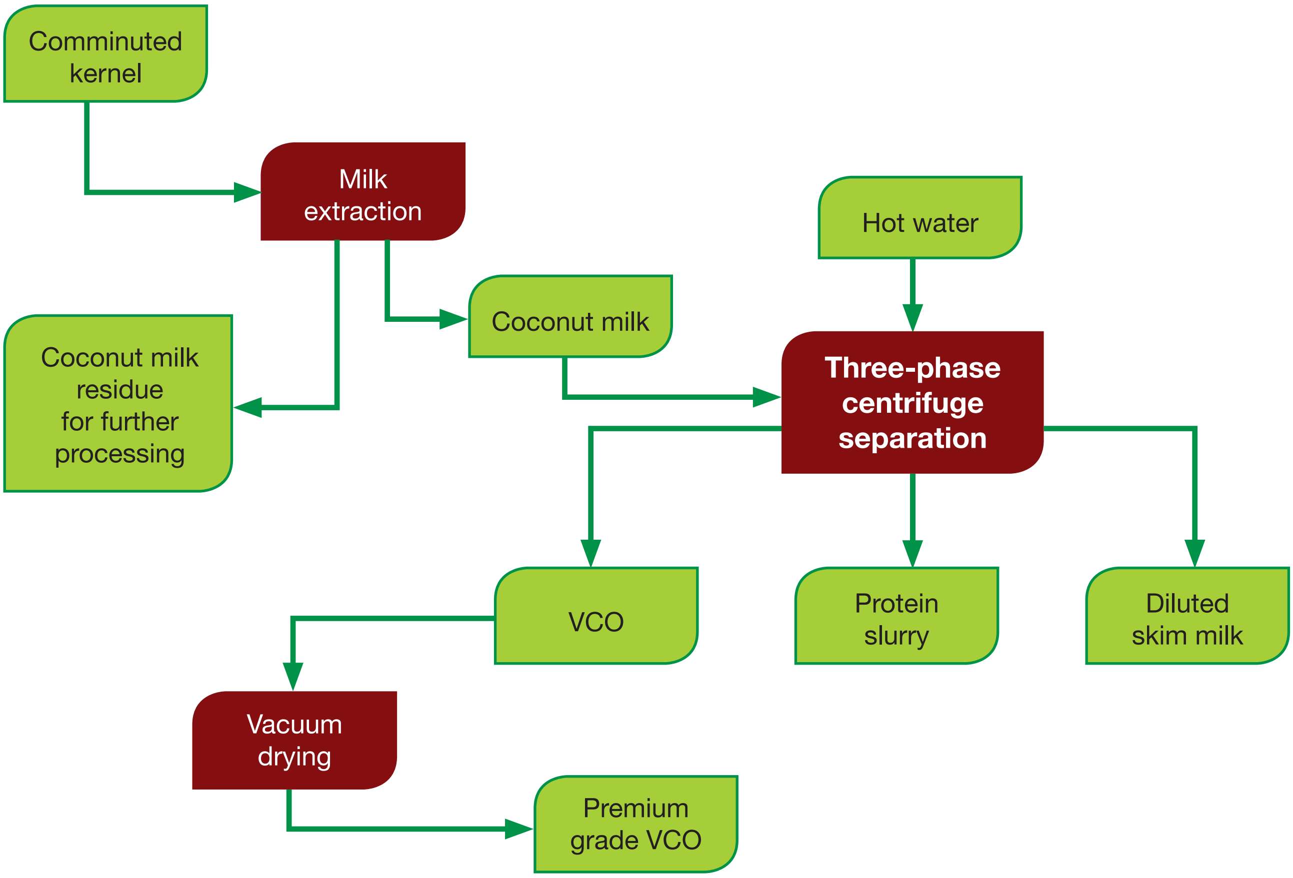


Figure 41. The fresh-wet three-phase centrifuge method

Figure 42. The three-phase centrifuge

Source: Masa (2008)

3.2.3 The Bawalan-Masa Process for VCO production

The Bawalan-Masa Process can be considered a hybrid of the fresh-dry and the fresh-wet processes of VCO production. The starting material for VCO extraction is the coconut milk residue, a by-product of the fresh-wet VCO process. However, the manner in which VCO is extracted from the coconut milk residue is similar to the fresh-dry VCO process. This VCO processing technology can be used in tandem with the fresh-wet centrifuge method and in the processing of coconut milk, coconut cream and coconut cream powder to maximise the utilisation of coconuts and improve profitability.

Coconut milk residue represents approximately 25–50% of the weight of freshly grated kernel on a wet basis, depending on the coconut milk extraction process that is used (Bawalan and Chapman 2006). It still retains about 35–40% of the original oil content of the fresh coconut kernel. VCO and high-fibre, low-fat coconut flour can be produced by further processing the coconut milk residue using the Bawalan-Masa Process. For every tonne of wet coconut milk residue, 170 kg of VCO and 263 kg of coconut flour can be recovered.

VCO produced from the Bawalan-Masa process is very light in texture, much like water, easily absorbed by the skin and has a very mild coconut scent. For these reasons, this type of VCO is preferred by manufacturers of aromatherapy oils and operators of spas.

The utilisation of coconuts can be maximised by combining the centrifuge process of VCO production with the Bawalan-Masa process to produce two types of high quality VCO and coconut flour.

The production process (Figure 43) was developed by the author while working as Senior Science Research Specialist, Product Development Department (PDD), Philippine Coconut Authority (PCA), together with Ms Dina B. Masa, Manager, PDD – PCA.

The process involves blanching the residue, drying it at a specific moisture content level and subsequently defatting the dried residue under controlled conditions using specially designed equipment to produce VCO and low-fat, high-fibre coconut flakes. The flakes are further ground to produce coconut residue flour. The technology was adopted for commercialisation in 2002 by Sirawan Foods Corporation, a coconut milk manufacturer, through a technology transfer agreement with PCA. The technology has an approved patent from the Philippine Intellectual Property Office in the name of the PCA.

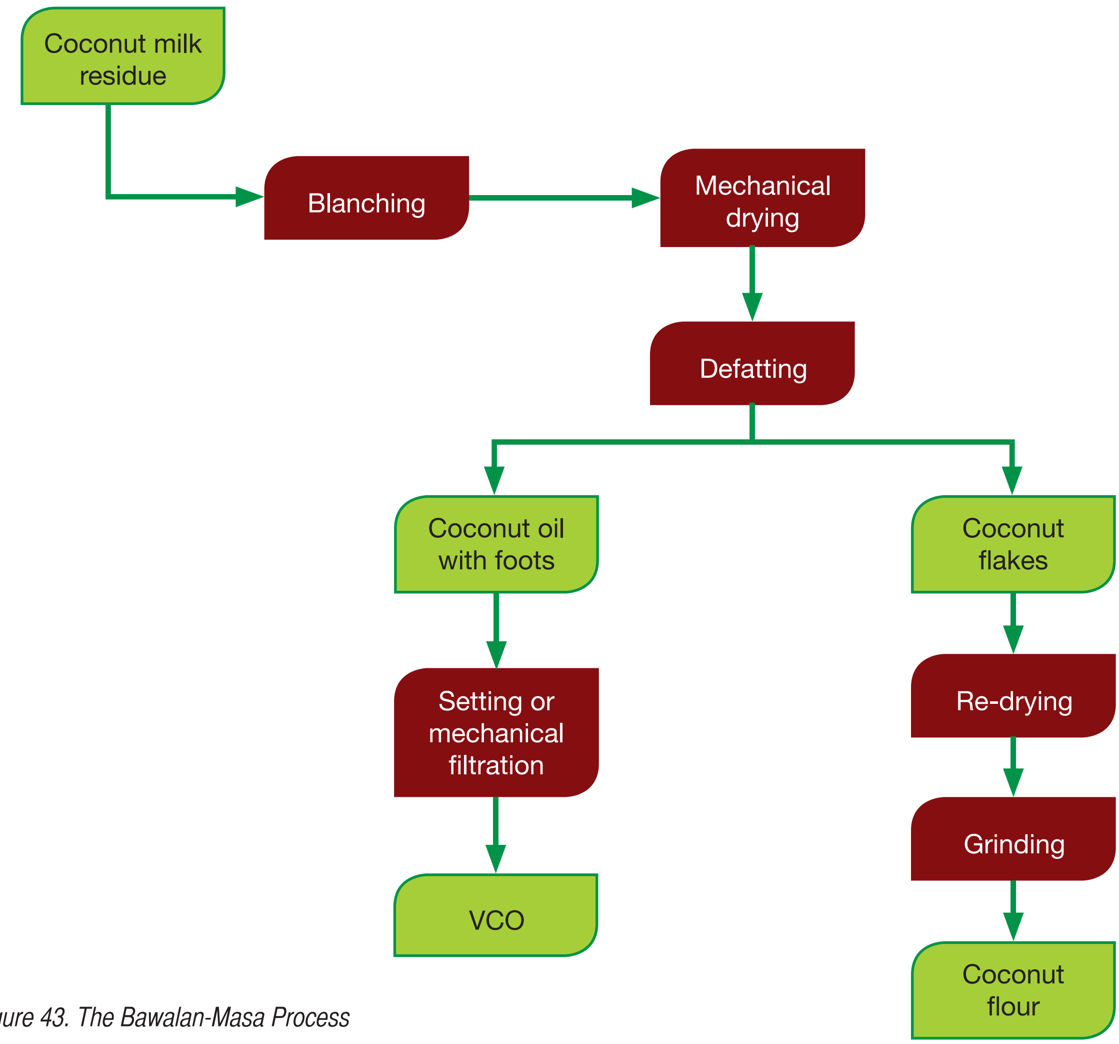


Figure 43. The Bawalan-Masa Process

A more detailed process description of the Bawalan-Masa process is presented in Annex 11 and discussed in conjunction with the utilisation of by-products in Chapter 6.

3.3 Post-processing stage

The post-processing stage covers the additional steps that have to be taken to ensure that the VCO will be of the highest quality, will have a long shelf-life and a fresh coconut scent/aroma. The steps that need to be taken depend on the technology used to produce the VCO.

3.3.1 Oil drying

GMP 4.3.1

The presence of water in VCO will cause it to go rancid and shorten its shelf-life. Hence, entrained moisture in the oil should be reduced to as low a level as possible (not more than 0.1%).

Oil drying as a post processing step is recommended for the VCO produced by the following processes:

- the direct micro expelling (DME) method
- the modified kitchen method
- the modified natural fermentation method
- the fresh-wet centrifuge process.

Based on experience, the moisture content of VCO produced by the high pressure expeller process is already at a level of 0.1% or less after oil extraction. However, residual moisture content is particularly critical in the VCO produced by the fresh-wet process since the oil is being recovered from coconut milk, which has high moisture content. On the other hand, while the DME process is also categorised under the fresh-dry process, oil extraction is done when the moisture content of the kernel is still relatively high. Likewise, the subjective way of determining the final moisture content of dried kernel prior to oil extraction under the DME process causes the oil to have variable quality. This can be corrected by an additional oil drying step.

Bawalan and Chapman (2006) recommend the drying methods described below.

- Place the extracted oil in a double boiler (Figure 44) and simmer for about fifteen minutes or until the oil has turned water-clear.
- Incubate or air heat the open oil-filled container at 50°C for 12 hours or until the oil has turned water-clear.
- Vacuum drying.

An improvised double boiler can be made by placing a stainless steel mixing bowl inside a pot half full of water. The oil is placed in the mixing bowl. Ensure that the bottom of the mixing bowl is touching the water inside the pot. In this way, heating of the oil is regulated. Once the water in the pot starts to boil, reduce the flame to the lowest possible setting such that the temperature of the hot water will just be maintained. NEVER HEAT oil directly in a pot or pan as this will cause it to turn yellow.

Figure 44. Improvised double boiler

Incubation or air heating of the oil at 50°C can be done in a specially designed cabinet fitted with an air heater and thermostat control.

Vacuum drying is the most effective way of drying oil without the risk of it turning yellow. A vacuum dryer is a standard feature in a VCO plant using the fresh-wet centrifuge process in a medium scale operation, but is not viable for an individual micro-scale processor because the investment cost is high. If, however, there is a vacuum dryer in a central location to which processors could bring their raw VCO to dry under a user-pays scheme, it could be viable.

3.3.2 Ageing

GMP 4.3.2

VCO obtained by the modified natural fermentation process normally develops a sour smell if operating conditions and fermentation time are not controlled properly. Ageing of VCO is an additional process done in the Philippines to ensure the removal of any faint sour smell.

Ageing is done by placing VCO in stainless steel pots, covering the pots with coarse cheese cloth and storing them for a week in a warm room (50°C) or in a cabinet specially designed for the purpose. In this way, the aromatic compounds responsible for the sour smell are volatilised and removed. Likewise, whatever residual moisture the oil contains settles at the bottom of the container. Hence, ageing and drying are done simultaneously.

After ageing, transfer the VCO to another container by scooping it up. Leave about two centimetres of oil in the bottom of the pot because any residual moisture in the oil will be in this bottom layer. This oil that is left can be dried using an appropriate oil-drying technique as described above and sold as cooking oil (after accumulating enough volume) or mixed with second grade VCO for further processing into downstream products (see Chapter 7).

3.3.3 Fine filtration of VCO

Based on experience, very fine particles of dried kernel (foots) entrained in the VCO produced using the low pressure oil extraction method /DME process and the high pressure expeller method are not totally removed even after gravity settling for two weeks. This is manifested in unsightly residue that settles at the bottom of VCO bottles in retail stores and it puts prospective buyers off. This problem can be solved through fine filtration using motorised pressure filters before packaging. However, pressure filters are relatively expensive and not economically viable for small scale operations using the DME process.

One way of solving this problem is for government or a development project to set up filtration centres that will service small-scale VCO producers using the DME process. Such facilities can be operated on a user-pays scheme, i.e. a fee is charged for each litre of VCO filtered in order to cover operating and maintenance expenses.

3.4 Packaging and storage

GMP 4.4

The most appropriate packaging for VCO is glass bottles in tropical climates and widemouthed glass jars in temperate climates. This is especially important if the VCO is to be sold in stores where it might stay on the shelves for long periods.

However, bottles made of PET (a thermoplastic resin) have evolved as the preferred packaging material because glass is quite heavy to transport and there is the risk of breakage. Plastic bottles similar to those used for mineral water can also be used, provided the VCO is consumed within a month.

For domestic sales, VCO is normally packaged in white 20 litre food-grade plastic containers if it is to be sold in bulk, or in 500 ml or 250 ml PET bottles (Figure 45) if it is to be sold in retail stores. For export in bulk, it is packed in 200 litre food-grade plastic drums.

Packed VCO should be stored in an enclosed area with screened windows, protected from rain, direct sunlight and materials with strong odours.

Figure 45. Packaged VCO in PET bottles

3.5 Comparative analysis of different processes for producing VCO

Table 4. Comparative analysis of different processes for producing VCO

Type of Process	Quality of Oil and Recovery	Advantages and Limitations
Fresh-dry processes		
High pressure expeller method wet milling route MC of dried kernel for extraction should be at 3-4%	FFA - 0.05–0.08% MC - 0.07–0.1% Colour - water-clear Oil recovery - 60 kg per 100 kg of dried milled kernel; 31 kg per 100 kg of fresh milled coconut kernel with testa (based on 50% initial MC of fresh kernel) **Highest extraction efficiency**	Produces full-protein, medium-fat coconut flakes with testa as a co-product which can be further processed into coconut flour or sold as an aflatoxin-free animal feed ingredient. Long shelf-life of oil – 1 year and above. Uses mechanical type of equipment to produce the oil. Applicable in a village scale plant operation (5,000+ nuts/day).
High pressure expeller method Desiccated coconut route MC of dried kernel for extraction should be at 3-4%	FFA - 0.05–0.08% MC - 0.0–0.1% Colour - water-clear Oil recovery - 58 kg per 100 kg of desiccated coconut ; 30 kg/100 kg of fresh pared, ground kernel (based on 50% initial MC of fresh kernel)	Produces full-protein, medium-fat coconut flour without testa as a co-product. Long shelf-life of oil – 1 year and above. Uses mechanical type of equipment to produce the oil. More appropriate to be used in tandem with an existing DCN processing plant.
High pressure expeller method Grated nut route MC of dried kernel for extraction should be at 3–4%	FFA - 0.05–0.08% MC - 0.07–0.1% Colour - water-white Oil recovery - 30 kg per 100 kg of fresh grated kernel (based on 50% initial MC of kernel)	Produces full-protein, medium-fat coconut flour without testa as a coproduct. Long shelf-life of oil – 1 year and above. Uses mechanical type of equipment to produce the oil. Applicable in a village scale plant operation (5,000+ nuts/day).
Low pressure extraction method MC of dried kernel for extraction should be within the range of 10–12%.	FFA - 0.1–0.2% MC - 0.17% and below Colour - water-clear Oil recovery - 25 kg per 100 kg of fresh grated coconut kernel (based on 50% initial MC of kernel)	Uses manually operated equipment to produce the oil. Produces a semi-dry coconut residue that has to be further dried or processed to have market value. Shelf-life of oil can be very short if milled or grated coconut kernel is not properly prepared prior to oil extraction. Oil drying is recommended to ensure long shelf-life.

Centrifuge method MC of dried kernel prior to micro-pulverisation at 5%	FFA - 0.05–0.08% MC - 0.1% and below Colour – water-clear Oil recovery - 60 kg per 100 kg of dried ground kernel without testa; 31 kg per 100 kg of fresh pared kernel (based on 50% MC of fresh kernel) **Second highest oil extraction efficiency.**	Produces low-fat, high-fibre coconut milk as a co-product. Long shelf-life of oil – 1 year and above. Can also be used in tandem with DCN processing. High investment cost since it uses highly specialised equipment and is energy intensive. Very intense, fresh coconut aroma.
Fresh-wet processes		
Modified kitchen method	FFA - 0.1% MC - 0.14% and below if heating is done long enough to remove water in the coconut milk Colour - water-clear to pale yellow depending on the heating process Oil recovery - 16.5 kg per 100 kg of fresh grated coconut kernel (based on 50% initial MC of kernel)	Very low investment cost. Can be produced on a home scale operation using ordinary kitchen utensils. Produces a wet coconut residue that has to be further dried or processed to have market value. Produces a by-product (proteinaceous residue) which does not have commercial value at present. Oil drying is recommended to prolong shelf-life. Hardest to control in getting the correct colour and low MC.
Modified natural fermentation method	FFA - 0. 1% MC - 0.12% and below Colour - water-clear Oil recovery - 34 litres per 100 litres of coconut milk (about 19 kg oil per 100 kg of fresh grated kernel) (Based on 50% initial MC of kernel)	Very low investment cost. Lowest labour and energy input. Can be produced quickly on a home scale operation using ordinary kitchen utensils or on small/medium scale operation using semi-mechanised equipment. Disposal of fermented skim milk could be a big problem if done on a medium scale plant operation. Oil produced has a faint sour smell which can be removed by ageing. Produces premium and class B grades of VCO. Uses a lot of potable water.

Fresh-wet centrifuge method (2-phase centrifuge)	FFA - 0.04–0.08% MC - 0.1% and below Colour - water-clear Oil recovery - about 28 litres oil per 100 litres of coconut milk (about 17 kg oil per 100 kg fresh grated kernel) (Based on 50% initial MC of kernel) Reported oil recovery rate was computed from the information provided by a VCO producer using a 2-phase centrifuge. Oil recovery rate using a 3-phase centrifuge may be different.	Produces the best quality coconut oil with best sensory attributes if done in a two stage centrifuge process. Can only be applied in a medium scale operation as investment cost is very high. Optimisation of the process is still required to improve oil recovery rate. Current oil recovery rates are much lower than the modified fermentation process. Lowest extraction efficiency. Further processing of the coconut skim milk into health beverage and the sapal generated into coconut flour can improve profitability
Bawalan-Masa process (VCO from coconut milk residue)	FFA - 0.05–0.08% MC - 0.07–0.12% Colour – water- clear Oil recovery - 17 kg per 100 kg of wet residue Coconut flour - 26.3 kg per 100 kg of wet residue	Further recovery of high value oil from residue makes coconut milk/VCO processing more profitable. Long shelf-life of oil – 1 year and above. Produces low fat high fibre coconut flour as a by-product. Requires mechanical type of equipment to produce the oil. Production process has to be attached or integrated to an existing coconut milk processing plant or a high capacity VCO plant. Maximises the income from coconut kernel when used in tandem with coconut milk processing or the fresh-wet centrifuge process of VCO production.

Source: Updated and revised table from Bawalan (2002)

3.6 Issues in VCO processing

3.6.1 Misconceptions in VCO processing and labelling

a) Process temperature

One of the biggest misconceptions in VCO processing is that the use of heat will make coconut oil lose the attributes of being 'virgin' oil. A lot of people think, and a lot of VCO producers claim, that coconut oil should be processed without any heat to retain its virgin quality. These producers claim that VCO processed without heat is the best quality and is priced higher, regardless of its quality and sensory characteristics. Admittedly, VCO processed without heat has a relatively higher Vitamin E content than VCO processed with heat but, in terms of value, the Vitamin E content of coconut oil is not high enough (36 mg/kg) for it to be considered a deciding factor in the grading of VCO. Vitamin E is also lost when the oil is exposed to sunlight.

It should be emphasised that the main reason virgin coconut oil is bought at a much higher price than any other edible oil is the high percentage of medium chain fatty acids (MCFAs) it contains, particularly lauric acid. Studies have suggested that they have anti-microbial properties, promote weight loss, boost the immune system and have other health benefits. Information on the stability of different nutrients to temperature, light, acid and other factors tells us that essential fatty acids are not affected by temperature as long as the smoke point of the oil is not reached. It is the vitamins that are susceptible to increases in temperature.

To sum up, VCO extraction at a high temperature, as long as it does not discolour the oil, is permissible and does not diminish the health benefits that can be obtained from it. It should be noted that the VCO standard stipulates that VCO should be colourless. This in itself is a self-checking mechanism on how high the processing temperature can be because having too high a temperature discolours the oil.

In addition, internet research revealed the following basic criteria for any vegetable or seed or nut oil to be entitled to the label 'virgin'. The processing temperature is not a requirement in these criteria:

- The oil is not refined or no other processing is done on the oil after extraction other than filtration.
- The oil is fit for human consumption after extraction and filtration.
- The oil retains the aroma of the seed or nut from which the oil is extracted, i.e. if it is olive oil, it should have the aroma of olives; if coconut oil, it should retain the natural aroma of coconut, etc.

Therefore, coconut oil that has been extracted by means of drying the fresh kernel under sanitary conditions and immediately extracting the oil using an expeller can qualify for the label 'virgin'. Likewise, existing quality standards for VCO do not stipulate any upper processing temperature (see Annex 4).

b) Testa or brown skin of coconut kernel

Another misconception in VCO processing is that if the brown skin, or testa, of the coconut kernel is not removed, it will discolour the VCO. Hence, most VCO producers make it a point to remove the testa prior to extraction of the oil. This practice increases the VCO production cost in terms of additional labour for removing the testa and there are also raw material losses, as the removed brown skin (plus some closely attached white meat) comprises about 13% to 15% of the total weight of the fresh coconut kernel. Removing the testa strips the VCO of linoleic acid, an essential fatty acid required by the body at a maximum level of 3.5% of total fat intake.

From 1991–1996, the author did countless coconut oil production trials from fresh coconut where the brown skin was included. The resulting coconut oil was still water-clear. Moreover, in the research studies under the RP-UK Aflatoxin Reduction in Copra Project, where the author worked as counterpart engineer, it was found that any colour in the coconut oil after extraction is normally caused by microbial action on improperly handled fresh kernel or copra and a very high processing temperature.

c) 'Extra virgin' and 'cold pressed' label for VCO

A number of VCO producers in different coconut-producing countries, including Fiji, that are selling on the retail market are placing 'extra virgin' and 'cold pressed' on their label without actually understanding what that label means. There is even pale yellow coconut oil being sold with the label 'extra virgin VCO'.

To gain a full understanding of the terminologies involved, a literature and internet research survey was conducted which revealed that the term 'extra virgin' is exclusive to olive oil. However, the term 'virgin' can be applied to olive oil as well as other types of oil, provided that the criteria listed in Section 3.6.1a) are satisfied. The main reason for the 'extra virgin' label being exclusive to olive oil is that, when fresh olives are pressed, what comes out can be called 'olive oil juice'. This is essentially a mixture of olive oil and water from which, after settling or centrifugal separation, the olive oil can be recovered. On the other hand, when fresh coconut kernel is pressed, what comes out is coconut milk which is an emulsion of oil and water, with globules of oil surrounded by membranes made of phospholipids (fatty acid emulsifiers) and proteins. To recover the coconut oil, the membranes and bonds have to be broken, either by heating, or by natural or biological fermentation, or by centrifugal action, or some other means.

Information on internet websites gave conflicting information as to what constitutes 'cold pressed' oil. A lot of websites mentioned that the term 'cold pressed' does not have any legal definition in the United Kingdom and the USA. It is a marketing strategy. For oil to be efficiently extracted from its plant-based source (seeds, nuts, etc.), it has to be heated to a certain extent to allow the oil to flow freely. Likewise, oil can be extracted by pressing only from seeds or nuts or any other plant source with oil content above 30%. It was also mentioned that most plant-based oils cannot be produced in big/commercial quantities if only cold pressing is used. In most websites, the term 'cold pressed' is associated with olives for reasons stated above. On the other hand, some websites mention that the term 'cold pressed' is associated with oil that has been extracted/processed at a temperature below 50°C. Therefore, under this condition, coconut oil that is produced by drying the fresh comminuted kernel and subsequently extracting the oil using high pressure expellers, does not qualify for the label 'cold pressed' since temperatures higher than 50°C are generated inside the expellers, but it does qualify to be labelled 'virgin'. However, it was also noted that some manufacturers are placing the term 'cold pressed' on their labels although their process is done at temperatures higher than 50°C. **Only VCO produced using the modified natural fermentation process and the fresh-wet centrifuge process with vacuum evaporation is entitled to the labels 'virgin' and 'cold pressed'.**

Based on the author's experience, the only major difference that can be discerned between 'cold pressed' VCO and expeller-pressed or heat-processed VCO is that the 'cold pressed' or low temperature-processed VCO does not leave an oily after-taste in the mouth when ingested. Likewise, VCO processed at low temperatures also solidifies much faster and liquefies much more slowly than the expeller-pressed VCO. Customer preferences will determine which type of VCO is preferred for particular end use(s).

3.6.2 Organic certification

Consumers' preferences when it comes to agricultural products, especially products from developed countries, have dramatically changed in recent years with the growing awareness and concern for health and environmental issues. Organic farming and labelling of food as organic is a steadily growing sector of agriculture.

Organic agriculture as defined by the International Federation of Agriculture Movement and cited by Idroes, Muhartoyo and Arancon (2007) includes all agricultural systems that promote the environmentally, socially and economically sound production of food and fibres. These systems take local soil fertility as the key to successful production. Organic agriculture dramatically reduces external inputs by refraining from the use of chemo-synthetic fertilisers, pesticides and pharmaceuticals. Instead, it works with the laws of nature to increase both agricultural yield and pest resistance.

FAO/WHO Codex Alimentarius Commission 1999 as cited by Idroes et al. (2007) states that:

> Organic agriculture is a holistic production management system which promotes and enhances agro ecosystem health, including biodiversity, biological cycles and soil biological activity. It emphasizes the use of management practices in preference to the use of off farm inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using where possible agronomic, biological and mechanical methods, as opposed to using synthetic materials to fulfill any specific function within the system.

At present, there are two niche markets to which VCO is generally being supplied. These are:

- the nutraceutical market, i.e. VCO as a functional food is sold in stores specifically catering to the demand for products intended for wellness and health;
- cosmetics and skin care products markets, where VCO is used as a base oil in the manufacture of hypoallergenic cosmetics and skin care products.

Major institutional buyers for both markets normally prefer organically certified VCO as an assurance that the product does not have any trace of synthetic pesticides, chemical fertilisers and other likely harmful residues that might have an effect on their intermediate buyers and consumers.

On a general note, it can often be said that the majority of coconut plantations and wild stands in PICTs are organic by default, inasmuch as they are not actually being tended. The growth of coconut trees and their fruit-bearing capacities are left to the care of Mother Nature. However, the norm in international trade is that one cannot claim a product is organically produced unless it has been certified as organic by an internationally recognised and authorised body.

The Organic Certification Center of the Philippines mentions the following:

> Certification is the procedure by which an independent third party gives written assurance that a clearly identified production or processing system is methodically assessed and conforms to specified requirements/standards.
>
> Certification of organic agriculture combines certification of products and quality systems, but it is primarily certification of a production system or method. All operation in the product chain, including farmers, processors and distributors, must be certified as acting in conformity with the standards and regulations of the certification program.
>
> Certification is one way of ensuring that products claimed to be organic are actually produced according to organic farming principles. It is a way of protecting consumers, producers, and traders against the use of misleading or deceptive labels. It is also a marketing instrument enabling producers to access markets for organic products and obtains premium prices. It also creates transparency as information in certified producing organizations and their products are made public.
>
> (http://www.occpphils.org/certification.htm)

Before deciding to undertake or apply for an organic certification, a VCO producer should be aware of the following information which was collated from Idroes et al. (2007).

1. A company or an individual who is interested in obtaining an organic certificate from an authorised certifying body has to satisfy certain requirements and procedures. The procedures are set by the certifying body in compliance with a particular standard such as the National Organic Program of the United States Department of Agriculture, the Organic Production Method of the European Union and the Organic Certification Program of Japan Agriculture Standard. There is also the National Association for Sustainable Agriculture of Australia.

   Each of these standards has its own requirements and procedures. Consequently, interested companies have to decide which standard they want to comply with. In essence, the choice depends on which market or countries the VCO producer intends to supply. There is no single certifying body which is accepted or recognised worldwide.

2. The transition to organic agriculture takes at least three years, during which period the products cannot be sold as organic. However, the transition period can be reduced to six months by implementing a retroactive system, provided certain conditions and procedures are complied with.
3. The following criteria should be considered in selecting coconut farms:
   - the location must be free from contamination by forbidden chemicals, inorganic fertilisers and pesticides (verified through the site visit and interview with the farmer and/or owner);
   - the location must be safe from possible contamination from adjacent nearby farms (verified by inspecting the topographic position of the coconut farm and adjacent nearby farms);
   - the coconut farm is not intensely intercropped and is, ideally, far from villages;
   - the coconut farm should be close to the processing site.
4. The applicant for an organic certification has to pay the registration fee of USD 3500 to an internationally accredited certifying body. In addition, the applicant has to shoulder the expenses of the inspector from the certifying body. Expenses include air fare, accommodation, transport and daily subsistence allowance during the inspection.
5. If the application is approved, the organic certificate given is valid for one year and is subject to renewal the following year.

Chapter 4
Good manufacturing practices and sanitation standard operating procedures

As the world population continues to grow, the global market for food products is expanding, together with an increased emphasis on food safety. Consumers have become more discerning in the type of foods they buy and how these foods affect their health and well-being.

Food safety is generally defined as the assurance that the food will not cause any harm to the consumer when it is prepared and/or eaten according to its intended use (Alba 2006). To achieve food safety, a management system has been developed which focuses on preventing problems before they occur, rather than trying to detect failures through end product testing. It also places more responsibility for ensuring food safety on food manufacturers, who have to develop control and traceability of their products from 'farm to plate'. The system requires the identification of specific hazards throughout the entire process of food production, concentrates on the points in the process that are critical to the safety of the product, and highlights measures for their control. This food safety management system is referred to as HACCP or hazard analysis critical control points.

VCO is considered a functional food and is increasingly consumed and/or processed into nutraceutical products. It is not only used as a food ingredient but also as a food supplement that people take for its health benefits. As such, it has to be carefully processed with food safety considerations at the forefront.

While it is not generally required for a VCO plant to be HACCP compliant when it is just starting its operation, strict adherence to the prerequisite programmes of HACCP by processors is strongly recommended. These prerequisite programmes are described below.

- **Good manufacturing practices (GMPs)** – This is a set of guidelines and procedures that have to be followed to ensure that the food products manufactured in a particular plant are free from the presence of dirt, contaminants and pathogenic microorganisms such that it will be safe for human consumption (Bawalan and Chapman 2006). These are regulations and procedures that guide food manufacturers in the development and proper implementation of food safety programmes (Kindipan et al. 2006). Adherence to GMP ensures the prevention of food adulteration and contamination due to unsanitary conditions.

- **Sanitation standard operating procedures (SSOPs)** – This is a set of activities related to the sanitary handling of raw materials, food products, work areas and equipment (Kindipan et al. 2006). It ascertains that conditions prescribed by GMP are met by plant facilities and operations. It ensures the effectiveness of maintenance, corrective actions and record-keeping activities.

GMPs in VCO production cover the adherence to a specific set of guidelines for each of the following stages:

- pre-processing stage – all the steps before the coconuts are opened for conversion into VCO: harvesting, collection, husking, transport, storage;
- processing stage – the actual steps in the processing of fresh coconut into VCO, from opening the nuts to recovering the VCO, varying according to the technology;
- post-processing stage – additional steps to further improve the quality of VCO: fine filtration, oil drying (if required) and ageing (if required);
- packaging and storage of the product.

SSOPs for VCO processing cover the following aspects:

- sanitation in the processing area;
- sanitation in the processing equipment;
- personal hygiene.

4.1 Pre-processing stage

4.1.1 GMPs for selection/harvesting

The fresh coconut kernel, as the raw material for processing VCO, requires special handling and control to ensure the production of high quality VCO. Fresh coconut kernel is a low acid substance with high moisture and nutrient contents. This makes it susceptible to microbial attack and contamination. While still on the tree or as a whole harvested mature nut (with or without husk) and as long as there are no cracks and the 'soft eye' of the nut is not damaged, the coconut kernel is edible and sterile, uncontaminated by any microorganism. However, once the nut is opened or the shell is cracked (in the case of husked nuts), the kernel is then susceptible to attack and deterioration by airborne micro-organisms. When this happens, the nut is no longer suitable for food processing.

Coconuts in PICTs are allowed to fall naturally at maturity and are collected off the ground. Since coconuts do not fall naturally from the tree unless they are mature or over-mature, on-farm selection of coconuts for VCO processing consists of segregating the good mature nuts (Figure 46) from the over-mature nuts with signs of germination or growth (Figure 47). The prevalence of germinating nuts is quite common in PICTs, since fallen coconuts are not collected daily.

Figure 46. Good, mature coconuts

Figure 47. Overmature coconuts with germination growth

Selection of the nuts for VCO processing starts at the farm when the nuts are collected. For VCO production, only sound, fully mature nuts (12–13 months old) should be selected as these have the highest oil content and the lowest moisture content. **Nuts with cracks, or a damaged soft eye or germination growth exceeding 1 cm must be discarded.** Under conditions in PICTs where nuts are not being picked from the tree but are picked up from the ground after they have fallen, it is difficult to get a batch of ungerminated nuts. One compromise is that if germinated nuts cannot be avoided, only nuts with a maximum germination growth of one centimetre should be accepted for VCO production.

Generally speaking, the maturity of whole unhusked coconuts can be determined by the indicators described below.

- Colour of the husk – mature nuts at 12–13 months old are light brown or yellowish brown; those at 10–11 months are green with a tinge of yellow. Immature nuts less than ten months old are generally green except for those varieties that have golden nuts (e.g. Sri Lankan golden king, Malaysian red dwarf).
- Colour of the shell – another indication of the maturity of the nut is the colour and the hardness of the shell. Mature coconuts have a hard, brown shell.
- The sound that the nut makes when it is shaken – immature nuts do not make a noise when shaken because the cavity is completely full of water. Mature nuts make a sloshing sound when shaken (Ranasinghe, Cataoan and Patterson 1980).

Over-mature nuts (above 13 months old), especially those which have already germinated, impart an off-flavour and oily taste to coconut products so they should be discarded. Likewise, the oil content of the kernel starts to decline once the haustorium (creamy, spongy tissue that fills a germinating nut) is formed. Aside from oil yield, the oil quality also deteriorates as the haustorium grows bigger.

4.1.2 GMPs for husking

Guidelines for husking coconuts

- If possible, do the husking early in the morning or in a shady area so the husked nuts are not exposed to direct sunlight.
- Cover the pile of husked nuts as a protection from direct sunlight. Exposure of husked nuts to direct sunlight for more than an hour will cause the shell to crack.
- If the coconuts are not to be processed within two days from the time of husking, keep the eye of the nut adequately covered by leaving a portion of the husk attached to it during husking (Figure 48).

After husking and before transport to a VCO processing plant, the nuts should be inspected.

Figure 48. Husked coconuts with the eye still covered by a portion of husk

4.1.3 GMPs for the transport of husked nuts to the VCO processing plant

Cover the coconuts if they are in an open vehicle, especially on hot, sunny days and if the transport time is more than an hour. Proper care must also be taken during loading and unloading of the nuts so that they are not exposed to sunlight or broken.

Ideally, husked fresh coconuts should be processed within seven days from the time of harvest. Accordingly, VCO processing facilities should be set up within the coconut producing areas to ensure the freshness of the raw material (Bawalan and Chapman 2006). This also lowers the transport cost.

4.1.4 GMPs for the inspection of nuts at the VCO plant

The nuts are inspected yet again on delivery to the plant. Husked nuts with a cracked shell, or a damaged soft eye, or germination growth exceeding one centimetre in length should be rejected.

For small deliveries, it is a common practice in Fiji to put husked nuts in plastic sacks. In this case, the husked nuts should be removed from the sack and inspected individually on arrival at the plant.

4.1.5 GMPs for the storage of nuts

- Husked nuts should be kept in clean storage areas with cement floors, good ventilation and adequate rain/sun cover.
- Storage bins should be designed and partitioned so that the principle of first in, first out can be easily implemented.
- The husked nuts should not be placed directly on a cement floor but on an elevated platform (pallet) with slats which is at least six inches above the floor. In this way, coconut water can flow away from the pile if coconut shell breakages occur.
- The stockpile of husked coconuts should be inspected daily to remove nuts with cracked shells and soft eyes.
- The height of a storage pile of coconuts should not exceed 1.8 metres.

(Bawalan and Chapman 2006)

In addition, NEVER store coconuts in plastic sacks. Since there is no air circulating inside the sacks, moisture emanating from the fresh nuts is trapped inside and will cause deterioration of the nuts. The situation is aggravated if there are nuts with a cracked shell or a deteriorating eye in the sack.

Another quality control and inspection needs to be done when the nuts are taken out of storage for processing to ensure that only good quality nuts enter the processing area.

4.2 GMPs for the processing stage

4.2.1 GMPs for handling coconut water

GMPs on the proper handling of coconut water are important because it spoils and ferments very fast once the nut is split.

Guidelines for handling coconut water

- Split the coconuts above the ground and put a receptacle underneath for the coconut water (Figure 49).
- Do not split the coconuts at too high a level above the coconut water receptacle because there will be a tendency for the water to splash on the floor.
- If the coconut water is not to be used in VCO processing or is not be further processed, remove it at intervals from the splitting area and dispose of it in dedicated septic tanks to prevent the generation of a foul odour in the process area. Do not dispose of large quantities of coconut water directly into drains or a sewage system, or into a creek, a river or the sea without proper treatment. Coconut water is considered a major pollutant because of its high biochemical

Figure 49. The correct way to split coconuts

oxygen demand (BOD5) or biological oxygen demand. This amounts to 14,000–15,000 mg/litre (Sison 1976).

- Immediately wash the floor with water if coconut water gets spilled on it. Spilled coconut water on the floor if not immediately cleaned will attract flies and become a source of contamination (Bawalan and Chapman 2006). It will also destroy the cement surface of the floor (if there are no tiles) since fermented coconut water becomes very acidic.

Selection of coconut kernels for processing

Quality control on the fresh coconut kernel should be done after splitting the nuts to ensure that only fresh, unspoiled coconut flesh is further processed (Figure 50). The kernel should be firm in texture and white/opaque in colour. Coconut kernel with a soft texture, slimy surface or discolouration should be segregated and discarded. Likewise, kernel from nuts with big haustorium or germination growth is soft and thin and has a rancid smell. Hence, it must be discarded as it will destroy the quality of the whole batch.

As a general rule, coconuts for food products should be processed within four hours from the time the shell is broken or the nut is split.

Figure 50. Left, good coconut kernel for processing. Middle, discoloured kernel for rejection. Right, kernel with haustorium.

There are three options for utilising split coconuts that fail the quality control for VCO processing. These are:

- convert them into copra by sundrying;
- use them as animal feed, e.g. for chickens and pigs;
- process them for second grade VCO using the modified natural fermentation process and use the resulting coconut oil for making soap and other downstream products (see Chapter 7).

4.2.2 GMPs for removal of the coconut kernel and particle size reduction

Whatever method is used to remove the coconut kernel from the shell and reduce the particle size of the flesh, all parts of the processing equipment that come into contact with the coconut kernel should preferably be made of food-grade stainless steel, which is preferable, or plastic containers.

This step needs to be done in as short a time as possible to prevent bacterial contamination.

Guidelines for manual grating of coconuts

- Before starting to grate, wash the grater blade thoroughly with soap and water. Use hot water for the last rinse.
- Manual grating should not be done while one is sitting on the ground/floor, but if there is no alternative, sit a clean cement floor.
- Use a clean container (stainless steel or white plastic basin) as a receptacle for the grated coconut kernel.
- Do not place any split coconuts on the ground.

Guidelines for motorised grating

- Ensure that the blades and housing of the grater are thoroughly cleaned with soap and water before starting the operation. Make certain that no soap residue is left on the surface by thoroughly rinsing with water. Use hot/boiling water for the last rinse to sanitise.
- Avoid touching the grated kernel with bare hands. Use a stainless steel ladle when removing the grated flesh that adheres to the surface of the grater housing.
- Make certain that only highly skilled operators do motorised grating. The rotating metal blades of the grater may cause injury if the grater is handled by unskilled or untrained workers.
- Clean the grater blades and housing immediately after each use. Use a pressurised water hose if necessary to dislodge fine coconut kernel particles. Make certain that there is not a speck of coconut left adhering to the grater head.

4.2.3 GMPs for fresh-dry process

4.2.3.1 GMPs for drying of freshly comminuted kernel

Drying of the freshly comminuted kernel is the most critical step in the fresh-dry process. Delay in drying or the use of improper drying techniques produces second grade VCO.

Guidelines for drying — all methods

- Dry the coconut kernel within four hours of splitting the nut. Beyond four hours, the nut will yield yellow or pink oil due to microbial attack. The risk is much higher in kernels of small particle size (as in this case) because more surface area of the kernel is exposed.
- Dry the comminuted kernel at the appropriate temperature (70–75°C) to prevent it from being burned or scorched. High temperature and improper drying techniques result in unacceptable pale yellow coconut oil with a burnt odour. If the drying temperature is too low, bacterial contamination may occur which also results in unacceptable yellow-coloured oil (Bawalan and Chapman 2006).
- Do not overload the dryer. Just load the amount of grated/shredded/milled coconut kernel according to the specified processing capacity. Overloading the dryer can cause deterioration of the kernel that is not reached by heat and may also result in yellow-coloured oil.
- Dry the comminuted kernel to the right moisture content as specified in the type of VCO fresh-dry processing technology that is used (e.g. 10–12% for the low pressure method, 3–4% for the high pressure expeller and fresh-dry centrifuge process).

Guidelines for the flat-bed conduction type dryer or DME dryer

- Regulate the dryer temperature by regulating the amount of coconut shell fed into the burner for a specific period of time, i.e. feeding a constant number of shells per unit of time, e.g. 25 half shells every ten minutes. The exact number of half shells should be determined by doing actual drying trials.
- Do not load wet comminuted kernel onto the surface of the hottest portion of the dryer. Place it first on the cooler portion and reduce the moisture content before it is moved to the hotter portion. This is because any material with high moisture content tends to stick when placed on a very hot surface.
- Do not allow the kernel to stay long on the dryer surface. Constant moving and fast turning of the grated kernel is required to prevent it from getting scorched. If this happens, the resulting oil will be pale yellow and have a burnt odour.

Guidelines for drying in a forced draught (with fan) tray-type dryer (Figure 51)

- Spread the freshly comminuted coconut kernel thinly in each of the loading trays. The thickness of the layer of kernel in each loading tray should not exceed one centimetre.
- Set the thermostat control of the dryer at 75°C for the first hour of drying. Then reduce the temperature setting to 70°C and maintain this temperature until the kernel has reached the desired moisture content.
- Regularly change the position of the trays inside the dryer. Likewise, regularly mix the loaded kernel in the trays to assist with a more uniform drying regime.

It should also be noted that, under conditions of low humidity and hot midday temperatures, solar drying of the grated kernel can be done. A well designed solar dryer normally generates a drying temperature of about 70°C, which is suitable for drying grated/shredded coconut kernel intended for VCO production (Bawalan and Chapman 2006). Solar, not sun, drying is done to prevent the grated kernel from being contaminated with dust and insects.

Figure 51. Electrically heated forced draught tray-type dryer at the Food Processing Centre, Kiribati

4.2.3.2 GMPs for low pressure oil extraction/DME

All containers, receptacles and utensils used during extraction of coconut oil should be made of stainless steel. If stainless steel is not available, food-grade plastic white containers may be used.

- All parts of the equipment that come into contact with the dried kernel and VCO should be made of stainless steel. The quality standard for VCO stipulates certain limits for metal contaminants including iron, lead and copper.
- Thoroughly dry all containers and equipment parts that come into contact with the dried kernel and VCO prior to starting operations.
- Clean all equipment at the end of each production shift. Remove all adhering particles of coconut kernel from the equipment. Rinse with hot water and allow to dry for the next operation.
- Always watch the colour of the oil that is extracted. If it is cloudy (i.e. there is some opaque white colour in it) do the gravity settling to remove fine particles in a room or specially designed cabinet heated at 50°C. This will prevent the oil from turning rancid during the two-week gravity settling period as the oil will be dried as well.

4.2.3.3 GMPs for high pressure oil extraction (from Bawalan and Chapman 2006)

The critical factors in the high pressure extraction of VCO are the moisture content of the feed material and the processing temperature in the expeller. Optimum recovery of oil is obtained if the granulated fresh kernel is dried to a moisture content of 3–4%. The temperature in the expeller should not be allowed to exceed 90°C in order to prevent the oil from turning yellow. A high pressure expeller with a water-cooled worm shaft is required to ensure that the temperature inside the expeller remains within acceptable levels.

The oil extraction efficiency of high pressure expellers is determined by the following factors:

- moisture content of the feed material
- temperature of the feed material
- choke clearance
- particle size.

Guidelines for high pressure oil extraction to ensure optimum recovery and the production of high quality VCO

- The dried granulated/milled coconut kernel should have a moisture content of 3–4% when fed into the expeller.
- Extract the oil immediately after drying. It is better to process the dried kernel while it is still warm to help ensure that the oil flows easily during the extraction process. The Anderson expeller, which is generally used in the coconut oil milling industry in the Philippines, has a built-in conditioner-cooker to adjust the moisture content and temperature of the milled copra.
- Adjust the choke clearance to a setting which will yield optimum oil recovery. The thickness of the pressed cake coming out of the expeller gives an indication of the oil extraction efficiency in the expeller, i.e. experienced operators know whether the oil extraction rate is at the optimum level by looking at the thickness of the pressed cake. Corresponding adjustments in the choke clearance are normally made if the thickness of the pressed cake is greater than 1 mm. (Please refer to the glossary of terms for the meaning of choke.)
- Dried coconut kernel to be fed into the expeller should be in granulated or milled form with a particle thickness of 3 mm. Very thin particles as in grated or sliced or shredded coconut kernel tend to slide out of the choke, thereby reducing the yield of oil.
- High pressure extraction causes the temperature in the expeller to rise, so a cooling system is required. Use an expeller with a built-in cooling system in the worm shaft to ensure that

the temperature does not rise above a level that will cause the coconut oil to turn yellow. For expellers without a cooling system, one way of reducing the temperature inside the expeller is to adjust the choke to a wider clearance and to use feed material with slightly higher moisture content. However, this method sacrifices the oil extraction efficiency and in turn reduces the profitability of VCO production.

- Ensure that all materials, containers and utensils used during oil extraction are thoroughly dried.

4.2.3.4 GMPs for settling and filtration of newly extracted VCO

VCO extracted using a low pressure press (e.g. bridge press, DME press, New Zealand press) or a high pressure expeller contains very fine particles of dried kernel called foots which are entrained and then suspended in the oil. For the low pressure oil extraction process, the general practice is to filter the newly extracted oil with cheese cloth to remove larger particles of entrained kernel. The oil is then allowed to undergo gravity settling for a minimum of two weeks to clarify the oil. VCO extracted using a high pressure expeller is allowed either to undergo gravity settling or is passed through a motorised plate and frame filter press.

The use of a motorised plate and frame filter press or any type of pressure filter is preferable to gravity settling. Based on experience, foots are not completely removed, even after two weeks of gravity settling, and form a residue that settles at the bottom of VCO or VCO-based body oil after packaging and standing for a long time. The presence of residue at the bottom of a VCO bottle puts buyers off.

If a VCO operation using the fresh-dry process is too small to warrant procurement of a motorised pressure filter, then gravity settling using containers with a conical bottom is recommended. An improvised settling container that satisfies this requirement is the 20 litre plastic water container used in water dispensers. Remove the bottom and position it upside down in a manufactured stand. Place it in a room in which the temperature is maintained at about 50°C. In this way, whatever residual moisture there is in the oil will also be removed during the process of settling. The theory is that, at relatively high temperatures, oil molecules will move upwards more rapidly and the settling process will be hastened.

The designated gravity settling room can be heated using a heater similar to those used for chicken brooders in poultry farms. It can also be heated using charcoal briquettes as fuel (see Annex 8.3). Ensure that the heater is placed at a distance from the coconut oil containers when using charcoal briquettes as fuel to heat the room.

As an additional guideline, always ensure that the container to be used for settling VCO or any filtering device is totally dry and free from dirt or any extraneous matter before putting in the oil.

4.2.4 GMPs for fresh-wet processes

4.2.4.1 GMPs for coconut milk extraction

Coconut milk is categorised as a low acid food. It contains proteins and other nutrients in which microorganisms from the air and other sources can thrive. In addition, coconut milk has a high moisture content which allows microorganisms to multiply very fast. Correct handling of coconut milk is therefore critical in the fresh-wet VCO process, since there is a very high risk of spoilage if is not processed under strict conditions.

- All containers, receptacles and utensils used during the extraction of coconut milk should be made of food-grade stainless steel. If stainless steel is not available, food-grade plastic white containers should be used.
- Ensure that all materials, utensils and equipment are thoroughly cleaned and rinsed with hot water. They should be free from any soapy residue (Bawalan and Chapman 2006).
- Water used for dilution for a second milk extraction should be of high quality, free from microbial contamination and of low mineral content (Bawalan and Chapman 2006). Coconut water

can also be used for dilution purposes but specific handling procedures need to be followed, especially during hot weather (i.e. filtration and immediate storage in a refrigerator or ice box while waiting for the grating and first milk extraction to be finished). Otherwise, the coconut water will start to ferment, which will make it unsuitable for dilution purposes.

- Thoroughly wash your hands with soap and water before doing any preparation work.

In addition to the above general guidelines, the following should be observed if coconut milk is extracted manually.

- Remove rings from fingers when directly handling and mashing grated coconut kernel for milk extraction.
- Do coconut milk extraction on top of a table. Any plastic containers used as receptacles should be food-grade and white (Figure 52).
- Ensure that the cloth is clean and sanitised.
- Do not use bark, such as bark of the beach hibiscus, known in Fiji as *vau*, for straining and extracting coconut milk. It imparts a pink colour to the VCO produced (Figure 53).

For processing VCO via the coconut milk route at a capacity higher than home scale production, manually operated coconut milk presses (hydraulic or vertical screw type) or motorised hydraulic presses are generally used in coconut-producing countries like the Philippines and Thailand. In these types of milk presses, grated coconut kernel is normally placed in bags to make it easier to remove the residue after milk extraction.

Figure 52. Food-grade white plastic container

Figure 53. VCO with a pink colour as a result of using a Fijian vine to extract the coconut milk

In addition to the above general guidelines, the practices listed below need to be observed if the coconut milk is to be extracted using a manually operated and motorised hydraulic press.

- All parts of equipment which come into contact with coconut kernel and coconut milk should be made of stainless steel.

- Equipment should be rinsed with hot water before use and cleaned every four hours during operation in order to prevent contamination. All equipment is to be thoroughly cleaned at the end of the day's shift.
- Never leave the equipment with adhering grated coconut kernel and film of coconut milk on the surface after use because it will develop a bad odour and attract flies and other insects.
- Bags for holding the grated coconut kernel should be made either of white plastic nets with fine mesh or sanitised cheesecloth or canvas cloth (Figure 54).
- The person who does the bagging should observe proper personal hygiene (e.g. not report for work if ill, remove rings from the fingers, wear gloves, etc.) before starting work.

4.2.4.2 GMPs for recovery of VCO from fresh-wet processes

4.2.4.2a GMPs for recovery of VCO by the modified kitchen method

Aside from proper handling of coconut milk, heating of the coconut milk or cream is the major critical step in the modified kitchen method, as this will determine whether the recovered oil is water-clear or yellow, which will preclude it from being classified as virgin.

Figure 54. White plastic net bag for grated coconut kernel for extraction in a manually operated milk press

Source: PCA Product Development Department

The following control measures should be observed at all times to ensure that only waterclear VCO is recovered:

- Heating should be done with proper temperature control. For the first hour of heating, the temperature can be allowed to reach 90°C (a stove setting between medium and high). Subsequently, and once the proteins have started to coagulate, the temperature should not exceed 80°C (a medium stove setting). Reduce the stove setting to low when the oil starts to separate from the coagulated protein. Constant stirring is needed during heating of the coconut cream.
- Do not allow the proteinaceous residue to turn brown as this will give yellow-coloured coconut oil. Once the oil separates out from the *sinusinu* (Figure 55), take the oil out. Then toast the *sinusinu* to recover the residual oil which is entrained in it. Note that this type of oil will be yellow and suitable only for skin care products.

- Dry the recovered oil using one of the techniques discussed in Section 3.3.1 to prolong its shelf-life.

Figure 55. Separation of coconut oil from the coagulated protein (sinusinu) *during heating*

4.2.4.2b GMPs for recovery of VCO using the modified natural fermentation process

Settling and fermentation are the critical steps in this process, and they require proper control of operating conditions and observance of strict sanitary measures (Bawalan and Chapman 2006). There are cases in which no oil separates, even after 24 hours settling. There are also cases when the coconut milk mixture that is left to settle for 12–16 hours generates big bubbles and no oil separates. To ensure that good quality VCO is produced, the measures below should be taken.

- Place the diluted coconut milk in food-grade transparent white plastic containers and allow it to settle for 12–16 hours, preferably at a temperature of 35°–40°C. Fermentation does occur at temperatures below 35°C but the oil recovery for premium grade VCO is lower. Fermentation continues up to 36 hours if allowed. However, fermentation time is set at 16 hours to get premium grade VCO. The longer the fermentation time, the more intense the sour smell in the coconut oil and the higher the risk of free fatty acids increasing to levels above those permitted in the VCO standard.

- Relative humidity within the area should be maintained below 75%.

- Loosely cover the container of coconut milk to allow the release of carbon dioxide which is generated during fermentation.

- Strict sanitary measures have to be observed at all times. The major cause of the bubbling over problem mentioned above is contamination, either through soap residue on the fermenting container or invasion of different types of microorganism. *(Note: If this problem occurs, immediately put the mixture in the evaporating pan and follow the modified kitchen method so that oil can still be recovered, instead of wasting the whole batch. Also note that the coconut oil that is recovered is second grade VCO and should only be used for making herbal soap and skin care products.)*

Remember that, in PICTs, the freshness of the coconut cannot be accurately ascertained because coconuts are not actually harvested but picked up off the ground. It was ascertained during the training courses in Marshall Islands and Papua New Guinea that VCO does not separate naturally from coconut milk obtained from fallen coconuts if the water used to dilute the coconut milk is at room temperature. The problem can be corrected if hot water (about 60°C) is used to dilute the coconut milk prior to settling. This was successfully done in training courses in Solomon Islands and Fiji.

Hence, the general rule for PICTs is to use hot water for dilution of coconut milk if the coconuts are known to be not newly fallen or just bought from the market.

- Dispose of the fermented skim milk (watery phase) and gummy portions properly in a designated septic tank. Do not put it directly into the sewage system.

  Fermentation of the curd can be allowed to continue for another 24 hours after recovering the premium grade VCO. The curd still contains a lot of oil, especially the top layer, and can be used to recover second grade VCO.

The following guidelines should be followed for recovering the oil produced in the modified natural fermentation process.

- Use a stainless steel strainer and soup ladle for taking the VCO out of the fermenting container.
- Great care needs to be taken not to touch the water layer with the ladle whilst removing the VCO.
- Ensure that all containers and utensils used in recovering and holding the VCO are clean and thoroughly dried.

4.2.4.3 GMPs for filtration of VCO produced from the fresh-wet processes

The suspended particles (coagulated protein in the modified kitchen process and fermented curd in the modified natural fermentation process) are floating on the surface of the oil. They can be removed by a simple filtration method (Figure 56) using fine strainer, cheese cloth or course filter paper (Figure 57) or any material that will allow only the passage of liquid. This method does not leave any unsightly residue at the bottom of the bottle after it is packed and left on the shelf for some time.

Guidelines

- Always ensure that the container to be used to hold the oil or any filtering medium is totally dry and clean, free from any dirt or extraneous matter.
- If cheese cloth is used as the filtering medium, it should be free from any soapy residue, thoroughly dried and ironed (for sanitation) before using.

Figure 56. Simple filtration using sterilised cotton balls
Figure 57. Filtration using filter paper

Source: PCA Product Development Department

Source: PCA Product Development Department

4.3 Good manufacturing practices for the postprocessing stage

4.3.1 GMPs for oil drying

- NEVER heat oil directly in a pot or pan as this will cause it to turn yellow.
- In using an improvised double boiler for oil drying, ensure that the bottom of the mixing bowl holding the oil is touching the water in the pot.
- Ensure that all process containers and utensils are thoroughly cleaned and dried.
- Ensure that the specially designed cabinet where incubation or air heating of VCO is done is clean at all times and free from insects.

4.3.2 GMPs for ageing of VCO produced from the modified fermentation process

- Ensure that all process containers and utensils are thoroughly cleaned and dried.

- Ensure that the cheese cloth used to cover the VCO container is sanitised and dry.
- When transferring VCO to packaging containers after ageing, always leave behind about 2 cm of oil at the bottom. Any residual moisture in the oil settles in this bottom layer after aging.

4.4 GMPs for packaging and storage of VCO

Guidelines for packaging

- In selecting plastic bottles for packaging, always ensure that they are food-grade and do not impart any flavour to the oil.
- Always ensure that the container (glass or plastic) is thoroughly clean and dry before filling it with VCO.
- If packaging VCO in glass bottles with metal caps that automatically seal with a vacuum, fill the bottle up to the top. Moisture in trapped air in the empty space may condense and cause the oil to become rancid.
- Cover the container immediately after filling (Figure 58).

Guidelines for storage

- Store packaged VCO in an enclosed area with screened windows, protected from rain and away from direct sunlight and materials with a strong odour.
- Keep the room temperature at 27°C or above, preferably with a dehumidifier.

Figure 58. Filling bottles with VCO

Source: PCA Product Development Department

4.5 Sanitation standard operating procedures (SSOPs)

Sanitation standard operating procedures (SSOP) are activities related to the sanitary handling of raw materials, food products, work areas and equipment (Kindipan et al. 2006). They ascertain that conditions prescribed by GMPs are met by plant facilities and operations. They ensure the effectiveness of maintenance, corrective actions and record keeping activities.

Cleanliness and sanitation of plant and premises include both maintenance of clean and well sanitised surfaces of all equipment coming into contact with food, good housekeeping in and about the plant, and correct disposal of waste (Frazier and Westhoff 1988).

4.5.1 Sanitation in the processing area

Cleaning and disinfecting processing areas should not be neglected: they can substantially reduce the risk of VCO not meeting consumer and government standards. Translated into business terms, strict adherence to sanitary procedures will mean zero or fewer rejections and complaints and zero involvement in outbreaks of food poisoning.

Guidelines for cleanliness and sanitation

- Frequent and continuous cleaning must be done at the various process section areas (e.g. regular removal of waste and by-products) as well as cleaning at the end of every eight hour period and/or at the end of every production shift. The purpose of continuous cleaning is to keep waste from accumulating during the operating day, which not only improves sanitation, but also reduces the time needed for end-of-shift cleaning.
- Every weekend (or once a week), every process area should be scrubbed with soap and water and rinsed. An anti-bacterial agent must be applied.
- Ceilings and roof spaces should be regularly monitored and appropriate measures taken to keep them free of insects, geckos and rodents.
- The grating and milk extraction areas (in the case of the fresh-wet VCO process) or the shelling, washing and kernel grinding area (in the case of the fresh-dry VCO process) should be regularly cleaned every eight hours to prevent microorganisms from building up. The cleaning can be done by washing off all coconut flesh using a high pressure hose. It should be noted that immediate flushing with water is required whenever coconut water is spilled in the floor.
- An exhaust fan should be installed in the fermentation room of the VCO facility using the modified natural fermentation method. The exhaust fan should be run for at least half an hour at the end of every fermentation cycle to remove stale air, laden with carbon dioxide, from the room. Likewise, the fermentation room should be airy, allowing fresh air to circulate.
- Packaging areas should be equipped with a white formica-topped table and should be cleaned after every use. Any spillage of oil in the floor must be immediately cleaned with soap and water to prevent accidents.

Guidelines for handling the by-products

- Coconut shells should be regularly removed from the grating area. Please refer to Section 6.1 for the options for processing coconut shells.
- If coconut water is not to be further processed, regularly dispose of it in an assigned disposal area or septic tank after proper treatment to prevent the generation of a foul odour in the process area. It should be noted that coconut water starts to ferment within four hours of splitting the nuts.

  Flush the area with water if coconut water gets spilled on the floor. Spilled coconut water on the floor, if not immediately cleaned, attracts flies and becomes a source of contamination. It will also destroy the surface of a cement floor since fermented coconut water is very acidic.
- In the case of a plant producing VCO from coconut milk, the coconut milk residue generated after milk extraction should be regularly transferred to the drying area or the area where it will be further processed. Please note that wet coconut milk residue, if left unattended for more than four hours, will deteriorate and cause a foul odour and microbial contamination.

4.5.2 Sanitation in processing equipment

Food-grade stainless steel is the recommended material of construction for all parts of VCO processing equipment that come in contact with coconut kernel or milk.

Bawalan and Chapman (2006) list the following sanitation guidelines that should be followed for equipment.

- All equipment where fresh coconut kernel is being handled /processed should be cleaned after every four hours of use. It must all be cleaned at the end of each production cycle. Cleaned equipment should be free of grease and adhering product particles, detergent residue, brush bristles, etc.
- Use hot or boiling water for the final rinse of the equipment.
- Special attention should be given to the internal parts of coconut milk presses to ensure that no coconut kernel particles are left adhering to the surface of the equipment filter or perforated cage or loading cylinders at the end of production day. They should be flushed out with pressurised water.
- The blades of coconut graters, including the housing, must be thoroughly cleaned with water every four hours of operation and with soap and water at the end of the production day. Use hot or boiling water for the final rinse to prevent bacterial contamination.
- The intake, internal and discharge points of the grinder or shredder need to be cleaned with cold water and rinsed with hot water every four hours. They should be thoroughly cleaned and free from any adhering particles of coconut kernel at the end of production day.
- In the case of the VCO plants using the low pressure oil extraction method and the high pressure expeller process, dryers should be cleaned every eight hours. This includes complete removal of coconut particles, specifically the yellow/scorched particles adhering to the dryer surface which holds the coconut kernel (e.g. tray for tray type dryer, apron for conveyor type dryer, metal surface for DME dryer). It should be noted that dried coconut particles should not be left in the area for more than 24 hours.
- All tools and equipment accessories should also be thoroughly cleaned before and after use.

4.5.3 Personal hygiene (from Bawalan and Chapman 2006)

A major source of contamination is through the people who are actually involved in the processing of VCO. Hence, in maintaining sanitation, personal hygiene has to be given equal consideration to other HACCP aspects, such as building layout and processing equipment. A washing area should be placed near the entry point so that workers can wash their hands with soap and water, prior to dipping them in an antiseptic solution.

Only healthy personnel should be working in the processing areas. This means that the person is free from the following disorders:

- respiratory tract infections such as the common cold, sore throat, pneumonia and tuberculosis;
- intestinal disorders such as diarrhoea, dysentery, typhoid fever and hepatitis B and C;
- skin disorders such as sores, abrasions and lesions, infected ears, boils, scabies and severe rashes.

Plant personnel who are ill, or suspected of being ill, from any of these diseases should stay well away from the processing area and other personnel until they are completely cured.

Proper work clothes must be worn in the processing area (Figure 59). These comprise hair cover, facial masks as may be necessary, uniform, apron and boots or other appropriate footwear. Work attire is preferably white so that dirt can be easily seen. Street clothes and shoes should never be worn inside the processing area. Occasional visitors or inspectors to the production area are also required to put on sanitary attire before entering.

Figure 59. Work attire in a VCO processing facility that conforms to sanitation requirements

Source: Bawalan and Chapman (2006)

Hair cover (Figure 60)	This is necessary to prevent hair from falling into the VCO product. Any packaged food product seen with strands of hair in it is a big turn off to customers. Wearing a clean hair cover also prevents microbial contamination of hands if they touch the hair.
Facial mask (Figure 60)	This is worn while handling coconut milk, recovering the oil separated from the fermentation process and during packaging. Masks must cover the nose and mouth. They prevent microorganisms expelled from the mouth and nose from contaminating the air and they also prevent the worker from touching the nose and mouth. They also minimise talking during work, thereby increasing productivity.
Apron and uniform	The wearing of an apron and uniform has a positive psychological effect on plant personnel and makes them conscious of maintaining cleanliness at all times in the processing area. Aprons and uniforms should preferably be white or light coloured so that dirt can easily be seen and indicates the need for washing.

Footwear	Footwear can be a source of contamination, so specific footwear should be assigned to be worn inside the process area. Plant personnel should change their footwear when going outside the production area and at the toilet. Street shoes should never be worn inside the process area.

Figure 60. Trainees at SPC's Community Education Training Centre wearing proper work attire

High standards of personal hygiene include having clean hands at all times. This is the reason a wash area is provided near the entrance of processing plants. The hands should be washed with soap and water:

- before starting work
- after touching or scratching the head, hair, mouth, nose, ears, or any uncovered part of the body
- after using the toilet
- after a break, smoking, eating or drinking
- after touching dirty dishes, equipment and utensils
- after coughing, sneezing or blowing one's nose
- after chewing gum or using toothpicks
- after touching trash, floors, soiled objects etc.
- after using cleaners or chemicals
- after cleaning, taking out the trash or putting away supplies.

4.5.4 Record keeping and production data

A daily record of production and other data should be kept and maintained in the VCO plant. This is necessary for computing production costs as well as determining if production efficiency and productivity are improving. Likewise, each batch of product needs to be given a coded identification number to make it easier for management to trace the possible causes if there are some customer complaints about a particular batch that has been delivered. A sample production data sheet and other relevant forms are shown in Annex 7.

Chapter 5
General requirements for setting up VCO processing plants

As mentioned before, VCO is increasingly being considered as a functional food product. Hence, all the requirements for setting up a food processing facility have to be applied to VCO processing plants. The plant should be designed in such a way that the entire location, construction, operation and maintenance are in accordance with sanitary design principles. In the Philippines, VCO processing plants are required to get a license to operate (LTO) from the Food and Drug Administration. An LTO is issued only if plant buildings and facilities comply with the requirements for a food processing plant as stipulated in the Presidential Decree No. 856, otherwise known as the Sanitation Code of the Philippines.

5.1 Site requirement

Bawalan and Chapman (2006) list the following criteria in choosing the site for setting up a VCO processing facility.

- Availability of abundant potable water supply. This is particularly critical in VCO plants employing the modified kitchen and natural fermentation methods.
- Abundant raw material supply base that is near enough so that fresh coconuts can be delivered to the plant within one day after husking.
- Processing plant to be located well away from materials or facilities that have associated strong and foul odours (e.g. piggery or poultry, chemical plants)
- Availability of electric power. For the high pressure expeller process, a three-phase electrical line is required.
- A good drainage system around the site.

In addition, the site should be high enough to be safe from flooding during heavy rains. For PICTs, the land area or plant premises should be big enough to allow the setting up of rain water collection tanks and the construction of dedicated septic tanks for coconut water disposal. It should also be big enough to allow delivery vehicles to enter and manoeuvre within the area.

5.2 Plant building design and features

In compliance with the Sanitation Code for a food processing facility, the plant building should have the following features and specifications.

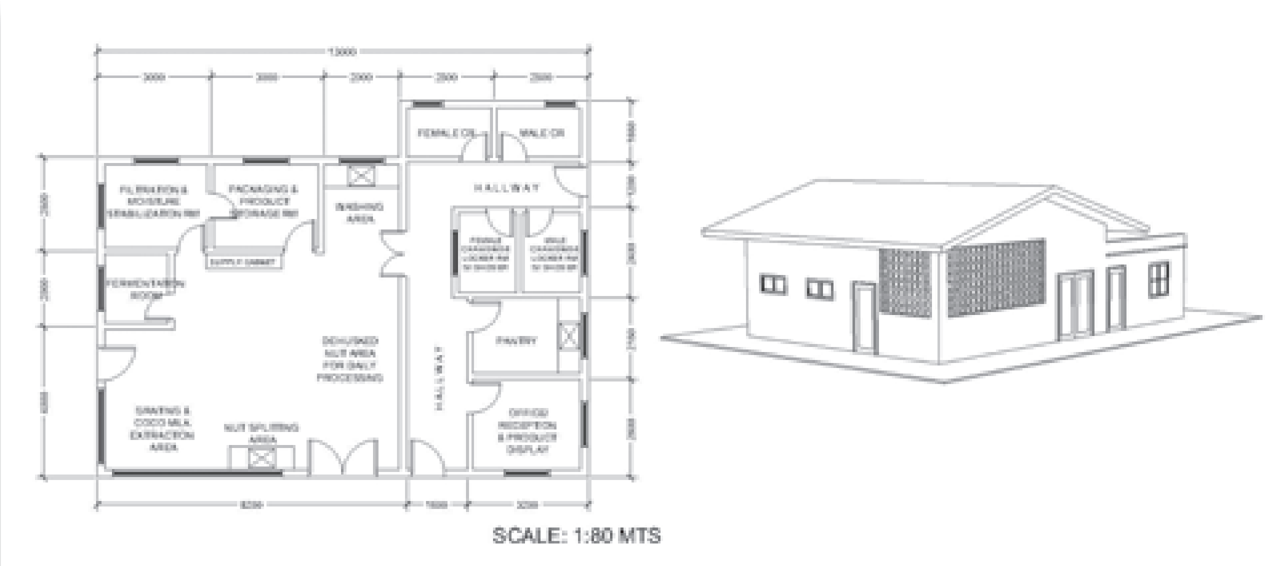
- It must be designed to permit easy cleaning.
- The construction materials should not transmit undesirable substances (e.g. asbestos).
- The walls should be made from water-proof, non-absorbent, washable material such as concrete; preferably painted white; smooth without crevices, holes or cracks; and easy to clean and disinfect.
- The ceilings should be designed to prevent dirt accumulation, and to minimise condensation, mould development and flaking.
- The floor must be made from non-absorbent and moisture-proof material, be easy to clean, have appropriate drains, and be free of joints and cracks where dirt can accumulate.
- The provision of natural lighting and ventilation through screened windows needs to be incorporated in the building design whenever appropriate; ceiling lights should have shatter-proof covers to prevent contamination in case of breakage.

- The design must incorporate provision for the installation of devices (ventilators, exhaust fans, etc.) that will help control odours and humidity.
- Exit and entry points need to be pest-proof, preventing rodents from gaining access to the building.

In designing the floor plan and machinery lay-out for the building, Bawalan and Chapman (2006) mention the following features that ought to be considered.

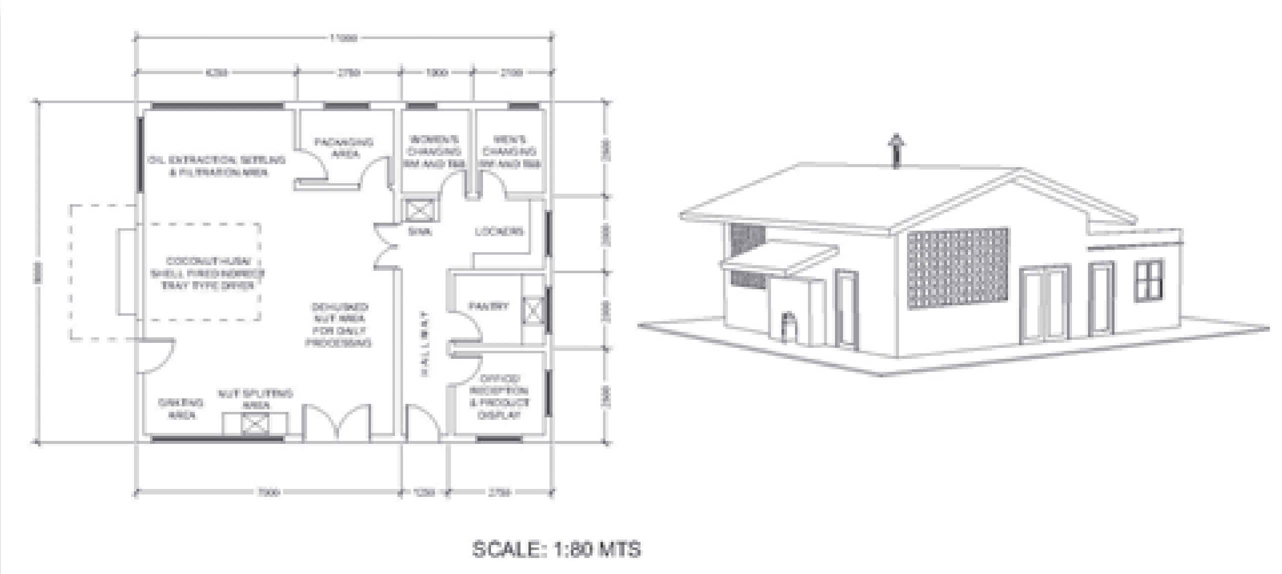
- Process flow should be done in such a way as not to cause contamination, i.e. a continuous linear flow of processing steps instead of having the personnel going to and fro between different production areas. This is to minimise cross-contamination of materials being processed.
- Processing steps that are critical in the operation and highly susceptible to microbial contamination must be done in an enclosed area where strict sanitation can be implemented and only authorised personnel can enter (e.g. drying of fresh kernel if the intention is to produce coconut flour with VCO from the high pressure expeller method).
- Plant and equipment lay-out must be designed to facilitate easy access for cleaning the specific areas and decontamination of assigned personnel.
- Entrance to the processing area should be separate from the entrance to the general access area where non-plant personnel and outsiders enter, e.g. office and display room, pantry.
- A washing area must be provided near the entrance to the processing area so that production personnel can wash their hands whenever necessary.

A suggested floor plan and building perspective to minimise risk of contamination in a village scale VCO plant using the fresh-wet process and the fresh-dry process are shown in Figures 61 and 62. The main entrance to the processing plant needs to be opened only once a day to receive the nuts to be processed that day. Processing personnel should enter only through the personnel entrance near the changing room and wash room.



Source: Bawalan and Chapman (2006)

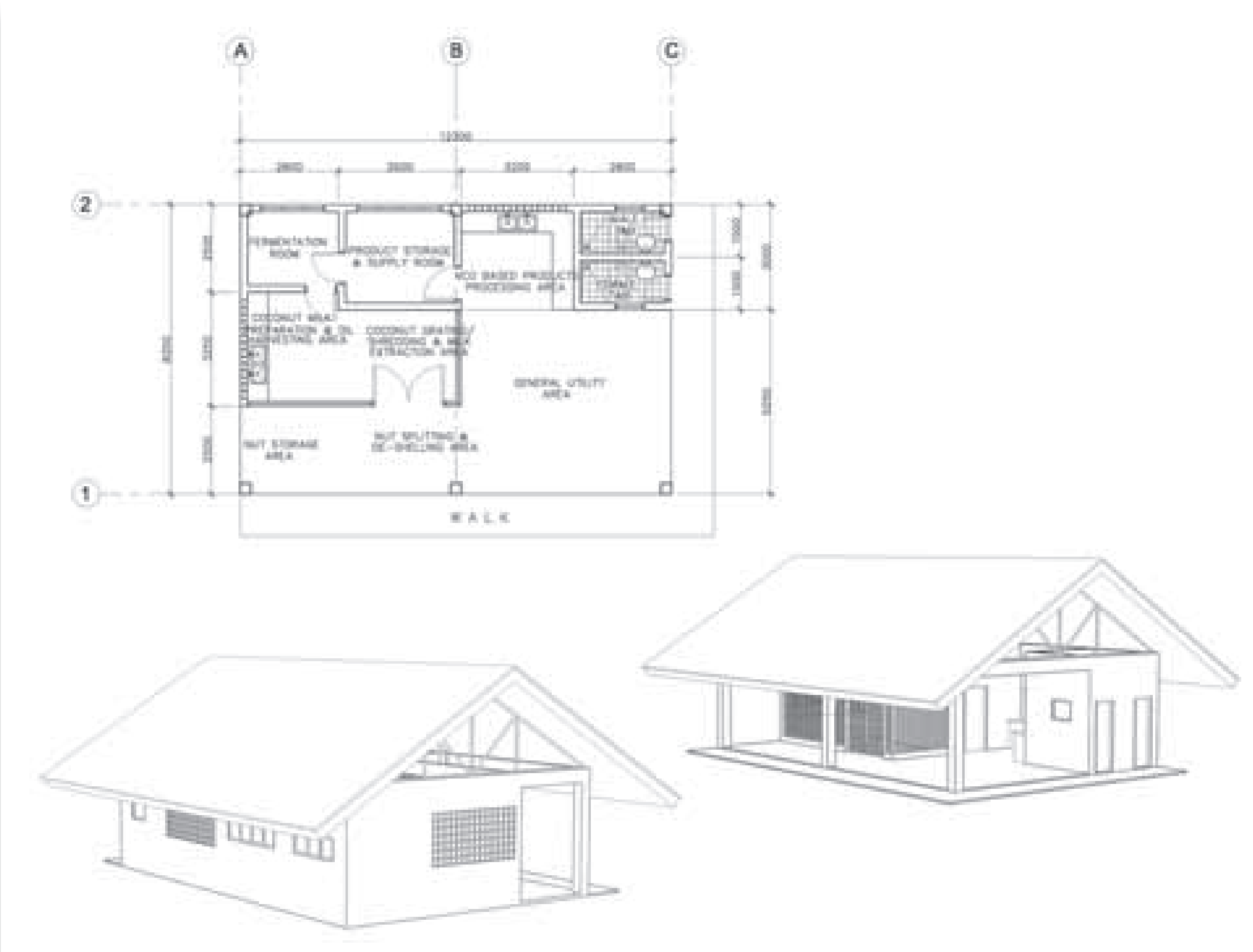
Figure 61. Suggested floor plan and building perspective for VCO plant using the fresh-wet process



Source: Bawalan and Chapman (2006)

Figure 62. Suggested floor plan and building perspective for VCO plant using the fresh-dry process

A suggested floor plan and building perspective for a pilot VCO processing facility with space provision for downstream products and which is also intended for demonstration and training is shown in Figure 63.



Source: Bawalan and Chapman (2008)

Figure 63. Suggested floor plan and building perspective for pilot processing, training and demonstration plant with space provision for processing of VCO-based downstream products

Chapter 6
By-products processing

6.1 Coconut shells

Coconut shell is one of the primary by-products of VCO processing since it is typically husked coconut that is brought to the plant. Coconut shell or endocarp (Figure 64) is the thin, hard, dark brown, layer between the coconut husk (mesocarp) and the kernel of the mature coconut. It is soft and dark cream in colour when the nut has not reached maturity. The chemical composition of coconut shell is given in Table 5.

Generally speaking, coconut shell is not processed in PICTs. In Fiji, most coconut husks with the attached coconut shell are allowed to rot after the green copra has been cut out. To a limited extent, shells are used as fuel for drying copra and in the DME flat-bed conduction dryers. Hoff (2008) reported that coconut shell handicrafts are made in Samoa for tourists. The most widely known use of coconut shells in Fiji is their use as a cup for drinking kava during social and cultural gatherings.

Figure 64. Coconut shells

Table 5. Chemical composition of coconut shell

Constituent	Country of Origin of Nuts		
	Philippines[a]	Sri Lanka[b]	Philippines[d]
	Percentage (Dry Basis)		
Ash	0.23	0.61	0.55
Lignin	33.30	36.51	27.26
Cellulose (crude)	44.98	53.06	33.52
Pentosan cellulose	17.67	20.54	5.26
True cellulose	27.31	32.52	28.26
Methoxyl	5.39	-	5.84

Source: Carbonell (1979)

The usefulness of coconut shell is clearly illustrated by the description of Dr W.R.N. Nathanael, former director of the Coconut Research Institute in Ceylon (now Sri Lanka) cited in Guarte (1993):

> In the hands of the beggar, a coconut shell serves as his begging bowl; in the hands of the artist, it turns into a thing of beauty; it provides the humble housewife with a brightly burning fire to cook her simple fare; it lets the chemist unlock its secrets and yields a dozen new things. Such is the coconut shell, versatile part of the world's most versatile tree – the coconut palm.

There are four ways in which coconut-producing countries in Asia are using large quantities of coconut shell. These are:

a. as a fuel in copra drying and direct combustion burners/furnace for process heating applications;

b. conversion into coconut shell charcoal for various heating applications or further conversion into activated carbon;

c. processing into coconut shell fashion accessories and novelty items;

d. processing into coconut shell flour.

The next sections have more information about each of these uses.

6.1.1 Fuel for heating applications by direct burning

Coconut shell is an agricultural residue that has a very high heating value—5,500 kcal/kg (Paddon and Harker 1979). As such, it is considered a good solid fuel for heating applications. In the villages of coconut-producing countries in Asia, coconut shell is used for cooking. In Sri Lanka and Malaysia, coconut shell is the major fuel used for drying copra in the so-called Ceylon kilns where the half-cup shells are bonded together in interlocking positions and arranged like a snake in an enclosed area underneath the copra loading bed (Figure 65). In the Philippines, coconut shell is used as fuel in biomass fired boilers for steam generation in desiccated coconut processing plants. In Sri Lanka and the Philippines, a major portion of coconut shells is converted into charcoal.

Figure 65. Formation of coconut shell charcoal as fuel in a Sri Lankan copra dryer

In PICTs where VCO is produced using the DME process, coconut shell is generally used as a fuel in DME flat-bed type conduction dryers to dry grated coconut kernel prior to oil extraction. In Fiji, coconut husks with attached coconut shells are used as fuel for copra drying in estate plantations or on farms if copra cutting is done near the dryer. Otherwise, they are allowed to rot on the ground, often providing a habitat for dengue-carrying mosquitoes. It should be noted that in Fiji, the general practice is that farmers sell the green copra and traders do the copra drying. In this case, firewood is generally used as fuel. At the Cocoa and Coconut Research Institute in Papua New Guinea, coconut shell is used as fuel in big copra dryers.

At Wainiyaku Estate Plantation in Taveuni, Fiji, dried coconut husks with attached shell are used as fuel in a biomass-fired boiler to generate steam, which is piped to a steam turbine to produce electricity to supply the power needs of the estate, including the operation of machines for coconut oil production. The heat given out when the exhaust steam from the turbine condenses heats the air that is blown through the condenser. This heated air is then directed to blow through an enclosed bed of green copra for drying.

6.1.2 Conversion to coconut shell charcoal

Coconut shell is converted to charcoal to increase its calorific value and for use as a smokeless, clean fuel for cooking in urban areas and for industrial heating applications. Coconut shell charcoal (Figure 66) is generally defined as the product of carbonisation of coconut shell from mature nuts in a limited or controlled amount of air. It contains the highest percentage of fixed carbon of all ligneous charcoal. High grade coconut shell charcoal is uniformly black in colour and snaps with a clean shiny fracture. It is free from dust and ash and produces a metallic sound when dropped on hard ground.

Figure 66. Coconut shell charcoal

Shell charcoal has higher calorific value than wood charcoal. The calorific values of coconut shell charcoal as measured and reported by different researchers are shown in Table 6. Comparative data on the calorific value and composition of coconut shell, coconut husk and ipil-ipil (Leucaena wood) charcoals are shown in Table 7.

Table 6. Calorific values of coconut shell charcoal (as reported by different authors/researchers)

Author	Calorific value, kcal/kg
Lozada (1978;1980)	6540
Cruz (1978)	6654
Tamolang (1978)	6784
Grimwood (1975)	7500 to 7600
Paddon and Harker(1979)	7204
Breag and Harker(1979)	7108 to 7339

Source: Guarte (1993)

Table 7. Comparative composition and calorific value of different types of charcoal

Product		Coconut shell charcoal	Coconut husk charcoal	Ipil-ipil (wood) charcoal
Calorific value	MJ/kg	27.0 – 31.8	25.0 – 27.0	25.5 – 28.5
Fixed carbon	%	80.5 – 88.5	75.5 – 80.0	79.5 – 85.0
Volatile matter	%	11.5 – 14.8	8.0 – 10.0	10.5 – 17.5
Ash content	%	3.0 – 4.7	7.0 – 12.0	3.0 – 7.0
Moisture content	%	2.0 – 3.5	3.0 – 5.5	4.0 – 10.0

Source: Hauser (1995)

In coconut-producing countries in Asia, coconut shell charcoal is traditionally used as a fuel for household cooking, for barbecue grills in restaurants and for irons (to iron clothes) in areas where there is no electricity. It is a clean-burning fuel with high heating value. Granulated coconut shell charcoal is used as a deodoriser for refrigerators, bedroom closets and kitchen cabinets. However, the processing technologies and uses of coconut shell charcoal are not generally known in PICTs. There is a need for information dissemination and training to introduce these technologies for wider adoption in the Pacific region.

Processing of coconut shell into charcoal in the Philippines is generally done on-farm and is a corollary activity to copra-making. It is done either through the pit method or by using second-hand 200 litre metal drums or manufactured metal kilns. Hence, coconut shell charcoal-making can be easily done in PICTs. For more detailed information on coconut shell charcoal characteristics, uses, processing and quality standards, please refer to Annex 8.

Activated carbon

In the Philippines, coconut shell charcoal is processed to produce activated carbon, which brings in a lot of foreign exchange because it is one of the most highly valued coconut products in the world market.

Activated carbon from coconut shell charcoal has certain natural outstanding properties and some specific purposes. It is superior to other amorphous carbon. It has more resistance to abrasion, higher capability for adsorption and less ash (Hauser 1995). It is specifically superior for gas adsorption because of its small micropore structure. Activated carbon is used in large quantities in sugar, waste-water treatment, mining and mineral processing, oils and fats, food and beverages, pharmaceuticals, and electroplating industries. It is also currently used for reducing polycyclic aromatic hydrocarbons (PAHs) levels in crude coconut oil, which is a result of making copra in direct type dryers where combustion gases from burning coconut husks and wood are allowed contact with the coconut kernel to take out the moisture, or when atmospheric air contaminated with PAH gets into contact with the kernel. Owing to the fact that activated carbon is the best all-around adsorbent for toxic gases, it is almost universally used in most gas masks and for removing and abating industrial stench (Guarte 1993).

In the process of making coconut shell charcoal and granulated shell charcoal for activated carbon processing, considerable amounts of very small charcoal pieces (fines) are generated, which charcoal producers and granulators dismiss as waste. These charcoal fines may amount to 15–20% of the total charcoal yield per batch. Charcoal fines cannot be burned by the usual simple charcoal burning method or converted into activated carbon. There are two uses for them:

- They can be converted into charcoal briquettes, also called patent fuel, which is a compacted mass of fuel material made from a mixture of charcoal fines and a binder and moulded under pressure (FPRDI 1992). While Filipinos generally prefer shell charcoal for grilling and barbecues, charcoal briquettes are already used as household fuel in Europe, America and some countries in Asia, where big hotels and restaurants use them for grilling and roasting. A major portion of charcoal briquettes produced in the Philippines is exported to Japan and South Korea.

  When properly processed, a charcoal briquette has a slow burning rate and delivers intense heat per unit volume (Caro 1999). It also burns with very little smoke. As such, it is a cheaper alternative to electric bulbs or LPG when used as a heating medium for eggs and newly-hatched chicks in poultry farms. Most poultry farms in the southern Philippines use charcoal briquettes in their chicken brooders.

  The procedure for making charcoal briquettes is given in Annex 8.

- Charcoal fines can also be blended into the soil as biochar to provide very long-term and sustainable improvements in soil fertility and carbon sequestration.

6.1.3 Processing coconut shell into fashion accessories and novelty items

Using coconut shell to make novelty items like bags, necklaces and other fashion accessories (Figure 67) is currently practised in the Philippines and Thailand. In both countries, these coconut shell handicrafts are made on a cottage level. The technology used there can be easily adapted in PICTs, especially in countries where there is a well-developed tourist industry.

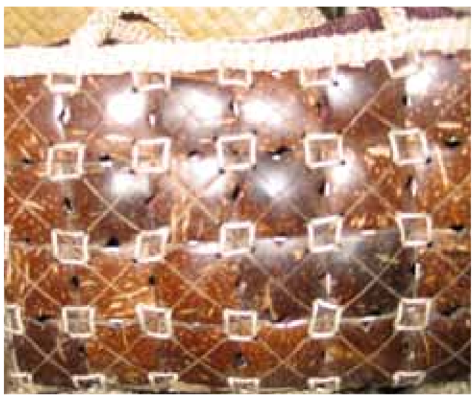


Figure 67. Fashion accessories made from coconut shell

Already, coconut shell handicrafts are made in Samoa to a limited extent. The equipment consists of simple motorised punching/cutting and grinding machines. A set comprising two puncher/cutters (Figure 68), one grinder and one finishing machine costs about USD 1300 (FOB price ex Cebu City, Philippines). In Fiji, potential products are coconut shell buttons (Figure 69) for *bula* shirts, novelty items, such as bags and cellphone holders, and fashion accessories, such as belts and necklaces, that can be sold in souvenir shops.

Figure 68. A punching/cutting machine for coconut shell handicrafts

Figure 69. Buttons and souvenirs made of coconut shell

6.1.4 Processing coconut shell into coconut shell flour

Coconut shell flour is a high value product which has a special niche in the world market. Coconut shell is cleaned, ground and pulverised into very fine particles of 100, 300 and 600 mesh grades. In one processing run, all mesh grades are produced at the same time and separated using vibrating fine screens and cyclone separators. Coconut shell flour is used extensively as a compound filler for synthetic resin glues and as a filler and extender for phenolic moulding powders. This unique filler is also used successfully with specialised surface finishes, liquid products (as an absorber), mastic adhesives, resin casting, mild abrasive products, hand cleaners, polyester type laminates, and bituminous products (Guarte 1993). The most common application of coconut shell flour is in the production of mosquito repellant coils.

6.1.5 Investment costs

Among the various technologies for coconut shell, the production of coconut shell flour and the downstream processing of coconut shell charcoal into activated carbon require high initial investment and start-up costs. However, both products are amongst the most highly valued coconut products. The current (2010) export price for activated carbon is USD 1200–1700 per metric tonne (depending on the country of supply).

Since PICTs will start processing coconut shell at almost zero level, it should initially consider expanding its utilisation for fuel (either as is or as charcoal) for heating applications and the making of specialty coconut shell handicrafts where investment requirements are relatively low. For instance, coconut shell charcoal can be easily produced in used petroleum drums which currently cost FJD 14.00 per piece. Later, after doing a feasibility study, Fiji can consider the processing of a high value product such as coconut shell flour.

6.2 Coconut water

Coconut water from mature nuts is another by-product generated during VCO processing. Coconut water is the liquid endosperm inside the coconut fruit. In Fiji, it comprises about 12% of the weight of the whole nut or 22% of the weight of the husked nut. The changes in the composition of coconut water at different stages of maturity are shown in Table 8. Coconut water spoils/ferments very fast once the nut is opened so it is essential for VCO processors to know whether it will be set aside for further processing or whether it will be discarded as a waste product.

Table 8. Composition of coconut water at different growth stages

	Without kernel	With soft kernel (0–4 mm)	With semi-hard kernel (2–6 mm)	With hard kernel (10–12 mm)
Ph	4.8	4.9	4.9	5.3
NaCl, per cent	0.280	0.252	0.268	0.383
Reducing sugar, per cent	3.95	5.25	5.26	5.24
Sucrose, per cent	0.148	0.329	0.484	0.160
Vitamin C mg/ml water	2.5	3.71	3.44	2.24
Volume water, ml	295	230	235	210

Source: Carbonell (1979)

There are two commercial products that can be made from coconut water, namely, coconut water beverage and coconut water vinegar. The Philippines is the biggest exporter of coconut water beverage, with Taiwan, the United Kingdom, Canada and Japan as its major markets.

The average export volume for the period 1997–2006 was 827,464 litres with an average value of USD 642,250 or an average price of USD 0.78/litre. The Philippines also exports coconut vinegar at an average price of USD 0.75/litre.

Under the present condition of the coconut industry in PICTs, the most appropriate utilisation of coconut water is to convert it into vinegar rather than the beverage for the following reasons:

a. All types of vinegar sold in most PICTs are imported and relatively expensive.

b. Processing of coconut water vinegar can be done even on a micro scale operation and requires minimal investment. For PICTs where coconut toddy is collected, the recommended process is to use three-day old toddy as a starter, since this is a much simpler and shorter process than the addition of 'mother vinegar', which has to be prepared initially from a microbial culture.

c. Processing of coconut water into a beverage can be done only in a plant operation and requires a much higher investment because special pasteurisation and packaging equipment are needed. The ordinary pasteurisation method (80°C for 20–30 minutes) to kill pathogens cannot be used because the coconut water flavour is destroyed by heat. The beverage is made using either the steam-heated UHT (ultra high temperature) or HTST (high temperature short time) system of pasteurisation. In the Philippines, this system is normally integrated with the processing of coconut milk/cream, as it uses the same equipment such as steam boilers, the UHT packaging system in the case of tetrapak packaging, or the canning equipment and retort in the case of the canned product. **Even with careful processing, however, the taste of the beverage is altered, and people who are familiar with the taste of natural coconut water do not enjoy the taste of the processed beverage.** Hence, it is unlikely that a local market for the processed beverage can be developed in PICTs as tourists would much prefer to drink natural coconut water than the processed product. In the Philippines, it is exported to countries that do not grow coconuts.

Processing of coconut water into vinegar could be a viable option for PICTs where coconut toddy is harvested, such as Cook Islands, Kiribati, Marshall Islands, Solomon Islands and Tuvalu. In this way, the simple process of using three-day old toddy as a starter can be adopted instead of using starter culture that requires preparation by a microbiologist. Initially, these countries can develop a domestic market for coconut water vinegar and then export to neighbouring markets such as Australia and New Zealand. It should be noted that there is now an emerging market for naturally processed products like coconut water vinegar.

Another possible use of coconut water is to make coconut sauce, which can be easily made in a kitchen. Coconut sauce can be used as a substitute for soy sauce in household cooking.

Please refer to Annex 9.1 for the process technology and quality specifications for coconut water vinegar and to Annex 9.2 for the recipe for making homemade coconut sauce.

6.3 Coconut milk residue

Coconut milk residue is the solid material left behind when coconut milk is extracted from grated or shredded coconut kernel. It is generated as a by-product of wet processing production (coconut milk route) of VCO. This residue represents approximately 25–50% of the weight of the grated kernel on a wet basis, depending on the coconut milk extraction process that is used. In most Pacific households, the coconut milk residue left after the milk has been extracted is used as animal feed or discarded as waste. The residue has a bland taste, since most of the protein and fat is extracted with the coconut milk.

Studies done at the Philippine Food and Nutrition Research Institute (FNRI) reveal that coconut residue has a much higher dietary fibre content (32%) than oatmeal (8%) and flax seed (23%), which are being promoted by American food companies as healthy foods. Based on FNRI analysis, dried coconut milk residue has the following percentage composition: 51% carbohydrates, 32% dietary fibre, 38% fat, 5% protein, 4% moisture and 2% ash.

Coconut milk residue can be used either dried or wet, depending on the application. The different options for using it are schematically shown in Figure 70.

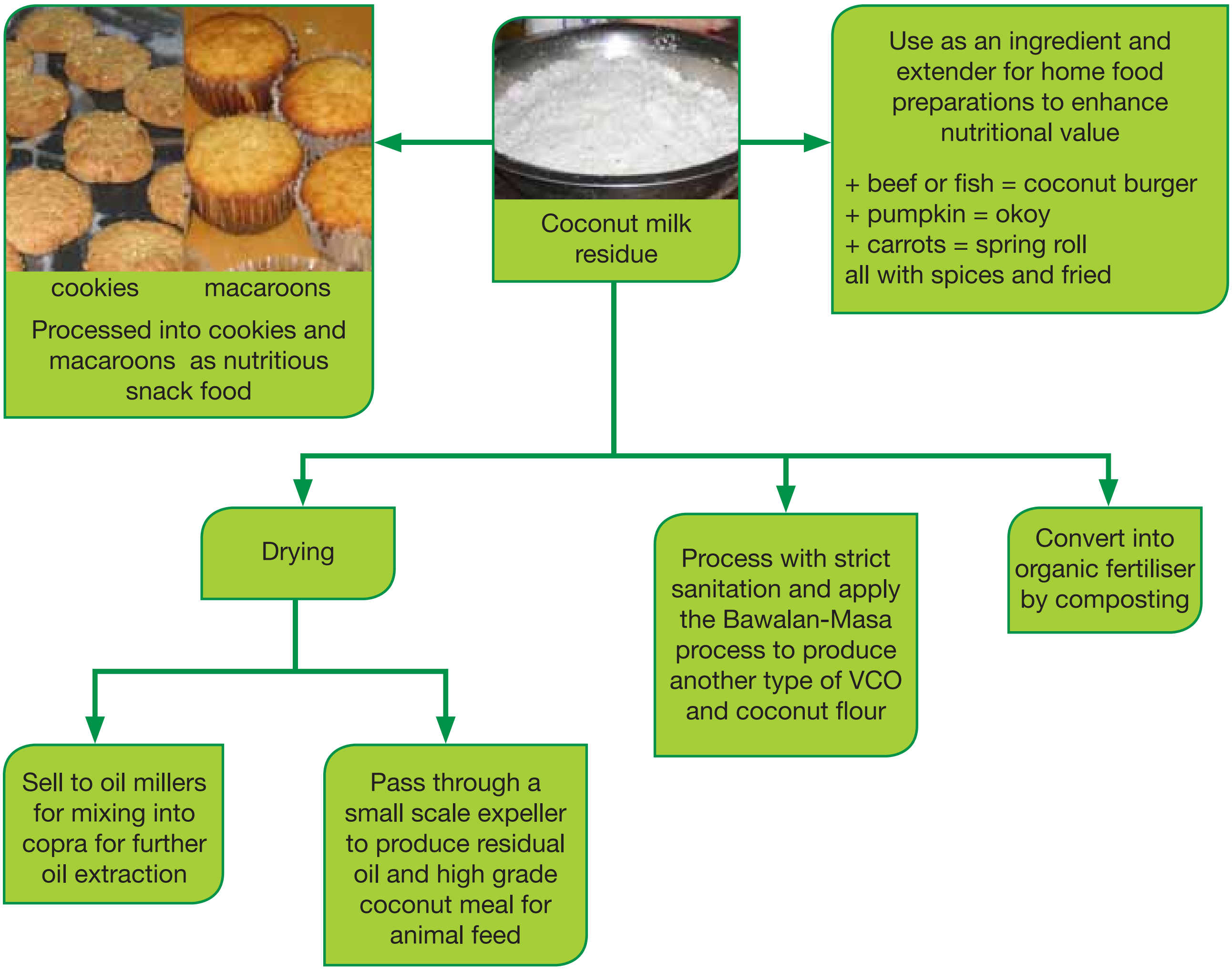


Figure 70. Options for utilisation of coconut milk residue

6.3.1. Utilisation of coconut milk residue for food and nutrition

Wet coconut milk residue can be used as an extender in meat or fish dishes for family meals, i.e. it can be mixed with meat or fish to make burgers or spring rolls and other fried food items, adding to the nutritional value of the meal, as well as being economical. Coconut milk residue is a healthy food, rich in dietary fibre and healthy fats, mainly medium-chain length saturated fatty acids. Studies done at FNRI indicate that dietary fibre from coconut residue is good for lowering cholesterol and for people who are suffering from type II diabetes (mature onset). Likewise, coconut milk residue also contains coconut dietary fat, which studies suggest has antimicrobial properties and can boost the immune system, aside from providing food energy.

Dried coconut milk residue, when processed under strict sanitary conditions, can be used as a substitute for desiccated coconut in baked food products such as breads and cookies. Because of its bland taste, it does not detract from other flavours that may be added to cookies to enhance their taste. It can also be used in making fibre-enriched foods and in the formulation of functional foods because of its high dietary fibre content.

Various recipes developed by the Philippine Coconut Authority on the processing and utilisation of wet and dry coconut milk residue for food products are presented in Annex 10. These food products can be made using ordinary kitchen equipment and tools.

6.3.2. Production of VCO and coconut flour through the application of the Bawalan-Masa process

Coconut flour (Figure 71) is another coconut-based product for which the demand is increasing. Coconut flour was found to have high dietary fibre, much higher than oatmeal and flax seed, and is being promoted as a heart-healthy product in the USA. The colour of the coconut flour varies, depending on the processing routes. If the coconut flakes failed the standard microbial count for food products, then it can still be sold as an aflatoxin-free animal feed component.

Based on analyses done at the PCA laboratory, and depending on the milk extraction process used, coconut milk residue still contains 36–42% oil on a dry weight basis. It should be noted that coconut kernel contains 67–69% oil on a dry basis. This is actually the reason VCO recovery from the fresh-wet process is lower than from the fresh-dry process (i.e. part of the oil originally contained in the fresh kernel is retained in the coconut milk residue). Hence, to improve profitability of operation in a VCO facility using the fresh-wet process, the coconut milk residue should be utilised.

In large scale VCO production using the coconut milk route, where relatively large volumes of coconut residue are generated, the Bawalan-Masa Process to produce coconut flour and VCO is appropriate. This technology enhances its economic viability; for every ton of wet coconut milk residue, 170 kg of

Figure 71. Coconut flour

VCO and 263 kg of coconut flour can be recovered. The VCO produced from coconut milk residue is generally preferred for application in aromatherapy products because it is easily and rapidly absorbed through the skin and has a very mild coconut scent. Please refer to Annex 11 for details of the Bawalan-Masa Process.

It should be noted that coconut milk residue from coconut milk processing plants is a food-grade raw material and should not be used for low value purposes such as an animal feed ingredient.

6.3.3. Drying for further oil extraction

Coconut milk residue still contains 36–42% oil on a dry basis. Coconut kernel contains 67–69% oil on a dry basis. Hence, there is still a considerable amount of oil that can be recovered when it is passed through a high pressure expeller.

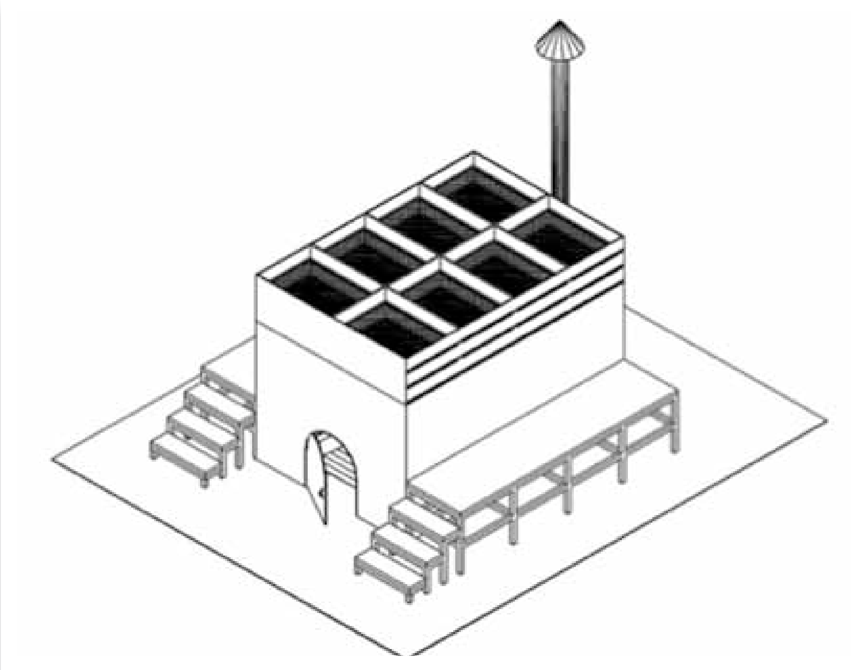


Figure 72. Natural draught coconut shell/husk-fired tray dryer

Source: Bawalan and Chapman (2006)

Drying coconut milk residue for mixing with copra for further oil extraction is not as critical as drying it for VCO and coconut flour production. Drying can be done either by sun-drying or lightly toasting it in a pan or using a coconut husk-fired, indirect natural draught dryer (Figure 72), similar to the copra dryer currently being used in Fiji with minor modification or a coconut shell-fired DME flat-bed dryer (Figure 16).

To determine the approximate amount of oil that can be recovered from coconut milk residue mixed with copra, a rough material balance computation was made, based on the situation in Fiji. The Coconut Industry Development Authority estimates that about 35% of the total coconut production in Fiji or about 45 million nuts per year are used in households for the extraction of coconut milk for use in food preparations and for making traditional village coconut oil (Bawalan 2008). Based on the average weight and composition of Fijian coconuts, an equivalent amount of about 6,561 tonnes of wet coconut milk residue is generated. If this residue is dried and mixed with milled copra for pressing, it will yield an additional 1115 tonnes of coconut oil, which is equivalent to USD 1.3 million at USD 1200/tonne (a typical price in 2010).

This is a new concept for PICTs. It will need negotiation with oil millers to make the concept work. In the Philippines, there are already buyers of wet coconut milk residue who take the residue from VCO producers immediately after coconut milk extraction. These buyers also dry the residue.

6.3.4. Composting to produce organic fertiliser

Wet coconut milk residue can be mixed with other agricultural farm wastes and animal manure, with or without the addition of useful inoculums (micro-organisms), to produce organic fertiliser. These useful micro-organisms can be nitrogen-fixing, phosphate-solubilising and cellulose-degrading types. They enhance the production and availability of plant nutrients from natural sources through accelerated microbial processes. Hence, conversion to organic fertiliser is much faster with added inoculum. Composting can be done in a compost pit or on a plastic sheet laid out on the ground and covered by another plastic sheet for moisture retention.

6.3.5 Quality control and handling of wet coconut milk residue

The still relatively high moisture content (about 42%), as well as the residual protein and other micronutrients of wet coconut milk residue, makes it highly susceptible to microbial contamination and attack, much like the fresh coconut kernel. Hence, immediate processing or drying of wet coconut milk residue within four hours of opening the nut is essential. In addition, since it is already in the form of small particles, special care should be taken to prevent contamination by any foreign matter while it is being handled. Small particles of metal are to be avoided at all cost since they will destroy the oil expeller if it is mixed with milled copra for further oil extraction. Once dried, it should be processed immediately for the production of VCO and coconut flour, or else packed in polyethylene bags for delivery to the oil mill.

6.4 Coconut skim milk

Coconut skim milk is the watery phase that separates out from the coconut cream when coconut milk is allowed to stand for two hours or when it is passed through a two-phase (liquid-liquid) centrifuge. In the two-stage centrifuge process of VCO production, coconut skim milk is generated as a by-product since it is only the separated cream that is processed into VCO. Coconut skim milk is a low fat substance that has a sweetish flavour characteristic of young coconuts. It can be pasteurised, frozen or packed in cans or tetrabrik, or passed through a spray dryer to produce coconut skim milk powder.

Table 9. Comparative nutritional values of coconut skim milk, coconut milk, soybean milk, cow's milk and human milk

	Coconut skim milk	Coconut milk	Soybean milk	Cow's milk	Human milk
Moisture, %		56.9			
Food energy, calories	27	318	33	65	77
Protein, g	1.6	5.5	3.4	3.5	1.1
Fat, g	0.4	34.8	1.5	3.5	4.0
Carbohydrate, g	4.5	1.9	2.2	4.9	9.5
Calcium, mg	26	15	21	118	33.0
Phosphorus, mg	36.0	100	48	93	14.0
Iron, mg	0.7	1.6	0.8	trace	0.1
Potassium, mg		324			
Vitamin A, I.U.	-	-	40	140	240
Thiamine, mg	0.01	0.02	0.08	0.03	0.01
Riboflavin, mg	0.01	0.01	0.03	0.17	0.04
Niacin, mg	0.4	0.3	0.2	0.1	0.2
Ascorbic Acid, mg	2.0	trace	0.0	1.0	5.0

Source: Banzon et al. (1990)

Coconut skim milk can be used as an ingredient for ice-cream and as a non-fat nutritious beverage (with or without additional flavour such as chocolate or strawberry) that is suitable for people who cannot take dairy milk because of lactose intolerance. This is actually the niche market that can be filled by coconut skim milk.

The nutritional composition and values of coconut skim milk compared to coconut, soybean, cow and human milk on a per 100 gram basis are shown in Table 9.

It should be noted that coconut skim milk is a highly perishable food item. Hence, it should be processed immediately (blast freeze or pasteurise and pack or spray dry) if produced in commercial quantities through the two-stage centrifuge process, or consumed immediately if produced at home through the modified kitchen method.

A VCO manufacturer in the Philippines who uses the centrifuge process is currently producing and selling frozen coconut skim milk as a non-flavoured beverage and coconut skim milk-based ice-creams and popsicles.

Chapter 7
Downstream products from virgin coconut oil

Profitability in VCO production can be enhanced by processing some of the VCO into downstream products such as hand-made bath soaps (ordinary and herbal), massage oils, moisturising body oil, body butter and other skin care products, and hair conditioner. This was demonstrated in the Philippines, where small scale producers of VCO survived the competition with big processing plants by going into VCO-based downstream products. The VCO industry in the Philippines started with farmer producers linked to traders/exporters and with small producers. However, when the world demand for the product became bigger, big manufacturers of coconut milk and desiccated coconut added VCO to their product lines. These plants, which have been in the coconut manufacturing business for decades, hold all quality certifications (ISO, HACCP etc.) with some also having organic certification. Hence, the majority of small scale producers, who were producing only VCO, had to cease operations because institutional buyers preferred the VCO produced by the larger, better accredited companies.

In Fiji, there are several companies, including Pure Fiji Ltd, Fiji Mana/Origins Pacific Ltd, Natural Oils of Fiji Ltd, Organic Earth Fiji, Mokosoi Products Fiji Ltd, that are processing soaps and skin care products using VCO or high quality coconut oil. The Pure Fiji brand of soaps, creams, lotions and other skin care products is well advertised, reasonably priced and sold in duty-free shops in Fiji and Australia and on international flights of Air Pacific. Likewise, small VCO producers in Samoa under the auspices of the Women in Business Development Inc. are supplying VCO to The Body Shop International of the United Kingdom for processing into its coconut bath and body range of products. One company in Tahiti is also producing VCO-based body oil for tourists. In most of these cases, it is not the VCO producers producing the downstream products; it is the companies that buy their VCO. The profitability of the VCO operation is, therefore, dependent on maintaining the goodwill of the companies that buy it.

7.1 Moisturising toilet/bath soap

Soap is a household necessity, assuring manufacturers of a ready market. There are now several home-scale producers of VCO in the Marshall Islands, Fiji, Kiribati and Papua New Guinea who use this method. One former trainee in Papua New Guinea is producing VCO and converting it into soap. It was reported that miners in Papua New Guinea prefer the VCO-based soap that he produces because it lathers and cleans well, even in hard water. Another trainee in the Marshall Islands has, since 2006, been producing VCO and converting some of it into a fragrant body oil by infusion with aromatic leaves. In Fiji, a trainee from Vanua Levu is producing VCO which she converts into herbal soaps for tourist shops. There is now an association of small-scale VCO producers using the modified natural fermentation method in Fiji.

Figure 73. Moisturising bath soap

Soap (Figure 73) is the solid material obtained when an alkali reacts with the fatty acids in animal, vegetable and seed oils and fats under a process known as saponification. The type of oil or fat used defines the characteristics of the resulting soap, i.e. whether it is mild or drying to the skin, whether it will form good lather, whether it will have good detergency or cleaning properties, etc. Soap using coconut oil as a base oil has two advantages.

- It lathers, even in very hard (brackish) water.
- It has superior cleaning and detergent properties because of the predominant lauric fatty acid content.

Based on Philippine's export data, the demand for coconut oil-based soap has been steadily growing. The United Coconut Association of the Philippines (UCAP) newsletter reported that, as of February 2010, the export of toilet/bath soaps ranked second among the Philippine export of non-traditional coconut products, with an average price of USD 2.08/kg (www.ucap.org.ph). UCAP further reported that the export volume for bath soaps increased by around 200% since February 2009. This is even higher than VCO export performance, which ranked third in the Philippines export of non-traditional products.

One of the reasons for the increasing popularity of coconut oil-based bath soap is its inherent natural glycerine content, which moisturises the skin. Such types of soap are produced under cold process saponification, whereas bath soaps produced in large manufacturing plants are normally made from soap noodles using the hot process. Soap noodle is a semi-processed substance composed of fatty acids with carbon chains ranging from C_{12} to C_{18}. It is produced by removing the glycerol component and the fatty acids with carbon chains C_6–C_{10} of coconut oil through a steam hydrolysis and distillation process. Hence, cheaper varieties of commercial bath soaps that do not have added emollients tend to be drying on the skin since the natural glycerine component of coconut oil has been removed.

Herbal soap is a cold-processed soap with added natural plant material/extracts that are known to have therapeutic or beneficial effects on the skin. This type of soap has gained popularity because it is reputed to address specific skin problems. For example, ti-tree, lemon ti-tree and lemon soaps are said to be useful in preventing pimples and acne. One of the most popular herbal soaps is pawpaw (papaya) soap because of the general belief that it can lighten the dark patches of skin. Herbal soaps are priced much higher than ordinary toilet/bath soaps, and comprise a large proportion of the Philippine export of soaps.

Pawpaw, morinda and other types of herbal soaps can be produced easily in most PICTs because of the abundance of suitable plant resources. For instance, in Fiji, pawpaw trees grow by the roadside and in backyards, and the fruits are just eaten by birds and fruit bats. Guava, in many places an invasive woody weed, and morinda (*noni* or *kura*) grow in abundance throughout the Pacific Islands.

For soap formulations, soap making procedures and other related information, please refer to Annex 12.1.

Caustic soda is an ingredient of soap. It requires careful handling. To reduce the risk involved in handling caustic soda and to ensure that the amount of caustic soda to be used for specific formulation does not exceed the requirement for saponification, a stock caustic soda solution with known concentration is prepared first (i.e. mixing 1 kg of caustic soda flakes/crystals with a specific amount of water). It is much easier and safer to weigh caustic soda solution than small amounts of caustic soda/crystals.

Where there is a group of women producing soap, one person can be assigned to handle the preparation and weighing of the caustic soda solution for distribution to members of the group, who can then do the mixing and addition of desired herbal extracts to produce the soap. In this way, the risks associated with preparation of caustic soda solution are negated.

7.2 Aromatherapy/massage oils

Aromatherapy is the general term used for the application of essential oils from aromatic plants, shrubs and trees for the treatment of both medical and psychological conditions, and for wellness and beauty, as in cosmetic preparations. Essential oils are extracted from different parts of different plants, e.g. lavender and ylangylang from flowers; eucalyptus, lemon ti-tree, tea tree and patchouli from leaves; cinnamon from leaf and bark, etc. Each essential oil has specific therapeutic values and applications to address a particular human condition. For example, certain essential oils are believed to ease aching muscles and relax a tired body, and others to decongest stuffy noses and promote easier breathing.

Massage is the main method used by aromatherapists for the application of essential oils for various purposes. The oils are combined with specific plant oils, generally called carrier oils, to form the massage oil. This is done so that the aromatic scent from the essential oil can be dispersed to a wider skin area and because the use of pure essential oil for direct application to the skin is potentially dangerous, as it can irritate or even burn the skin.

Massage is an effective means of ensuring that the essential oils which have been diluted with carrier oils are penetrating a person's skin. A proportion of the volatile oil vaporises with the heat generated by the hands on a person's skin when a massage is performed and extra benefit is gained from inhaling it.

A carrier oil has to be hypoallergenic (i.e. it does not irritate even the most sensitive skin) and it must be easily absorbed by the skin.

Virgin coconut oil (VCO) has been shown to be an excellent carrier oil, and carrier of choice among expert masseurs and therapists, because it is hypoallergenic and easily absorbed, as well as having anti-microbial properties. Results of several researches done at the Dermatology Department of the Makati Medical Center in the Philippines as reported by Verallo-Rowell (2005) have confirmed VCO's anti-microbial properties. It should be noted that VCO obtained from the fresh-wet process (coconut milk route) is better suited to aromatherapy application because it is very light in texture.

Except for the atoll islands in the Pacific, where agricultural resources are limited, PICTs abound with aromatic roots, flowers and leaves (Figure 74) which can easily be used for making aromatherapy oils with VCO. Many of them can be found in backyards or growing wild. Pacific Islanders are aware of the therapeutic applications of such aromatic plants but not in conjunction with aromatherapy.

Figure 74. Aromatic roots and leaves in Fiji

There are two methods of preparing massage oils using VCO.

a. Addition of an appropriate essential oil to VCO This can be done if pure, natural essential oils are available or can be purchased. It is the simplest method of making aromatherapy oil.

A single essential oil or a combination of two or more oils can be used to create the specific aroma and therapeutic value that are needed. For example, lavender and ylangylang essential oils are known for their relaxing/anti-stress properties, tea tree and lemongrass oil have antimicrobial properties, while cineole-rich eucalyptus oils are considered excellent for decongesting stuffy noses.

The mixing of essential oils should always be done in dark coloured bottles to prevent the therapeutic value of the essential oil from being destroyed by sunlight, and it should be done on a drop by drop basis (e.g. one drop of tea tree oil plus two drops lemon grass). When the scent is right, the percentage or proportion of each oil is noted. This oil blend can then be mixed with virgin coconut oil.

Normally, 20 drops (almost 1 ml) of essential oil or a blend of essential oils is added per 30 ml of carrier oil. For very strongly scented essential oils like patchouli, just 2 ml patchouli oil are added to 98 ml VCO to make a 2% solution. (Annex 12.2 has some formulations for aromatherapy oils.)

Only 100% pure essential oils should be used. Essential oils mixed with alcohol or any other substance should not be used at all because it will destroy the quality of the aromatherapy oil.

b. Oil infusion of aromatic herbs, roots and leaves

Oil infusion can be done using either dried or fresh herbs, roots, bark and leaves. It should be noted that flowers are not generally recommended for oil infusion. Essential oils from flowers have to be extracted by steam distillation or some other means so as not to destroy the scent.

A simple method of oil infusion is to simmer a mixture of VCO and the aromatic plant material in a double boiler (Figure 75). An improvised double boiler can be made by putting a stainless steel mixing bowl over a pot of water (Figure 43). The water level inside the pot should be touching the bottom of the mixing bowl. The procedure is described below.

1) Pound the dried or fresh herbs/aromatic materials in a mortar and pestle and put them in the stainless steel mixing bowl.

Figure 75. Infusion of aromatic roots and leaves in oil

2) Add VCO. For every 60 grams of dry herbs, add 480 ml of VCO. For fresh herbs or aromatic materials, the ratio is 120 grams fresh materials for every 480 ml of VCO. A more concentrated oil infusion can be done by doubling the amount of herbs/aromatic leaves. However, the resulting concentrated oil infusion may need to be diluted with VCO prior to it being used as a massage oil.

3 Put the mixing bowl over the pot of water. Cover it loosely and put the improvised double boiler on the stove. Heat the mixture gently for at least one hour for dry leaves and two hours for dry roots and bark. It should be noted that, when fresh materials are used, the VCO turns cloudy at the start due to the water content of the fresh material. This moisture has to be completely removed, under low-moderate heat, to prevent the aromatic oil from turning rancid. Heat the mixture until it becomes clear.

4) Cool the mixture. Strain it and store it in dark coloured bottles away from direct sunlight and heat. A small amount of Vitamin E oil (1 capsule per 240 ml of infusion) will help preserve the quality of preparation.

Please refer to Annex 12.2 for the formulation of massage oil for rheumatism and muscle pain using VCO infused with ginger root as the base oil.

7.3 Skin care products

The use of coconut oil as skin moisturiser has been known in PICTs and other coconut-producing countries for hundreds, if not thousands, of years. VCO does not cause skin irritation and can be applied to even the most sensitive skin. Hence, one of the major applications of VCO is as a base oil for hypoallergenic cosmetics and skin care products. This end-use comprises the bulk of the VCO currently being exported from the Philippines.

Adding attractive or therapeutic fragrances to VCO either through the use of essential oils or by oil infusion will enhance its marketability as a skin conditioner. In addition, a VCO-based product which can be used as a natural substitute for petroleum jelly can be easily made in the kitchen.

Note: The skin care formulations (Annex 12.3) presented in this manual are those in which the ingredients are locally available. They do not require the addition of water and emulsifiers. Emulsifiers are substances that stabilise the oil and water mixtures, i.e. they prevent oil and water from separating. Creams and lotions where water is added as part of the formulation to give the product the desired consistency require chemical preservatives. This is to prevent the base oil from getting rancid and to retard the growth of microorganisms which might have adverse effects on the skin.

7.4 Hair care products

Coconut oil conditions the hair and scalp. Pacific Islanders, especially women, have been massaging coconut oil in their scalp and hair for thousands of years. In many countries, not only women, but men and children also put coconut oil in their hair. VCO is, however, much better than crude, copra-derived coconut oil for hair conditioning. The addition of essential oils like ti-tree, rosemary and patchouli, which are believed to have a good effect on the hair and scalp, enhance the efficacy of VCO as a hair conditioner. When using rosemary, the procedure for oil infusion should be followed (Section 7.2). It should be noted, however, that the concentration of the essential/herbal oils in scented oils for hair care should be lower than that used for massage oils. Hence, after infusion using the procedure described in Section 7.2, the infused oil is diluted with VCO on a 1:1 ratio and then it is packaged and sold as hair conditioner. Rosemary, patchouli and ti-tree can be easily cultivated in PICTs' tropical weather. Rosemary is well known as a herb for cooking and can be bought in supermarkets.

7.5 Utilisation of residual coconut oil and off-quality VCO for downstream products

In producing VCO from the modified kitchen and natural fermentation methods, some residual oil or second-grade coconut oil can be recovered after the premium grade VCO is harvested (Bawalan and Chapman 2006). It is recovered by further heating the *sinusinu* (in the case of the modified kitchen method) or by allowing the curd to ferment for another 24 hours (in the modified natural fermentation method). The residual oil obtained by further heating the *sinusinu* is already yellow in colour and has a strong coconut aroma, since a high temperature is required to fully release the entrained oil from the *sinusinu*. However, the grade B residual oil obtained through further settling of curd from the fermentation process is still white (or in some cases a very pale yellow). This amounts to about 10–15% of the harvested class A VCO.

In cases where there are lapses in strictly following the critical control procedures and in maintaining the sanitary conditions, the quality of VCO produced may not pass the VCO standard. In these circumstances, further processing of the oil into downstream products is necessary to recoup production costs and obtain additional income.

The residual, second grade VCO can be processed into toilet/bath soap (ordinary and herbal) without the need to reprocess it. Likewise, it can also be used for making oil infusions for massage oils, and skin and hair conditioners. However, it may need to be further processed to remove unpleasant or strong coconut odours if it is to be mixed with pure essential oils or if it is to be used as cooking oil.

Based on information obtained by the author from VCO traders in the Philippines, North American health food traders and Australasian chefs, there is a growing number of people who demand an odourless, chemical-free, clear VCO for culinary purposes rather than the traditional refined, bleached and deodorised (RBD) copra-derived coconut oil.

The standard commercial process for removing odour and taste in a copra-derived coconut oil is by putting it in contact with high pressure (150 psig) steam under vacuum conditions. This process is called deodorisation. Equipment for deodorisation is a common feature in commercial oil mills which produce RBD coconut oil or cooking oil. However, application of this process is not economically viable in a village-scale operation because of the high process capacity of equipment, and the high investment and operating costs. It should be emphasised that the quality and nutritional value of second grade VCO from the modified kitchen and natural fermentation methods is still very much higher than the copra-derived, crude coconut oil. Hence, it can be converted into cooking oil without undergoing the standard refining and bleaching process.

Bawalan (GTZ Report 2005) and Bawalan and Chapman (2006) provide the following home-scale procedure for removing the odour and taste in a grade B VCO produced using the modified kitchen and modified natural fermentation process. *Note: This procedure is not suitable for removing odour and taste from copra-derived crude coconut oil.*

a. Place water in the mixing bowl of an improvised double boiler as described in the oil infusion section above. Add second grade VCO to the water in a ratio of two parts oil to one part water. Do not stir.

b. Simmer for about three hours. When the water at the bottom of the mixing bowl is hot, water vapour rises through the oil, carrying with it the aromatic components which give odour and taste to a particular substance.

c. After three hours, scoop out the top portion (oil) and transfer it to a stainless steel pot while still hot. Be careful not to scoop out the water as well.

d. Cool the oil to room temperature. Place it in an icebox or freezer to solidify for at least two hours.

e. Remove it from the ice box or freezer and allow it to liquefy at room temperature.

f. Transfer the oil to a dry storage container, leaving behind a 2 cm layer at the bottom. This layer can be mixed with the next batch for re-processing or can be mixed with the residual oil earmarked for soap.

Annex 1
Fatty acids and chemical composition of coconut oil

Coconut oil, like most plant-derived oils, is composed of triglycerides of fatty acids of varying lengths.

For a layman to understand the chemical composition of coconut oil, the meaning of the terms triglycerides and fatty acids have to be understood first.

A triglyceride is a substance consisting of fatty acids, chemically bound to glycerol in a ratio of 3:1. The three fatty acids are held together through a special attachment to the glycerol and thus form a single molecular structure (Enig 2000). This is shown in the general chemical formula below:

$$
\begin{array}{l}
\quad\;\;\; O \\
\quad\;\;\; \| \\
R - C - O - CH_2 \\
\qquad\qquad\quad\; | \\
\quad\;\;\; O \qquad\;\; | \\
\quad\;\;\; \| \qquad\;\;\, | \\
R - C - O - CH \\
\qquad\qquad\quad\; | \\
\quad\;\;\; O \qquad\;\; | \\
\quad\;\;\; \| \qquad\;\;\, | \\
R - C - O - CH_2
\end{array}
$$

Rs are hydrocarbon chains of varying lengths normally found in natural fats or oils.

R could be:

$CH_3(CH_2)_4$ –
$CH_3(CH_2)_{10}$ –
etc

Fatty acids are essentially chains of carbon atoms with attached hydrogen atoms. These chains come in varying lengths (1 to 24 carbon atoms) with carboxyl (acid) group (-COOH) at one end (Enig 2000). They are represented by the chemical formula **RCOOH** where R represents the hydrocarbon chain with the methyl group (-CH_3) at the beginning of the chain. Thus, lauric fatty acid (with 12 carbon atoms) which is predominantly present in coconut oil, has the chemical formula:

$$\mathbf{CH_3(CH_2)_{10}COOH}$$

Fatty acids are either **saturated or unsaturated**, depending on the type of bonds that connect their carbon atoms. Fatty acids that have only single bonds in their carbon chain are called saturated. Oils and fats that are predominantly composed of saturated fatty acids are more stable and more resistant to oxidation and rancidity. This is because all carbon atoms are filled up with attached hydrogen atoms and there are no open points where oxygen can react. Coconut oil is predominantly composed of saturated fatty acids (about 92%) so it is considered a saturated oil in tropical countries and a saturated fat in temperate countries. (This was actually the basis of the smear campaign levied on coconut oil by the American Soybean Association in the 1980s.)

Saturated fatty acids are further classified into **short chain**, **medium chain** and **long chain**, depending on the length of the carbon chain and the number of carbon atoms on it. Short chain fatty acids have 4–6 carbon atoms, medium chain acids have 8–12 and long chain fatty acids have 14 or more. The medium chain saturated fatty acids are metabolised differently from long chain saturated fatty acids. Coconut oil is unique in the sense that, among fats and oils, it contains the highest percentage, about 64%, of medium chain fatty acids (MCFA).

Fatty acids that have double bonds linking their carbon atoms are categorised as **unsaturated**. The presence of a double bond in fatty acids represents a point of instability because this point in between two carbon atoms is open and susceptible to reaction with oxygen and other substances. **The more double bonds, the higher the instability**. Oils and fats that contain predominantly unsaturated fatty acids, such as soybean oil (about 84% unsaturated) and corn oil (about 86% unsaturated), are unstable and prone to oxidation. These types of oil have to be partially hydrogenated to prolong their shelf-life.

Hydrogenation is a process where hydrogen gas is bubbled through unsaturated oil in the presence of nickel as a catalyst. The resulting reaction forces unsaturated fatty acids to accept additional hydrogen atoms and become partially saturated. Full hydrogenation converts liquid oil into solid fat. Partial hydrogenation limits the time exposure of the unsaturated vegetable oil to the stream of hydrogen gas, thereby converting it either into a semi-solid state similar to butter or retaining its liquid state.

Unsaturated fatty acids are further classified into **mono-unsaturated** and **poly-unsaturated**, depending on the number of double bonds they have. Mono-unsaturated fatty acids contain one double bond in their carbon chain and poly-unsaturated fatty acids contain two or more double bonds. It should be noted that all naturally occurring unsaturated fatty acids have long carbon chains. Olive oil is categorised as a mono-unsaturated oil while soybean oil falls into the poly-unsaturated class. The comparative fatty acid profile of common fats and oils is shown in Figure 76 while the classification of fats and oils is diagrammatically shown in Figure 77.

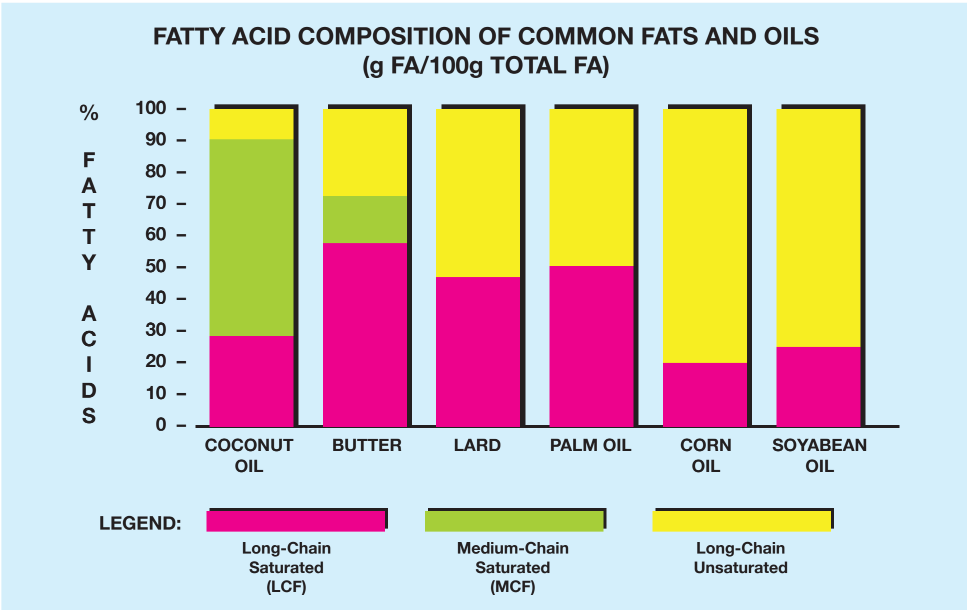


Figure 76. Comparative fatty acid profile of common fats and oils

Source: UCAP Brochure on Coconut Oil

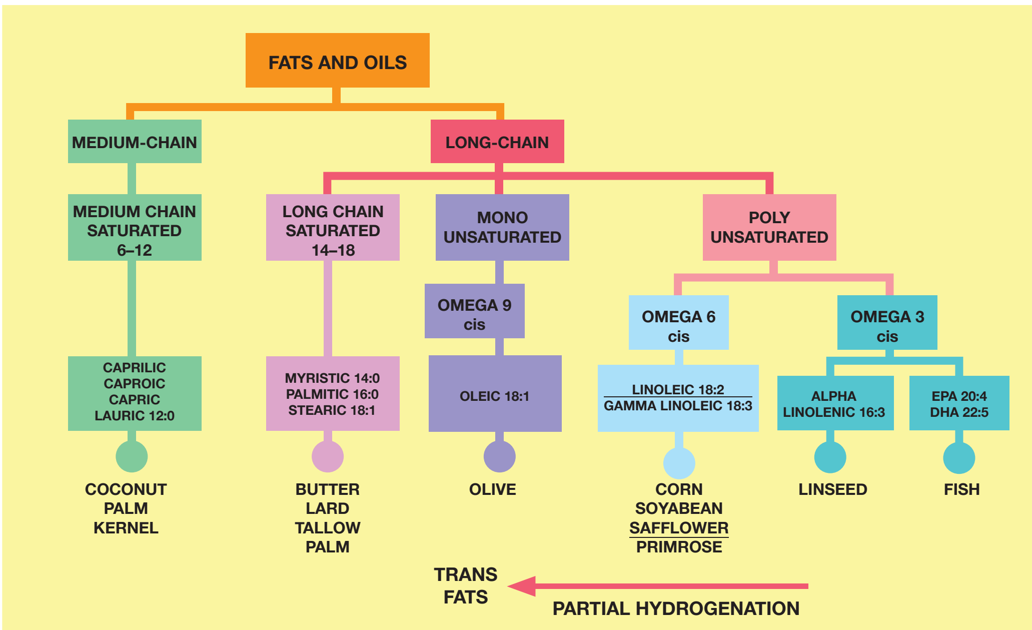


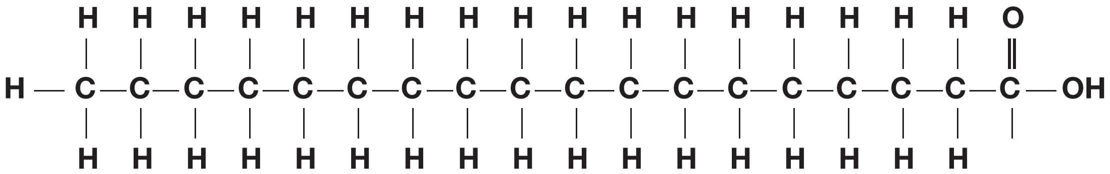
Figure 77. Classification of fats and oils

Source: UCAP Brochure

The degree of saturation and length of the carbon chain of fatty acids help to determine their properties, corresponding uses and effect on human health. The more saturated the fat and the longer the chain, the harder the fat and the higher the melting point (Fife 2001).

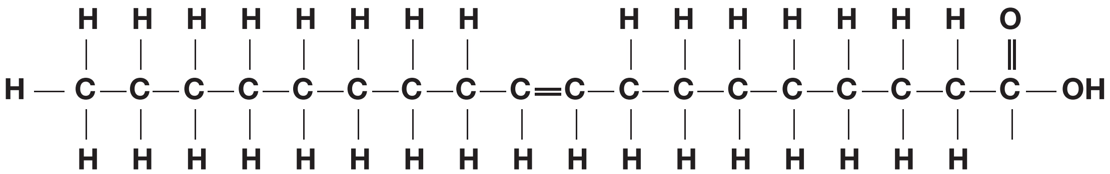
The difference in structure between saturated, mono-unsaturated and poly-unsaturated fatty acids is shown in the diagrams below.

SATURATED FATTY ACID



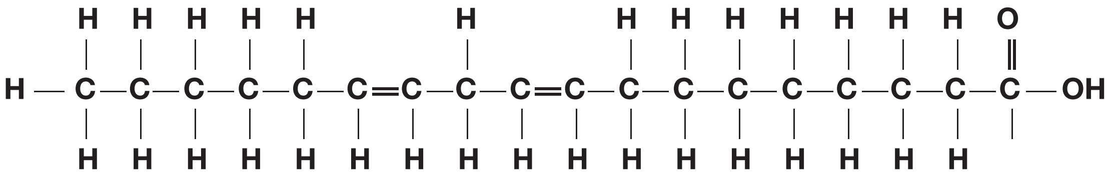
Stearic Fatty Acid (18 Carbon chain)

MONO-UNSATURATED FATTY ACID



Oleic Fatty Acid (18 Carbon chain, 1 double bond)

POLY-UNSATURATED FATTY ACID



Linoleic Fatty Acid (18 Carbon chain, 2 double bonds)

In subjecting unsaturated vegetable oils like soybean and corn oil to a partial hydrogenation process to prolong their shelf-life, another type of fatty acid is created. This is the so called **trans fatty acid**. With partial hydrogenation, most of the double bonds of the unsaturated oil remain but their hydrogen atoms change position and become trans, or across, from each other (Verallo-Rowell 2005). Hence, **trans fatty acids** are artificially altered unsaturated fatty acids in which hydrogen atoms attached to the carbon atoms linked with the double bonds have shifted position from the same side (cis) to the opposite side (trans). It should be emphasised that the cis position (same side) is the natural position and trans is the abnormal position. The partial hydrogenation process straightens the fatty acid molecules to enable them to be 'packed' in solid form like saturated fats, while remaining unsaturated (www.ucap.org.ph). Oils that have been partially hydrogenated increase their plasticity and substantially lengthen their shelf-life, unlike the original, highly unsaturated oils they were made from.

The composition, type and most common sources of fatty acids are shown in Table 10.

Table 10. The composition, type and most common sources of fatty acids

Common Name[1]	Composition[1]	Type[1]	Remarks/Most Common Food Sources[2]
Butyric acid	C 4:0	Saturated short chain	Butter (approx. 4%)
Caproic acid	C 6:0	Saturated short chain	Butter (approx. 2%); coconut and palm kernel oil (< 1%)
Caprylic acid	C 8:0	Saturated medium chain	Coconut (8%) and palm kernel (4%) oils; butter (1%)
Capric acid	C 10:0	Saturated medium chain	Coconut and palm kernel oils (4–6%); butter (2%)
Lauric acid	C 12:0	Saturated medium chain	Coconut and palm kernel oils (45–53%); butter (3%)
Myristic acid	C 14:0	Saturated long chain	Nutmeg butter (87%); Coconut and palm kernel oils (16–18%); butter (12%); animal tallow (3–5%)
Palmitic acid	C 16:0	Saturated long chain	Palm oil (45%); cocoa butter (25%); chicken fat (23%); butterfat (26%); animal tallow (approx. 25%); cottonseed oil (25%); other temperate seed oils (approx 10–12%)
Palmitoleic acid	C 16:1	Mono-unsaturated long chain, omega 9	Marine animal oils; chicken fat; ruminant tallow; lard; butterfat; olive oil
Stearic acid	C 18:0	Saturated long chain	Cocoa butter (35%); chicken fat (6%); butterfat and lard (12.5%); animal tallow (20-25%); seed oils (2-5%)
Oleic acid	C 18:1	Mono-unsaturated long chain, omega 9	All animal and vegetable fats and oils; olive (approx. 70%); hybrid safflower and sunflower (approx. 80%); canola (approx. 64%); animal tallow and butterfat (30– 35%); peanut oil (approx. 50%); palm oil (40%); other temperate seed oils (15–30%)
Linoleic acid	C 18:2	Poly-unsaturated long chain Omega 6	All animal and vegetable fats and oils (2–8%); safflower oil (80%); sunflower oil (68%); corn oil (57%); soybean and cottonseed oil (53%); peanut oil (46%); lard, olive and palm oil (40%); animal tallow and butterfat (2–4%);
Gamma linolenic acid (GLA)	C 18:3	Poly-unsaturated long chain Omega 6	Evening primrose oil (9%); black currant seed oil (15–19%); borage oil (approx 20%)
Alpha linolenic acid	C 18:3	Poly-unsaturated long chain Omega 3	Soybean and rapeseed oils (7–10%); flaxseed oil; linseed oil[1]
Arachidic acid	C 20:0	Saturated long chain	Peanut oil
Eicosa Pentanoic acid (EPA)	C 20:5	Saturated long chain Omega 3	Unhydrogenated fish oil
Behenic acid	C 22:0	Saturated long chain	Peanut oil
Erucic acid	C 22:1	Mono-unsaturated long chain Omega 9	Rapeseed oil *Authors note: The high erucic acid content of rapeseed oil makes it inedible since erucic acid is toxic to humans*
Docosa Hexaenoic acid (DHA)	C 22:6	Saturated long chain Omega 3	Fish oil

[1] Source: Dayrit (2005)
[2] Source: Enig (2000)

Annex 2
Process description and quality standard RBD coconut oil

Process Description

Copra in the Philippines is generally produced by small coconut farmers using a wide variety of sun-drying or smoke-drying methods, or a combination of both and to a certain extent, natural-draught indirect (hot air) drying. From the farm, the copra goes to a series of traders before it is delivered to the mills to produce crude coconut oil. In contrast, the common practice in most PICTs is to cut the fresh kernel (green copra) and sell it to traders, who do the drying and subsequent delivery of copra to the oil mills.

At the mill, the copra undergoes the following steps shown in Figure 78.

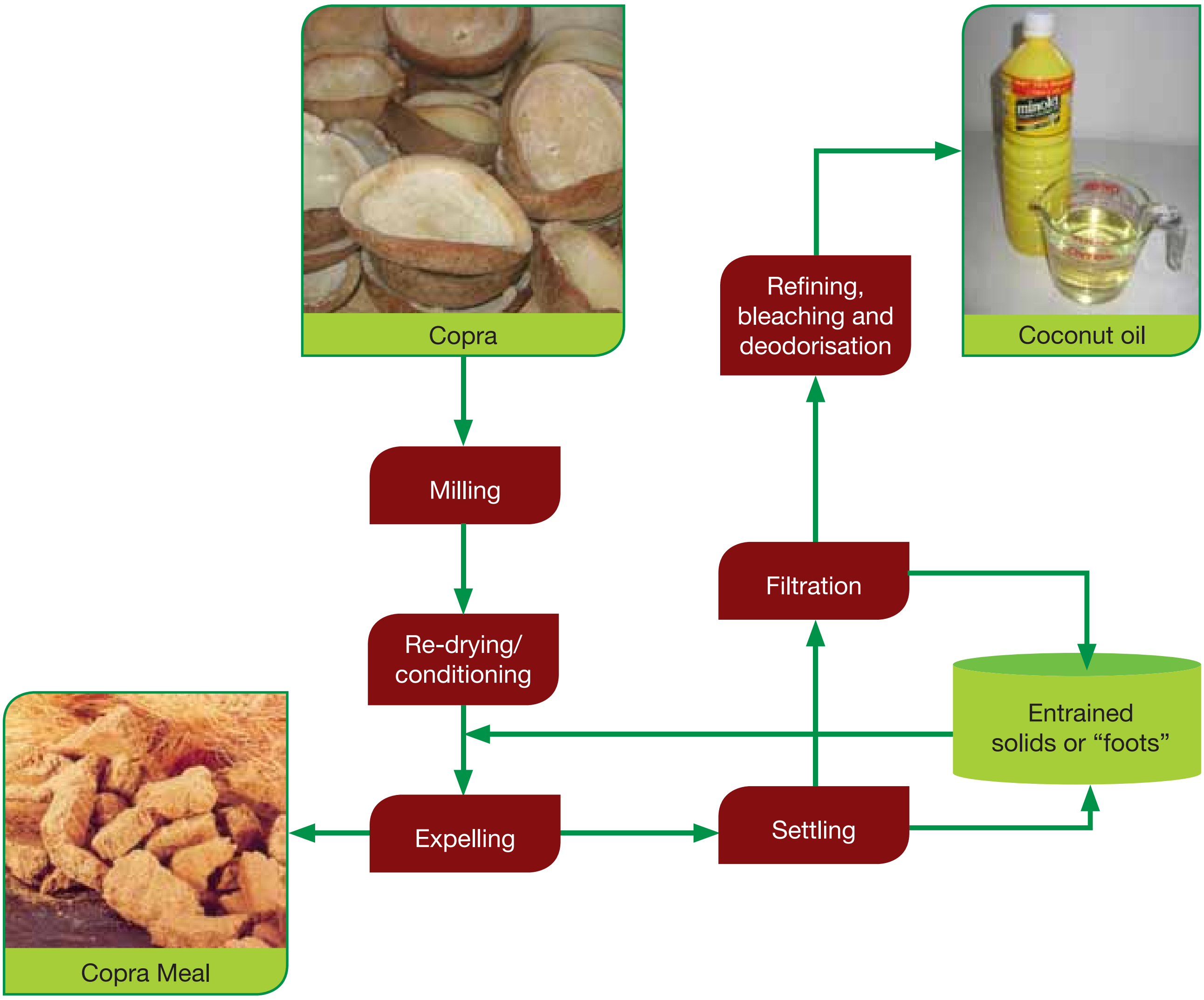


Figure 78. Process flow chart for the production of RBD coconut oil

Cleaning – copra is transferred from the warehouse to the mill by a series of floor conveyors, rotor-lifts and overhead conveyors. The copra is cleaned of metal fragments, dirt and other foreign matter, manually or by the use of shaking or revolving screens, magnetic separators and other similar devices.

Milling – to facilitate oil extraction, copra is broken into fine particles by high speed vertical hammer mills. It is reduced to a particle size of about 1/16" to 1/8".

Re-drying/Conditioning – the milled copra, which has about 5–6% moisture content, is passed through a steam-heated cooker where the moisture content is reduced to about 4%. At the same time, the cooker brings the temperature of the copra to the conditioning temperature of about 104°C (220°F). At the conditioner, the copra is maintained at about 104°–110°C (220°–230°F) for about 30 minutes. This will ensure uniform heat penetration into the copra before oil extraction. Moderately high temperature facilitates the expelling action. Oil is able to flow out more easily due to the decrease in viscosity. Also, obstruction due to gums, proteins etc. in the copra becomes less because the heating dries and shrinks these substances. The moisture content of copra when it leaves the conditioner is about 3%.

Oil extraction – the milled copra is subjected to high pressure oil extraction using an expeller, first by a vertical screw, and finally by a horizontal main screw. The oil extraction efficiency and the thickness of the cake are controlled by a choking mechanism at the end of the discharge end of the main screw. The normal setting of the choke is for 3/8" to 1/2" cakes. With this setting, the oil content in the cake is kept at about 7%. 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°C (200–215°F) to produce light coloured oil and effect good extraction.

Screening – the oil extracted in the expeller flows into the screening tanks to remove the entrained particles in the oil, generally referred to as 'foots'. The foots settle at the bottom and are continuously scooped out by a series of chain-mounted scrapers, which lift them to the screen on top of the tank. While the foots are travelling across the screen, oil is drained out of them. The foots leaving the screen are conveyed back and mixed with the copra entering the expeller. Screening reduces the solid content of the oil to about 10%.

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.

Crude coconut oil from the dry (copra) process is dark; turbid; high in free fatty acids (FFAs), phosphatides and gums; has an unpleasant odour; and may be contaminated by bacteria and moulds. To render this oil edible, it has to undergo further processing as shown below.

Figure 79. Copra-derived coconut oil in a Fijian supermarket

Refining – consists of neutralisation, bleaching and deodorising. Neutralisation reduces the FFAs to improve the taste and appearance of the oil. It is done by reacting sodium hydroxide with free fatty acids to form an oil-insoluble precipitate called soapstock. This is removed once it settles out. Phosphatides and gums are removed by spraying hot water on the oil. The oil is then dried under vacuum. Typically, 5% of the weight of the crude oil is lost in refining but the loss can be as high as 7.5% (Hagenmaier 1980)

Bleaching – takes out most of the dissolved or colloidal pigments responsible for the colour of crude oil. Either activated carbon or bleaching earths such as bentonite or a combination of both are added to the neutralised oil under vacuum while heating it to 95°–100°C. The bleaching agents are removed afterwards 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 of 150°C while in contact with live steam under vacuum conditions (29 psi pressure).

It should be noted that most oil mills in PICTs do not undertake refining, bleaching and deodorisation processes. Instead, the copra-derived oil undergoes only physical refining, using phosphoric or citric acid to reduce the gums. The appearance of coconut oil sold in the supermarkets in Fiji is shown in Figure 79.

The power and utilities needed for the production of RBD coconut oil are roughly estimated as follows:

a. power consumption – 120 kWh per ton of copra

b. steam consumption – 100 to 120 kg per ton of copra at 100 psi

c. water consumption – 3 to 5 cubic metres per ton of copra

Quality standard for RBD coconut oil

The Philippine Standard for RBD coconut oil is shown in Table 11.

Table 11. The Philippine Standard for RBD coconut oil

Parameter	Values
Moisture Content, %	0.1% max
Free Fatty Acid (as % oleic)	0.1% max
Colour*	10 Y (yellow), 1 R (red)
Saponification Value	250–264
Iodine Value **	7.5–10.5
Odour	Odourless

* Colour is measured in the laboratory with an analytical tool called the Lovibond Tintometer. It works on the principle of measuring the wavelength of light that passes through a sample of oil.

** The iodine value is a measure of the degree of saturation or unsaturation of the oil, the lower the iodine value, the more saturated the oil or fat is.

Annex 3
Frequently asked questions[1]

1. What is virgin coconut oil (VCO)?

The Philippine National Standard for VCO (PNS/BAFPS 22:2007/ ICS 67.200.10) officially defines VCO as an:

> oil obtained from the fresh, mature kernel of the coconut by mechanical or natural means, with or without the use of heat, without undergoing chemical refining, bleaching or deodorizing, and which does not lead to the alteration of the nature of the oil. Virgin coconut oil is an oil which is suitable for consumption without the need for further processing.

It is the purest form of coconut oil, water white in colour, contains natural Vitamin E and has not undergone hydrolytic or atmospheric oxidation as attested by its very low free fatty acid content and peroxide value. It has a mild to intense fresh coconut scent depending on the type of process used for production.

2. What is RBD coconut oil?

RBD coconut oil refers to refined, bleached and deodorised oil that is generally used as edible/cooking oil in the Philippines. It is derived from copra and has to undergo chemical refining, bleaching and deodorisation processes after extraction to make it suitable for human consumption. It is yellow or pale yellow in colour and does not contain Vitamin E since this is removed when the oil is subjected to high temperature and the various chemical processes. It is odourless and tasteless.

3. What are the ideal quality characteristics of VCO?

Colour – water-clear; reading of 1 yellow, 0.1 red using Lovibond Tintometer
Free fatty acid (as lauric) – 0.1% max
Moisture – 0.1 % max
Peroxide value – 1 meq/kg and below
Lauric fatty acid content – 45–56%
Scent – fresh coconut scent, mild to intense

4. What is the Philippine National Standard for VCO?

Colour – water-clear
Free fatty acid (as lauric) – 0.2% (maximum)
Moisture – < 0.1 %
Matter volatile at 120 0C (w/w) – 0.12% to 0.2 %
Peroxide value – 3 (maximum)
Food additive – none permitted

Contaminants:	Iron – 5 mg/kg
	Copper – 0.4 mg/kg
	Lead – 0.1 mg/kg
	Arsenic – 0.1 mg/kg

[1]This is a reprinted and updated version of Bawalan D.D. 2004. Frequently asked questions on virgin coconut oil. Cocoinfo International11(2) Jakarta, Indonesia: Asian and Pacific Coconut Community.

5. What causes the yellow colour in coconut oil?

- Bacterial contamination of the coconut kernel before oil extraction
- High process temperature

Therefore, for the coconut oil to be categorised as virgin, its colour should be water-clear.

6. What is the simplest method of producing VCO?

- The modified natural fermentation process

7. How many coconuts are required to produce one litre of VCO?

- 10–15 mature, husked (12–13 months old) coconuts, depending on the size and the process used

8. What is the effect of high temperature processing on VCO?

- The Vitamin E and sterol content are removed.
- The colour becomes yellow.
- In the presence of high moisture, the triglycerides may break into free fatty acid and glycerol. In this case, it will give a false free fatty acid reading which measures the degree of hydrolytic rancidity that the oil has undergone.

9. Does VCO need to be kept in the refrigerator and how long does it last?

No, VCO does not need to be kept in the refrigerator. Coconut oil is the most stable among the plant-derived oils being traded in the world. If properly processed, its natural antioxidants give it a longer shelf-life compared to other oils. Samples of VCO which the author produced in 1998 and stored in transparent glass bottles at the processing laboratory in PCA Davao Research Center still smell fresh after five years.

10. What are the current major uses of VCO?

- a hair conditioner
- a body oil or a substitute for moisturising lotion
- carrier oil for aromatherapy and massage oils
- a nutriceutical and functional food

11. Why is VCO considered a nutraceutical substance or a functional food?

A nutraceutical substance and a functional food are almost the same thing. Generally speaking, they both mean foods or food components that provide other health benefits aside from the nutritional function that they perform when ingested. In layman's terms, nutraceuticals are substances which not only nourish but also heal. VCO is considered a nutraceutical substance and functional food because, apart from providing instant energy to the human body, it is said to prevent infections, boost immunity, reverse disease states and assist in the cure of many types of illnesses. Coconut oil is far superior to other functional foods because of its believed beneficial effect. Several studies indicate that the medium chain (C_8–C_{12}) fatty acids in coconut oil are similar to the fats in mother's milk that gives babies immunity from disease.

12. What are the distinguishing characteristics of coconut oil compared to other oils traded in the world market?

- a high percentage of lauric (C_{12}) fatty acid, ranging from 45–56% depending on the coconut variety
- a high percentage of medium chain fatty acids (C_8–C_{12}), generally about 64%

13. What is the importance of medium chain fatty acids (MCFAs) and lauric fatty acid?

- Since 1984, increasing amount of literature has been published discussing the antiviral, antimicrobial, antifungal and antiprotozoal properties of medium chain fatty acids (C_8, C_{10}, C_{12}). Lauric acid (C_{12}) and its monoglyceride form, monolaurin, are mentioned as the most potent against lipid-coated microorganisms such as HIV, the measles virus, the herpes simplex virus, Helicobacter pylori and others that are not normally cured by ordinary antibiotics.
- Studies also indicate that MCFAs are directly converted into energy in the liver and increase the metabolic rate of an individual. This in turn promotes weight loss and reduces the deposit of fats in the body.

14. What do the experts say regarding coconut oil-derived lauric fatty acid and its monoglyceride form, monolaurin?

According to Professor Jon Kabara, Professor Emeritus, Department of Pharmacology, Michigan State University, who pioneered research on monolaurin:

- **monolaurin** as a dietary supplement has shown very good results as an antibiotic and antiviral agent, particularly in its potency against lipid-coated viruses;
- it does not cause resistance organisms to appear and has also shown that it can reduce the resistance of germs to antibiotics;
- when coconut oil is consumed, the body makes the disease-fighting monolaurin.

According to Dr Mary Enig, a noted nutritional biochemist, formerly with the University of Maryland, now with the Nutrition Department, Enig Associates:

- recently published research has shown that natural coconut fat in the diet leads to a normalisation of body lipids, protects against alcohol damage to the liver and improves the immune system's anti-inflammatory response;
- the antimicrobial fatty acids and their derivatives are essentially nontoxic to man and they are produced in vivo by humans when they ingest those commonly available foods that contain adequate levels of medium chain fatty acids like coconut oil;
- the medicinal properties of lauric acid and monolaurin have been recognised by a small number of researchers over nearly four decades and this knowledge has resulted in more than 20 research papers and several US patents.

15. What are lipid-coated viruses and bacteria?

Lipid is the medical term for fat. Lipid-coated micro-organisms such as viruses and bacteria have an envelope of fat covering their basic life structure called nucleotides (DNA and RNA). This is the reason for ordinary antibiotics not being able to penetrate easily and kill this type of pathogenic microorganism. However, several researchers have reported that MCFAs, particularly lauric acid that is predominately present in coconut oil, can penetrate and dissolve the lipid coating.

16. What are the lipid-coated microorganisms that have been reported to be inactivated by lauric fatty acid and its monoglyceride, monolaurin?

Table 12. Lipid-coated microorganisms reported to be inactivated by lauric fatty acid and monolaurin

Lipid-coated viruses	
Human immunodeficiency virus (HIV)	*Visna virus*
Measles virus	*Cytomegalovirus*
Herpes simplex virus	*Epstein-Barr virus*
Herpes viridae	*Influenza virus*
Sarcoma virus	*Leukemia virus*
Synctial virus	*Pneumonovirus*
Human lymphotropic virus (Type II)	*Hepatitis C virus*
Vesicular stomatitis virus	
Lipid-coated bacteria	
Listeria monocyatogenes	*Streptococcus agalactiae*
Helicobacter pylori	*Groups A,B,F and G streptococci*
Hemophilus influenza	*Gram-positive organisms*
Staphylococcus aureus	*Gram-negative organisms (if pre-treated with chelator)*

Source: Fife (2001)

17. What are the bacteria that have been reported to be inactivated by MCFAs and their monoglycerides, such as monocaprin and monolaurin?

Table 13. Bacteria reported to be inactivated by MCFAs and their monoglycerides

Bacterium	Diseases caused
Streptococcus	throat infections, pneumonia, sinusitis, ear ache, rheumatic fever, dental cavities
Staphylococcus	staph infection, food poisoning, urinary tract infections, toxic shock syndrome
Neisseria	meningitis, gonorrhea, pelvic inflammatory disease
Chlamydia	genital infections, lymphogranuloma venereum, conjunctivitis, parrot fever, pneumonia, periodontitis
Helicobacter pylori	stomach ulcers
Gram positive organisms	anthrax, gastroenteritis, botulism, tetanus

Source: Fife (2001)

18. What is the link between coconut oil and severe acute respiratory syndrome (SARS)?

According to the late Dr Conrado Dayrit, former Professor Emeritus in the Department of Pharmacology at the University of the Philippines, the coronavirus, which has been identified as the virus causing SARS, is also lipid-coated, which means that lauric fatty acid and monolaurin could possibly have an inactivating effect on it.

The pathogenic organisms causing influenza and pneumonia are both on the list of lipidcoated viruses and bacteria that are found to be inactivated by lauric fatty acid and monolaurin. As mentioned by Kabara (2000), monolaurin is derived by the human body from coconut oil. It should be noted that the symptoms exhibited by SARS infected patients are similar to the symptoms of pneumonia and influenza.

Therefore, by inductive reasoning, it can be postulated that lauric fatty acid and monolaurin (which are derived by the body from coconut oil) could be potential cures for SARS.

19. What are trans fatty acids?

Trans fatty acids are artificially altered unsaturated fatty acids in which hydrogen atoms attached to the carbon atoms linked with the double bonds have shifted position from the same side (cis) to the opposite side (trans). This happens when unsaturated oils like soybean and corn oil are subjected to the partial hydrogenation process. This process straightens the fatty acids molecules to enable them to be ‘packed’ in solid form like saturated fats, while remaining unsaturated (www.ucap.org.ph). Oils that have been partially hydrogenated increase their plasticity and substantially lengthen their shelf life, unlike the original, highly unsaturated oils they were made from.

20. Why are trans fats bad for the health?

The body cannot metabolise trans fats for lack of proper enzymes, thus making these artificial fats unhealthy. The primary health risk identified with trans fat consumption is an elevated risk of coronary heart disease (CHD). A comprehensive review of studies of trans fats published in 2006 in the New England Journal of Medicine indicates a strong and reliable connection between trans fats consumption and CHD (www.ucap.org.ph). In addition, studies on both humans and animals have shown that trans fats lower the HDL (‘good’) cholesterol; raise the LDL (‘bad’) cholesterol; increase the risk of heart attack and diabetes; and may cause certain cancers.

21. Do RBD coconut oil and VCO contain trans fatty acids?

No, RBD coconut oil and VCO do not contain any trans fatty acids. As a very stable oil, coconut oil is never subjected to the partial hydrogenation process.

22. Is the lauric fatty acid in VCO reduced if it is processed using high temperatures?

No, the lauric fatty acid content of any coconut oil is highly dependent on the variety of coconut and not on the process used.

23. Is VCO that solidifies in an air-conditioned room or in a refrigerator still usable as a nutraceutical substance or functional food?

Yes, it is natural for coconut oil, virgin or RBD, to solidify when placed in the refrigerator or a cool air-conditioned room because coconut oil is solid at temperatures of 22°C and below and liquid at temperatures of 27°C and above. Coconut oil that does not solidify when placed inside the refrigerator is not pure coconut oil but is mixed with some other oils.

24. What is the maximum recommended dosage to obtain health benefits from VCO?

- 50 ml or 3.5 tbsp. of virgin coconut oil or
- the kernel of half a mature coconut or
- 66 grams of desiccated coconut (can be mixed with breakfast cereal).

25. What is the best time to take VCO?

It depends on what benefit you want to achieve.

a. If you want to use it for controlling weight, take it 30 minutes before lunch and dinner.

b. If you are using it as a treatment for constipation, take a full dose before bedtime.

c. If you want to boost your immune system, take it any time of the day, in single or divided doses.

26. IMPORTANT REMINDERS!!!

- The information provided in this annex is not in any way meant to encourage readers to substitute VCO for the drugs or antibiotics prescribed by their doctor for treating illnesses. Please note that VIRGIN COCONUT OIL IS NOT A DRUG but a functional food and should be used only as such.
- Further, always remember that anything in excess is bad, so do not take more than 3½ tablespoons of VCO a day.

Annex 4
Standards for virgin coconut oil

A. PHILIPPINE STANDARD FOR VCO (PNS/BAFPS 22:2007/ICS 67.200.10)

The Philippine National Standard for VCO presented here is the revised version of PNS/BAFPS 22:2004/ ICS 67.2000.10 which was issued in 2004 . This revised version took into consideration the results of several studies done to characterise VCO and validate some of the provisions stipulated in the 2004 standard.

1 Scope

This standard applies to virgin coconut oil in a state of human consumption.

2 References

The titles of the standards publications referred to in this standard are listed on the inside back cover.

3 Definitions

For the purpose of this standard, the following definitions apply:

3.1 General

3.1.1

free fatty acids (FFA)

a specified fatty acid liberated by hydrolysis from naturally occurring fats

3.1.2

glyceride

an ester formed by the combination of glycerol and fatty acid. Glycerides occur naturally in oils and fats

3.1.3

virgin coconut oil (VCO)

oil obtained from the fresh, mature kernel of the coconut by mechanical or natural means, with or without the use of heat, without undergoing chemical refining, bleaching or deodorizing, and which does not lead to the alteration of the nature of the oil. Virgin coconut oil is an oil which is suitable for consumption without the need for further processing

Virgin coconut oil (VCO) consists mainly of medium chain triglycerides, which are resistant to peroxidation. The saturated fatty acids in VCO are distinct from animal fats, the latter consisting mainly of long saturated fatty acids.

4 Essential composition and quality of factors

4.1 Identity characteristics

4.1.1 Gas liquid chromatography (GLC) ranges of fatty acids composition 2 shall be in accordance with Table 1.

Table 1 – Gas liquid chromotagraphy range of fatty acid composition

Common name	Composition	(%)
Caproic acid	C 6:0	0.1 – 07
Caprylic acid	C 8:0	4.0 – 10.0
Capric acid	C 10:0	4.0 – 8.0
Lauric acid	C 12:0	45.1 – 56.0
Myristic acid	C 14:0	16 – 21
Palmitic acid	C 16:0	7.5 – 10.2
Stearic acid	C 18:0	2.0 – 5.0
Oleic acid	C 18:1	5.0 – 10.0
Linoleic acid	C 18:2	1.0 – 2.5

4.2 Quality characteristics

4.2.1 Colour, odour and taste

Virgin coconut oil shall be colourless, sediment free, with natural fresh coconut scent and free from rancid odours or tastes.

4.2.2 Virgin coconut oil shall conform to the requirements specified in Table 2.

Table 2 – Virgin coconut oil property requirements

Properties	Specification
% Moisture content	$\leq$ 0.1
% Matter volatile at 120°C (w/w)	0.12 – 0.20
% Free fatty acids (expressed as lauric acid)	0.20
Peroxide value, meq/kg oil, max.	3.0
Food additives	None permitted

5. Contaminants

Table 3 – Allowable limits of contaminants in Virgin Coconut Oil (VCO)

(Heavy metal, mg/kg, max.	
Iron (Fe)	5.0
Copper (Cu)	0.40
Lead (Pb)	0.10
Arsenic (As)	0.10

6. Hygiene

It is recommended that the product covered by the provisions of this standard shall be in accordance with the appropriate Sections of the General Principle of Food Hygiene recommended by the Codex Alimentarius Commission (CAC/RCP 1-1969, Rev.3-1997).

The total aerobic microbial count does not exceed 100 cfu per ml, the total combined molds and yeast count does not exceed 10 cfu per ml and it meets the requirements for the tests for the absence of Salmonella species and Escherichia coli.

7. Packaging

Virgin coconut oil (VCO) should be packed in any suitable food grade container that can withstand transportation, handling and storage conditions.

8. Labelling

The label of each package shall have the following information:

1. Name of product: “Virgin coconut oil”
2. Brand name or trade name
3. Net content
4. Lot identification
5. Name and address of the manufacturer and/or packer, or distributor
6. The phrase “Product of the Philippines”
7. Type of Process (See Annex)
8. Date manufactured and “Best Before”
9. BFAD registration number and bar code (Optional)

9 Methods of analysis and sampling

9.1 Determination of fatty acid composition

According to IUPAC 2.301, 2.302 and 2.304 or ISO 5508:1999 or ISO 5509:1999.

9.2 Determination of Moisture Content

According to AOAC 984.20 (Karl Fisher Method)

ANNEX

Type of Production Processes recognized by the Philippine Coconut Authority (PCA) on the production of Virgin Coconut Oil (VCO) as per PCA Administrative Order 01 Series of 2005

Implementing Rules and Regulations to Enforce Standards on the Production and Marketing of Virgin Coconut Oil

Section V: Production Processes

Producers/processors shall state in their product label sufficient information to identify the process used in the production of virgin coconut oil such as traditional process (latik), fermentation with heat, fermentation without heat, centrifuge process, expelling process (with or without cooling system), or equivalent process which insures that the product conforms with the definition and chemical and physical characteristics in the Philippine Virgin Coconut Oil Standards herein adopted.

B. APCC STANDARDS FOR VIRGIN COCONUT OIL

1. Scope

This standard applies to virgin coconut oil.

2. Description

Coconut oil is derived from the kernel/kernel/copra of the coconut (Cocos *nucifera* L.). Virgin coconut oil is obtained from the fresh, mature kernel by mechanical or natural means with or without the application of heat. Virgin coconut oil is suitable for human consumption in its natural state.

3. Essential composition and quality factors

	Interim APCC Standards
Identity Characteristics	
Relative density	0.915 – 0.920
Refractive index at 40 degree-C	1.4480 – 1.4492
Moisture % wt. max.	0.1 – 0.5
Insoluble impurities per cent by mass. max.	0.05
Saponification Value	250 – 260 min.
Iodine value	4.1 – 11.00
Unsaponifiable matter % by mass. max.	0.2 – 0.5
Specific gravity at 30 degree./30 degree-C	0.915 – 0.920
Acid Value max.	0.5
Polenske Value min.	13
GLC Ranges of Fatty Acid Composition (%)	
C 6:0	0.4 – 0.6
C 8:0	5.0 – 10.0
C 10:0	4.5 – 8.0
C 12:0	43.0 – 53.0
C 14:0	16.0 – 21.0
C 16:0	7.5 – 10.0
C 18:1	2.0 – 4.0
C 18:2	5.0 – 10.0
C 18:3 – C 24:1	1.0 – 2.5
	< 0.5

Quality Characteristics	
Colour	**Water clean**
Free Fatty Acid	**? 0.5%**
Peroxide Value	**?3 meq./kg oil**
Total Plate Count	**< 10 cfu**
Odour and Taste	**Free from foreign and rancid odour and taste**
Contaminants	
Matter volatile at 105 degree C	**0.2%**
Iron: (Fe)	**5 mg/kg.**
Copper	**0.4 mg/kg.**
Lead	**0.1 mg/kg.**
Arsenic	**0.1 mg/kg.**

4. **Food Additives**

   None permitted

5. **Hygiene**

   It is recommended that the product be prepared in accordance with the GMP and HACCP standards.

6. **Labelling**

   The name of the food on the label be "Virgin Coconut Oil". The provisions of the General Standard for the labelling of Packaged Food (CODEX STAN 1 – 1985)

   (Rev. 1 – 1991) shall apply.

7. **Methods of analysis and sampling**

   Based on Codex Alimentarius (Volume 13).

Annex 5
Recommended procedure to indicate the moisture content of grated kernel in a DME dryer

Background information

The DME dryer is the most common dryer used by VCO processors in PICTs. It is a flat bed direct contact type dryer where the batch of fresh grated coconut kernel is spread thinly on the surface of the dryer. The load is regularly turned to prevent it from getting scorched. As a requirement of the DME process, the grated kernel has to have a moisture content within the range of 10–12%. A study done on the low pressure oil extraction process which works on the same principle as the DME revealed that optimum oil recovery can be obtained if the moisture content of the dried grated kernel is at 11% before extraction. Under the existing standard process for DME, the moisture content of the dried grated kernel before it is unloaded from the dryer is determined by feel by dryer operators. This subjective method of determining moisture content is the major reason why batches of VCO produced by the DME process have variable quality.

There is a science-based procedure that can be followed to ensure that the 10–12% range of moisture content will be reached. However, before implementing a more scientific approach, there is a need to first determine the average moisture content of the coconuts supplied to the VCO plant. This system is relatively simple to implement in PICTs because there is little variation in the moisture content of the coconuts. It is certain that coconuts supplied to VCO plants in PICTs are fully mature since they have fallen from the tree instead of being plucked.

Recommended procedure

The procedure is described as follows:

1. Using the previously determined average initial moisture content of the kernel as a basis, do a material balance computation to determine the final weight of the kernel when its moisture content is reduced to 11% for a specific weight of freshly grated kernel to be loaded in the dryer per batch.
   - For instance, using a standard 3.5 kg freshly grated kernel per batch and assuming an initial moisture content of 50 %, the final weight of the dried kernel at a moisture content of 11% should be 1.97 kg or approximately 2 kg.
   - For an initial weight of 12 kg at the same initial moisture content, the final weight of the dried kernel at 11% moisture content should be 6.74 kg or roughly 6.75 kg *(Note: In the modified DME process, the weight of fresh grated kernel loaded in the dryer is 12 kg per batch.)*
2. Station a weighing scale near the dryer that can take the weight of the kernel per batch plus the weight of the basin. Designate at least three basins with the same weight as the weighing container. Tare the weighing scale with the weight of the basin by resetting the reading on the weighing scale to zero while the empty basin is still placed in the weighing scale.
3. Every time a batch of freshly grated kernel is loaded, weigh it. Make the weight of loaded fresh kernel the same for every batch (i.e. 12 kg for the modified DME process).
4. Unload the dried grated kernel in the designated weighing container. Weigh again.
   - If the weight of the dried kernel is still higher than the computed final weight (e.g. 6.75 kg if the initial moisture content of fresh kernel is 50%), return the batch to the dryer and dry further.
   - If the weight of the dried kernel is already lower than the computed weight, sprinkle a little water (while the basin of dried kernel is positioned on the weighing scale) until the computed weight is reached. Mix thoroughly after sprinkling with water.

Annex 6
Virgin coconut oil production equipment

A6.1 Husking equipment

- Manual husking tool – These are different variations of metal spike with a sharp tip standing vertically in the ground (Figure 80).

Figure 80. Manual husking tools from Kiribati (left), Marshall Islands (centre) and Fiji (right)

- Motorised coconut husking machine – Husking is done by bringing down a cutter to a positioned whole coconut that moves through a hydraulic mechanism (Figure 81). The machine has a husking capacity of 1800 nuts per eight-hour day using a 1.5 hp single-phase electric motor. It is currently used by Tailevu Milk Products Ltd., Viti Levu, Fiji for their coconut product line. Fabricated by Method Machine Works Sdn Bhd (729390-M) 51-1, Jalan Puteri 5/16, Bandar Puteri, 47100 Puchong, Selangor, Malaysia. Tel: 603-8060-1925; Fax: 603-8060-1935; URL: www.coconutmachine.com

Figure 81. Motorised husking machine

Shelling equipment

- Motorised shelling machine – a standard feature in coconut milk and desiccated coconut processing plants in Asia. It is composed of vertical tool with sharp tip mounted in front of a rotating gear where the shell of whole husked coconut is held and moved on top of the sharp tool. Untrained and inexperienced operators should not handle this machine as it might result in cut fingers.

  The Philippine shelling machine (Figure 82) has a processing capacity of 200–250 nuts per hour based on the skill of the operator. It is run by a 1/2 hp gear motor, 3-phase, 220 volts, 40 rpm output. Designed and fabricated by Princena's Machine Shop, 3rd St. Villa Antonio Subdivision, San Pablo City, Philippines. Tel. +6349-5624618; E-mail: pms.since1979@yahoo.com

  The Malaysian shelling machine is currently used at Tailevu Milk Products Ltd, Viti Levu, Fiji (Figure 82). Shelling capacity is 180 nuts per hour depending on the skill of the operator. It is also run by a 1/2 hp gear motor, 3-phase, 220 volts, 40 rpm output.

  The Philippine shelling machine differs from the Malaysian equipment in terms of the sharpened tip of the vertical tool as shown in the figures below. Likewise, it occupies a smaller space.

Figure 82. Motorised shelling machines from Philippines (left) and Malaysia (right)

A6.2 Comminution equipment: grating, shredding, cutting, scraping, grinding

Grating equipment

- **Manual graters**

Manual graters (Figure 83) are a standard feature in most Pacific households. They remove the fresh kernel from the coconut shell and reduce its particle size to fine pieces at the same time.

Figure 83. Manual graters from Kiribati and Marshall Islands

- **Motorised graters**
  - The DME grater, the Fijian grater, the Thailand grater and the Philippine grater (Figure 84) all work on the same principle, differing only in the type of head. The Philippine grater has a stainless steel blade and housing, a ½ hp electric motor and direct drive. The Thai grater is considered the safest, but also the least durable. The Fijian grater is manufactured by On Time Engineering, G.P.O. Box 12437, Suva, Fiji. Tel. (679) 3385337/3384776; Fax: (679) 3385337.

Figure 84. Motorised graters from Fiji (left), the Philippines (centre) and Thailand (right)

The processing capacity of motorised coconut graters depends on the skill of the operator. Based on the Philippines experience, the grating capacity can go as high 80 nuts per hour. However, the grating capacity is reduced as the hands of the operator get tired holding the half nut towards the rotating grater head.

- **Coconut Shredding/Cutting/Scraping/Grinding Machines**

  The Malaysian coconut grinding machine and the Thai coconut scraping machine (Figure 85) can be called coconut shredding equipment since both work on the same principle of shredding the coconut kernel into thin pieces. Both have a stainless steel drum with spikes and a stainless steel rod which rotate in opposite directions (Figure 86). The coconut kernel is first removed from the shell using either a manual shelling tool or a motorised shelling machine. The kernel is then dropped in between the rotating drum and the rod.

  ○ The Malaysian coconut grinding machine is currently being used at Tailevu Milk Products Ltd, Viti Levu, Fiji. It runs on a 3 hp electric motor and has a shredding capacity of 180 nuts per hour. It is manufactured by the same company that supplies the coconut husking and shelling machines.

  ○ The Thai coconut scraping machine runs on a 2 hp single-phase electric motor, 220 volts, 50 Hz. All parts are made of stainless steel. The processing capacity of kernel is equivalent to about 220 nuts per hour. It is designed and manufactured by Ngow Huat Yoo Machinery, 107 Verngnakom Kasem Lane New Road, Soi 10 Samphantawong, Bangkok 10100, Thailand. Tel: +66-2-2225571/2247648-9; Fax: +66-2-2247649.

Figure 85. Coconut grinding machine from Malaysia (right) and coconut scraping machine (another model) from Thailand (left)

Figure 86. Stainless steel drum with spikes and rod in the coconut scraping machine from Thailand

The coconut shredding machine has several advantages.

- It is safe to use, inasmuch as the hands of the operator are remote from the rotating blade, in contrast to standard motorised graters.
- It has a higher process capacity than standard motorised graters and is well suited for larger scales of operation when coupled with a shelling machine.
- Higher oil recovery is achieved on a per nut basis inasmuch as there is no coconut kernel left on the shell.

○ Multi-purpose power grinder complete with accessories and 1-unit induction motor, 3-phase, 220 volts, 1750 rpm for spindle drive, 1-unit 1hp gear motor, 3-phase 220 volts for screw feeder. Food-grade stainless steel for all parts in contact with the fresh coconut kernel. The equipment is available in process capacities of 550 and 300 nuts per hour (coconut kernel equivalent). Designed and manufactured by Princena's Machine Shop, 3rd St. Villa Antonio Subdivision, San Pablo City, Philippines. E-mail: pms.since1979@yahoo.com; Tel: +6349-5624618.

The same advantages as mentioned for the Thai coconut shredder are obtained from this coconut kernel grinder. In addition, it has a high processing capacity. However, the grinder is considerably more expensive and uses a special type of motor

○ Knife mill – 2 hp, 3-phase, 220 volts motor, process capacity of 100 kg per hour, food-grade stainless steel for all parts in contact with the fresh coconut kernel. It is exactly the same design as the knife mill used for copra except that food-grade stainless steel is used instead of mild steel.

○ SIMPLEX granulator – Can be used for both fresh and dried kernel; has an input capacity of up to 80 kg per hour; is driven by a 1.5 hp single-phase TEFC electric motor with push button magnetic contactor with overload cut-off. Designed and manufactured by VFV Trinity Machine Works, 44E Rizal Avenue Ext. Grace Park, Caloocan City. Tel: +632-3648648; Fax: +632-3658742; E-mail: vfvtrinity@hotmail.com

A6.3 Coconut milk extraction

Manually operated equipment

- Manually operated vertical screw type (bridge press), with perforated holding basket and receptacle trough; all materials in contact with the coconut kernel are made of stainless steel; 9 kg grated coconut kernel per load (about 20 nuts equivalent); 15–20 minutes pressing cycle per load; process capacity of about 60–80 nuts per hour (Figure 87).

  Manufactured in the Philippines by PCDR Metalwerke Enterprise, No. 11 Lourdes St., Marcela, Kalookan City, Metro Manila, Telefax: +632- 2874834. Original design from the Agro Processing Division, Natural Resources Institute, Chatham, Kent, United Kingdom.

Figure 87. Philippine Bridge press for coconut milk and oil extraction

Source: Bawalan and Chapman (2006)

- Manually operated hydraulic jack (10 tonnes capacity); table model; all materials in contact with the coconut kernel are made of stainless steel; 2.5 kg grated kernel per load (about 4–5 coconuts equivalent); five minutes pressing cycle per load, process capacity of about 48–60 nuts per hour (Figure 88).

Source: Bawalan and Chapman (2006)

Figure 88. Manually operated hydraulic jack type coconut milk press from the Philippines, stand alone (left) and table (right) models

Motorised equipment

- Motorised horizontal screw type coconut milk press (Figure 89) – Equivalent to 300–350 nuts per hour process capacity (freshly grated or ground coconut kernel input); 2 hp electric motor, single phase, stainless steel screw, built-in filter and housing. A higher capacity model at 500 nuts per hour is also available. Designed and manufactured by Princena's Machine Shop, 3rd St. Villa Antonio Subdivision, San Pablo City, Laguna, Philippines. E-mail: pms.since1979@ yahoo.com; Tel: +6349-5624618.

Figure 89. Two models of motorised horizontal screw type coconut milk extractors from the Philippines

- Motorised coconut squeezing machine (screw type) (Figure 90) – Equivalent to 250 nuts per hour process capacity (freshly grated or ground coconut kernel input); stainless steel worm shaft/screw and stainless steel cage and frame fitted with 3 hp single-phase 220 volts, 50 Hz. Designed and manufactured by Ngow Huat Yoo Machinery, No. 107 Verngnakom Kasem Lane New Road, Soi 10 Samphantawong, Bangkok 10100, Thailand, Tel: +66-2-2225571/2247648-9; Fax: +66-2-2247649.

Figure 90. Motorised horizontal screw type coconut milk extractor from Thailand

- Motorised hydraulic coconut milk press (Figure 91) – Designed and manufactured by Ngow Huat Yoo Machinery, Bangkok, Thailand. Contact numbers as above.

Figure 91. Motorised hydraulic coconut milk press from Thailand

A6.4 Coconut milk separation equipment

Two-phase centrifuge/cream separators (Figure 92) – This is actually designed for the separation of dairy milk from skim milk but is adapted for separation of coconut milk into coconut cream and skim milk where the cream is further processed into VCO. The centrifuge is manufactured in India and has a stainless steel separation bowl and disc; milk separation capacity of 300 litres per hour; 31 discs, 7500 rpm; separation temperature at 35°–40°C; 1/2 hp electric motor, 110/220 volts, 50 Hz; 25 litres holding capacity of milk reservoir.

Figure 92. Two phase (liquid-liquid) centrifuge

A6.5 Drying equipment

The choice of dryer depends on the scale of production, the availability of construction materials (if needed to be constructed on site), the operator's preference in terms of ease of operation, and the price and drying efficiency of the dryer.

- **DME dryer** (Figure 93) – This is essentially a flat bed, direct contact type of dryer where heat is directly transferred by conduction to the grated coconut kernel through the surface of the metal sheet. It is constructed on site, based on the design specifications of the technology developer. The dryer is composed of a stainless steel sheet (1.21 m x 4.86 m) mounted over a concrete base with heating stones underneath. A burner/furnace made of used (mild steel) petroleum drums is mounted on the front end for burning coconut shells and a chimney is attached to the other end.

Figure 93. DME flat bed direct contact dryer

Advantages

- ○ It uses the generated by-product, coconut shells, for fuel.
- ○ It has a relatively fast drying rate because of the direct heating.

Disadvantages

- ○ It is labour intensive since it requires a minimum of three persons: one on each side of the dryer to do the constant layering of the freshly grated kernel on the metal surface, turning and moving it fast, and another person to regularly feed fuel into the dryer.
- ○ There is a high risk of the kernel getting scorched or burned, since there is a tendency for the wet grated kernel to stick to the surface of the metal. Once the kernel is scorched or burned, the resulting oil will be pale yellow and no longer entitled to the label 'virgin'.

- **Electrically-heated or gas-fired forced draught tray dryer** (Figure 94) – This is a standard dryer that can be bought from known manufacturers. It comes in different capacities and sizes. It is generally equipped with a thermostat control that allows the operator to set the drying temperature as desired. It is also equipped with a blower that circulates hot air around and on the surface of the dryer trays.

Figure 94. Electrically heated forced draught tray dryer at Food Processing Centre in Tarawa, Kiribati

Advantages

- ○ Drying of the kernel is assured to be under the highest sanitary conditions.
- ○ With proper temperature setting, loaded grated kernel for drying can be safely left untended without the risk of it getting scorched or burned.
- ○ The thermostat control allows for a constant temperature drying.

Disadvantages

- ○ It uses electric power or gas for heating, so the drying cost is much greater, and so is the carbon footprint.

- The investment cost is higher.
- It is labour intensive in terms of loading the fresh kernel into trays and mixing it at regular intervals during the drying process.

• **Continuous conveyor (apron) dryer** (Figure 95) – Coconut shell or gas-fired heat exchanger, 9.3 m long, 4 blowers of 1.5 hp each, single-phase 220 volts, dryer drive, 1 hp single phase, 220 volts, 30–50 kg per hour dried kernel output depending on moisture content. Output moisture content can be adjusted by adjusting the speed of the conveyor; output end of the dryer can be connected to the feed hopper of the expeller. A large capacity dryer is also available. Manufactured by Princena's Machine Shop, 3rd St. Villa Antonio Subdivision, San Pablo City, Philippines. E-mail: pms.since1979@yahoo.com; Tel: +6349-5624618.

Figure 95. Mini conveyor dryer from the Philippines

Advantages

- It uses the generated by-product, coconut shells, for fuel.
- It can be used continuously, thereby ensuring low downtime in production.
- It prevents the drying pieces of kernel from getting scorched or burned, since it is hot air that is in contact with the kernel.
- It offers more flexibility in operation, since the desired output moisture content of the kernel can be set by adjusting the speed of the conveyor.
- It requires only one dryer operator.
- It can be used for drying other products.

Disadvantages

- The investment cost is high.
- It requires a bigger space because of the length of the dryer.
- The electric power cost is relatively high because of the electric motors to run the conveyor and the air blowers.

- **Indirect, natural draught coconut shell/husk-fired tray dryer** (Figure 96) – This dryer is constructed on site and is a modified version of the indirect type of copra dryer developed by the author at the PCA Davao Research Center. Suitable frames to hold a series of trays with screens were made in lieu of the loading bed of copra. Drying is essentially a batch type operation. The dryer is composed of a furnace and a metal cylindrical heat exchanger with baffles (made of used metal drums) attached to a chimney, from which hot combustion gases generated from burning coconut husks or shells are released after transferring the heat to the air surrounding the metal exchanger. The furnace and heat exchanger are enclosed in a dryer body (2.44 x 3.05 x 1.82 m) with concrete or brick walls provided with air intake ports on the side. As the air is heated through contact with the metal heat exchanger and the surface of the furnace, it rises to surround the grated coconut in the trays. It has a total of 30 drying trays which can be loaded with 1.5–2.0 kg of freshly grated coconut kernel. The temperature in the dryer is controlled by regulating the fuel feed.

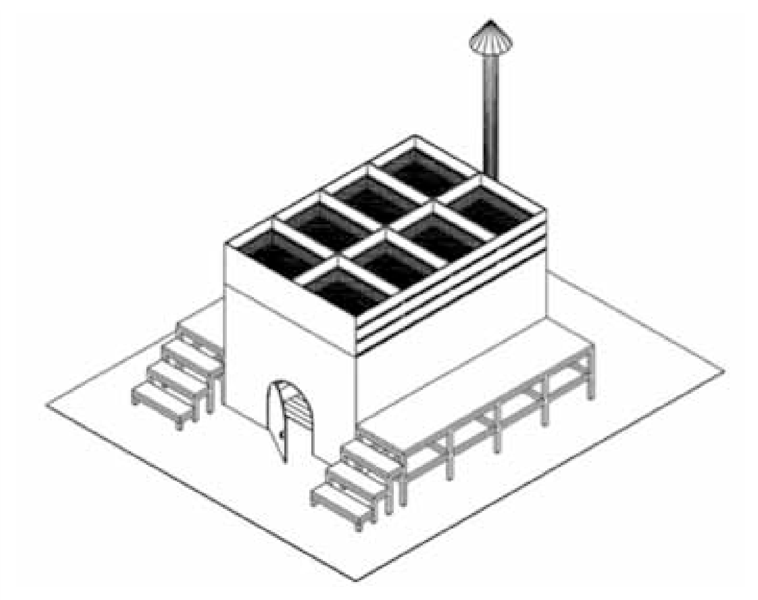


Figure 96. Natural draught coconut shell/husk-fired tray dryer

Advantages

- It uses the generated by-products, coconut shells and husks, for fuel.
- It prevents the grated kernel from getting scorched or burned since it is hot air that is in contact with the kernel.

Disadvantages

- The drying efficiency is highly dependent on the prevailing ambient conditions and wind velocity.
- It has a relatively lower process capacity since it is a batch type operation.
- It is labour intensive in terms of loading the fresh kernel in trays and the need for changing the position of the trays at regular intervals during the drying process.

- **Solar dryer** – In areas where there are long periods of sunshine, solar drying of grated kernel could be the cheapest option for producing VCO from the low pressure oil extraction method under a micro-scale operation. There are different designs of solar dryer that can be constructed on site using polyethylene transparent plastic sheets and wood. Some solar heat collectors can be incorporated to make the solar dryer achieve a higher drying temperature. Previous solar drying trials done by the author revealed that a temperature of 70°C, which is just right for coconut drying, can be easily achieved in a properly designed solar dryer.

A6.6 Coconut oil extraction equipment

- **Manually operated vertical screw type bridge press trough** (Figure 87) – Has a perforated holding basket and receptacle; all materials in contact with the coconut kernel are made of stainless steel, 9 kg partially dried grated coconut kernel per load (about 45 nuts equivalent); 15–20 minutes loading, pressing and unloading cycle per load; process capacity of about 135–180 nuts per hour. Manufactured in the Philippines by PCDR Metalwerke Enterprise, No. 11 Lourdes St., Marcela, Kalookan City, Metro Manila, Telefax: +632-2874834; upscale model of the original design from the Agro Processing Division, Natural Resources Institute, Chatham, Kent, United Kingdom.
- **DME press** (Figure 18) – Kokonut Pacific described this as a 'robust rack and pinion SAM™ Press with its interchangeable stainless steel cylinders and pistons'. The press, is mounted on a wall, has a ratchet mechanism for bringing up and down a lever that pushes the piston positioned on top of the partially dried grated kernel inside the cylinder. It can press 1.5–2.0 kg partially dried grated kernel loaded in the cylinder to recover the oil at eight pressings per hour.
- **New Zealand Press** (Figure 19) – This is manufactured by the Axis Industrial Ltd of Auckland, New Zealand and is currently being used by Women in Business Development Inc. in Samoa and Origins Pacific Ltd. in Fiji for VCO production. The press is a combination manually operated vertical screw and hydraulic jack-type press. The average processing time per cycle per 7 kg dried kernel load is about 15 minutes.
- **SIMPLEXTRACTOR high pressure expeller** (Figure 97) – Process capacity of 50 kg dried kernel per hour, 5 hp motor, 3-phase, 220 volts with built-in cooling system for worm shaft. Also available in process capacity of up to 80 kg per hour with 7.5 hp 3-phase motor. Designed and manufactured by VFV Trinity Machine Works, 44E Rizal Avenue Ext. Grace Park, Caloocan City. Tel: +632-3648648; Fax: +632- 3658742; E-mail: vfvtrinity@hotmail.com.

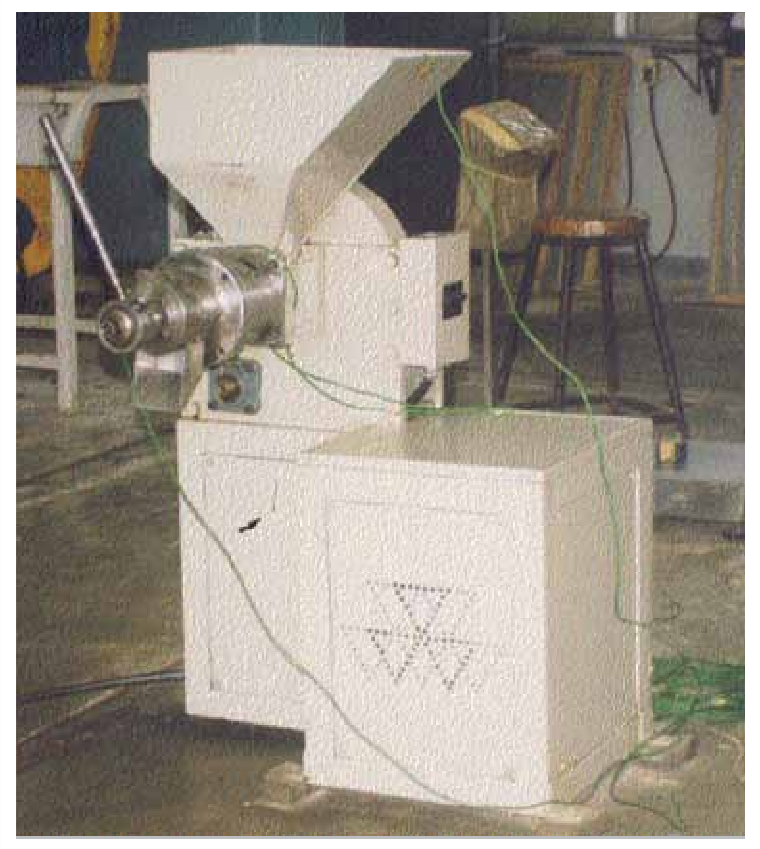


Figure 97. SIMPLEXTRACTOR high pressure expeller (Philippines)

A6.7 Filtration equipment

- **Gravity type filtering device** (Figure 98) – Designed by the author, this filtering device is suited for clarifying VCO produced using the modified kitchen and natural fermentation methods. It is composed of two 20-litre cylindrical water containers (normally used in water dispensers) with the bottom cut out. These are placed one on top of the other over a stainless steel pot receptacle and everything is held together by a manufactured mild steel frame. The filtering medium is sterilised cotton wool placed in the neck of the water container. It can filter 18 litres per batch. This gravity type filtering device cannot be used for filtering oil obtained from the low pressure oil extraction method or the high pressure expeller method.

Figure 98. Gravity type filtering device designed by the author

- **Plate and frame filter press** – This is the standard equipment used for filtration in commercial oil milling plants to ensure that all foots are speedily removed. The foots are trapped in the canvas cloth positioned between each plate as the oil is pushed through. A conventional plate and frame filter press for a commercial oil milling operation can have as many as 18 plates with each frame measuring approx 40 x 40 cm. A mini plate and frame filter press is also available (Figure 99).

- **Vertical pressure filters** (Figure 100) – These are normally used for fine filtration of coconut oil from a high pressure expeller.

A6.8 Fermentation cabinet

One way of ensuring that the right temperature is maintained during the fermentation process is to make a properly designed fermentation cabinet with electric light bulbs placed in strategic positions that can raise the temperature inside as needed. A small electric heater with built-in thermostat control can also be installed in the fermentation cabinet *(Note: Use incandescent bulbs, not the energy-saving compact fluorescent lamp (CFL) for warming the air in the fermentation box or cabinet. CFL bulbs give more light but very little heat.)*

Figure 99. Mini plate and frame filter press from Australia (left) and standard plate and frame filter press at Wainiyaku Estate Plantation, Fiji (right)

Figure 100. Vertical pressure filter at Wainiyaku Estate Plantation, Fiji

Annex 7
Production data sheet and other relevant record forms in a VCO processing facility

DAILY PRODUCTION DATA SHEET
MODIFIED KITCHEN METHOD

Date of production:______________________________

A. Selection of nuts

No. of nuts selected	No. of nuts rejected (if any)	No. of nuts actually processed

B. Grating

Time started	Time finished	Total grating time, hours/minutes

Weight of grated nut ______________________ kgs

C. Milk extraction

	Time started	Time finished	Total extraction time hours/ minutes
1st extraction			
2nd extraction			

Weight of first milk extract________________________________ kgs
Weight of water added___________________________________ kgs
Weight of second milk extract ____________________________ kgs
Weight of wet coconut milk residue_______________________ kgs

D. Settling for two hours

Weight of cream, kgs	Weight of skim milk, kgs

E. Heating of cream

Time started	Time finished	Total heating time, hours/minutes

Weight of wet proteinaceous residue______________________ kgs

Wt. of premium oil, unfiltered	Wt. of premium oil, filtered	Wt. of residual oil, unfiltered	Wt. of residual oil, filtered

Weight of toasted residue ________________________ kgs

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DAILY PRODUCTION DATA SHEET
MODIFIED NATURAL FERMENTATION METHOD

Date of production:__________________________________

A. Selection of nuts

No. of nuts selected	No. of nuts rejected (if any)	No. of nuts actually processed

B. Grating

Time started	Time finished	Total grating time, hours/minutes

Weight of grated kernel __________________ kgs

C. Milk extraction

	Time started	Time finished	Total extraction time hours/ minutes
1st extraction			
2nd extraction			

Weight of first milk extract ___________________________ kgs
Weight of water added_______________________________ kgs
Weight of second milk extract _________________________ kgs
Weight of wet coconut milk residue _____________________ kgs

D. Settling/fermentation of coconut milk

Time started	Time finished	Total fermentation time, hours/minutes

E. Harvesting of separated oil

Time started	Time finished	Total harvesting time, hours/minutes

Weight of wet fermented curd ___________________ kgs

Wt. of premium oil, unfiltered	Wt. of premium oil, filtered	Wt. of residual oil, unfiltered	Wt. of residual oil, filtered

Weight of toasted curd ___________________ kgs

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DAILY PRODUCTION DATA SHEET
LOW PRESSURE EXTRACTION METHOD

Date of production: ___________________________________

A. Selection of nuts

No. of nuts selected	No. of nuts rejected (if any)	No. of nuts actually processed

B. Grating

Time started	Time finished	Total grating time, hours/minutes

Weight of grated kernel ___________________ kgs

C. Drying of grated kernel

Time started	Time finished	Total drying time, hours/minutes

Weight of dried kernel ____________________ kgs

D. Extraction of oil

Time started	Time finished	Total extraction time, hours/minutes

Weight of extracted oil, unfiltered ________________________ kgs
Weight of coconut meal ________________________________ kgs

E. Settling of oil

Date/Time started	Date/Time finished	Total settling time, hours/minutes

F. Filtration of oil

Time started	Time finished	Total filtration time, hours/minutes

Weight of filtered oil ______________________ kgs
Weight of "foots'_________________________ kgs

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DAILY PRODUCTION DATA SHEET
HIGH PRESSURE EXPELLER PROCESS

Date of production: ________________________________

A. Selection of nuts

No. of nuts selected	No. of nuts rejected (if any)	No. of nuts actually processed

B. Shelling of coconut kernel

Time started	Time finished	Total shelling time, hours/minutes

Weight of coconut kernel ________________ kgs

C. Grinding of coconut kernel

Time started	Time finished	Total grinding time, hours/minutes

Weight of ground/granulated kernel ____________________ kgs

D. Drying of granulated kernel

Time started	Time finished	Total drying time, hours/minutes

Weight of dried granulated kernel ______________________ kgs

E. Extraction of oil

Time started	Time finished	Total extraction time, hours/minutes

Weight of extracted oil, unfiltered ______________________ kgs
Weight of coconut meal ________________________ kgs

F. Settling of oil

Date/Time started	Date/Time finished	Total settling time, hours/minutes

G. Filtration of oil

Time started	Time finished	Total filtration time, hours/minutes

Weight of filtered oil ____________________ kgs
Weight of “foots’________________________ kgs

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PRODUCTION DATA SUMMARY
MODIFIED KITCHEN AND NATURAL FERMENTATION METHOD

Production Date	Batch No.	No. of Nuts Processed	No. of Nuts Rejected	Weight of VCO Recovered, kgs	Lot Identification No. for VCO	Weight of Wet Residue, kgs	Weight of Wet Latik or Curd, kgs	Weight of Residual Oil, kgs

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PRODUCTION DATA SUMMARY

LOW PRESSURE OIL EXTRACTION AND HIGH PRESSURE EXPELLER PROCESS

Production Date	Batch No.	No. of Nuts Processed	No. of Nuts Rejected	Weight of VCO Recovered, kgs	Lot Identification No. for VCO	Weight of Coconut Meal, kgs	Weight of Foots, kgs

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Annex 8
Coconut shell processing technologies and quality grading

A8.1 Charcoal processing technologies

There are two methods that are generally used for small scale production of charcoal in the Philippines, the pit method and the kiln method.

A8.1.1 Pit method

Pits for charcoal making are made by digging holes in the ground to the desired size. Guarte (1993) mentions that circular or rectangular pits (Figure 101) are generally used. The size of the pit varies according to the availability of shells and the capacity desired. He adds that most rectangular pits in the Philippines are approximately one metre wide, two metres long and one metre deep, and circular pits are a minimum size of one metre in diameter and one and a quarter metres deep. Rectangular pits should have rounded sides on the bottom part to minimise the amount of air that might be trapped there which could cause over-burning of charcoal in that part.

Figure 101. A rectangular pit for charcoal making

The steps for making charcoal by the rectangular pit method are given below.

a. Place 100 coconut shell halves at three equidistant points in the pit leaving a space in between the groups of shells.
b. Start the burning of three or four shells outside the pit and drop them in the space at the bottom of the pit to initiate burning.
c. Once the other shells start burning, cover them with additional shells. The aim is to prevent the shells from breaking out into flame as this will turn the shell to ashes.
d. Additional shells are added progressively as the fire spreads upward until eventually the heap reaches the top of the pit. At this point, large volumes of dark smoke are generated.
e. Cover the pit with a metal sheet or any material that will not burn and allow the carbonisation to continue.
f. Once the smoke becomes clear and transparent, completely seal the cover of the pit by putting clay soil over the cover and sides. Ensure that the seal is airtight to prevent the charcoal from turning into ash.
g. Allow two or three days for the charcoal to completely cool.
h. Remove the charcoal and store it in bags.

The pit method has both advantages and disadvantages.

Advantages	Disadvantages
Zero or very low capital investment	Fixed position
Low maintenance cost	Removing the charcoal from the pit is troublesome
Flexible size	Charcoal is normally contaminated with dirt

A8.1.2 Kiln method

There are three types of kiln that are currently being used in the Philippines, the drum kiln (Figure 102) which is the most popular for individual farmers, the fabricated metal kiln or Pag-Asa kiln (Figure 103) for a bigger scale of operation and the PCA brick kiln (Figure 104) for long term usage.

Drum method

A 200 litre, used petrol or steel drum is used as a kiln. The top is cut off and used as a cover during carbonisation. The drum is cleaned and washed thoroughly, especially if it was used as container for corrosive materials. The capacity of a drum is 450 to 500 whole shells (900 to 1000 half shells) depending on the size. The procedure takes six hours plus overnight cooling. A skilled worker can operate eight or nine drum kilns at the same time. Charcoal recovery is 27.5% of the total weight of shells, provided the shells are properly dried and come from fully mature nuts.

Figure 102. Two versions of the drum kiln for charcoal making

There are different versions of drum kiln: one type with four equidistant holes at the bottom, another type with several equidistant holes along the sides of the drum at different heights, and a very simple type that has no holes at all. Procedures vary depending on the type of drum kiln. The charcoal making steps for the drum without any holes are described below.

a. Place the drum on flat, clean ground.
b. Ignite two pieces of coconut husk or three or four pieces of coconut shell, and carefully drop them into the bottom of the drum. Arrange them evenly around the bottom by poking them with a stick, and allow them to burn vigorously.
c. When these husks or shells are burning vigorously, add about 20 half coconut shells. Loosely cover the drum with the top portion which was removed before. Allow the shells to carbonise. The start of carbonisation is signified by the release of heavy dark smoke.

d. Add more shells whenever the smoke becomes lighter or when you see flames. Replace the cover after each addition.
e. Continue putting in fresh batches of shells until the pile reaches the top of the drum.
f. When the smoke coming out of the loosely covered drum becomes clear, fit the cover on the lid of the drum.
g. Turn the covered drum upside down. (The bottom of the drum becomes cooler as the carbonisation moves towards the top, which allows the worker to hold the bottom portion.)
h. Seal the kiln by pressing relatively wet soil around the lid. The absence of smoke indicates that the drum is completely sealed.

It should be noted that some charcoal makers do not turn the drum kiln upside down. The lid is sealed with wet clay when the smoke becomes transparent and clear. Sealing of the lid is easier when the drum is turned upside down but it takes a lot of skill to turn the drum upside down without spilling the contents.

Fabricated metal kiln (Pag-Asa kiln)

The best known charcoal kiln designed in the Philippines is the Pag-Asa kiln (Figure 103), which is normally used by commercial charcoal producers. It is a fabricated metal kiln composed of two parts: a cylindrical base and a conical top part. Unlike the drum kiln with only the top open, the Pag-Asa kiln is open at the top and the bottom. The size of the kiln depends on the capacity that is desired and needed by the user. A kiln with a cylindrical base diameter of 46”, a height of 41” and a conical top with a diameter of 16” can take about 3000 half shells. The procedure takes 7 to 8 hours with a cooling time of 16 to 17 hours. A skilled worker can operate three Pag-Asa kilns at the same time. Charcoal recovery is 25–27 % based on the weight of input.

The steps for making charcoal using the Pag-Asa kiln are described below.

a. Pile on the ground about 50 shell halves, leaving a space in the middle.
b. Ignite two to three pieces of dry coconut shell or husk and place them in the central space.
c. Once the other shells in the pile are burning strongly, place the Pag-Asa kiln over the pile of shells, completely containing or enveloping them.
d. Add more shells whenever the smoke becomes lighter or when flames break out.
e. Continue adding shells until the kiln is full.
f. When the smoke coming out of the kiln becomes lighter and transparent, seal around the bottom of the kiln with soil, cover the top with a metal sheet and seal it with clay or any material that will make it airtight.
g. Allow the charcoal to cool for 16 to 17 hours.
h. Collect the charcoal after removing the soil and tilting the kiln to expose the charcoal inside.
i. If the charcoal is intended for delivery to a charcoal granulation or activated carbon plant, separate small particles by passing the charcoal through a mesh screen sieve.
j. If the charcoal is intended for delivery to the local market, pack it in sacks without screening it.

Figure 103. Fabricated metal kiln (Pag-Asa kiln)

PCA brick kiln

The PCA brick charcoal kiln (Figure 104) was developed by the Philippine-German Coconut Project (PGCP)[1] and was evaluated and popularised by the Philippine-Korea Cooperation project to provide coconut farmers and charcoal manufacturers with an alternative device for charcoal making. The kiln is intended for a centralised type of operation since it is constructed on site and not moveable like the drum and Pag-Asa kilns. It is constructed using bricks which do not corrode and are resistant to heat so it is expected to have a longer service life than metal kilns. The capacity of the kiln is approximately 3,000 half shells. The kiln is mainly made of 2”x 4”x 8” standard rectangular fire bricks. It is dome-shaped to optimise the carbonisation process. The dimensions of the kiln are: base diameter (inside): 1.20 m., height (net): 1.10 m., volume: 0.73 cu. m. A total of 24 air inlet ports, each with a diameter of one inch, are placed in four rows around the circumference of the kiln. Each row has six air intake ports equidistant from each other. The first row is positioned at the base of the kiln. The distance between each row is equivalent to the height of five bricks (i.e. the succeeding rows of air intake ports are made after the addition of five layers of bricks during construction).

A skilled charcoal maker can operate four kilns at a time for an average of eight hours from ignition to covering. The operating time depends on the moisture content of the shells (using dry shells shortens carbonisation time and ultimately reduces cost) and on how well the procedures are followed. Proper operating procedures should be followed to produce good quality charcoal. The average charcoal recovery rate is 28.4% based on dry weight of input.

The procedure for making charcoal using the PCA brick kiln is described below.

Figure 104. PCA brick kiln charcoal making (Pag-Asa kiln)

a. Start by igniting about 50 dry coconut shells or husks and wait for about five minutes to allow them to burn strongly.
b. Close the brick door and then add another batch of dry coconut shells, usually about 500 shells.
c. Seal all joints of the brick door with wet ash.
d. Wait until the colour of the smoke changes from blackish to whitish and then add another batch of coconut shells. Repeat this procedure until the kiln is full.
e. Close the air inlet ports at the base with wet ash when embers are visible or on the level of the second row of air inlets. Repeat this procedure on the third row. The fourth row of air inlets is closed at the same time as the removable kiln cover (similar to a clay pot cover) is placed on top.
f. The number of coconut shells added in each batch decreases near the end of the operation.
g. Close the kiln after the last batch is fully burned. Seal the top cover first with dry pulverised ash or fine sand and finish with wet ash.
h. Check for any leaks.
i. Unload the charcoal on the following day by opening the top cover and brick door. Use a spade to transfer the charcoal from the kiln to the containers.
j. Check for live embers on the surface of the charcoal. Ignition sometimes happens due to the high charcoal temperature and sudden exposure to air.
k. Store the charcoal in a well-ventilated warehouse away from passageways to prevent and/or reduce fire risk.

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[1]The Philippine-German Coconut Project is a technology transfer and self-help type of project involving R and D on coconut post-harvest technologies and strengthening of farmers’ capabilities. It was co-funded by GTZ and was implemented by PCA from 1992–2000.

A8.2 Quality parameters and grading of coconut shell charcoal

Coconut shell charcoal contains the highest percentage of fixed carbon of all ligneous charcoal. Accordingly, a good charcoal has the following average composition: 3% moisture, 10% volatiles, 2% ash, and 85% fixed carbon. The following are the quality parameters of coconut shell charcoal when analysed quantitatively:

Fixed carbon content – is the amount of carbon contained in a particular type of charcoal. The fixed carbon content of charcoal ranges from a low of about 50% to a high of around 95%. Thus charcoal consists mainly of carbon. The carbon content is usually estimated as a 'difference', i.e. all the other constituents are deducted from 100 as percentages and the remainder is assumed to be the percentage of 'pure' or 'fixed' carbon.

Ash – is determined by heating a weighed sample to red heat to burn away all combustible matter. The residue is the ash. It consists of mineral matter, such as clay and silica, and calcium and magnesium oxides, which were present in the original wood and picked up as contaminants from the earth during processing.

Moisture content – is the water that is physically bound in the charcoal. Quality specifications for charcoal usually limit the moisture content to around 5–15% of the gross weight of the charcoal. Moisture content is determined by oven-drying a weighed sample of the charcoal. It is expressed as a percentage of the initial wet weight.

Volatile combustible matter content – is defined as the water and other organic matter that is released as a result of various chemical reactions that occur when biomass is heated in the presence of limited air. The volatile matter content in charcoal (other than water) is composed of all those liquid and tarry residues not fully driven off in the process of carbonisation. The amount can vary from a high of 40% to a of 5% or less. It is measured by heating away from air, a weighed sample of dry charcoal at 90°C to constant weight. The weight loss is the volatile matter. Volatile matter (VM) is usually specified free of the moisture content, i.e. volatile matter minus moisture content.

Foreign matter content – refers to any material mixed in the batch of charcoal, e.g. pebbles, stones, metals, bits of wood, husk, etc.

A8.2.1 Grades and standards of charcoal

Good quality charcoal must conform to the standard grade set by the industry on export. Charcoal is classified into metallurgical grade A, and commercial grades A and B under the Philippine standard for shell charcoal. The limits for each parameter are shown in Table 14.

Table 14. Grading parameters for coconut shell charcoal

Parameters	Metallurgical Grade A	Commercial Grade A	Commercial Grade B
Fixed carbon	80% max.	75% max.	65% max.
Ash	3% max.	3% max.	3% max.
Moisture Volatile	10% max.	10% max.	10% max.
Combustible matter	10% max.	10% max.	20% max.
Sieve analysis	Not more than 5% shall pass a ¼ inch mesh sieve	Not more than 5% shall pass a ¼ inch mesh sieve	Not more than 5% shall pass a ¼ inch mesh sieve

A8.2.2 Physical grading

On a farm, quantitative analysis of charcoal can never be done, simply because it is not practical to do so. However, farmer producers may conduct their own quality assessment based on the physical attributes of their produce. The following quality assessment guide can be used (Table 15).

Table 15. Charcoal quality assessment guide

Parameters	Attributes of good quality charcoal	What to do
Colour	Uniformly bluish-black colour. Glistens in sunlight.	Get a piece of charcoal and allow the sunlight to touch the surface. Observe the colour.
Appearance	Clean, shining fracture and free of fibres.	Get a piece of charcoal and observe it under light. Tap it on top of a piece of paper and observe the amount of dust/fibres that fall out.
Sound	Produces a high, metallic sound when snapped or dropped on a hard surface.	Drop a piece of charcoal on a hard surface and listen to the sound of the fracture.
Foreign matter	Should be free of dust, fibres, pebbles and other materials.	Screen the charcoal using a ¼ inch mesh screen.

Under-burnt shells do not give a metallic sound when snapped, while over-burnt shells are friable and a fracture sounds dull.

Source of Information: Engr. Evelyn T. Caro
Agriculturist 1 and Technology Transfer Specialist
PCA Region XI, Davao City, Philippines.

A8.3 Processing of coconut shell charcoal briquettes

Equipment

Binder cooker	This is used for binder preparation. The size and type of cooker largely depends on the plant capacity and mode of operation. A biomass-fired (coconut husk or shell) cooker is necessary to have a continuous supply of boiling water during operation.
Mixer	This is used to evenly distribute the binder with the charcoal fines. Good mixers are characterised by their ability to achieve a homogenous mixture in the shortest time possible.
Briquettor (Figure 105)	This equipment converts the charcoal fine-binder mixture into a solid substance with defined shape. Briquettes can be made into various shapes (egg-shaped, oblong, hexagonal, cylindrical, circular and pillow-shaped) depending on the type of mould and briquetting machine used. The pillow-shaped briquette is commonly produced. For home scale production and use, a manually operated briquetting machine can be used.
Dryer	This is necessary to immediately dry and harden newly formed briquettes. Tray type mechanical and natural draught indirect dryers can be used for drying. Sundrying can be done but, due to unpredictable weather condition, it is not recommended for large scale production.

 

Figure 105. Briquetting machine (left) and manual briquetting press (right)

Raw materials

Charcoal fines	The best raw material for making charcoal briquettes is coconut shell charcoal fines due to their high heating value compared to charcoal fines from other biomass materials. Charcoal fines are generated as a waste product in granulating charcoal intended for activated carbon production. Another way of obtaining charcoal fines is by segregating and grinding small particles of shell charcoal from carbonisation operation.
Binder	Cassava starch is commonly used as binder because this is the cheapest and most readily available material.
Water	This is used for dissolving starch prior to cooking it. Any clean and chemical-free water can be used.

Steps in charcoal briquette making

1. Weigh exact amounts of charcoal fines, water and binder — just enough for one mixing. The recommended ratio is 1:10:20 (starch:water:charcoal fines).
2. Dissolve the starch in a small amount of water until the solution is homogenous. Pour in boiling water. Stir until cooked or gelatinised.
3. Place charcoal fines in the mixer and pour in the binder while still hot. Stir until all particles are coated by the binder.
4. Pour freshly prepared mixture into the briquettor mould and press or feed it into a motorised briquetting machine (Figure 105).
5. Arrange freshly moulded briquettes in the drying trays to allow circulation of air and operate the dryer when all the trays are full.
6. Remove deformed and cracked briquettes. Pack good briquettes in plastic bags and seal.

Source of Information: Engr. Evelyn T. Caro
Agriculturist 1 and Technology Transfer Specialist
PCA Region XI, Davao City, Philippines.

Annex 9
Simple processing technologies for coconut water utilisation

A9.1 Coconut water vinegar

Vinegar is generally defined as an alcoholic liquid that has been allowed to sour. It is considered one of the oldest fermentation products known to man (Banzon et al, 1990).

Coconut water vinegar uses coconut water as starting material. Coconut water is the liquid endosperm found inside a coconut. It is one of the by-products generated during the processing of coconut kernel. In its natural form, coconut water contains micro minerals which are beneficial to human health, as shown in Tables 16 and 17.

Table 16. Average composition of coconut water

Sugars (levulose and dextrose)	2.6 %
Chlorides	0.17%
Protein	0.55%
Oil	0.74 %
Total solids	4.71 %
Ash	0.46 &
Specific gravity	1.02
pH	5.6

Source: Anzaldo et al. (1985)

Table 17. Electrolyte composition of coconut water from coconuts of various ages (milliequivalent per litre)

AGE (months)	Potassium (mEq/litre)	Sodium (mEq/litre)	Calcium (mEq/litre)	Magnesium (mEq/litre)	Chlorine (mEq/litre)	pH
4	43.86	1.11	13.23	6.46	44.00	4.90
5	40.13	1.68	10.20	5.87	38.16	4.87
6	35.53	1.58	9.60	4.27	33.00	4.92
7	36.40	2.06	10.67	4.27	35.83	4.92
8	36.73	2.20	10.80	5.14	45.67	5.17
9	42.67	2.47	11.20	5.34	30.34	5.40
10	44.26	3.05	17.07	6.13	37.67	5.40

Source: Anzaldo , (1987)

The composition of coconut water vinegar as analysed by the Philippine Food and Nutrition Research Institute and reported by Banzon et al. (1990) is shown below:

Food energy value	3 calories/gram
Moisture	98%
Fat	0.1%
Total carbohydrates	1.4%
Ash	0.3%
Calcium	24 mg/100 grams
Phosphorous	34 mg/100 grams
Iron	0.1 mg/100 grams
Riboflavin	0.01 mg/100 grams
Protein	trace
Thiamine	trace
Niacin	trace

Source: Banzon et al, 1990

Vinegar is primarily used to flavour and preserve foods and as an ingredient in salad dressings and marinades. It has also been used as a medicine and a preservative. A dilute solution of vinegar has been found to be an effective rinse for fresh salad vegetables to remove traces of pesticide.

In the Philippines, coconut water vinegar is used as a table condiment and sauce for some Filipino dishes. It is used as a seasoning for meat, fish and vegetables during cooking; as an ingredient in the manufacture of vegetable pickles, catsup and other tomato products, mayonnaise, mustard, dressing and sauces; and as additive in many manufactured foods to enhance flavour (Banzon et al, 1990). In addition, it is used as a cleaning agent.

There are two methods for making coconut water vinegar on a home and micro scale production. These are:

- by using yeast and microbial culture (e.g. acetobacter acetii) as fermenting medium (Table 18)
- by using three-day-old coconut toddy as a starter (Table 19).

The yeast and microbial culture process

Table 18. The yeast and microbial culture process for coconut water vinegar production

Process Steps	Critical Control Points/Remarks
Part A: Alcoholic Fermentation	
1) Collect three litres fresh coconut water. Strain through cheese cloth.	Coconut water should come from ungerminated, unspoiled and newly opened nuts.
2) Dissolve 1/4 kg sugar in the coconut water.	This is to increase sugar concentration of the coconut water.
3) Pasteurise by heating at 65°C for 20 minutes or boil for five minutes. Cool at 40°C.	Avoid overheating as this may spoil the flavour.
4) Dissolve half a teaspoon Fleischmann dry yeast in one cup of sterilised coconut water and pour into the mixture.	**IMPORTANT: Make sure that the yeast is still active. This is indicated by bubbles while the yeast is being dissolved and after it is dissolved.**
5) Pour the mixture into a sterilised narrow-mouth jar (preferably glass).	
6) Cover the narrow mouth with clean brown paper or newsprint and seal it with a rubber band.	**IMPORTANT: Do not use cellophane or plastic. Keep the cover slightly loose, not tight.**
7) Allow the mixture to ferment for four to seven days or until there are no more bubbles of carbon dioxide formed.	
8) Transfer into wide-mouthed jar using rubber tubing to siphon out the solution.	**IMPORTANT: Be careful not to disturb the sediments.**
Part B : Acetic Acid Fermentation	
1) To the alcoholic solution prepared in procedure A above, add 1.5 litres of mother vinegar. Mix thoroughly.	Mother vinegar is started from a microbial culture of selected fermenting micro organisms, e.g. Acetobacter aceti, and is generated for every batch of coconut water vinegar produced. In the Philippines, there are government agencies producing mother vinegar for sale to would-be producers of coconut water vinegar.
2) Loosely cover the container with clean brown paper or newsprint and seal with a rubber band.	**IMPORTANT: Do not use cellophane or plastic.**
3) Allow to ferment for 30 days or until maximum sourness is obtained.	

4) Set aside 1.5 litres to be used as mother vinegar for the next batch.	
5) Pasteurise at 65°–80°C to kill the fermenting micro-organism before bottling the product.	IMPORTANT: Pasteurisation is needed at the right time to kill the micro-organisms responsible for fermentation. Otherwise, fermentation will continue and the vinegar will be converted into water and carbon dioxide. **Use a stainless steel vessel during pasteurisation. Do not use aluminum, copper or brass containers.**
6) Cool and pack in sterilised bottles.	

Considering the situation where PICTs will start from zero base in coconut water vinegar processing, it is recommended to use the simple process where three-day-old coconut toddy is used as starter and will be mixed with coconut water The other process for making coconut water vinegar requires the addition of sugar and yeast to coconut water to ferment it into alcohol, then a suitable microbial culture is added to the alcoholic mixture to ferment it into vinegar. It should be noted that coconut toddy contains a natural fermenting enzyme. Three-day-old coconut toddy is actually an alcoholic mixture already and if it is distilled off, it will yield coconut liquor. Mixing three-day-old toddy with coconut water as the fermenting medium actually shortens the fermentation time into vinegar since there is no longer any need to ferment the coconut water into alcohol. Processing of coconut water into vinegar using three-day-old toddy as starter can be easily done in Cook islands, Rabi Island (Fiji), Kiribati, Marshall Islands, Solomon Islands and Tuvalu, where coconut toddy collection is regularly done.

Table 19. Processing of coconut water vinegar using three-day-old coconut toddy

Process Steps	Critical Control Points/ Remarks
1) Collect five litres of fresh coconut water. Strain through cheese cloth.	The coconut water should come from ungerminated, unspoiled, newly opened nuts.
2) Pasteurise by heating at 65°C for 20 minutes or boil for five minutes.	Avoid overheating as this may spoil the flavour of the product. **Use stainless steel container during pasteurisation.** **Do not use aluminum, copper or brass containers.**
3) Pour into fermenting containers.	Food grade plastic containers can be used. They should be washed properly with soap and water and rinsed with hot water before use.
4) Add five litres of the three–day-old coconut toddy. *Note: Three-day old coconut toddy is the toddy which is left to stand for 72 hours after collection from the coconut tree.*	The sugar content of the toddy has already been naturally converted to alcohol.
5) Loosely cover the mouth of the container with cheesecloth or muslin. A cloth diaper for babies can also be used.	**IMPORTANT: Do not use cellophane.** **Keep the cover slightly loose.**
6) Allow the mixture to ferment for seven days.	
7) Collect by siphoning.	**IMPORTANT: Be careful not to disturb the sediment.**

8) Pasteurise at 65°–80°C to kill the fermenting micro-organisms before bottling	**Important: pasteurisation is needed at the right time to kill micro-organisms responsible for fermentation. Otherwise, fermentation will continue and the vinegar will be converted into water and carbon dioxide.** **Use a stainless steel container during pasteurisation.** **Do not use aluminum, copper or brass containers.**
9) Cool and pack in sterilised bottles.	

A9.2 Coconut sauce

Ingredients

2 cups coconut water

½ cup brown sugar

½ cup salt

MSG (optional)

Procedure

1. Heat pan
2. Heat sugar until dark brown. Adjust stove flame to medium.
3. Add coconut water, salt and MSG if desired.
4. Stir and boil for 15 minutes
5. Remove from heat and strain.

Source : Philippine Coconut Authority
Region VIII (Davao City), Philippines

Annex 10
Food products from coconut milk residue

These recipes were selected from the coconut recipes developed by staff of the Philippine Coconut Authority and tested by the author.

Coconut Burger

Ingredients

1 cup fresh coconut milk residue

1 cup minced beef or minced chicken or canned tuna flakes

2 eggs, well beaten

¼ cup onions, chopped

1 tbsp garlic, minced

½ tsp ground pepper plus other spices to taste

fresh green chilli, chopped (optional)

3 tbsp soy sauce

6 tbsp corn starch

1/2 tsp salt

cooking oil for frying

tomato catsup for garnish

Procedure

1. Beat the eggs. Completely dissolve the cornstarch in the beaten eggs. Set aside.
2. Mix the fresh coconut residue thoroughly with the minced beef/chicken or tuna flakes, onions, garlic, ground pepper, soy sauce, salt, chopped fresh green chili (if desired).
3. Add the egg mixture and mix thoroughly.
4. Shape into thin patties (two tablespoons per patty).
5. Heat cooking oil in a frying pan. Deep-fry the patties until done.
6. Drain off excess oil. Serve with catsup while hot.

Note: The addition of fresh coconut residue (from coconut milk extraction) to the usual burger recipe provides dietary fibre which helps to prevent constipation, lowers cholesterol. It also provides coconut dietary fat, which has been shown to have antimicrobial properties and boosts the immune system, aside from providing food energy. It also utilises coconut residue (which is normally thrown away or used as animal feed) thereby reducing the cost of the food as well.

Source of basic recipe: Product Development Department
Philippine Coconut Authority
Diliman, Quezon City

Coconut Okoy

Ingredients

½ cup all-purpose wheat flour
½ tsp baking powder
½ cup matured pumpkin/squash, grated together with skin
1 cup fresh coconut milk residue
1 cup shrimps or minced chicken
1 egg, well beaten
½ cup onions, chopped
½ tbsp ground pepper plus other spices to taste
½ tsp salt
MSG to taste (optional)
Cooking oil for frying
Vinegar seasoned with salt and garlic

Procedure

1. Mix all ingredients.
2. Shape into patties.
3. Deep fry in oil until golden brown.
4. Serve hot with vinegar seasoned with salt and garlic.

Source of basic recipe: Philippine Coconut Authority
Region IV-A (Lucena)

Macaroons

Ingredients

1 can (big) condensed milk
3 eggs, well beaten
1/2 cup butter
1/4 cup sugar
½ cup all-purpose flour
2 cups dried/toasted coconut milk residue
1 tsp vanilla
2 tsp baking powder

Procedure

1. Preheat the oven to 350ºF.
2. Mix all ingredients well.
3. Spoon mixture into paper cups. Fill the cups only half full to avoid overflow of mixture during baking.
4. Place on baking sheets or muffin pans and bake at 350ºF for 15–20 mins.

Source: Product Development Department
Philippine Coconut Authority

Peanut Sapal Cookies

Ingredients

3/4 cup sifted all purpose wheat flour
1 cup toasted coconut residue
1/2 tsp baking powder
1/2 tsp baking soda
1/4 tsp salt
1/2 cup margarine or butter
3/4 cup sugar
1/4 cup peanut butter
1 egg
1/2 cup finely chopped peanuts

Procedure

1. Pre-heat oven to 350°F.
2. Sift together flour, baking soda, baking powder and salt. Set aside.
3. Cream butter, peanut butter, sugar and egg.
4. Blend in the dry ingredients and toasted coconut residue.
5. Cover and chill.
6. Shape dough into 1-inch balls. Roll in peanuts. Place three inches apart on slightly greased baking sheet. Press thumb in centre of each cookie.
7. Bake for 15 minutes or until set but not hard.

Source: Product Development Department
Philippine Coconut Authority

Cinnamon Sapal Cookies

Ingredients

½ cup shortening or butter
1 cup sugar
1 egg, well beaten
½ cup evaporated milk
1 cup toasted coconut residue
1½ cups sifted flour
½ tsp salt
1 tsp cinnamon powder
2½ tsp baking powder

Procedure

1. Cream the butter or shortening and sugar together until light and fluffy.
2. Add the egg, then stir in the milk.
3. Add the toasted coconut residue.
4. Sift the flour, salt, cinnamon and baking powder and add to the mixture. Mix well.
5. Drop by teaspoonful onto a greased baking sheet.
6. Bake in a moderate oven 375°F until brown, about 15 minutes.

Source: Product Development Department
Philippine Coconut Authority

Figure 106. Coconut burgers (left) and macaroons (right)

Annex 11
Production of coconut flour and VCO from coconut milk residue using the Bawalan-Masa process

The Bawalan-Masa Process (Figure 43) has the following major steps:

Blanching – blanching coconut milk residue is done through the injection of live steam using a blanching machine at a minimum temperature of 85°C for about seven minutes or immersion in boiling water for 1½ minutes in order to kill harmful micro-organisms which might have contaminated the milk residue during handling. Blanching is a necessary step in coconut flour production, although it increases the moisture content of the coconut milk residue.

Drying – the wet coconut residue is dried using a tray type mechanical dryer to a specified moisture content. The dryer could be gas fired, electrically heated or steam heated. For large scale operation, the conveyor type dryer, similar to the one used in a desiccated coconut plant, is more practical to use.

Defatting – the dried coconut residue is passed through a high pressure screw press with a cooling system under a specified expeller setting to reduce oil content of the flour to 9% or less. A co-product of this process is another type of VCO with very mild coconut scent, easily absorbed by the skin. It is important to reduce the oil content of the coconut flakes to the lowest possible level to prolong the shelf-life of the coconut flour.

It should be noted that conventional designs of oil expellers as used in the coconut industry are not suitable for VCO and coconut flour production. Conventional expellers generate too much heat during operation, which destroys the nutritive value and affects the colour of the flakes.

Re-drying – the defatted coconut flakes are re-dried to reduce their moisture content to 2.5–3.0%.

Grinding – the dried coconut flakes are then ground to reduce particle size to a fine mesh (at least 100 mesh) as required in food product formulation.

Filtration of Oil – the VCO produced when it leaves the defatting equipment has entrained very fine particles of dried coconut milk residue which should be removed to clarify the oil. This is done through the use of a plate and frame filter press similar to what is done in copra oil milling operations.

The Bawalan-Masa Process is patented under the Philippine Patent Office in the name of the Philippine Coconut Authority. The process was developed by the author while working as Senior Science Research Specialist and Ms Dina B. Masa, Manager, Product Development Department, Philippine Coconut Authority.

Annex 12
Formulations and procedures for downstream products from VCO

A12.1 Toilet/bath soap

Weighing scale

Stick blender

SS wire whisk

Heat resistant plastic container

Eye goggles, gloves and mask

Plastic basin

Soap moulds

Figure 161. Soap-making tools and equipment

Notes on soap-making tools and equipment

1. **All equipment should be stainless steel, plastic or glass. Never use aluminium as this will react with caustic soda.**

2. **Soap moulds can be a fabricated wood with formica lamination or heat-resistant plastic. If non-heat resistant plastic is used, the desired shape of the soap plastic mould will not be retained.**

Additives in soap-making

Additives are substances that not only alter the overall appearance of a given soap but which also lend their own special qualities to it (hollydeyo@millenium-ark.net, 2004).

Additives include:

Colouring materials – can be food grade dyes, spices (such as turmeric) that have the pigment for a specific colour, or any non-allergy-causing substance that provides colour to the soap. The author found that children's crayons are a cheap alternative to commercial dyes for home-scale soap-making.

Essential oils or fragrance oils – give the soap the desired scent; they should not contain any alcohol.

Chelating agent – this is either citric acid or ethylene diamine tetra acetic acid (EDTA), which acts as a sort of metal scavenger or water softener, preventing the formation of bathtub rings when the soap is used in hard water.

Mineral oil or glycerine – this is added to enhance the emollient properties of soap and prevents its skin-drying effect. For special moisturising effect, cocoa butter or avocado oil or jojoba oil can be added instead of mineral oil.

Basic formulation for moisturising herbal bath soap are shown in Table 20.

Table 20. Basic formulation for moisturising herbal bath soap

Coconut oil	1,000 grams
Caustic soda solution, 35°Be	578 grams
OR	
Coconut oil	550 grams
Palm oil	300 grams
Sunflower oil	200 grams
Caustic soda solution, 35°Be	550 grams
OR	
Coconut oil	800 grams
Canola oil	200 grams
Caustic soda solution, 35°Be	548 grams
OR	
Coconut oil	800 grams
Sunflower oil	200 grams
Caustic Soda Solution, 35°Be	548 grams
Essential oil (optional)	20 grams
Colour (optional)	children's crayon or oil soluble dye, amount depends on desired intensity of colour

For special effects to convert formula into herbal soap	
Add at trace:	
Aloe vera extract	50 grams
or lemon extract	50 grams
or green papaya extract	50 grams

Soap-making procedure

The preparation of caustic soda is shown in Table 21 and the preparation of soap is shown in Table 22.

Table 21. Processing steps and safety measures for the preparation of caustic soda solution

Process Steps	Safety Measures/Remarks
a. Put on rubber gloves. b. Weigh 1 kg caustic soda flakes.	Caustic soda flakes should be of high purity and free from metal content. Buy them from chemical suppliers. Do not use caustic soda for cleaning drains. Use rubber gloves when handling caustic soda flakes. Special care should be taken in handling caustic soda flakes as they are highly irritating to the skin.
c. Using a graduated cylinder, measure 2.3 litres of water and place in a heat-resistant plastic or stainless steel container.	The water should be as pure as possible. Distilled or filtered rain water is best.
d. Place the container of purified water over a basin of cold water.	When caustic soda flakes are dissolved in water, they generate a lot of heat so this reaction should be counteracted by the basin of cold water.
e. Put on eye goggles, gas mask and rubber gloves before mixing the caustic soda solution. f. Place vinegar and water nearby to neutralise caustic soda in case of an accidental spill or if the solution comes in contact with the skin.	Caustic soda solution is a very corrosive substance and can burn the skin and irritate the eyes. It also emits a lot of fumes in the initial stage of dissolving.
g. **ADD CAUSTIC SODA FLAKES TO WATER — NOT WATER TO CAUSTIC SODA FLAKES —** and mix thoroughly until all the crystals or flakes are dissolved.	The mixing of the caustic soda solution should be done in a well-ventilated, open area.
h. When cool, store the solution in a plastic container. Label it properly.	**Lye flakes or crystals and lye solution can be fatal if swallowed so put them out of reach and sight of small children and animals. Keep containers of lye properly labelled and sealed.**

Table 22. Processing steps and critical control points for soap-making

Process Steps	Critical Control Points/Remarks
a. Weigh the required amount of oil or fat and place in a mixing bowl.	The oil or fat can be one kind only (e.g. coconut oil, palm oil, beef tallow) or a mixture of different kinds. The fatty acid composition of oil determines the quality of soap with regard to cleaning efficiency, lathering properties and moisturising effect. Hence, it is best to mix oils to get the special properties one wants in a soap. Always remember that in making soap, weight and not volume is used as a unit of measure.
b. Weigh the required amount of caustic soda solution prepared as described above.	**Please remember all the safety precautions mentioned above when handling caustic soda solution.**
c. Slowly add the caustic soda solution to the oil in the mixing bowl and stir in one direction using a large stainless steel egg whisk or an electric stick blender or an electric hand mixer. Set the speed to 1 or low.	This is done to ensure that the oil and caustic soda solution are mixed properly to undergo the saponification reaction.
d. Stir continuously for 15 minutes, then stop for 5 minutes. Stir for 5 minutes then stop for 5 minutes. Do this sequence of alternate stirring and resting until the mixture reaches a 'light trace' consistency. It is like the consistency of condensed milk. Mixing should be done in one direction only.	The amount of time required for the soap mixture to reach the 'trace' stage depends on the fatty acid composition of the oil. Saturated oils like coconut and palm oil reach the 'trace' stage more quickly than polyunsaturated oils like soybean and sunflower oils, which take longer to 'trace'. Coconut oil takes about 45 minutes. 'Trace' is a term in soap-making to describe the consistency (thickness) of soap when it is ready to pour into moulds. When caustic soda solution and fat/oil first combine, the mixture is thin and watery. Gradually, the caustic soda and fat/oil react to form soap. The mixture thickens to a trace consistency and turns opaque.
e. Add colour to the desired intensity. (The colour can come from crayons melted in oil over a water bath or from oil-soluble dye dissolved in oil. Stir for 5 minutes.	The oil used for dissolving dye or melting with crayons should be taken from the previously weighed oil for making the soap.
f. Add the desired additives (emollients and scents) and stir.	Fragrance oils or essential oils used as scents should be added at a time when the soap mixture is very near the 'full trace' stage to prevent the caustic soda from destroying the scent. If synthetic fragrance is used to scent the soap, please make certain that the fragrance is oil-based and has no alcohol content. The addition of alcohol-based fragrance to the soap mixture will cause it to curdle.

g. Test the soap mixture to see if it has reached the 'full trace' stage.  *Figure 162. Appearance of soap mixture at 'full trace'*	Drip some soap mixture from a spoon across the surface of the mixture. It should leave a 'trace' or a small mound. Draw a line in the surface of the soap mixture with a spoon or rubber spatula. If a 'trace' of the line remains for a few seconds, the soap has traced (Figure 162).
h. Pour the soap mixture into the soap mould, cover the surface of the soap with plastic or wax paper and allow to stand at room temperature for 24 hrs.	Covering the surface of the soap mixture will prevent it from having white spots on the surface when the soap solidifies. 24 hours is needed for complete saponification and solidification.
i. Remove the soap from the mould and cut into desired sizes.	For smoothly-cut soap, a fabricated soap cutter using guitar chords as the cutting medium can be used (Figure 163).
j. Stamp, dry and age the soap for at least two weeks.	
k. Pack the soap in desired packaging material and label.	

Source: Bawalan and Chapman (2006)

Figure 163. Soap cutter for rectangular (left) and for circular (right) shaped soaps

Quality control in soap-making

Soap cannot be made without any alkali solution. The two most common alkali solutions in use for soap making today are caustic soda, or sodium hydroxide ($NaOH$), and potassium hydroxide (KOH). For bar soap, it is always sodium hydroxide that is used. Potassium hydroxide is mostly used for liquid soap because it produces very soft soap and is slow to trace. Caustic soda is a chemical classified as a strong base; it is highly corrosive and burns the skin. Hence, the amount of caustic soda solution added to oil to form soap should be computed and measured accurately, as any amount in excess will result in soap that has an irritating effect on the skin. The main reason a cold-processed soap is allowed to age for at least two weeks is to make certain that all caustic soda in the soap has reacted completely with the oil.

Based on the foregoing, quality control of soap is always made by measuring its pH value. In layman's term, pH is defined as a measure of the degree of acidity or alkalinity of a substance where the values are measured on a range of one to fourteen. A neutral substance (neither acidic nor basic), such as water, is given a value of seven. A pH below seven means the substance is an acid and pH above seven means the substance is a base (alkaline). The greater the pH difference from seven, the stronger the acidity or alkalinity of the substance. The strength of an acid or base can be measured by means of a pH meter or (and more quickly) by litmus paper, special paper with chemicals in it that change the colour of the paper depending on the pH of the substance being tested.

To test a bar of soap's pH, wet the bar in running water and rub the bar with your hands until you get some bubbles or a thin film of liquid soap on the outside of the bar. Wet the litmus paper on it, observe the change in the colour of the paper and compare it to the colour chart that is provided by the manufacturer to determine the pH value. Soap as a general rule is alkaline in nature. However, the pH should not be more than ten. A pH of nine or less is better. If the pH of the soap is more than ten, it will probably cause a burning sensation on the skin. As the soap ages, the pH drops, so it is better to test the pH at the end of the two weeks' ageing period (for cold processed soap).

A12.2 Aromatherapy/massage oils

This section deals with some formulations for aromatherapy oil that were prepared and tested by the author. All prepared aromatherapy and massage oils should be stored in dark coloured bottles. Thoroughly cleaned and dried cough syrup bottles can be used.

a. Massage oils for relaxation or to relieve stress

Formulation a1
Lavender oil – 3 ml
Virgin coconut oil – 97 ml

Formulation a2
Ylang Ylang Oil – 2 ml
Virgin Coconut Oil – 98 ml

b. Deodorising body oil
Lemongrass oil – 2.5 ml
Virgin Coconut oil – 97.5 ml

Author's Note: The same formulation has also been tested for the prevention of smelly feet; the oil is massaged into the foot and in between the toes before putting on socks.

c. Massage oil for respiration (easy breathing in case of colds)
Eucalyptus oil – 1.5 ml (about 30 drops)
Peppermint oil – 1.0 ml (about 20 drops)
Virgin coconut oil – 97.5 ml

d. Massage oil for rheumatism and muscle pain
Eucalyptus oil – 1 ml
Ginger oil infused virgin coconut oil – 99 ml

Note: Do the oil infusion with ginger by following the procedure discussed in Section 7.2 of the manual.

A12.3 Skin care products

In all of the formulations listed below, it is advisable to do the mixing in thoroughly cleaned and dried heat-resistant glass beakers.

Coconut moisturising jelly (substitute for petroleum jelly)

Ingredients

Virgin coconut oil	1/2 cup (120 ml)
Grated beeswax	30 grams
Essential oil of choice	2 ml or depending on desired intensity of scent

Procedure

Melt the beeswax slowly in a double boiler or put the container of beeswax in a pan with heated water. Heat the VCO in the same way as the beeswax. Mix the oil and melted beeswax together. Cool to 50°C while stirring constantly. Add the essential oil and stir thoroughly. Put into cosmetic jars and allow to cool.

Note: Wait for the VCO-beeswax mixture to cool to at least 50°C (warm feel) before adding the essential oil. Otherwise, the scent will be destroyed by heat.

Lip balm

Ingredients

Cocoa butter	15 grams
Grated beeswax	15 grams
Virgin coconut oil	30 grams

Procedure

Melt the beeswax slowly in a double boiler or put the container of beeswax in a pan with heated water. Heat the VCO and cocoa butter in the same way as the beeswax. Mix the oil cocoa butter and melted beeswax together. Cool to 50°C while stirring constantly. Add a few drops of peppermint flavouring oil. Put into cosmetic jars and let cool. If you want a softer balm, add more VCO. If you want a harder balm, add more beeswax.

Moisturising body butter

Ingredients

Beeswax	20 grams
Cocoa butter	60 grams
Sesame oil (deodorised)	20 grams
Virgin coconut oil	30 grams
Olive oil 10 grams	
Essential oil of choice	2 ml or depending on the preferred intensity of the scent

Note: Use deodorised or odourless sesame oil. Virgin sesame oil has a very strong odour which will destroy the scent of the product. Remove from the formulation if you cannot find an odourless sesame oil.

Procedure

Melt the beeswax slowly in a double boiler or put the container of beeswax in a pan with heated water. Add the cocoa butter and blend with the beeswax without removing from the heat. Slowly blend in the oils, one at a time. Let the mixture cool to 50°C and add the essential oil. Blend well. Pour into moulds and cool to solidify.

Glossary

Alkali – is a primary ingredient in soap making. This is either caustic soda (sodium hydroxide) or caustic potash (potassium hydroxide). Soap produced using caustic soda is much harder than soap produced using potassium hydroxide. This is why potassium hydroxide is normally used when making liquid soap. Alkali used for soap making should be pure and free from any metal content.

Ash – is the residue that remains when a substance is subjected to high heat in the presence of air and all combustible matter is burned.

Ball copra – is a dehydrated whole kernel, an edible copra unique to India and certain parts of Sri Lanka. Fully mature, unhusked coconuts are placed in specially constructed ball copra stores or on a wooden platform above the kitchen fire-place just below the roof and allowed to dry for eight to twelve months (Ranasinghe et al. 1980).

Biochemical oxygen demand (BOD) – is the quantity of oxygen used by aerobic microorganisms and reducing compounds in the stabilisation of decomposable matter during a selected time at a certain temperature (Frazier and Westhoff 1988). A period of five days at 20°C is generally used and results are expressed in five-day BOD (BOD_5). It is the amount of dissolved oxygen needed to decompose the organic matter in waste water; a high BOD indicates heavy pollution with little oxygen remaining for fish (Webster's New World College Dictionary, 2010).

Charcoal briquette – also called patent fuel - is a compacted mass of fuel material made from a mixture of very small charcoal pieces (fines) and a binder and moulded under pressure (FPRDI 1992).

Chelating agents – include citric acid, or ethylene diamine tetra acetic acid (EDTA), and are used as soap-making additives. They act as metal scavengers or water softeners, preventing the formation of tub rings when soap is used in hard water.

Choke – is the very small opening at the end section of a high pressure expeller which the dried, milled kernel is forced to pass through to effect the extraction of oil. The dried kernel is pushed to this opening through the rotation/movement of a worm shaft, or screw. Adjustment in the choke clearance determines the oil extraction efficiency and the thickness of the coconut flakes.

Cochin oil – the coconut oil industry term for semi-refined, copra-derived coconut oil which is generally used for inedible or industrial applications (e.g. raw material for the production of coconut chemicals).

Coconut flour – is the ground, solid residue/flakes obtained after extraction of virgin coconut oil from dried, comminuted coconut kernel, or coconut milk residue that is processed under sanitary conditions.

Coconut milk – is the white opaque fluid, an emulsion of oil and water, obtained when freshly grated or comminuted coconut kernel is pressed either by manual or mechanical means with or without the addition of water.

Coconut milk residue – is the solid material that is left behind when coconut milk is extracted from fresh grated or shredded coconut kernel. It represents approximately 40–52% of the weight of freshly grated kernel on a wet basis, depending on the coconut milk extraction process that is used.

Coconut shell – or endocarp - is the hard, stony, dark brown, thin layer between the coconut husk (mesocarp) and the kernel of the mature coconut. It is soft and dark cream in colour when the nut is immature. This is where the coconut kernel is attached.

Coconut shell charcoal – is the product derived from carbonisation of coconut shell from fully matured nuts under a limited or controlled amount of air. It contains the highest percentage of fixed carbon of all ligneous charcoal.

Coconut skim milk – is the watery phase which separates out from the coconut cream when coconut milk is allowed to stand for two hours or when it is passed through a two-phase (liquid-liquid) centrifuge. In the centrifuge process of VCO production, coconut skim milk is generated as a by-product, since it is only the separated cream that is processed into VCO. Coconut skim milk has a sweetish flavour characteristic of young coconut. It can be pasteurised, frozen or packed in cans or tetrabrik or passed through a spray dryer to produce coconut skim milk powder.

Coconut water – is the liquid endosperm contained in a central almost spherical hollow of the coconut fruit. This is one of the by-products generated during the processing of coconut kernels. In its natural form, coconut water contains micro minerals and vitamins which are beneficial to human health.

Copra – is the dehydrated/dried coconut kernel, the primary product known in all coconut growing countries of the world. It is the oldest known coconut product and the principal commodity by which farmers normally convert their coconuts into income. Copra-making prevents the spoilage of fresh coconut kernel by greatly reducing its moisture content.

Cup copra – is dehydrated kernel halves, the most common type of copra available in the market. It is produced by drying coconut kernels in their shell (husked or unhusked) by sun drying, kiln drying or a combination of both, and removing them from the shell either after the kernel has partially dried or at the end of the drying operation.

Desiccated coconut – is the pure white, shredded, dehydrated food product obtained from fresh, pared coconut kernel which is processed under very strict sanitary conditions.

Fatty acid – is a term given to substances in which the chemical formula is represented by RCOOH where R is essentially chains of carbon and hydrogen of varying length (e.g. CH_3CH_2COOH). For a detailed discussion on fatty acids, please refer to Annex 1.

Filled Milk – also known as evaporated or reconstituted milk, a liquid milk formulation in which the butterfat in dairy milk is removed and substituted with coconut oil to make the product cheaper, i.e. it is dairy skim milk that is homogenised with coconut oil. It is normally available in Asian supermarkets as canned liquid milk.

Finger copra – is dried kernel in small pieces; the fresh kernel is removed from split unhusked coconuts and dried by kiln drying (direct or indirect) and by sun drying.

Fixed carbon content – the amount of carbon contained in a particular type of charcoal.

FOB – stands for freight on board. A commercial term, it is used in exporting products and means that the quoted price is based on the place of origin, and does not include shipping and insurance costs.

Food safety – is the assurance that food will not cause any harm to the consumer when it is prepared and/or eaten according to it is intended use. It is the achievement of all conditions and the implementation of all measures that are necessary during production, processing, storage, distribution and preparation of food so that it does not present an appreciable risk to health when consumed.

Free fatty acid – is the amount of fatty acid in oil which is not bonded to glycerol. It exists in an uncombined state as a definable chemical unit. The acid content in an edible fat or oil is given by the quantity of free fatty acids derived from the hydrolytic breakdown of the triglycerides which gives the oil the rancid smell. In most vegetable oils, free fatty acids are expressed as percentage acidity calculated as oleic acid (a mono-unsaturated fat). The uncombined fatty acid comes from the breakdown of fat (as triglycerides) into a unit of fatty acid and glyceride. However, for virgin coconut oil, it is expressed in terms of its predominant fatty acid, i.e lauric acid. The higher the free fatty acid content, the lower the quality of oil.

Foreign matter content – refers to any materials mixed in a batch of specific products which by properties and characteristics of the substance should not be there.

Functional food – refers to any edible substance which provides health benefits aside from the nutrients that it gives to the human body.

Good manufacturing practices – is a set of guidelines and procedures that must be followed to ensure that the food products manufactured in a particular plant are free from rubbish, dirt, contaminants and pathogenic microorganisms so as to be safe for human consumption.

Green copra – refers to the fresh coconut kernel in PICTs in finger-size pieces which are normally taken out from split coconuts by means of a knife or a special tool.

Haustorium – is the creamy/light yellow spongy structure that grows inside the coconut kernel when germination starts (known as *vara* in Fiji). The longer the germination growth, the bigger the haustorium. The coconut kernel becomes thinner, slimy and rancid as the haustorium grows.

Herbal soap – is a cold-processed soap with added natural plant material/extracts that are known to have a therapeutic or beneficial effect on the skin.

Hot air dryer – is the general term for dryers in which the medium that picks up the moisture from the wet material to be dried is hot air with blower (forced draught) or without blower (natural draught). The technical term is convection type dryers. Heating of the air is done either through steam or a biomass-fired or gas-fired burner attached to a heat exchanger. On the other hand, the DME dryer is an example of a conduction or direct type dryer where heat is directly transferred from the hot metal surface to the wet material.

Hydrogenation – is a process in which hydrogen gas is bubbled through unsaturated oil in the presence of nickel as a catalyst. The resulting reaction forces unsaturated fatty acids to accept additional hydrogen atoms and become partially saturated. Full hydrogenation converts liquid oil into solid fat. Partial hydrogenation limits the time exposure of the unsaturated vegetable oil to the stream of hydrogen gas, thereby converting it either into a semi-solid state similar to butter or retaining its liquid state.

Low fat desiccated coconut – is actually coconut milk residue which is dried under strict sanitary condition. Its protein, fat and sugar content are much lower than the traditionally known full fat desiccated coconut. Its selling value is its lower fat and high dietary fibre content.

Moisture content – is a measure of the amount of water that is physically bound in a particular solid or substance and that can be removed to a certain extent by directly or indirectly heating the substance.

Moisture content in coconut oil – is a measure of the amount of water expressed as a percentage that is left adhering or entrained in the oil molecules after extraction and post processing of oil. It has to be kept at the lowest level possible and preferably totally removed because it causes deterioration in the shelf-life or keeping quality of the oil.

Monolaurin – the monoglyceride of lauric fatty acid (i.e. lauric acid linked glycerol on a 1:1 ratio). It is available commercially in pellets and capsule form in the United States. It is produced by reacting lauric fatty acid crystals with glycerol under specified conditions. The resulting product is then purified using a molecular distillation process.

Nutraceuticals – are natural food components that provide health benefits or reduce the risk of chronic disease above and beyond their basic nutritional function. In layman's term, nutraceuticals are substances which not only nourish but also heal.

Peroxide value – is a measure of the extent of oxidative absorption and entrainment of oxygen in a fat or oil. The peroxide content present in an edible fat or oil indicates its state of primary oxidation and its tendency to go rancid. The lower the peroxide value, the higher the quality of the oil.

pH – is defined as a measure of the degree of acidity or alkalinity of a substance where the values are measured on a range of 1–14. A neutral substance (neither acidic nor basic), like water, is given a value of 7. A pH below 7 means the substance is an acid and a pH above 7 means the substance is a base. The greater the pH difference from 7, the stronger is the acidity or alkalinity of the substance.

RBD coconut oil – refers to refined, bleached and deodorised coconut oil derived from copra. The crude coconut oil is subjected to chemical refining, bleaching and deodorisation processes after oil extraction to make it fit for human consumption. RBD coconut oil is generally used as cooking oil in the Philippines.

Sanitation Standard Operating Procedures – is a set of activities related to the sanitary handling of raw materials, food products, work areas and equipment. It ascertains that conditions prescribed by GMPs are met by plant facilities and operations.

Sinusinu – is the Fijian term for the proteinaceous residue or coagulated coconut protein that forms when coconut milk is boiled. It is a by-product of the traditional process of producing coconut oil, and currently does not have market value but is used as toppings for rice cakes and as an extender for meat-based food recipes.

Soap – is the solid material obtained when an alkali reacts with the fatty acids in animal, vegetable and seed oils and fats under a process known as saponification. The type of oil or fats used defines the characteristics of the resulting soap, i.e. whether it is mild or drying to the skin, whether it will form good lather, whether it will have good detergency or cleaning properties, etc.

Soap noodle – is a semi-processed substance composed of fatty acids with carbon chains ranging from C_{12}–C_{18}. It is produced by removing the glycerol component and the fatty acids with carbon chains C_6–C_{10} of coconut oil through a steam hydrolysis and distillation process.

Trace – is a soap-making term that describes the consistency (thickness) of soap when it is ready to pour into moulds.

Trans fatty acids – are artificially altered, unsaturated, fatty acids in which hydrogen atoms attached to the carbon atoms linked with the double bonds have shifted position from the same side (cis) to the opposite side (trans). This happens when unsaturated oils like soybean and corn are subjected to the partial hydrogenation process. This process straightens the fatty acid molecules to enable them to be 'packed' in solid form like saturated fats, while remaining unsaturated (www.ucap.org.ph).

Vinegar – is generally defined as an alcoholic liquid that has been allowed to sour. It is considered one of the oldest fermentation products known to man (Banzon et al. 1990). Coconut water vinegar is one type of vinegar that uses coconut water as starting material.

Virgin coconut oil (VCO) – is the oil obtained from the fresh, mature kernel of the coconut by mechanical or natural means, with or without the use of heat, without undergoing chemical refining, bleaching or deodorising, and which does not lead to the alteration of the nature of the oil. VCO is suitable for consumption without the need for further processing. VCO is the purest form of coconut oil, water white in colour, containing natural Vitamin E and not having undergone atmospheric or hydrolytic oxidation, as attested by its low peroxide value and low free fatty acid content.

Volatile combustible matter content – is defined as the water and other organic matter that are released as a result of various chemical reactions which occur when biomass is heated in the presence of limited air. The volatile matter in charcoal (other than water) is composed of all those liquid and tarry residues not fully driven off in the process of carbonisation.

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