

Virgin Coconut Oil

production manual for micro- and village-scale processing

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micro- and village-scale processing**

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Preface

Virgin coconut oil (VCO) is the newest, high-value coconut product very much sought after for its human, nutraceutical benefits and as a functional food. World demand for VCO is rapidly increasing. VCO production, which at present is mostly done at household, micro- or village-scale levels, is rising rapidly and has excellent potential for improving coconut farm incomes by five to eight-fold over traditional copra production or sale of fresh nuts.

Asian Pacific Coconut Community (APCC) and member countries are strongly promoting VCO for health and improving livelihoods of smallholder coconut processors.

However, one major concern is that unless VCO is produced correctly under well-managed, hygienic conditions, the poor quality oil produced will not meet prescribed standards, and may not be suitable for human consumption. A number of products currently on the market claiming to be VCO, do not meet prescribed standards. The FAO Regional Office for Asia and the Pacific has been involved with improving and developing VCO technologies over the previous four years with a view to establishing safe, hygienic methods for production.

The FAO research and development work with Thai institutions has resulted in this manual — a guideline for producing safe, hygienic VCO for micro- and village-scale processing systems. It is part of the FAO/Thailand TCP/THA3002 Project on Improvement of Coffee Quality and Improvement of Ochratoxin A on Robusta coffee, implemented with the Thailand Horticulture Research Institute, Department of Agriculture, Chumphon, Horticultural Research Centre (HRC). Chumphon HRC has the mandate for all coconut and Robusta coffee research and development in Thailand. The Robusta coffee industry of South Thailand is to a significant extent, integrated with coconut production and Robusta coffee is frequently planted under the shade of coconut trees. A part of this TCP coffee project examined socio-economic aspects of the coffee farm system. In addition to improving agricultural practices, processing and quality of the coffee, developing the complete farm system is very important for significantly increasing farm incomes and improving livelihoods.

Divina Bawalan, formerly of the Philippine Coconut Authority, is an international coconut processing specialist and food engineer and has worked with the development of virgin coconut oil and other coconut products for more than 20 years. Divina and co-author Keith Chapman, collaborated with the Thailand Institute of Scientific and Technological Research (TISTR) and the Chumphon HRC of the Department of Agriculture, to bring VCO technologies to Thailand through a complementary FAO supported initiative.

Divina's work in Thailand has assisted the essential virgin coconut oil research and development and product development, and by way of her training, TISTR and Chumphon HRC have provided key technical information for the manual. VCO production and product technologies at farm level via outreach support by FAO to coconut communities have contributed valuable practical skills for documentation.

The manual is intended as a primary source of practical knowledge on good management practices (GMP). It will assist Asian Pacific Coconut Community (APCC) member country farmers and their families, entrepreneurs, processors, researchers, extension agents and technicians with the practical information on VCO and related products in this manual.

FAO sincerely thanks the authors and staff of TISTR, Chumphon HRC, Horticulture Research Institute of DOA, the Thailand Department of Agriculture Extension, and participating villages for VCO production, for their assistance in establishing the technologies that help make the preparation of this manual possible.

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and the manually operated horizontal screw type coconut milk press currently being used in the province of Leyte, Central Philippines; Mrs Charita Puentespina of Malagos Garden Resort, Davao City, Southern Philippines for allowing photos to be taken of their VCO processing facility; Dr Bruce Fife, author of The Healing Miracles of Coconut Oil and other books pertaining to the health benefits obtained from coconut for granting the permission to reproduce pertinent tables and to quote appropriate information.

We are very much indebted to Loraine Chapman, Australia, who has generously provided the English editing, indexing, design and electronic layout and managed the publication process of the book.

Acronyms and abbreviations

AO	Administrative Order
APCC	Asian Pacific Coconut Community, Jakarta
BAFPS	Bureau of Agricultural and Fisheries Product Standard
CRI	Coconut Research Institute of Sri Lanka
DOA	Department of Agriculture, Thailand
HRC	Horticulture Research Centre
HRI	Horticulture Research Institute
NRI	Natural Resources Institute
PCA	Philippine Coconut Authority
TISTR	Thailand Institute of Scientific and Technological Research
UCAP	United Coconut Association of the Philippines
DME	Direct micro expelling
Foots	Sediment
FFA	Free fatty acid
GLC	Gas liquid chromatography
GMP	Good Management Practices
HACCP	Hazard Analysis Critical Control Points
M.C.	Moisture content
MCFA	Medium chain fatty acid
Meat	Coconut kernel
Php	Philippine peso
Psi	Pounds per square inch
RBD	Refined, Bleached and De-odourised
ROI	Return on Investment
VCO	Virgin Coconut Oil
Water-clear	Clear, white VCO

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Chapter 1

Micro- and village-scale processing



Introduction

Coconut (*Cocos nucifera* L.) has been part of peoples' diet and livelihoods in the tropical countries of Asia, the Pacific, South and Central America and Africa for thousands of years. In these areas, native meals are cooked with either coconut milk or coconut oil. In the Cook Islands in the South Pacific, particularly Rarotonga Island, slices of fresh, mature coconut kernel are served with fruits every after meal. In India, the use of coconut for food and its applications in the Ayurvedic medicine, were documented in Sanskrit 4000 years ago (Kabara, 2000). Records show that in the United States, coconut oil was one of the major sources of dietary fats, aside from dairy and animal fats, prior to the advent of the American edible oil (soybean and corn) industry in the mid 1940s (Dayrit, 2005).

The long history of usage and the diverse studies done to characterise and define the composition of the various components of the coconut tree, its fruit and the related products derived from it, established the coconut's uniqueness and superiority among agricultural crops. Every part of the coconut tree and its fruit can be either consumed by humans or animals or converted into other valuable products. If properly utilised, the coconut has the highest economic value among the palm family. This is why the coconut is normally referred to as the Tree of Life, Man's Most Useful Tree, King of the Tropical Flora, Tree of Abundance.

Desiccated coconut, coconut milk/cream in liquid and powder form, and coconut oil are the most popular edible commercial products derived from fresh coconut meat (kernel). The meat is very nutritious as it contains dietary fat, dietary fibre, protein, carbohydrates, microminerals such as potassium and phosphorus, and vitamins such as niacin and riboflavin. See Tables 1 to 5 in Annex 1 for the composition and nutritional values of coconut meat, desiccated coconut and coconut milk. Coconut water, which is the liquid inside the coconut fruit, has also been shown to contain microminerals and nutrients which are essential to human health. Because of health benefits and special flavour of young coconut water, domestic sales and export of young coconuts are major income-generating activities for coconut farmers and traders in Thailand. See Tables 6 to 9 in Annex 1 for the composition of coconut water at various stages of maturity, and the electrolyte composition that is a first-rate oral rehydration agent for diarrhea patients (Anzaldo et al 1985).

The newest high value coconut product, which is becoming a by-word in coconut producing countries, the United States and other developed countries, is Virgin Coconut Oil (VCO). The growing demand for VCO can be attributed to the increasing number of published books, literature, results of medical research, anecdotal reports and internet information extolling the beneficial effects of coconut oil on the human

body. Most people generally believe that the demand for VCO as a functional food was generated by the publication of the book, *The Healing Miracles of Coconut Oil* — later revised and updated as *The Coconut Oil Miracles*. Written by American certified nutritionist and naturopathic doctor, Bruce Fife, the book discusses in layman's terms, the results of medical research and anecdotal reports on the health benefits obtained from coconut oil. Dr Fife also stated, "Coconut oil is the healthiest oil on earth".

Dr Fife has since written *Eat Fat, Look Thin* and *Coconut Cures*. Another book, *Rx Coconut (Perfect Health Nut)*, was written by Dr Vermen Verallo Rowell, Chief Dermatologist, Makati Medical Center in Metro Manila, Philippines and founder of VMV hypoallergenics line of cosmetics. The latest book on VCO, *The Truth About Coconut Oil (The Drugstore in a Bottle)*, by Dr Conrado Dayrit, Professor Emeritus of the Department of Pharmacology, University of the Philippines College of Medicine, who at 86 yrs old, is Director of Victor Potenciano Medical Center in Metro Manila, Philippines and a practicing cardiologist. These latest books are expected to finally persuade unconvinced doctors and consumers to look at the health benefits that can be derived from coconut oil.

The fast developing niche and high value markets for VCO as a food supplement, as a body moisturiser and carrier oil for aromatherapy, as a hair conditioner and as other applications, is generating a great deal of interest among coconut farmers and landowners, businessmen and entrepreneurs. The attraction is in the different processes for producing VCO with the goal being a possible source for improving livelihoods and incomes.

This manual provides basic information on VCO and small-scale VCO processing technologies for trainers, potential processors, businessmen and anyone interested in producing VCO for home consumption or in micro- and small-scale enterprises. For purposes of clarification and discussion, the terms micro-scale and village-scale coconut processing enterprises will have the following meaning as defined by Bawalan (2003).

Micro-scale enterprises include all those with coconut processing capacities below 1,000 nuts per day. Process operation is either completely manual or semi-mechanised, normally using not more than three simple, single-phase motorised machines. In the Philippines, micro-scale enterprises, which also include cottage level operations, normally produce coconut food products. Capitalisation normally ranges from Php 50,000 to Php 500,000 (approximately USD1,000 to USD10,000).

Village-scale enterprises include all those with coconut processing capacities of 1,000 to 5,000 nuts per day. Process operation is semi-mechanised and uses a combination of single-

Fast developing niche and high value markets for VCO products are a possible source for improving livelihoods and incomes of coconut farmers and landowners, businessmen and entrepreneurs

Micro-scale enterprises and Village-scale enterprises



Figure 1. Virgin coconut oil

The most significant physical property of coconut oil is that unlike most fats, it does not exhibit gradual softening with increasing temperature.

phase and three-phase motorised machines. Capitalisation normally ranges from Php 500,000 to Php 5,000,000 (approximately USD10,000 to USD100,000).

Product definition

The *Philippine National Standard for VCO* (PNS/BAFPS 22:2004/ICS 67.2000.10) officially defines VCO (Figure 1) as:

- Oil obtained from the fresh, mature kernel (meat) of the coconut by mechanical or natural means, with or without the use of heat, without undergoing chemical refining, bleaching or de-odourising, and which does not lead to the alteration of the nature of the oil. Virgin coconut oil is suitable for human consumption without the need for further processing.
- 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-chain saturated fatty acids.
- VCO is the purest form of coconut oil, essentially water-clear or colourless. It contains natural Vitamin E and has not undergone any hydrolytic and atmospheric oxidation as demonstrated by its very low, free fatty acid (FFA) content (even without refining) and low peroxide value. It has a fresh coconut aroma that can be mild to intense depending on the oil extraction process used.
- VCO differs greatly from traditionally produced, copra-derived coconut oil, which must undergo chemical refining, bleaching and de-odourisation processes to make it suitable for human consumption. RBD (refined, bleached and de-odourised) coconut oil made from copra, is yellow in colour, odourless, tasteless and does not contain natural Vitamin E, since this is removed when the oil is subjected to high temperature and various chemical processes.

Product characteristics and uses

The degree of saturation and length of the carbon-chain of the fatty acids comprising a particular fat or oil determines its properties, corresponding uses and its effects 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). Coconut oil is unique amid fats and oils, as it contains the highest percentage of medium chain fatty acids (MCFA) with a carbon-chain length of 8 to 12 carbon atoms. VCO behaves and metabolises differently in the human body to other saturated and unsaturated fats or oils. MCFA in coconut oil is about 64%, with lauric fatty acid (C12) as the highest ranging from 47 to 53% depending on the coconut variety.

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. In this respect, it resembles cocoa butter (*Spectrum of Coconut Products*, Philippine Coconut Authority, undated). Coconut oil is liquid at about 27°C or higher and solidifies at about 22°C when it has the consistency of butter in temperate countries. The comparative fatty acid profile of common fats and oils is shown in Figure 2.

Copra-derived coconut oil has been produced and used commercially for almost a century. As such, its use for edible and inedible applications has already been well established.

For edible purposes, coconut oil is generally used as a frying and cooking oil because of its excellent resistance to rancidity development. It is also used as a substitute for expensive butterfat in filled milk, filled cheese and ice cream making these products cheaper without changing their palatability. When hydrogenated, coconut oil is used as margarine, shortening and baking fat. Other edible applications of coconut oil are:

- as a source of fat in infant formulas and baby foods because of its easy digestibility and absorbability;
- as a spray oil for crackers, cookies and cereals to enhance flavour, increase shelf-life and impart a glossy appearance;
- as an ingredient in confectionaries such as candy bars, toffee, caramels, etc.

The *Spectrum of Coconut Products* 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 a lubricating action in dressings or leavening effect in baked items.
- It acts as carrier and protective agent for fat-soluble vitamins.
- It enhances the flavour of food.

The major inedible use of coconut oil is as a raw material in the manufacture of laundry and bath soaps; as coconut chemicals for production of biodegradable detergents, shampoos, shower gels and other cleaning agents; for cosmetics and toiletries; for foam boosting of non-coconut oil based soaps; for the production of synthetic resins and plasticisers for plastic etc.

With the advent of energy crisis in the 1970s, the use of coconut oil and coconut oil-derived coco methyl ester have been successfully used as a diesel fuel substitute. At present, coco methyl ester is

VCO has excellent resistance to rancidity development.

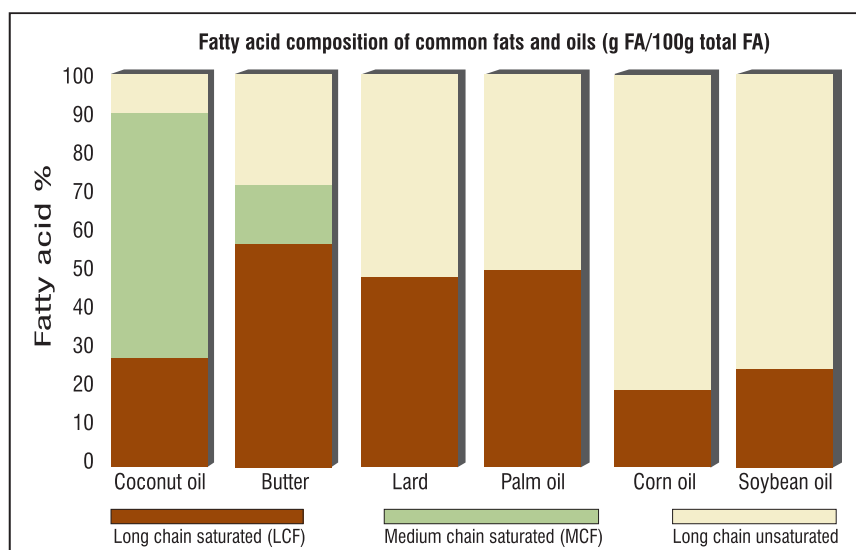


Figure 2. Comparative fatty acid profile of common fats and oils

Emerging major uses of VCO are as nutraceuticals, cosmetic and skin care products, and massage or carrier oils.

being used in the Philippines as a fuel additive or fuel enhancer for diesel (up to 5% blend) to support the Clean Air Act of the country. It has been proven by several studies that the addition of coco methyl ester in diesel fuel substantially reduces smoke emission and nitrous oxide formation.

In Thailand, coconut oil is mixed with 10 to 20% kerosene, settled to remove free fats, filtered and used as a diesel fuel substitute. In Vanuatu and other Pacific Islands, coconut oil is used directly as a substitute for diesel.

VCO can also be used in all applications where crude, cochin and refined, bleached, de-odourised (RBD) coconut oils are normally used, and would be a much better alternative if it could be made available in large volumes at affordable prices.

In the manufacture of oleochemicals reserved for cosmetic applications, the use of VCO instead of copra-derived oil will enhance the quality of the final product because of its hypoallergenic properties. One interesting development to note, is that VCO is being focused on specific applications distinct from the traditional uses of coconut oil listed above.

The emerging major uses of VCO are as:

- 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.

Mr. Arthur Bautista of the Splash Research Institute defines nutraceutical as:

Natural food components that provide health benefits or reduce the risk of chronic disease, above and beyond their basic nutritional function.

Simply put, nutraceuticals are substances that not only nourish but also heal. Virgin coconut oil is considered a nutraceutical because studies have shown the following facts.

- The medium chain (C8 – C12) fats in coconut oil are similar in structure to the fats in mother's milk that gives babies immunity to disease. There are also similar beneficial effects in adults, (Kabara, 2000).
- VCO possesses anti-inflammatory, antimicrobial and antioxidant properties which work together to protect arteries from atherosclerosis and the human heart from cardiovascular disease, (Fife, 2004).
- VCO boosts the immune system.
- VCO protects against heart disease by increasing high-density lipoprotein (HDL) that collects the excess or unused cholesterol in the body for excretion by the liver.
- VCO provides protection from infectious diseases not easily cured by known antibiotics.



Training a village group in VCO soap making

- VCO is digested easily without the need for bile and goes directly to the liver for conversion into energy, (Dayrit, 2003).
- VCO stimulates metabolism, boosts energy and prevents deposition of fats thereby preventing obesity, (Dayrit, 2003).
- VCO improves the nutritional value of food by increasing absorption of vitamins, minerals and amino acids, (Fife, 2004).
- VCO is the world's only natural, low-calorie fat, (Fife, 2004).
- VCO inhibits the action of cancer-forming substances (Clara Lim Syliangco, 1987).

For further information on the health benefits of coconut oil, see Annex 2: Frequently Asked Questions.

Identity characteristics

Gas Liquid Chromatography (GLC) range of fatty acids composition of VCO shall be in accordance with Table 1.

Table 1. Gas Liquid Chromatography range of fatty acid composition of VCO

Common name	Composition	(%)
Caproic acid	C 6:0	ND – 0.7
Caprylic acid	C 8:0	4.6 – 10.0
Capric acid	C 10:0	5.0 – 8.0
Lauric acid	C 12:0	45.1 and above
Myristic acid	C 14:0	16.8 – 21
Palmitic acid	C 16:0	7.5 – 10.2
Palmitoleic acid	C 16:1	ND*
Stearic acid	C 18:0	2.0 – 4.0
Oleic acid	C 18:1	5.0 – 10.0
Linoleic acid	C 18:2	1.0 – 2.5
Linolenic acid	C 18:3 C 24:1	ND – 0.2 ND

* ND= non-detectable

VCO is the world's only natural, low-calorie fat

The fatty acid profile of virgin coconut oil is greatly dependent on the coconut variety. Studies done by the Philippine Coconut Authority (PCA) Zamboanga Research Centre, revealed that coconut hybrid varieties have a higher lauric fatty acid content (above 50%) than local tall varieties.

Thai village group at an FAO sponsored training session with TISTR in Prachap Khiri Kh an, Thailand. The people are trained in all areas of producing virgin coconut oil and improving their farm incomes.



Colour, odour and taste

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

Specifications

Virgin coconut oil shall conform to the requirements specified in the table below.

Table 2. Virgin coconut oil property requirements

Properties	Specification
Moisture and volatile content	0.20% max.
Free fatty acids (expressed as lauric acid)	0.20% max.
Peroxide value	3.0 meq/kg oil max.
Food additives	None permitted
Contaminants	
Matter volatile at 105°C	0.20% max.
Heavy metal	mg/kg max.
Iron (Fe)	5.0
Copper (Cu)	0.40
Lead (Pb)	0.10
Arsenic (As)	0.10

In the absence of a laboratory analysis report, the quality of VCO can be assessed through sensory evaluation by testing the following attributes:

Colour. Virgin coconut oil has a clear water appearance. Based on the studies done under the Philippines/UK Aflatoxin Reduction in Copra Project, the colour of the oil is either brought about by contaminants in the oil (as in tapahan drying of copra), or by high temperature processing and microbial contamination of the coconut meat prior to oil extraction. Depending on the type of micro-organisms that cause the contamination, the oil colour can appear yellow or pink or red-orange (Figure 3).

Aroma. A good quality VCO does not have any rancid smell. It has a sweet coconut aroma which may range from mild to intense depending on the process used for extraction.

Taste. A good quality VCO should not have off-flavours or a sour taste. It should not cause any itchiness in the throat when ingested as this is an indication that the free fatty acid content is already higher than the prescribed standard.

Quality assurance in processing VCO

Quality assurance in the context of any industry should be viewed in two ways.

1. Ensure that the product produced by any processor conforms to domestic and internationally accepted product standards. The Philippines is the largest producer and exporter of coconut, so quality assurance is essential in VCO processing as the oil is becoming a highly lucrative export commodity. The market for VCO, whether local or international, has to



Figure 3. Different colours of coconut oil caused by contamination and high temperature extraction

be protected and sustained by ensuring that only VCO of the highest quality is produced.

2. Quality assurance should be strictly implemented to protect the consumer. The VCO on sale must be of the highest quality since there is no way for a consumer to check the quality when it is bought in a packaged container. At present, VCO is generally bought as a food supplement or nutraceutical because of the increasing quantity of literature indicating its beneficial effect on human health. In this instance, quality is of paramount importance since the product is being ingested directly and not as a food ingredient or a cooking medium.

The *Philippine National Standard for VCO* (PNS/BAFPS 22:2004) promulgated for adoption by all producers, processors, traders and exporters of virgin coconut oil in the Philippines under PCA Administrative Order 01 Series of 2005, has the following specifications.

Socio-economic significance of VCO processing

Since 2001, when VCO was first shipped by a herbal company from the Philippines to the United States, demand for the product has been steadily growing in there and in other developed countries (Canada, Australia, United Kingdom). VCO is the latest addition in the line of coconut products that the Philippines has introduced to the world. Other coconut producing countries like India, Indonesia, Fiji, Papua New Guinea are now exporting VCO products because its average value is about 400 to 500% higher than the export value of copra-derived coconut oil. At present, demand for VCO is still higher than the supply since most production is from small-scale operations.

Home production

The fast developing and high value niche market for VCO, offers good prospects of increased living standards for the farmer. Virgin coconut oil can be produced in homes and by micro- and village-scale operations, creating a situation where coconut farmers can directly participate in a larger share of the industry profit instead of being mere producers of copra. In addition to normal work routine, a husband and wife team using home utensils, can process 50 nuts per day to produce three to five litres of VCO. Scraping of coconuts is done by hand.

Income

Generally speaking, coconut meat from 15 fully mature coconuts is required to produce one litre VCO if done in a home or micro-scale operation. Fifteen coconuts are roughly equivalent to 3.3 kg of copra. Using the average domestic price of copra for 14 years in the Philippines at Php 10.70 (USD0.19) per kilo,

VCO must meet prescribed quality standards.

Meat and oil contact with metals other than stainless steel must be avoided at all costs to stop heavy metal contamination.

In a home or micro-scale operation, coconut meat from 15 fully mature coconuts is usually required to produce one litre of VCO.

15 coconuts will generate an income of USD0.63. However, if the 15 coconuts are processed into VCO, the income generated will be Php 130.00 (about USD2.40), which is the current bulk buying price per litre for VCO traders in the Philippines. The income obtained will be even higher if the VCO is sold locally in retail markets. In areas where VCO is produced, farmers are benefiting from an increased price per nut from Php 3.00 (USD0.05) to Php 5.50 (USD0.10). However, there are instances when copra prices fall to very low levels so it is no longer viable for farmers to harvest and process coconuts. Under these conditions, processing of coconut into VCO instead of copra is a much more profitable option.

On the macro-economic level, the value addition in terms of foreign exchange earnings of the Philippines on the export of coconut oil is also very high. The average international price for copra-derived coconut oil (1994 to 2004) is USD582/MT (UCAP statistics), while the recorded export price for VCO in December 2004 was USD3,134/MT (PCA). This means a value addition of about 500%. With this export price, VCO is now the highest valued coconut product in the world market.



Chapter 2

Processing technology



Processing virgin coconut oil

Virgin coconut oil can be produced directly from the fresh comminuted (grated, chopped, granulated) coconut meat, or from coconut milk, or from coconut milk residue (Figure 4).

The choice of the technology to be adopted, depends to a great extent on the scale of operation, the degree of mechanisation desired, the amount of investment available and the demands of the prospective buyer. The scale of operation to be implemented is significantly dependant on the available coconut supply base. Coconut supply base can be estimated by using Table 3 that shows specific processing capacities.

Figure 4. The different processes for producing VCO

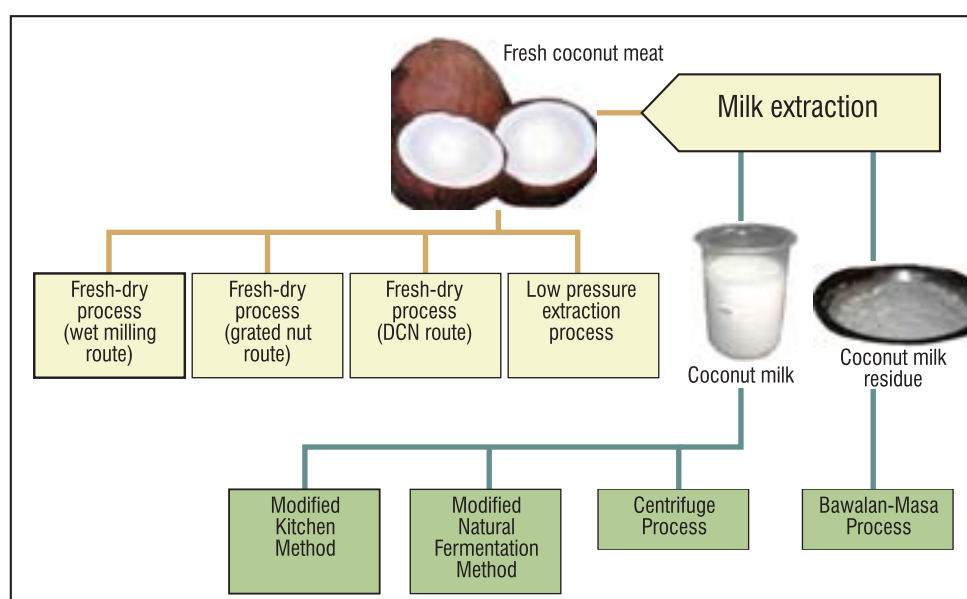


Table 3. Required coconut supply base (ha) for specific processing capacities at different tree productivity rates (nuts/tree/year)*

Desired processing capacity (nuts/day)	Productivity: Nuts/tree/year					
	35	40	50	55	60	65
Required coconut supply base (hectares)						
100	8.57	7.50	6.00	5.45	5.00	4.62
200	17.14	15.00	12.00	10.91	10.00	9.23
400	34.29	30.00	24.00	21.82	20.00	18.46
500	42.86	37.50	30.00	27.27	25.00	23.08
600	51.43	45.00	36.00	32.73	30.00	27.69
800	68.57	60.00	48.00	43.64	40.00	36.92
1000	85.71	75.00	60.00	54.55	50.00	46.15
2000	171.43	150.00	120.00	109.09	100.00	92.31
3000	257.14	225.00	180.00	163.64	150.00	138.46
4000	342.86	300.00	240.00	218.18	200.00	184.62
5000	428.57	375.00	300.00	272.73	250.00	230.77

* Calculations are based on 300 days per year of operation of the intended processing plant and the assumption that there are 100 productive coconut trees per hectare. Productivity rate is given in terms of number of nuts produced per tree per year.

Source: Bawalan (2003)

VCO produced by each process exhibits different organoleptic characteristics, so the process used for producing VCO can be identified by sensory evaluation. Coconut milk is an emulsion of oil and water that is stabilized by protein. To recover the oil from coconut milk, the protein bond has to be broken either by heat or by enzymes or some other mechanical means. For example, the different methods of the fresh-dry process 1 to 3 shown in Figure 4 and Table 4, use water-cooled, high pressure expellers. Methods 1 to 8 in Table 4, differ only by the manner in which the fresh meat is prepared prior to oil extraction.

The export market at present provides a lower price for VCO produced from expellers than VCO produced from coconut milk.

Table 4. Comparative assessment of different processes for producing VCO

Type of process	Quality of oil and recovery	Advantages and limitations
1. Fresh-dry process (Wet milling route) (High Pressure Expeller Method) M.C. of meat for extraction should be 3 – 4%	FFA: 0.05 – 0.08% M.C.: 0.07 – 0.1% Colour: water-clear Oil recovery: 31 kg/100 kg of fresh milled coconut meat (Based on 50 % initial M.C. of fresh meat)	Produces full protein, medium fat coconut flour as a co-product. Long shelf-life of oil: 1 yr and more. Uses mechanical type of equipment to produce the oil. Can be produced in a village-scale plant operation.
2. Fresh-dry process (Desiccated coconut route) (High Pressure Expeller Method) M.C. of meat for extraction should be 3 – 4%	FFA: 0.05 – 0.08% M.C.: 0.07 – 0.1% Colour: water-clear Oil recovery: 30 kg/100 kg of fresh, pared, ground meat (Based on 50 % initial M.C. of fresh meat)	Produces full protein, medium fat coconut flour without testa as a co-product. Long shelf-life of oil: 1 yr and more. Uses mechanical type of equipment to produce the oil. High investment cost, suited only to medium scale plant operation (10,000 nuts/day and above).
3. Fresh-dry process (Grated coconut route) (High Pressure Expeller Method) M.C. of meat for extraction should be 3 – 4%	FFA: 0.05 – 0.08% M.C.: 0.07 – 0.1% Colour: water-clear Oil recovery: 30 kg/100 kg of fresh grated meat (Based on 50 % initial M.C. of fresh meat)	Produces full protein, medium fat coconut flour without testa as a co-product. Long shelf-life of oil: 1 yr and more. Uses mechanical type of equipment to produce the oil. Can be done in a micro-scale plant operation.
4. Low Pressure Method M.C. of meat for extraction should be 10 – 12% for bridge press and DME expeller, and 7 – 10% for Thai S. Steel Expeller ¹	FFA: 0.1 – 0.2% M.C.: 0.17% and above Colour: water-clear Oil recovery: 24.5 kg/100 kg of fresh grated coconut meat (Based on 50 % initial M.C. of fresh meat)	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 is very short if not immediately dried by gentle heating after extraction to remove water.

¹ Thai expeller costs about USD3500, while Bridge Press costs USD500 to USD600. The Thai Expeller can process 200 to 250 kg/hr of fresh meat to give coconut milk or about 30 kg/hr of 7% M.C. meat to give VCO.

Type of process	Quality of oil and recovery	Advantages and limitations
5. Traditional Wet or Modified Kitchen Method M.C. of fresh meat for extraction is approx. 50% Coconut milk is starting point for VCO extraction	FFA: 0.06 – 0.2% M.C.: 0.07 – 0.14% Colour: water-clear to pale yellow depending on the heating process (max temp 90°C). Oil recovery: 19 kg/100 kg of fresh grated coconut meat. (Based on 50 % initial M.C. of fresh meat). Milk extraction done using manually operated press or Thai wet-market type hydraulic coconut cream milk press or Thai S. steel VCO/cream expeller.	Very low investment cost. Can be produced in a home-scale operation using ordinary kitchen utensils. Produces a wet coconut residue that must be further dried or processed to have market value. Produces a by-product (proteinaceous residue) with no commercial value at present. After 5 days, oil becomes rancid if it is not properly heated to dryness after extraction to remove water. Class B oil can be recovered from residue after Class A oil is skimmed off. This will give 19 kg of total oil recovery (Class A + Class B).
6. Modified Natural Fermentation Method M.C. of fresh meat for extraction is approx. 50% Coconut milk is starting point for VCO extraction	FFA: 0.1% M.C.: 0.12% & below Colour: water-clear Oil recovery: 19.8 kg/100 kg fresh grated meat. (Based on 50 % initial M.C. of fresh meat). Milk extraction done using manually operated press or Thai wet-market type hydraulic coconut cream milk press or Thai S. steel VCO/cream expeller.	Can be produced in a home-scale operation using ordinary kitchen utensils or in a micro-scale operation using semi-mechanised equipment. Disposal of fermented skim milk could be a problem if carried out at capacities above 2,000 nuts/day. Skim milk must be diluted with water before disposal to waste. Oil produced could turn sour if fermentation period is prolonged. Oil must be properly heated to dryness after extraction to remove water and prevent rancidity development. Class B oil can be recovered from residue after Class A oil is skimmed off. This will give 19 kg of total oil recovery (Class A + Class B).
7. Centrifuge Process M.C. of fresh meat for extraction is approx. 50% Coconut milk is starting point for VCO extraction	FFA: 0.04 – 0.08% M.C.: 0.1% and below Colour: water-clear Oil recovery: 17 kg/100 kg fresh ground coconut meat. (Based on 50 % initial M.C. of fresh meat). Note: Reported oil recovery value here was calculated from information provided by a VCO processor in the Philippines using the two-stage centrifuge process. Single stage centrifuge process operation may have a different oil recovery rate. Milk extraction is done using a motorised milk extractor.	Produces the best quality coconut oil with sweet coconut aroma if done in a two-stage centrifuge process. Can only be produced in a medium to large-scale operation (above 10,000 nuts/day), as investment cost is very high. Further processing of skim milk into a health beverage and the meat residue into coconut flour can improve profitability. Tables 10 and 11 in Annex 1 give details on nutritional composition and amino acids in coconut skim milk.

There are eight different technologies available for producing VCO – only the processes which are applicable in micro- and village-scale operations are discussed in this manual.

Type of process	Quality of oil and recovery	Advantages and limitations
8. Bawalan-Masa Process The process uses coconut milk residue as raw material. The residue is blanched and dried at a specific moisture content and defatted under controlled conditions. Specially designed equipment produces VCO and low fat, high fibre coconut flakes. The flakes are ground to produce coconut flour with high dietary fibre.	FFA: 0.05 – 0.08% M.C.: 0.07 – 0.12% Colour: water-clear Oil recovery: 17 kg/100 kg of wet residue. From 100 kg of grated fresh meat generated 46.7 kg of wet residue which can be further processed to give 7.94 kg extra oil.	Further recovery of high value oil from residue makes coconut milk processing more profitable. Long shelf-life of oil: 1 yr and more. Produces low fat, high fibre coconut flour as a co-product. Requires mechanical type of equipment to produce the oil. Production process has to be attached or integrated into an existing coconut milk processing plant.

Source: Revised table from Bawalan D.D., 2002.

Critical Control Points in processing VCO

Common processing Critical Control Points

To ensure that only high quality VCO will be produced, the following Critical Control measures should be applied in all of the processes discussed in this VCO manual. Critical Control Points for individual processes are given later in manual.



These Critical Control Points are used in all the following processes and methods

Receipt and inspection of nuts

All de-husked nuts are inspected to segregate and reject immature, germinated or spoiled nuts when delivered to the plant. Only fully mature nuts, 12 to 13 months old, should be used for VCO production. As an indicator of maturity of the nut, the husk and shell is brown in colour and the nut makes a sloshing sound when shaken.

Always ensure that the nut, while fully mature, does not have a haustorium (Figure 5) because the oil content of the kernel starts to decline once the haustorium is formed and the quality deteriorates as the haustorium grows bigger.

Proper procedures must be adopted so that nuts do not break while unloading. Likewise, exposure to sunlight of the de-husked nuts during delivery, weighing and unloading should be avoided to prevent cracking of the shell that will cause spoilage. Nuts will crack and begin to decay after one hour in the sun.

Storage

De-husked nuts should be kept in clean storage areas with cement floors, good ventilation and adequate rain/sun cover. Avoid sun exposure of the de-husked nuts. Storage bins should be designed and partitioned so that the principle of first-in-first-out can be easily implemented. The pile of de-husked nuts should not be placed directly on the cement floor but on an elevated platform (pallet) with slats so that the coconut water can flow away if breakages occur. Maximum height for the storage pile of fresh nuts should not exceed 1.8 metres.



Figure 5. De-husked coconuts with haustorium; these are not suitable for VCO processing

Sanitation is covered in Chapter 4



See Annex 4 for how to make coconut vinegar

Remember!
Water is the arch enemy of oil!

Oil drying temperatures should not exceed 65°C or the resulting yellow oil will then be classified as Class B oil and not VCO.

De-husked, fresh coconuts should be processed within seven days from the time of harvest. Therefore the VCO processing facility should be placed within the coconut producing areas to ensure freshness of raw material and to lower transport costs of the nuts.

Handling of coconut water

Coconut water spoils and ferments very rapidly once the nut is opened. When the nut is split, coconut water should be collected in a container and properly disposed of in one of two ways. As another source of income it can be converted into vinegar — or other products including nata de coco and electrolyte drinks, or diluted with water and flushed into soakage pits or the sewage system.

Coconut water should not be left on the floor as it will attract flies and become a source of contamination. Undiluted coconut water becomes very acidic and will destroy the cement surface of the floor if it is not tiled. It also generates a foul smell once fermentation has started.

Drying and handling of VCO

Water in oil causes it to go rancid thus shortening its shelf-life. To ensure the VCO will have a long shelf-life, it should be subjected to an oil-drying process after recovery from coconut milk or extraction from dry grated or granulated coconut meat. Removal of residual moisture is critical in the VCO produced from the Modified Kitchen Method and the Modified Natural Fermentation Method. Because both are wet extraction processes, that is, recovery is from meat with an intermediate moisture content, the end product will contain more moisture than with high pressure expelling. Drying of the oil can be achieved using one of the following methods.

- Place the extracted oil in a double boiler and heat for about fifteen minutes or until the oil has changed from turbid to water-clear colour. Oil temperature should not exceed 65°C.
- Incubate or air-heat the oil in the container at 50°C for 12 hours or until the oil has changed from turbid to water-clear colour.
- Vacuum dry using a commercial vacuum dryer at 50°C.

Vacuum drying is the most effective way of drying oil without the risk of the colour turning yellow but the investment cost is high, so it is not a viable option for micro-scale processing.

A double boiler can be made by placing a stainless steel mixing bowl or basin in a larger pan that is half filled with water. Pour the oil into the smaller container. Once the water in the pan starts to boil, reduce the heat to the lowest possible setting so that the hot water remains at a simmer point.

Do not allow oil to boil or the container to boil dry!

Handling coconut milk

Modified Kitchen and Natural Fermentation Critical Control Points

Coconut milk contains protein and other nutrients, is low in acid and has a high moisture and nutrient content making it very susceptible to microbial contamination and rapid spoilage. Because of these characteristics, grating or milling of fresh coconut meat and subsequent extraction of the milk should be done in a clean environment and under very strict sanitary conditions. The following critical control measures must be applied at all times:

- Always ensure that grating or scraping of coconut meat and subsequent milk extraction is done under sanitary conditions by observing good personal hygiene. Wash hands with soap and water before doing any preparation work, wear the necessary protective clothing with hair cover. Do not wear jewellery on the hands or arms.
- Ensure that all materials, utensils or equipment used in extracting and holding coconut meat and milk are thoroughly cleaned and rinsed with hot water. Utensils should be free from any soap residues.
- High quality clean water should be used for the diluent or re-hydrating agent for the second milk extraction. It should be free from microbial contamination and low in mineral content. Filtered, purified or demineralized water is preferable. Coconut water can also be used as a diluent, but a specific handling procedure must be observed to avoid microbial contamination. The coconut water must be filtered and immediately placed in a refrigerator or ice box while waiting for the grating and first milk extraction to be completed.



Preparing VCO samples from expeller oil for quality checking

Personal and facility hygiene is absolutely essential!

NEVER HEAT VCO oil in a pan on direct heat as this will cause the oil to turn yellow.

Drying the oil by heating will ensure that the water content of the oil is less than 0.2% and preferably less than 0.1%. Processing containers and packaging material used for VCO storage must be thoroughly cleaned and dry before filling with the VCO.



Low Pressure Extraction and High Pressure Expeller Critical Control Points

The low pressure extraction methods and the high pressure expeller methods belong to the general category of Fresh-dry processing of VCO where the VCO is obtained by first drying the fresh, grated or comminuted coconut meat and then pressing the dried meat to separate the oil. Hence, in both processes, the most critical step is the drying of the meat. The following critical control measures must be observed when preparing the coconut meat for subsequent oil extraction.

- Dry the coconut meat within four hours of opening the nut. Delay in drying will allow bacterial contamination of the fresh meat and will result in an unacceptable yellow oil.
- Dry the grated or granulated coconut meat at a temperature of 70 to 75°C using an indirect, hot-air dryer, either steam heated or biomass fired. If the drying temperature is too low, bacterial contamination will occur resulting in an unacceptable yellow oil. On the other hand, if the drying temperature is too high, the grated meat will burn, also resulting in a yellow oil.
- Under conditions of low humidity and clear, hot days, the grated meat can be solar dried. A well-designed solar dryer can normally generate a drying temperature of about 70°C that is sufficient for the intended purpose. However, additional heat may be needed to ensure this temperature is reached on cloudy, rainy days. Open sun-drying is not recommended as grated meat can become contaminated with dust and insects and temperatures are too low to prevent bacterial breakdown of the meat.
- If using a direct contact dryer similar to the one being used in the South Pacific for the Direct Micro Expelling (DME) process, constant attention and turning of the grated meat is required to prevent it from becoming scorched or burnt, which will result in an unacceptable yellow oil.

Dry with care and maintain good hygiene handling

Remember that overheating makes oil yellow. Yellow oil does not qualify as VCO — it is Class B oil, not VCO

Modified Kitchen Method

For decades, people in coconut producing areas like the Philippines and India have boiled coconut milk extracted from freshly grated or comminuted coconut meat with or without the addition of water, to produce coconut oil for hair and massage applications. However, the oil produced from this process is dark yellow in colour with a very short shelf-life — it normally becomes rancid within three to five days. The Modified Kitchen Method for producing VCO follows this principle except that the heating is controlled to prevent the oil from turning yellow, and the recovered oil is further dried to ensure that the moisture content is kept at less than 0.2 % to prolong its shelf-life and prevent rancidity.

The Modified Kitchen Method produces VCO with an intense coconut aroma but it has the lowest VCO recovery of the available technologies because a large proportion of oil remains entrapped in the proteinaceous residue (latik). This method requires precise temperature control and timing during the heating process to prevent the oil from turning yellow. However, Class B oil can be recovered by further heating or toasting the latik after the Class A VCO is recovered at a lower temperature with a maximum of 90°C.

Making VCO by this method is tedious and requires precise temperature control. Generally, the process is not recommended except when the fermentation process fails.



See Table 6 Step 3, and Table 7 page 36, Step 5 for details

Extraction and preparation

The Modified Kitchen Method comprises two distinct parts – extraction/preparation of coconut milk and processing of the VCO from the milk. Figures 6 and 7 and Table 5 demonstrate the work-flow from de-husking of coconuts to the extraction of the coconut milk.

Read and follow the Critical Control Points in Chapter 1, before starting production of VCO using the Modified Kitchen Method.

See **Critical Control Points** page 23



Figure 6. Flow chart for the extraction and preparation of coconut milk

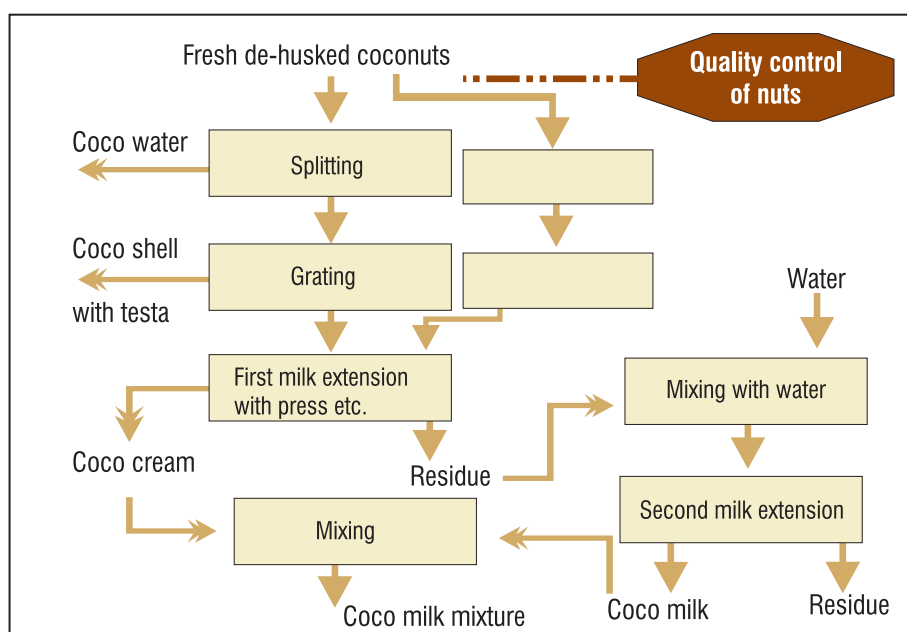


Table 5. Process for the extraction and preparation of coconut milk

Process	Action to take
Selecting nuts	Select fully matured nuts (12 to 13 months old) and de-husk; the husk should be turning brown — not green.
1) Splitting and grating	Split the de-husked nut into two and grate the meat either manually or through the use of motorised grater. Another method is to manually de-shell the coconut and feed the meat with testa into a Thai motorised coconut shredder.
2) First milk extraction	Extract the milk from the grated coconut meat either by hand or by manually operated or motorised coconut milk press. This can be the hydraulic type, vertical screw or horizontal screw type press, manually operated or motorised. Set aside the milk obtained. Prepare the coconut milk residue (sapal) for second extraction.
3) Second milk extraction	Do a second milk extraction by mixing water with the sapal obtained from the first milk extraction using a ratio 2 sapal:1 water. Press the residue again.
4) Mixing of first and second milk extracts	Mix thoroughly the first and second milk extracts by stirring vigorously for about 10 minutes.

Source: Revised excerpt from Bawalan, (2004)

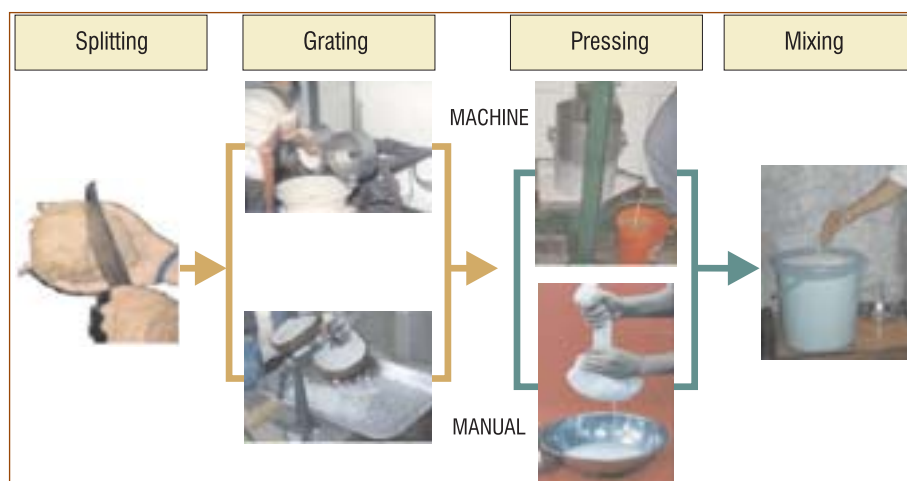


Figure 7. Major steps for preparation and extraction of coconut milk



Scraping coconuts using a hand rotary scraper machine in Sri Lanka



Preparing coconuts for scraping at the village processing facility in Thailand. The meat is then pressed to extract the VCO.

Processing of VCO

Figures 8 and 9 and Table 6 demonstrate the Modified Kitchen Method for processing of coconut milk to produce VCO.

Table 6. The Modified Kitchen Method for processing of coconut milk to produce VCO

Process	Action
1) Settling of the coconut milk mixture	<p>Allow the coconut milk mixture to stand for a maximum of three (3) hours.</p> <p>Note 1: If the settling is done in the refrigerator or in an ice box, coco skim milk which is a very nutritious beverage containing protein and micronutrients such as calcium, potassium, phosphorus, niacin, thiamine and riboflavin, can be recovered for human consumption (see Tables 10 and 11 in Annex 1 for the nutritional value of coconut skim milk). Likewise, the proteinaceous residue (latik) can be eaten with rice cakes or used in cooking as a meat extender. Skim milk is a very perishable food item so it has to be consumed immediately after separation or, to prolong its shelf for a day, it must be pasteurised at 67°C for 20 minutes in a double boiler. Heating it to higher temperature will destroy the flavour.</p> <p>Note 2: Settling the coconut milk at ambient temperature (not in the refrigerator) will cause the skim milk and resulting latik to turn sour — it is unsuitable for human consumption.</p> <p>Note 3: Settling of coconut milk can be bypassed by going directly to slow heating step 3. However, it will take a much longer heating time to recover the oil.</p>
2) Separation of coconut cream and coco skim milk	<p>Separate the cream (oily part) from the coco skim milk (watery part) by scooping the cream from the top.</p> <p>Note 4: Coco skim milk can be kept in the freezer for processing later into beverage or properly discarded if it has no further use.</p>
3) Slow heating of the coco cream	<p>Place the coco cream in a double boiler and heat very slowly to coagulate the protein and release the oil. After slow heating for about 2 to 2.5 hours, coconut protein (latik) will coagulate and the oil will separate out (Class A VCO). For the first hour of heating, temperature can be allowed to reach 90°C. After this time, the temperature should not exceed 80°C until the protein begins to coagulate. When the oil starts to separate from the coagulated protein, lower the temperature to 60°C.</p>
4) Separation of oil and latik	<p>Separate the oil from the latik by straining the mixture through a muslin cloth or in a stainless steel screen with fine mesh placed over a stainless steel pot. Set aside the latik.</p> <p>Note 5: If the settling of milk (Step 1) is done in a refrigerator or in an ice-box, the recovered latik can be eaten or used as meat extender in some food formulations.</p>
5) Oil drying	<p>This is required to ensure that all residual moisture is removed to prolong the shelf-life of the VCO. See <i>Drying and handling VCO product</i> for the Critical Control Points that must be observed.</p>
6) Final filtration of oil	<p>Oil is filtered to remove adhering fine particles of latik that passed through the muslin cloth.</p> <p>Note 6: One practical and simple way of filtering the oil is by pouring the oil over sterilized cotton wool placed in the hole of a big funnel, and allowing it to trickle down. For a large-scale operation, a fabricated pressure filter with filter cloth is recommended to increase filtration rate.</p>
7) Packaging and storage	<p>VCO may be stored in stainless steel containers and poly-lined drums. Pour oil into very dry bottles for marketing.</p> <p>Note 7: The recommended packaging material for VCO is glass. PET bottles (plastic bottles normally used for mineral water) can be used in cases where the VCO is immediately consumed. Glass is recommended if the VCO is sold in stores where it may remain on the shelf for several weeks.</p>

Source: Revised excerpt from Bawalan, (2004)

Critical Control Points specific to Modified Kitchen Method

Aside from the critical control points discussed previously, heating of the coconut milk or cream is the major critical step in the Modified Kitchen Method as this will determine whether the oil recovered will be water-clear (Class A) VCO, or yellow (Class B) oil which will preclude it from being classified as 'virgin'.



VCO must be water-clear

Figure 8. Flow chart for processing coconut milk to produce VCO

Oil recovery, 19 kg/100 kg of fresh coconut meat

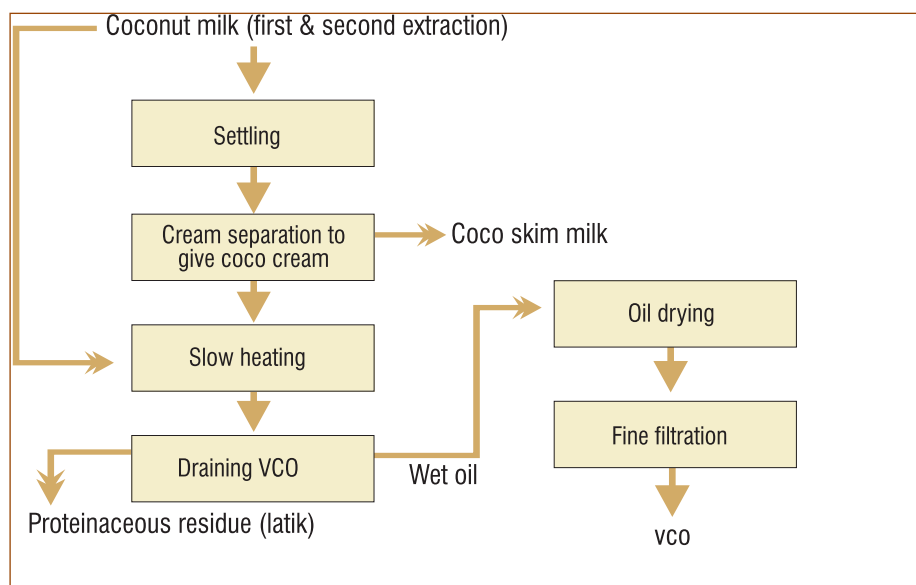


Figure 9. Major steps for processing coconut milk to produce VCO



Control measures should be observed at all times. Do not allow the proteinaceous latik to turn brown.

The following control measures should be observed at all times to ensure that only water-clear oil will be recovered.

- Begin by heating the coco cream in the double boiler at medium heat until it is almost boiling; then reduce the heat to low until the latik coagulates and the coconut oil separates out. Stir the coco cream to disperse the heat.
- Heating should be done in such a way that the coconut cream in the pan will just simmer and not boil (max temperature 90°C).
- Do not allow the proteinaceous latik to turn brown as this will give a yellow coloured coconut oil. Once the Class A VCO separates from the latik (Figure 9), remove it from the pan. The remaining latik can be further heated to recover more oil. However, this type of Class B oil will already be yellow and only suitable for skin care or massage products.

Equipment and accessories

The Modified Kitchen Method is often carried out in a home-scale operation. Hence, manual grating and manual squeezing of coconut milk is not uncommon. The following equipment list is applicable at micro- and village-scale operation.

1) Motorised coconut grater. Processing capacity of 50 to 80 nuts per hour depending on the skill of the operator, stainless steel blade and housing of the 1/2 HP electric motor, direct drive units. Fabricated in the Philippines and Thailand (Figure 10).

2) Coconut milk presses

Bridge press. Manually operated, vertical screw type press, with perforated holding basket and receptacle trough. All materials in contact with the coconut meat are made of stainless steel; 9 kg grated meat (20 nuts) per load; 15 to 20 minutes pressing cycle per load; process capacity about 60 to 80 nuts per hour (Figure 10). Fabricated in the Philippines; original design from the Agro Processing Division, Natural Resources Institute, Chatham, Kent, United Kingdom. Thai version is manufactured by Ngow Huat Yoo, Bangkok, Thailand.

Horizontal screw press. Manually operated; continuous feed without the need for a holding bag; 47 kg grated meat (100 nuts) per hour for a two-pass extraction. The first and second extraction requires mixing grated meat with water; all materials in contact with coconut meat are made of stainless steel. Designed and fabricated in Cavite, Philippines.

Hydraulic jack. Manually operated with fixed head; perforated holding basket and circular receptacle with downspout; 10 tons capacity hydraulic jack; all materials in contact with the coconut meat made of stainless steel; 2.5 kg grated meat per load (4 to 5 nuts); 5 minutes pressing cycle per load; process capacity of about 48 to 60 nuts per hour. Designed and fabricated by PCDR Metalwerke, Caloocan City, Philippines. Similar presses are available in Sri Lanka.

In Thailand, coconut milk is produced in wet markets using a coconut shredder to chop up the meat of the whole coconut after it is removed from the shell (Figure 10). The meat is then put into a triple layered material bag and the milk is extracted by a stainless steel motorised hydraulic press (Figure 11). This unit is suited to micro- and village-scale operations. Capacity of the press is 30 to 40 kg/hour (double-pressed) of fresh grated meat. Alternatively, a Thai motorised horizontal screw expeller can double press 200 to 250 kg/hr of fresh meat to produce coconut milk. This unit can produce VCO directly if moisture content of meat is 7 to 10%. All units are supplied by Ngow Huat Yoo, Bangkok, Thailand.

3) Wok, cast iron. Diameter 68 cm, 20 L capacity. Converts into an improvised double boiler with the addition of stainless steel



Figure 10. Motorised Philippine grater (top photo). Thai grater (centre) and shredder (bottom photo)



Figure 11. Vertical screw-type bridge press to produce milk
(a) Philippine bridge press
(b) Philippine horizontal screw press
(c) Hydraulic jack press; stainless steel, motorised

basin; fabricated metal support (stainless steel) with stainless steel funnel for adding water. Design concept for the improvised reboiler by Divina D. Bawalan. Electric woks may also be used.

4) Stove with appropriate housing to fit a wok. Coconut husk, shell, coconut shell-charcoal or gas fired stove (Figure 12).

5) Manual filtering device. Gravity type, 18 L capacity per batch; designed by Divina D. Bawalan (Figure 13).

Quality control

Laboratory analysis of a VCO sample should be done to make certain it meets the domestic and international standard approved for the product. However, for micro- and village-scale operation, submitting a sample for laboratory analysis for every production batch is not economically viable. In addition, properly equipped, quality control laboratories that can do the analysis of VCO samples are not always located close to the production areas. The practical approach to this problem then,

is to have the processors standardise their methods, and strictly adhere to the instructions and recommendations in this manual of the Critical Control Points that should be observed for every step.

This manual is a foundation for the establishment of the Good Management Practices (GMP) and HACCP systems that should be the goal in every VCO processing facility. The need for regular laboratory analysis on VCO production batch samples can be greatly reduced once the process has been standardised. The procedure in this manual, Critical Control Points, GMP and HACCP systems must be established and strictly adhered to by the processor who then develops confidence in the process and the quality of the products.

While standardising a particular process, the VCO processor is required to submit samples for laboratory analysis for benchmark data. The processor will be confident that a high quality product is being produced after the quality control systems have been set in place, and four laboratory analysis reports of samples from different production batches reveal the same results that pass the prescribed standard for VCO. The processor can limit the submission of samples for analysis to four times per year or when a buyer requests an analysis. In the meantime, a sensory evaluation and visual examination are routine quality checks.

Good Management Practices (GMP) and HACCP systems should be the goal in every VCO processing facility.



IMPORTANT

Coconut oil is not entitled to the label 'Virgin' if there is any other substance added to it.



Figure 12. Equipment for heating of cream and oil drying. Coco shell fired stove (top), improvised re-boiler (below)



Figure 13. Small gravity type filtering device (top) and storage container for VCO (lower)

On a bulk basis, the expeller-pressed process is being considered 'cold-pressed' and is currently priced lower than VCO produced from the Modified Fermentation Process. However, if the VCO is already packed in small bottles for retail, then the price is almost the same. Some producers are also putting the term 'cold pressed' on their labels and large repackers are buying expeller-pressed VCO.

The issue on heat or no heat process for VCO production is still being debated, but the VCO Association and concerned government agencies are now more vigilant in checking misleading labels and advertising. Any company or producer with misleading advertising will be asked to change this under the VCO standard which states that no additive is permitted, that is, the coconut oil is no longer entitled to the label 'Virgin' once there is any other substance added to it.



Training the trainers class in VCO technology and quality control (left) and acquiring the finer points of choosing coconuts (right).



TEACH BY
SHOWING!
LEARN BY
DOING!

Modified Natural Fermentation Method

Fermentation generally means the addition of yeast or enzyme or suitable micro-organism to a feedstock to obtain a desired product. However, in the case of the Natural Fermentation Method for producing VCO, no other substance is added. It has been observed that when a coconut milk mixture is allowed to stand for more than 10 hours under favourable conditions, the oil naturally separates from the water and the protein. The mechanism for this natural separation without the addition of any fermentation agent is unexplained. One theory is that the natural enzyme in coconut meat, which is subsequently transferred to the coconut milk, is being activated at some point. Another theory is that airborne lactic acid bacteria, which have the capability to break the protein bonds, act on the coconut milk causing VCO separation. It can be surmised that the term, Natural Fermentation Method, was coined because the water and the curd that separate out from the oil, smell and taste sour. It is 'natural' because no other substance is added to achieve the fermentation.

Of all the VCO processing technologies, the Modified Natural Fermentation Method has the lowest labour requirement and the least energy input. However, if the fermentation process is not properly controlled, then it produces oil with a sour smell and relatively higher free fatty acid content nullifying the saving in labour costs as the oil cannot be classed as VCO. Precise controls for the maturity of coconuts and the ambient conditions for the fermentation room are necessary to obtain good, high quality oil recovery.

The Modified Natural Fermentation Method comprises two distinct parts – extraction/preparation of coconut milk and processing of the VCO from the milk.

Extraction and preparation

Production of coconut milk for Modified Natural Fermentation Method is the same as for the Modified Kitchen Method.

Read and follow the Common Critical Control Points in Chapter 1 before starting production of VCO using the Natural Fermentation Method.

Processing of VCO

Figure 14 and Table 7 demonstrate the Modified Natural Fermentation Method of processing coconut milk to produce VCO. Pictorial photographs of major process steps for the Natural Fermentation Method are the same as those in Figure 8.

In the traditional Natural Fermentation Method, settling and subsequent fermentation of coconut milk is done for 36 to 48 hours. However, laboratory analyses of VCO produced using

The Modified Natural Fermentation Method has the lowest labour requirement with the least energy input of all the methods.

Oil recovery is 20 kg/100 kg fresh coconut meat.



See page 23 *Extraction and preparation*

See
Critical
Control
Points
page 23



this process, show that the free fatty acid (FFA) content (33% to 38%) greatly exceeds the prescribed standard of maximum 0.1%. Likewise, in many cases, coconut oil produced will be pale yellow in colour and will not meet the VCO standard.

Figure 14. Natural Fermentation Method of processing coconut milk to produce VCO

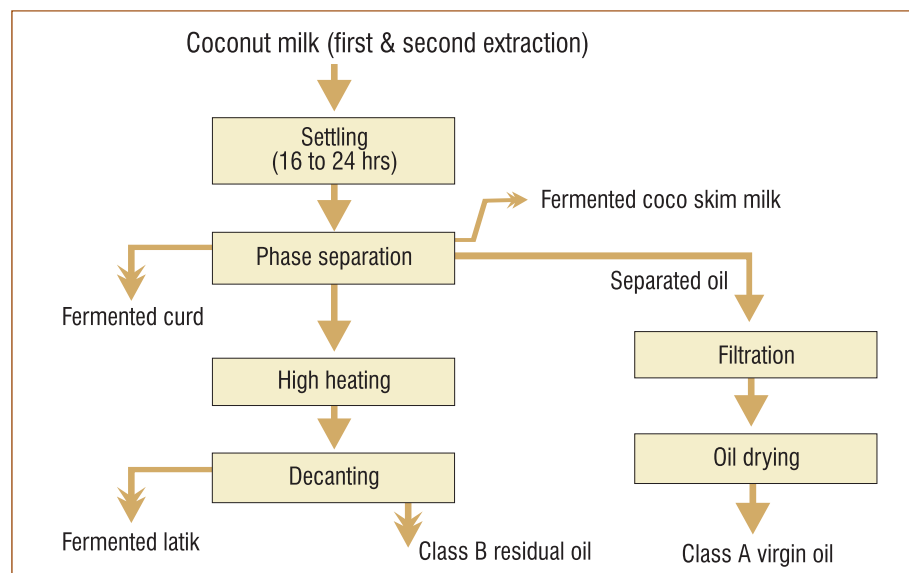


Table 7. The Modified Natural Fermentation Method of processing coconut milk to produce VCO

Process	Action
1) Settling of the coconut milk mixture	<p>Allow the coconut milk mixture to stand for 16 – 24 hours in a place where the temperature can be maintained at 35 – 40°C. (Figure 15).</p> <p>Note 1: If the intention is to recover coco skim milk for further use as a beverage, then two-stage settling has to be carried out (the first stage settling is done in the refrigerator or ice box for 3 hours (see Table 5 step 1). After separating the cream from coco skim milk, the cream is again allowed to settle (second stage settling at 35 – 40°C) for 13 – 21 hours.</p>
2) Separation of the oil and fermented curd layers	<p>Separate the oil from the fermented curd by using a ladle to scoop the oil off the top.</p> <p>Note 2: Dispose of the water phase (fermented skim milk) and gummy portions by diluting with water before draining into a grease trap and then into the sewage system or soakage pit. Put the fermented curd and the oil in separate containers.</p>
3) Oil drying	<p>Drying is required to ensure that all residual moisture is removed to prolong the shelf-life of the VCO. See Drying and handling for the options and the Critical Control Points that must be observed in oil drying.</p> <p>Note 3: Apart from removing the residual oil, heating the VCO in a double boiler or vacuum dryer will ensure that fermentation will be stopped. It will also remove the faint sour smell in the oil.</p> <p>Note 4: If the oil is subjected to incubation (air-drying) or vacuum drying, then it needs to be filtered first (Step 4).</p>
4) Filtration of oil	<p>Filter the VCO to remove adhering particles of fermented curd.</p> <p>Note 5: Filtration of the VCO produced from the Modified Natural Fermentation Method does not require special filtration equipment as only relatively large particles of curd near the surface of the oil need to be separated. Any filtering medium that can trap the curd will be appropriate.</p> <p>Note 6: One practical and simple way of filtering the oil is by pouring the oil over sterilized cotton wool placed in the hole of a big funnel, and allowing it to trickle down. For a large-scale operation, a fabricated pressure filter with filter cloth is recommended to increase filtration rate. See also the Bawalan Gravity Filter, Figure 13.</p>

Process	Action
5) Heating of fermented curd	<p>After VCO separation, the fermented curd is heated to recover the residual Class B oil that can be used for making skin care products and herbal soaps. The oil is separated from the heated curd by following the procedure in the Modified Kitchen Method (see Table 5 step 3). The temperatures are not as strictly controlled but should not exceed 90°C or the oil will become dark yellow.</p> <p>Note 7: After the Class B oil is recovered, the toasted curd can be mixed with other compost material and use as organic fertiliser.</p> <p>Note 8: The Class B oil recovered by heating should be dried in a double boiler. Do NOT MIX with the Class A VCO.</p>
6) Packaging and storage	<p>VCO may be stored in stainless steel containers and poly-lined drums. Pour oil into very dry bottles for marketing.</p> <p>Note 9: The recommended packaging material for virgin coconut oil (VCO) is glass. PET bottles (plastic bottles normally used for mineral water) can be used in cases where the VCO is immediately consumed. Glass is recommended if the VCO is sold in stores where it may remain on the shelf for several weeks.</p>



Figure 15. Different Stages in the Natural Fermentation of Coconut Milk. Initial stage (a), transition stage (b), final stage (c)

Critical Control Points specific to Modified Natural Fermentation Method

Aside from the general critical points discussed previously, settling and subsequent fermentation of coconut milk is the most critical step in the Modified Natural Fermentation Method. While the process appears very simple, it requires proper control of operating conditions and observance of strict sanitary measures and critical control procedures for good quality Class A VCO to be produced. Sometimes no oil is separated at all, even after 24 hours. Occasionally the coconut milk mixture that is left to settle for 16 to 24 hours will generate big bubbles and overflow the fermenting container with no oil being separated. To ensure that good quality VCO is produced, the following measures must be observed.

- Maintain a fermentation temperature of 35° to 40°C in the area where the fermenting container will be placed. Relative humidity within the area should also be maintained at a maximum of 75%. A properly designed fermentation cabinet with electric, incandescent bulbs strategically placed to help raise the inside temperature when needed is an ideal way to do this. A small electric heater with built-in thermostat control can also be installed in the fermentation cabinet.



Fermentation temperature is critical — 35° to 40°C is ideal.



Figure 16. Different layers of fermented coconut milk

Under these conditions, a fermentation time of 16 hours results in a relatively high yield of fine quality VCO. At lower temperatures, less oil is recovered.

- The major cause of the bubbling problem mentioned above, is contamination, either through soap residues in the fermenting container or invasion of micro-organisms. Hence, strict sanitary measures must be observed at all times.

Note: If this bubbling problem occurs, immediately put the mixture in the evaporating pan and apply the Modified Kitchen Method so that oil can be still recovered. However, this oil that will be considered Class B oil and should only be used for making herbal soap and skin care products. It is not suitable for human consumption.



Figure 17. Philippine continuous motorised horizontal screw type coconut milk press (top). Thai motorised expeller unit for coconut milk or VCO (bottom)

- After the coconut milk is placed in the settling/fermentation container, it must be covered with either a loose fitting lid or cloth to stop aerial contamination by yeast, moulds or bacteria.
- The Modified Natural Fermentation Method is very sensitive to the maturity and freshness of the nuts. Immature nuts contain a higher percentage of protein which makes the protein bonding in coconut milk much more difficult to break and release the oil. Likewise, the longer coconuts are stored, the higher the risk of spoilage and the higher the risk of contamination. To ensure that the oil will naturally separate from the coconut milk upon settling for 16 to 24 hours, only newly harvested, fully mature coconuts should be processed by this method.

If proper operating conditions and sanitary precautions are strictly followed, five distinct layers can be seen in the fermenting container after settling for 16 hours (Figure 16). The bottom layer is made up of gummy sediment. The next layer is the watery, fermented skim milk that is no longer fit for human consumption and has to be properly discarded. The next layer is a solid layer of spent, fermented curd. Above this is the separated oil for recovery as VCO. The top layer is floating fermented curd. Note that fermented curd still contains a considerable amount of trapped oil.

Equipment and accessories

In the Philippines, most of the micro- and village-scale processors of VCO use versions of the Modified Natural Fermentation Method. There is a standard design for coconut graters as shown in Figure 10 but different types of coconut milk presses are used, such as the table-top versions of the manually operated vertical and horizontal screw and hydraulic

jack type presses or motorised presses etc., described previously. All the equipment listed in the Modified Kitchen Method is also applicable to the micro- and village-scale production of VCO using the Natural Fermentation Method. In addition, the following equipment is used.

- 1) **Motorised horizontal screw type coconut milk press.** 300 to 350 nuts per hour (100 to 110 kg/hr) of freshly grated or shredded coconut meat; 2 HP electric motor, single phase; stainless steel screw, built-in filter and housing. Designed and fabricated by Princena's Machine Shop, San Pablo City, Laguna, Philippines (Figure 17).
- 2) **Stainless steel horizontal screw expeller.** Used in Thailand to make coconut milk or VCO, depending on moisture content or grated coconut meat; capacity 200 to 250 kg/hr of fresh meat (two passes), 3 HP electric motor, single or three phase. Designed and supplied by Ngow Yuat Yoo, Bangkok, Thailand (Figure 17).
- 3) **Stock pots.** Stainless steel, assorted sizes; ladles and other accessories.
- 4) **Fermenting container.** Made of food-grade, transparent plastic. It should be wide-mouthed for easy removal of fermented curd and separated VCO. Capacity optional (Figure 18).

Note: The ideal fermentation equipment for the Modified Natural Fermentation Method is a fabricated stainless steel cylindrical tank (maximum capacity 100 L) with a conical bottom and equipped with various outlet points at specified levels and a sight glass to see the different layers as the oil separates. Oil can then be withdrawn from the outlet points based on the levels shown in the sight glass. However, this type of equipment is quite expensive for micro- and village-scale operation so most processors use transparent plastic containers of 1 to 10 L or more.



Figure 18. Fermentation containers



Figure 19. Thai coconut shredder (right) commonly used in wet markets, with motorised hydraulic presses to produce the coconut milk



Thai hydraulic press

Other appropriate equipment for comminuting coconut meat (instead of grating) is the Thai coconut shredder where the coconut meat is first removed from the shell using manual de-shelling tools or a de-shelling machine and then fed to the shredder. This has the following advantages (Figure 19).

- Much safer to use. The operator's hands are not near the rotating blade as is the case of standard motorised graters.
- Higher processing capacity. Makes it suitable for large-scale operations when coupled with a de-shelling machine.
- Higher oil recoveries. Recover more meat from the shell to process into VCO.

Quality control

Quality control required for VCO produced by the Modified Natural Fermentation Method, is the same as for the Modified Kitchen Method (See page 32).



High quality VCO is
always water-clear.

Low Pressure Oil Extraction Method

In the early 1990s, oilseeds specialists² in Britain conducted a series of studies on the effect of moisture content on the extraction of oil from various oilseeds. They found that low pressures of 460 psi (32 kg/cm²) and lower could be used for extracting oil when the moisture content of the material is within the range of 10 to 13%. The traditional process of oil extraction from oilseeds is through the use of high pressure expellers (above 1600 psi), at a feed moisture content of 3 to 4%. National Resources Institute (NRI) made available the design of the prototype bridge press appropriate for low pressure VCO extraction. However, the technology was not promoted in the Philippines because the difference in price with copra-produced oil for micro-scale production made it uneconomical at that time. Currently, an upgraded version of the bridge press is being used by several producers in the Philippines using the Modified Natural Fermentation Method to produce VCO (Figure 20).

The Direct Micro Expeller (DME) process for VCO production developed by Kokopacific, Australia, functions on the same principle as the Low Pressure Oil Extraction Method. The hand ratchet driven DME unit is used in tandem with a contact/conduction type dryer (Figure 21). This process is operating in Fiji, Western Samoa, Timor Leste and other countries for producing VCO.

A user of a DME dryer and a DME expeller for VCO production has given the following comments, compared with the Modified Natural Fermentation Method.

- The DME process is labour intensive. It takes more people to do the drying, turning and moving of small batches of grated coconut meat being dried in the contact dryer. This is necessary to prevent the grated meat from burning, which will make the oil yellow. The dryer is the standard DME contact stainless steel plate dryer design except that it is gas fired (instead of using coconut shell and husks as fuel). In addition to the drying team, more people are required to load the DME cylinders with partially dried grated meat (1.5 to 2.0 kg per load), do the pressing and remove the defatted meat afterwards.
- The DME process requires skill to dislodge the defatted meat from the loading cylinder after oil extraction. The length of time required to dislodge the material depends on the skill of the operator in manipulating the ratchet mechanism pushing the piston inside the cylinder. This results in downtime during operation thereby reducing process capacity.



Figure 20. Prototype bridge presses based on the design originally provided by NRI; Philippine (top) and Thai (bottom)

² Terry Hammond and Stafford Head (pers. com) from the Natural Resources Institute (NRI) in Chatham, Kent, United Kingdom

Another advantage of placing the partially dried grated meat in fine muslin bag when pressing the oil as in bridge press operation, is that the muslin bag acts as a pre-filter which considerably reduces the number of fine particles of meat being transferred to the oil during extraction.

Six to eight pressings can be done in one hour. (Note: The main reason for this residue dislodging problem is that partially dried grated meat is being placed directly in the loading cylinder so when it is pressed, the particles form a hard solid mass inside the cylinder. With the Bridge press developed by NRI, partially dried grated meat is placed in fine muslin bag which is then positioned in the perforated cylindrical cage for pressing. The muslin bag then easily slides out of the cage after pressing. However, this practice could not be applied in the DME press because the diameter of the loading cylinder or tube is too small).

- Based on the information from producers and owners, it takes a minimum of seven days to settle and clarify the DME oil to remove fine particles of meat. After filtration, the oil is allowed to stand for another seven days (total 14 days) before bottling or shipment to ensure that all fine particles trapped in the oil are removed.

Two to three DME press machines, depending on the operators, are needed to match the capacity of one bridge press in terms of throughput per hour for making VCO from coconut meat dried to 10 to 12% moisture content (Figure 21).

The Engineering Department of the Coconut Research Institute (CRI), Sri Lanka, has also developed low pressure oil extraction equipment for VCO production. Two types of presses are available — a small vertical screw type with the screw mounted on the cover of the holding cylinder where the partially grated coconut meat is placed, and a hydraulic jack type press (Figure 22).

Difficulty in dislodging the defatted coconut meat after oil extraction is encountered because partially dried grated meat is also directly loaded and pressed in the cylinder instead of putting it in fine muslin bags as in bridge press operation.



Figure 21. (a) Contact dryer, Siquijor Island, Philippines. (b) DME press in Timor Leste. (c) Drying grated coconut meat on contact dryer Timor Leste

Note: Unlike the DME press, the practice of placing the partially dried grated coconut meat in muslin bags and positioning it in the cylinder for pressing, can be easily adopted using the two types of Sri Lankan presses since the diameter of the cylinders are large enough for proper positioning of the bags.

Extraction and preparation

Figure 23 and Table 8 describe the Low Pressure Oil Extraction Method for producing VCO.

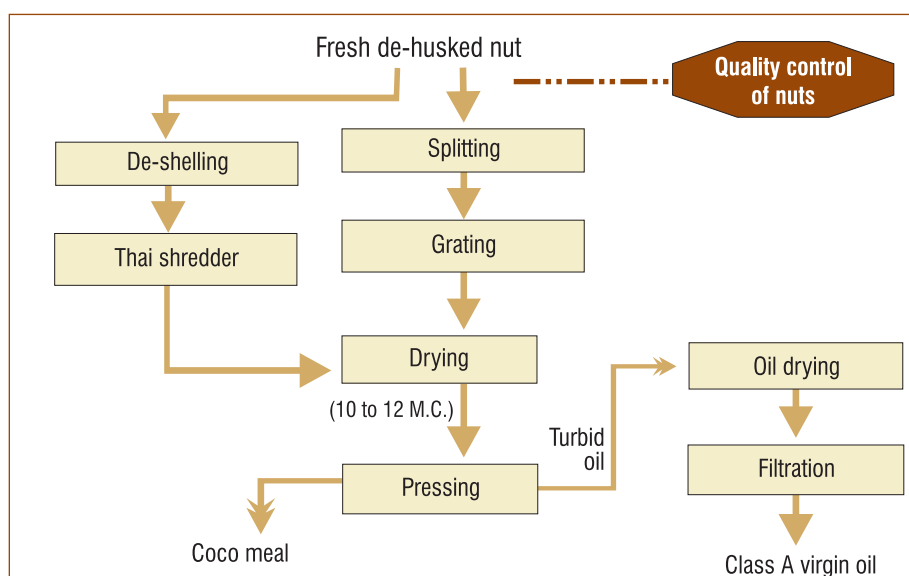
Processing of VCO

Read and follow the Common Critical Control Points before starting production of VCO by the Low Pressure Oil Extraction Method.

See
Critical
Control
Points
page 23



Figure 22. Sri Lankan vertical screw type (a) and hydraulic jack (b) type oil presses. Small Thai stainless steel hydraulic jack micro expeller at Chumphon HRC (c)



Oil recovery is
24.5 kg/ 100 kg
or fresh coconut
meat.

Figure 23. Process flow chart, Low Pressure Oil Extraction Method

Table 8. The Low Pressure Oil Extraction Method of processing

Process	Action
1) Selection of nuts	Select only fully matured nuts with no haustoria (12 – 13 months old)
2) Splitting and grating or shelling and shredding	Split the de-husked nut in halves and grate the meat, either manually or with a motorised grater. Note 1: Another option (similar to a desiccating plant process) is to de-shell the nuts and put the meat through a Thai coconut shredder or a knife mill.
3) Drying	Dry the grated or shredded coconut meat to a moisture content of 10 – 12% at a temperature of 70 – 75°C using an indirect type of hot air dryer, modified copra dryer, contact dryer or solar dryer. Note 2: Thai S. Steel Expeller works optimally for VCO extraction at 7% M.C. of shredded or grated coconut meat. Note 3: See previous sections for important considerations in drying the coconut meat to the prescribed moisture content.
4) Oil extraction	Extract the oil using a manually operated vertical screw type press (Bridge press), a DME press, a Sri Lankan press or Thai low pressure stainless steel expeller (Figure 24).
5) Oil drying	As oil extraction is done when the moisture content of the material is relatively high, drying of the oil is required to ensure that all residual moisture is removed to prolong the shelf-life of the VCO. See previous sections for the options and the Critical Control Points in oil drying. Note 4: Oil drying by double boiling before filtration is recommended to ensure that moisture remaining after extraction is removed immediately. If done by gravity, settling of the oil and subsequent filtration to remove fine particles of meat, takes longer. Unlike the latik in Modified Kitchen Method and the curd in Natural Fermentation Method that only adheres to the surface of the oil and can be easily removed, the Low Pressure Oil Extraction Method causes very fine particles of dried meat sediment (foots) to be trapped in the oil so it has to be settled first before filtration. If the moisture content of the oil is too high after extraction, then there is the risk that the oil may start to go rancid during settling. Note 5: The original technology on the Low Pressure Oil Extraction Method does not include an oil drying step (NRI), and neither does the DME process. However, it is deemed necessary to include this step as there is a strong probability that water in partially dried meat will remain in the oil during extraction causing the oil to rapidly turn rancid.
6) Settling of the oil	The oil is left for a minimum of 3 days to allow sufficient time for the trapped foots to settle.
7) Filtration of the oil	Filtration of the oil is done using a three-layered filter cloth bag. Note 6: Sometimes even after filtration, there will still be foots settling at the bottom of the container after long standing. Simply decant the oil to a clean container leaving the foots. Larger operations may use filter pad plate filters with pressurising pumps.
8) Packaging and storage	Pack the oil in a very dry bottle or container for storage. Note 7: The recommended packaging material for VCO is glass. PET bottles (plastic bottles normally used for mineral water) can be used in cases where the VCO is immediately consumed. Glass is recommended if the VCO is to sold in stores where it may remain on the shelf for several weeks.

Critical Control Points specific to Low Pressure Oil Extraction Method



Aside from the critical points discussed previously, the most critical step in Low Pressure Oil Extraction Method is getting the grated or ground coconut meat dried to the optimum range of 10 to 12% M.C. for good oil recovery and quality. If the moisture content of the meat is too low, no oil will be extracted as the Bridge press (Figure 24) can only generate about 400 psi. If the moisture content is too high, the press or expeller will produce a turbid oil — a mixture of oil and coconut milk. Note that the moisture content of coconut meat varies according to maturity of the nut when harvested, the variety, and the length of time that the nut has been stored before processing. The performance

of dryers used for micro- and village-scale operation varies with the design and the heating medium. Consequently, it is very difficult to predict at what point the drying of coconut meat should cease, to obtain a moisture content within the required range. The most practical way of solving this problem is to dry a batch of grated coconut meat to the lowest moisture content possible under the prevailing humidity conditions and store in a tightly sealed container.

At extraction, thoroughly mix bone-dry particles of coconut meat with freshly grated or comminuted meat at a ratio of 4 kg dry to 1 kg fresh meat. Leave the mixture stand for 30 minutes in a covered container to allow the moisture content to even out. This will bring the moisture content of the comminuted coconut kernel to within the required range of 10 to 12%.

The Thai S. Steel Expeller operates best at around 7% M.C. (approximately 6 kg dry:1 kg fresh meat).

Equipment and accessories

1) Equipment for particle size reduction

See pages 31 for a description of coconut graters and the Thai coconut shredder.

2) Dryers

The type of dryer used will depend on the scale of production, availability of construction materials (if it needs to be constructed on-site), preference of operators in terms of ease of operation, the price and drying efficiency of the dryer.

a) Modified copra dryer. An indirect, natural draught, coconut shell/husks fired tray type dryer constructed on-site. The dryer was developed by Divina Bawalan at the PCA Davao Research Centre, Philippines, where suitable frames to hold a series of trays with screens were made in lieu of the loading bed for copra. Drying is essentially a batch type operation.

The dryer comprises a furnace and a metal cylindrical heat exchanger with baffles attached to a chimney for emission of hot combustion gases generated after heating the metal heat exchanger. The furnace and heat exchanger are enclosed in a dryer body (2.44 m x 3.05 m x 1.82 m) with concrete or brick walls and air intake ports on the sides. As the air is heated through contact with the metal heat exchanger and the surface of



To obtain a possible drying time, dry a batch of grated coconut meat to the lowest moisture content possible under the prevailing humidity conditions and store in a tightly sealed container.

Figure 24. Low Pressure Oil Extraction using Bridge press (left) and Thai Stainless Steel Expeller (right)



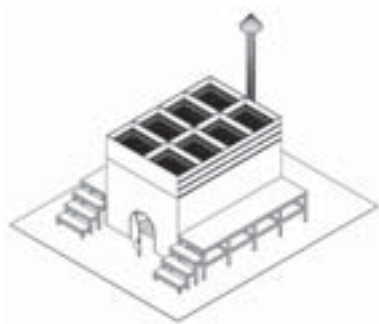


Figure 25. Indirect type coconut shell/husk fired tray type dryer

Drying of coconut meat and low pressure VCO extraction recovers about 18% more VCO than the Modified Fermentation Method.

the furnace, it rises to heat the grated coconut in trays above. There are 30 drying trays, and each can be loaded with 1.5 to 2.0 kg freshly grated coconut meat. Temperature in the dryer is controlled by regulating the fuel feed and air intake but must not exceed 70 to 75°C (Figure 25).

Table 9. Advantages and disadvantages of the modified copra dryer

Advantages	Uses the generated by-products, coconut shell and husks for fuel.
	Prevents the drying grated material from being scorched or burnt since only hot air is in contact with the meat.
	After the grated meat is loaded into the trays, only one operator is required to feed fuel and regularly change the position of trays.
Disadvantages	Drying efficiency is highly dependent on the prevailing ambient conditions and wind velocity.
	Relatively lower process capacity since it is a batch type operation and the dryer must be covered by a roof for protection from rain.

A similar type of modified copra dryer has been developed at Chumphon HRC in Thailand, using insulation on the sides of the heat exchanger and plywood walls instead of brick or concrete (Figure 26a).

b) DME dryer. This is essentially a direct contact type where heat is transferred by conduction through the surface of the S. steel sheet to the grated coconut meat to be dried. It is constructed on-site, based on the design specifications. The dryer comprises a long, stainless steel sheet mounted on a concrete base with heating stones underneath. A burner/furnace made of used, galvanized iron petroleum drums, is mounted on the front end and a chimney is attached to the other end. Drying is done by loading the fresh grated meat in thin layers onto the surface at one end of the sheet and continuously moving the meat with wooden paddles towards the other end of the dryer where it is then removed and loaded into the DME cylinder for pressing (See Figure 21 for a photo of the DME dryer).

Figure 26a. Modified copra dryer at Chumphon HRC, Thailand. Front (left) and side (right) views



Table 10. Advantages and disadvantages of the direct contact DME dryer

Advantages	Uses generated by-products, coconut shell and husks for fuel.
	Relatively fast drying rate as it is done in a continuous manner.
Disadvantages	Labour-intensive since it requires a number of people to constantly feed the fresh grated meat onto the metal surface, fast turn and move it along to the end, and to regularly feed in fuel.
	High risk of meat getting scorched or burnt since there is a tendency for the wet grated meat to stick to the surface of the metal. The resulting oil will be pale yellow and is no longer entitled to the label 'Virgin'.

c) Electric or gas heated Forced-draught tray type dryer.

This is a standard dryer with different capacities and sizes that can be bought easily from known manufacturers. It is generally equipped with a thermostat control that allows the operator to set the desired drying temperature and a blower to circulate hot air through and over the surface of the meat dryer trays (Figure 26b).

Extra oil recovery from dried coconut meat must be compared against the extra cost and time in processing.

Table 11. Advantages and disadvantages of the Forced-draught tray type dryer

Advantages	Drying of the meat is done under highest of sanitary conditions.
	Loaded grated meat for drying can be safely left without the risk of it being scorched or burned.
	Thermostat control allows for a constant temperature drying.
Disadvantages	Uses electric power or gas for heating so drying cost is much higher.
	Higher initial investment cost.

d) Solar dryer. In areas where there is a regular long duration of daily sunshine, solar drying of grated meat may be the cheapest option for producing VCO from the Low Pressure Oil Extraction Method under a micro-scale operation. There are various designs available of solar dryers that can be constructed on-site using polyethylene transparent plastic sheets and wood. Solar heat collectors can

Figure 26b. Gas heated, forced-draught tray type dryer at Chumphon HRC, Thailand. Close-up of meat on trays (left)

also be incorporated to make the solar dryer to achieve higher drying temperatures. Electricity or gas ancillary heaters with blowers will be needed for cloudy, rainy conditions.

3) Equipment for oil extraction

a) Manually operated vertical screw type (Bridge press). Perforated holding basket and receptacle trough (Figure 11a); all materials in contact with the coconut meat made of stainless steel; 9 kg partially dried grated coconut meat per load (about 45 nuts); 15 to 20 minutes cycle per load (loading, pressing and unloading); process capacity of about 135 to 180 nuts per hour (30 to 35 kg meat/hr). Fabricated in the Philippines; upscale model of the original design from the Agro Processing Division, Natural Resources Institute, Chatham, Kent, United Kingdom. The Thai Bridge press has the same dimensions and capacity; manufactured by Ngow Yuat Yoo, Bangkok, Thailand.

b) DME press (Figure 21b). Comprises piston and cylinder assembly with ratchet mechanism to push or release the piston; 1.5 to 2.0 kg partially dried grated meat per load; 8 pressings per hour; manufactured by Kokonut Pacific, Australia.

c) Sri Lankan Coconut Oil Expeller (Figure 22). Vertical screw type; medium scale batch operation, 0.75 kg grated dried meat per load; stainless steel holding cylinder and head; mild steel stand (height 60 cm); total weight 13 kg.

d) Sri Lankan Hydraulic Jack Operated Oil Expeller. Batch operation; 2.5 kg grated dried meat per load; stainless steel holding cylinder and head; cylinder diameter 150 mm; total weight 80 kg (Figure 22b).

e) Thai S. Steel Expeller. Suitable for oil extraction from ground dried meat 7 to 11% M.C.; capacity 20 kg per hour of meat producing 10 kg of VCO; manufactured by Ngow Yuat Yoo, Bangkok, Thailand (Figure 24).

4) Filtration equipment

A gravity or pressurised filtering device should be used with a fine cotton canvas cloth or filter paper as filtering medium. At present, a prototype pressurised filtering device made of stainless steel is being tested by a fabricator in the Philippines. We make no recommendation on this device until the work performance has been carried out. If pressurised, filter paper of 0.95 micron can be used. For gravity filtration, use 2.5 micron filter paper (TISTR, 2005). Filter paper presses quickly become blocked so it is better to settle, decant and use a canvas filter plate press (Figure 29).

Quality control

See quality control on page 32.

The gravity type filtering devices discussed previously which use sterilised cotton wool only as a filtering medium, cannot be used for filtering oil obtained from the Low Pressure Oil Extraction Method due to the fine foots in the oil.



High Pressure Expeller Method

The traditional process of extracting oil from coconut is by the use of high pressure expellers. The coconut is converted into copra either in half-cup form or finger pieces, then it is milled, conditioned at the right moisture content and the oil extracted using a horizontal screw type expeller or a combination of vertical and horizontal screw expellers.

Copra is produced by small holders either by sun-drying, smoke drying or a combination of both, and to a small extent by indirect drying. Prior to milling and expelling, copra is generally stored in a warehouse from two to eight weeks depending on the price speculations of copra traders. Because of this, copra has already undergone some deterioration resulting in low quality extracted oil. VCO cannot be produced from copra.

An expeller press is a screw type machine, which continuously moves the ground, dried meat to the other end of the expeller, forcing it into a very narrow clearance (choke) thereby creating high pressure to compress the material and subsequently release the oil. The extracted oil flows down through the slats and sieves of a barrel cage surrounding the screw (wormshaft). The defatted residue material forms into a hardened cake, and is released from the expeller. The thickness of the cake can be altered by adjustments made to the choke.

Fresh-dry process

The major difference between the traditional coconut oil extraction process and the High Pressure Expeller Method for VCO production, is that fresh coconut meat is quickly dried in a grated, ground or milled form and immediately expelled so that no deterioration of the meat can occur, thereby producing a very high quality oil fit for human consumption. The High Pressure Expeller method is generally referred to as the **Fresh-dry process** of VCO manufacture. There are several versions of this fresh-dry processing, mainly in the manner that the coconut meat is prepared prior to drying and expelling. High pressure expellers used for VCO production **must be made of stainless steel and must have a built-in cooling system in the wormshaft** to prevent the temperature increasing to a point where it will cause the oil to turn yellow.

Brown skin removal (testa)

With a suitably designed high pressure expeller and the correct operating conditions, the highest oil extraction efficiency is obtained, especially if the fresh coconut meat is milled and dried without removing the brown skin (testa) from the meat. Most processors of VCO remove this brown skin because there is a general belief that if this is included, it will cause discolouration of the oil. However, this is not true as proven by various production trial runs conducted since 1990 at the PCA,

VCO cannot be produced from copra.

High pressure expellers must be made of stainless steel and must have a built-in cooling system in the wormshaft.

Providing the fresh meat with the testa is handled and processed under the correct operating conditions, the recovered oil will be water-clear VCO.

See
Critical
Control
Points
page 23



Davao Research Centre, Philippines, when virgin coconut oil was unknown in the commercial market. Providing the fresh meat is properly handled, and processed immediately under the correct operating conditions, the oil that is recovered will be water-clear VCO.

Extraction and preparation

Figure 27 and Table 12 demonstrate the High Pressure Expeller Method for production of VOC.

Processing of VCO

Read and follow the *Common Critical Control Points* before starting production of VCO using the High Pressure Expeller Method.

Figure 27. High Pressure Expeller Method for VCO production

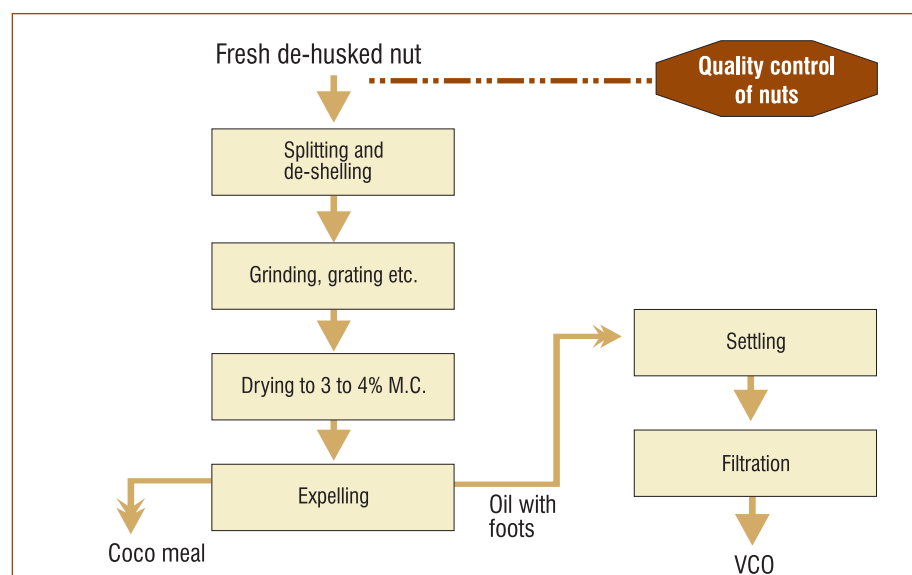


Table 12. High Pressure Expeller Method for VCO production

Process	Action
1) Selection of nuts	Select fully mature nuts free from haustoria (12 – 13 months old).
2) De-shelling	The shell is removed manually using a hand tool or with a de-shelling machine. Note 1: An experienced person in the Philippines can manually de-shell 1,000 nuts per 8 hour day. A de-shelling machine can process 200 – 250 nuts per hour depending on the skill of the operator.
3) Splitting and grinding or wet milling	Split the de-shelled fresh coconut to remove water and put the meat through a grinder or a knife mill. Note 2: Experienced de-shellers normally remove the shell from the nut without breaking the kernel. Note 3: Higher yield in oil extraction is obtained if the particles of dried meat fed into the expeller are in granular form. Hence it is better to grind or mill the fresh coconut meat instead of grating it.

Process	Action
3) Drying	<p>Dry the meat to 3 – 4% M.C., at a temperature of 70 – 75°C using an indirect type hot air dryer. Follow the common Critical Control measures to be observed in drying coconut meat (Page 24).</p> <p>Note 4: The conveyor type dryer, similar to those in desiccated coconut plants where drying is done continuously at a fast rate without scorching or burning the meat, is the best dryer to use for drying granulated fresh meat to 3 – 4% M.C. The output end of the dryer can be directly coupled to the feed hopper of the expeller. However, investment cost for this type of dryer is quite high so it is more suited to medium scale operation. Fluidised bed dryers are also ideal for drying granulated, fresh coconut meat.</p>
4) Oil extraction	Extract the oil using a High Pressure Expellers with a built-in cooling system.
5) Settling of the oil	<p>The oil is allowed to settle for a minimum of 7 days, which is sufficient time for the trapped foots to settle to the bottom before filtering.</p> <p>Note 5: Usually, oil extracted through well-designed High Pressure Expellers already has very low moisture content so there is no need to subject the oil to an oil drying step. However, the process traps a higher percentage of foots (10 – 15%).</p> <p>Note 6: Commercial oil milling plants processing copra have built-in settling tanks fitted with moveable screens and mechanical scrapers to continuously remove foots before the oil is filtered.</p>
6) Filtration of the oil	<p>Filtration of the oil is carried out using pressurised filtering devices.</p> <p>Note 7: The standard equipment used for filtration in commercial oil milling plants is the pressurised plate and frame filter press to ensure that all foots is removed.</p> <p>Note 8: When filtration is done using gravity filters, foots can still settle on the bottom of the container after long standing. Simply decant the VCO to another container leaving the foots behind.</p>
8) Packaging and storage	<p>Pack the oil in a very dry bottle or container for storage.</p> <p>Note 9: The recommended packaging material for VCO is glass. PET bottles (plastic bottles normally used for mineral water) can be used in cases where the VCO is immediately consumed. Glass is recommended if the VCO is sold in stores where it may remain on the shelf for several weeks.</p>

Critical Control Points specific to the High Pressure Expeller Method

Aside from the common Critical Control Points, special attention should be given to the oil extraction step as this is the most critical part of the High Pressure Expeller Method in terms of extraction efficiency and product quality.



Oil extraction

Oil extraction efficiency in high pressure expellers is determined by the following factors:

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

Well-designed coconut oil expellers, generally work efficiently when the moisture content of the feed material is at 3 to 4%. The dried granulated meat is heated, dried and fed while still warm so the oil flows out easily during the extraction process. This is why the standard Anderson expeller, generally used in the coconut oil milling industry in the Philippines, has a built-in conditioner — cookers adjust the moisture content and temperature of the milled copra. Adjustments in the choke

Generally high pressure expelling needs close control and very careful supervision to produce high quality VCO.



Equipment for training trainers and farmers supplied by FAO to Chumphon HRC, Thailand



Philippine knife mill



Philippine Simplextractor high pressure cooled expeller

clearance are made to extract the maximum oil yield possible. Experienced operators know whether the oil extraction rate is at the optimum level by the thickness of the pressed cake emerging from the expeller. Corresponding adjustments in the choke clearance are made if the pressed cake is greater than 1 mm. Granulate the coconut meat to a particle size of 3 mm diameter since very thin, flat particles as in grated, sliced or shredded coconut meat tend to slide out of the choke, thereby reducing the amount of oil extracted.

Cooling system

As mentioned previously, high pressure expellers for VCO production require a built-in cooling system for the wormshaft to control the increase in temperature at high pressure during the extraction operation. This cooling is to prevent the oil from turning yellow. For expellers without a cooling system, adjust the choke to a wider clearance and have the feed material at a higher moisture content. However, as with the Thai expeller, this method sacrifices the oil extraction efficiency.

Equipment and accessories

1) Manually operated de-shelling machine. 1/2 HP gear motor, 3 phase, 220 volts, 40 rpm output (200 to 250 nuts per hour based on the skill of the operator). Designed and fabricated by Princena's Machine Shop, San Pablo City Philippines.

2) Multi-purpose power grinder complete with accessories and 1-unit induction motor. 3 phase, 220 volts, 1750 rpm for spindle drive, 1-unit 1 HP gear motor, 3 phase 220 volt for screw feeder; food grade stainless steel for all parts in contact with fresh coconut meat. The equipment is available in process capacities of 550 and 300 nuts per hour. Designed and fabricated by Princena's Machine Shop, San Pablo City, Philippines.

3) Knife mill. 2 HP, 3 phase, 220 volts motor, process capacity 100 kg per hour, food grade stainless steel for all parts in contact with fresh coconut meat. Same design as the knife mill used for copra except that food grade stainless steel is used instead of mild steel. Designed and fabricated by Princena's Machine Shop, San Pablo City, Philippines.

4) Continuous conveyor dryer (Apron type). Coconut shell fired heat exchanger, 9 m long; 4 blowers of 1.5 HP each, single phase 220 volts, dryer drive 1 HP single phase, 220 volts; 30 to 50 kg per hour dried meat depending on moisture content. Output moisture content can be adjusted by adjusting the speed of the conveyor. Fabricated by Princena's Machine Shop, San Pablo City, Philippines. A bigger capacity dryer is also available.

5) Simplextractor expeller. Process capacity of 50 to 75 kg per hour, 5 HP motor, 3 phase, 220 volts, with built-in cooling system for wormshaft. Designed and fabricated by VR & E Enterprises, Caloocan City, Philippines. Also available in process capacity of up to 100 kg per hour with 7.5 HP 3 phase motor.

Plate and frame filter press is standard equipment used for filtration in commercial oil milling plants to ensure that all foots is removed quickly. The foots is trapped in the canvas cloth between each plate as the oil is pushed through it under pressure. A conventional plate and frame filter press for commercial oil milling operation can have as many as 18 plates with each frame measuring 40 cm by 40 cm. Shown in Figure 29 is a mini plate and frame filter press in which the parts in contact with oil are fabricated in stainless steel to make it suitable for filtration of VCO produced from High Pressure Expellers. Stainless steel 'Mono' type pumps with a capacity of 300 L/hr used for wine and alcohol production, are suitable for linking to filter presses.

Quality control

See quality control, page 32.



All VCO produced by high pressure and low pressure expelling requires settling or filtration to produce water-clear VCO.



Figure 28. Thai expeller for VCO or coconut milk production. Close-up of expeller with cover removed (bottom photo)

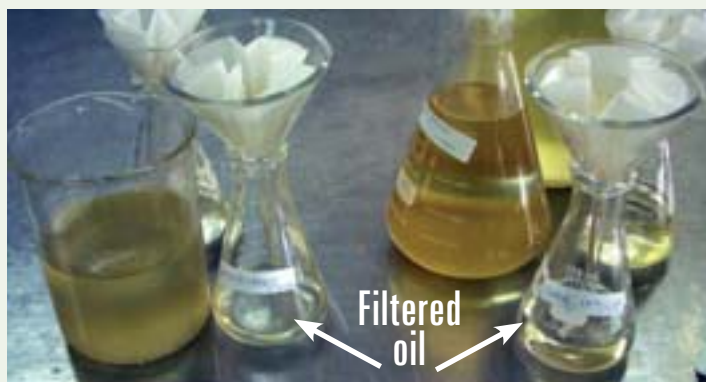


Figure 29. Mini plate and frame filter press



TISTR/FAO project virgin coconut oil products — soap, hand lotion, massage oil

VCO from a bridge press (left group) and an expeller (right group), before and after filtering



TISTR staff training DOA staff in using a Thai expeller at Chumphon Research Centre, Thailand



Coconut meat flakes after passing through the Thai expeller to make VCO

Burnt coconut meat in a Thai expeller. The meat will burn if it is too dry. The moisture content should be between 7% and 10% to retrieve the maximum VCO





Chapter 3

General operation requirements



Site requirements

In choosing the site for setting up a VCO processing facility, the following points should be considered.

- Availability of an abundant potable water supply. This is critical in VCO plants employing the Modified Kitchen and Natural Fermentation Methods.
- Abundant raw material supply base close by. Fresh coconuts can be easily delivered to the plant within one day after de-husking.
- Processing plants location. Should be located away from materials or facilities where strong odours can arise (e.g. piggery, poultry or chemical plants).
- Availability of electric power. For the High Pressure Expeller Method, a three phase electrical line is required.
- Availability of good drainage system. This is important for waste disposal.

Plant requirement

The major use of VCO at present is as a food supplement (it is being ingested as is and not just an ingredient or a medium for cooking), so all the requirements applicable to a food processing facility must also apply to a VCO plant.

Presidential Decree No. 856, otherwise known as the *Sanitation Code of the Philippines*, states the following requirements in constructing a food processing building:

- screened windows and doors;
- painted walls and ceiling;
- well-planned piping and closed drainage systems;
- concrete or tiled floor;
- well ventilated rooms;
- lights with metal guards;
- toilet and bathroom located in a separate section outside the processing area.

In designing the floor plan and machinery lay-out, the following should be considered.

- Process flow should follow the continuous processing steps to eliminate contamination.
- For maintaining sanitation, plant and equipment lay-out must be designed so that there is easy access for cleaning specific areas and sanitisation for assigned personnel.
- Entrance to the processing area should be separate from the entrance to the general access area for non-plant personnel (office and display room, pantry etc).

- Simpler more open plan buildings may be utilised if they are screened and located away from dusty areas. Sometimes the nut cracking, scraping and pressing or expelling may be done at one location and the fermentation etc and oil separation and drying done in an allocated area in an enclosed building.



Training a village group in VCO technology, Thailand



Trying the VCO product produced by TISTR, Thailand



Villagers have been trained in VCO technology by TISTR staff through the FAO project in Thailand



Chapter 4

Operation and maintenance procedures



Good manufacturing practices in VCO processing

Good Manufacturing Practice (GMP) 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 micro-organisms so as to be safe for human consumption. The emerging major use of VCO is as a food supplement, so all the guidelines for a food processing facility must be applied. If appropriate care is not taken, contamination of the product may occur during production, packaging, handling and storage.

Fresh coconut meat and coconut milk are low in acid, high in moisture and nutrients and are very susceptible to microbial contamination. Thus, strict sanitation in the plant area and equipment and strict personal hygiene must be practiced at all times to minimize the risk of contamination.

Sanitation in the processing area

Cleanliness in the VCO plant is maintained by frequent and continuous cleaning and washing down of various process areas and machines as well as a general cleanup at the end of each working 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. Each weekend, every process area must be scrubbed with soap and water, flushed with clean water again and a bactericidal agent applied. To prevent and eliminate insect and rodent infestation, roofs are sprayed with an insecticide twice a week. Cleaning and disinfection of processing area should not be underestimated because this can reduce the risk of VCO not meeting consumer and government standards. The Natural Fermentation Method for VCO production is very susceptible to microbial contamination which normally results in off-quality VCO or no VCO being separated from the residue.

In business terms, strict adherence to sanitary procedure will mean zero or fewer rejection/retention/complaints and no involvement in outbreaks of food poisoning.

Coconut shells should be regularly removed from the grating area to prevent contamination and foul odours occurring. When a plant produces VCO from coconut milk, the residue (sapal) generated after milk extraction, should be regularly transferred to the drying area or the area where it will be further processed. Sun-drying on a smooth-finish concrete patio is ideal for preparing a coconut meal for animal feed. Wet coconut milk residue left unattended for more than four hours will deteriorate causing foul odours and will develop microbial contamination.

Likewise, the grating and milk extraction area (in the Modified Kitchen and Natural Fermentation Methods), and the de-shelling, washing and meat grinding area should be regularly cleaned during and after every eight-hour shift to prevent micro-organisms from multiplying to high levels. This is done by pressure hosing away of all coconut meat and coconut water. As mentioned before, immediate flushing away of coconut water is necessary whenever it is spilled on the floor.

The fermentation room (in the VCO facility using the Natural Fermentation Method) should be equipped with an exhaust fan which should operate for at least 30 minutes at the end of every fermentation cycle to remove stale air and carbon dioxide and should be designed in such a way that there is regular entry of fresh outside air.

Packaging areas should be equipped with white formica, tiled or stainless steel tables and should be cleaned after every use. Any spillage of oil on the floor should be immediately cleaned with soap and water.

Sanitation with processing equipment

Food grade stainless steel is recommended for construction of all parts of VCO process equipment that will come in contact with coconut meat, milk or oil. Listed below are some sanitation points that must be observed.

1. All equipment, where fresh coconut meat is being handled/processed, must be cleaned after every four hours of use. Equipment must not be left un-cleaned at the end of a production day. Cleaned equipment should be free of grease and adhering product particles, detergent residue, brush bristles, etc.
2. Hot water should be used for the final rinse of the equipment. If hot water is not available, chlorinated water should be used followed by thorough rinsing with clean cold water.
3. Special attention should be given to the insides of coconut milk presses to ensure that not a single particle of coconut meat is left adhering to the surface of the filter, the perforated cage or loading cylinders at the end of a production day. Presses should be flushed with pressurised water.
4. The blades and housing of the grater, should be thoroughly cleaned with water every four hours, and with soap and water at the end of the production day. Use hot water in the final rinse to prevent bacterial contamination. If hot water is not available, chlorinated water should be used followed by thorough rinsing with clean cold water.
5. The feed, inside and discharge points of the grinder or shredder should be cleaned with cold water and rinsed with hot water every four hours, and should be thoroughly cleaned free of any adhering particles of meat at the end of a production day. If hot water is not available, chlorinated

Cleaned equipment should be free of grease and adhering product particles like detergent residue, brush bristles ...

water should be used followed by thorough rinsing with clean cold water.

6. Where the VCO plant uses the Low Pressure Oil Extraction Method and the High Pressure Expeller Method, coconut meat dryers should be cleaned every eight hours. Cleaning includes complete removal of coconut particles, especially the yellow/scorched crumbs adhering to the dryer surface which trap the coconut meat particles being dried, (e.g. the tray for tray type dryer, apron for conveyor type dryer, metal surface for DME contact dryer). Coconut particles should not remain in the area for more than 24 hours.
7. All tools and equipment accessories should be thoroughly cleaned before and after use.

Personnel hygiene

Much contamination can also come by way of the personnel and operators who are actually involved in the processing of VCO. For this reason, personal hygiene must be given equal consideration to the building and processing equipment sanitation. Washing facilities must be located near the entry point so that workers can wash their hands with soap and water before dipping their hands in the anti-bacteria solution and commencing work.

A high standard of personal hygiene must be maintained at all times. It is vital that only healthy personnel should enter and work in the process area. Healthy condition means that the person is free from the following sickness or disorders:

- respiratory tract infections such as common cold, sore throat, pneumonia, tuberculosis and others;
- intestinal disorders such as diarrhea, 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 sick with any of the above diseases must stay away from the processing area until they are well.

High standards of personal hygiene also means dressing in appropriate work attire before entering the processing area (Figure 32). Suitable attire consists of hair cover, facial mask (if required), uniform, apron and boots or appropriate footwear. Work attire should be white so that dirt can be easily seen.

Street clothes and shoes should never be worn inside the processing area. Occasional visitors or inspectors in the production area are also required to dress in sanitary garments before entering.

Personnel who are sick with any of the diseases mentioned here, must stay away from the processing area until they are well.



Figure 32. Proper work attire in a VCO processing plant

Each of the abovementioned work attire components has the following functions.

Hair cover (Figure 33)	Hair restraint is necessary to prevent hair from falling into the VCO products. Any packaged food product contaminated by hair is unacceptable to customers! A clean hair cover also acts as a barrier preventing microbial contamination of hands after touching the hair.
Facial mask (Figure 33)	Masks must cover the nose and mouth while handling coconut milk, harvesting the separated oil from the fermentation process and during packaging. A mask serves as a barrier to workers touching their nose and mouth so preventing microbial contamination.
Apron and uniform	Wearing an apron and uniform has a psychological effect on plant personnel about being conscious of maintaining cleanliness at all times in the processing area. Aprons and uniforms should be white or light coloured so that dirt can easily be seen.
Footwear	Specific footwear should be worn only inside the processing area. Plant personnel should change footwear when going outside the production area, and again when re-entering. Street shoes should never be worn inside the processing area.
Latex or plastic gloves	Gloves should be worn when handling coconut water and the by-product vinegar, to prevent future contamination of the oil and burning of the skin.

High standards of personal hygiene also means maintaining clean hands at all times since this is one of the major sources of contamination. A wash area is provided near the entrance to processing plants so that plant personnel are reminded about regular washing of hands. The hands should be washed with soap and water under the following circumstances:

- before starting work;
- after touching or scratching head, hair, mouth, nose, ears, or any uncovered part of the body;
- after using the toilet;
- after breaktime, smoking, eating or drinking;
- after touching dirty dishes, equipment and utensils;
- after coughing, sneezing or blowing the 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.



Figure 33. Illustration of hair cover and facial masks

Sample production data sheets and other relevant forms are available for photocopying in Annex 3.

Record keeping and production data

A daily record of production and other data should be kept and maintained in the VCO plant. These records are necessary to compute production costs and to ascertain if efficiency and productivity is improving. Each batch of product should be given a coded identification number to make it easier for management to trace back any customer complaints about a particular consignment. Sample production data sheets and other relevant forms are available for photocopying in Annex 3.



GOOD
MANAGEMENT
MEANS DOING
THE RIGHT
THING AT THE
RIGHT TIME



Chapter 5

By-products and downstream products



Don't waste it!
Residue usually retains about 35 to 40% of the original oil content of the fresh coconut meat

Coconut milk residue (sapal)

Coconut residue is a by-product of coconut milk, nata de coco and coconut jam processing and also of the VCO process based on coconut milk. The residue represents approximately 25 to 50% of the weight of freshly grated meat on a wet basis, depending on the coconut milk extraction process used. The residue usually retains about 35 to 40% of the original oil content of the fresh coconut meat and has a low market value if not further processed. The residue is dried and sold as animal feed, discarded as waste or used to make compost.

Analyses by the Food and Nutrition Research Institute (FNRI), Philippines, of dried coconut residue show it is very rich in dietary fibre with the following composition.

Protein	5.1%
Fat	38.3%
Moisture	4.0%
Ash	1.8%
Carbohydrates	50.8%
Dietary Fibre	31.9%

Coconut milk residue that can be utilised in various ways. These are shown in Figure 34 and Table 13.

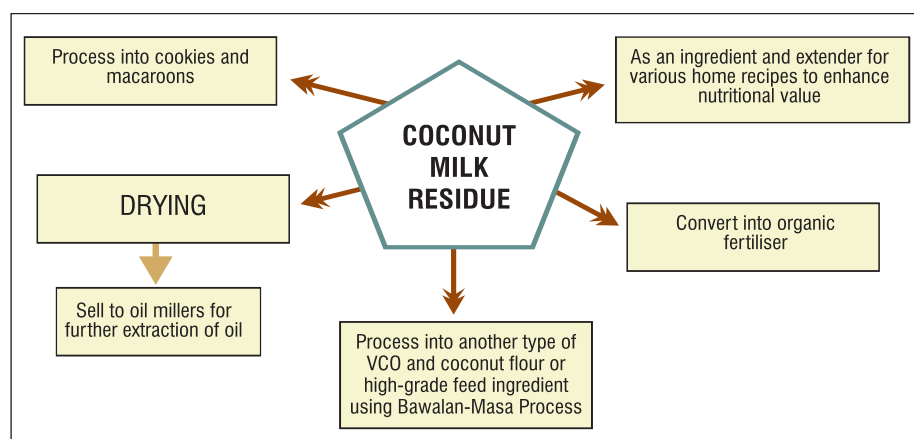


Figure 34. Various options for utilising coconut milk residue (sapal)



Table 13. Ways of utilising coconut milk residue

Utilisation options	Remarks
1) As an ingredient and extender for various home recipes to enhance nutritional value of food.	<p>The use of residue (sapal) as an ingredient and extender in various home recipes to enhance nutritional value of food, provides additional income and improves the health of people using sapal regularly.</p> <p>Adding sapal to recipes fortifies the food products with dietary fibre and fat (oil) essential for good nutrition. In the coco burger recipe, the residue acts as a meat extender in addition to the health benefits, thus making the product cost effective for large families.</p> <p>Note: Coconut dietary fat (oil) mainly comprises medium chain fatty acids which have been shown in several studies to have antibiotic, anti-obesity, anti-cancer and other beneficial effects on the human body and coconut dietary fibre has been shown to have cholesterol-lowering effects.</p> <p>Food recipes incorporating sapal and developed by the Philippine Coconut Authority are given in Annex 4.</p>
2) Processing into macaroons and cookies as a source of income	<p>Macaroons are cookies (biscuits) with desiccated coconut as the major ingredient. By substituting desiccated coconut in a recipe with sapal, the cost of the product is greatly reduced without sacrificing the taste and nutritional value. When using sapal for cookies by partially substituting wheat flour, the cost is reduced and the nutritional value of the product is enhanced by way of dietary fat and fibre.</p> <p>Processing of sapal into macaroons and cookies can be a livelihood improvement activity. The baked products can be sold in schools, shops or included in local government feeding programs.</p> <p>Recipes for making macaroons and cookies using sapal developed by the Philippine Coconut Authority are provided in Annex 4.</p> <p>Semi-commercial production of macaroons using sapal is shown in Figure 36.</p>
3) Drying coconut meat to sell to oil mills for further extraction of oil	<p>Based on the analysis of dried sapal as reported by FNRI, sapal contains 38% oil on a dry basis, which is still appropriate for High Pressure Expellers pressing. If oil millers are informed of this, then it is certain that they will buy sapal for further extraction of oil.</p>
4) Processing into another type of VCO and coconut flour, or high quality animal feed ingredient	<p>If processing is carried out under very strict sanitary conditions, the co-product of VCO can be sold as coconut flour, or as a high quality animal feed ingredient.</p> <p>The process for producing coconut flour and white coconut oil from sapal was developed at the PCA and the technology was commercially adopted in 2002 by a coconut milk manufacturing company in Davao City, Philippines.</p> <p>The process is only viable with a minimum processing capacity of 1,000 kg wet sapal per day. Application of Bawalan-Masa process to produce another type of VCO and coconut flour from sapal requires a higher investment and higher volume of sapal as raw material, and is not suited for micro- and village-scale operation.</p>
5) Processing into organic fertiliser	<p>The process involves decomposition of the sapal mixed with other agricultural residues and the addition of enzymes or other decomposition agents to make organic fertiliser/compost.</p>

Source: Revised excerpt from Bawalan, D. 2005, *GTZ Mission Report*

Recovering the residual oil (10 to 15 % of the harvested Class A oil) and processing it into downstream products, will further enhance profitability in VCO operations.

Residual or Class B oil

When producing VCO using the Modified Kitchen and Natural Fermentation Methods, it is always possible to recover some residual (Class B) coconut oil after the premium grade or Class A VCO is removed. Residual oil is recovered by further heating of the latik in the case of Modified Kitchen Method or the fermented curd if using the Natural Fermentation Method, to release the trapped oil. This residual oil, about 10 to 15% of the harvested Class A VCO, is yellow and has a strong coconut aroma because of the high heating required to fully release the trapped oil. Recovering the residual oil and processing it into downstream products will further enhance profitability in VCO operations.

Where there are lapses in strict critical control procedures or sanitary conditions, the quality of VCO produced may not pass the Class A VCO standard. If this is the case, further processing of the oil into other products is necessary to recoup production costs and possibly acquire additional income. There are several ways of utilising the residual oil so that additional income can be generated (see Figure 35 and Table 14).

Making other products

Downstream products include soap and biodiesel. When the odour is further removed, other products such as cooking oil, skin lotions, skin care products and massage and carrier oils for the spa and aromatherapy industry can be produced.

Figure 35 indicates a typical flowchart for processing Class B oil.

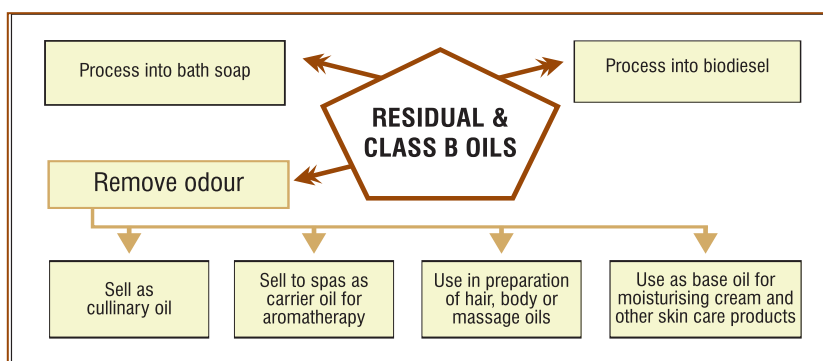


Figure 35. Downstream processing of residual oil (Class B)

Table 14. Other products produced from residual oil (Class B)

Downstream product	Remarks
1) Culinary oil	<p>Further processing of the oil is required to remove the odour and taste for consumers who do not like the coconut flavour that it imparts to food cooked in it or when used on salads etc.</p> <p>Based on information obtained from VCO traders in the Philippines and an owner of a health food company in Canada, there are now a growing number of people demanding odourless, chemical-free white coconut oil for culinary purposes and as a substitute for using the traditional RBD copra-derived coconut oil.</p> <p>Details on removal of odour are given in Annex 4 page 108.</p>
2) Oil for hair and scalp care	<p>Coconut oil has been used in coconut-producing countries for decades to maintain healthy hair and scalp. In the Philippines, older women in the rural areas regularly use coconut oil in their hair but young people should be encouraged to adopt the practice.</p> <p>One potential export market for this type of oil is Bangladesh. Based on the data gathered, both adult Bangla males and females use coconut oil in their hair. In Bangladesh supermarkets, coconut oil is found in the hair care section — a well-packaged copra-derived oil is being sold at an equivalent price of USD1.00 per 400 ml.</p> <p>The addition of natural essential oils of rosemary or patchouli will enhance the therapeutic value of coconut oil as a hair and scalp conditioner and will camouflage the coconut odour.</p>
3) Carrier oil for aromatherapy and massage oils	<p>The growing popularity of spas and health resorts worldwide will prove an excellent market for the promotion of the Class B VCO as a carrier oil. The oil massages evenly, eventually soaking into the skin and does not leave a heavy, sticky residue.</p>
4) Base oil for moisturising oil, body butter, cream and other skin care products	<p>VCO has been proven to have hypoallergenic properties and is specially suited to sensitive skin in moisturising body oil and other skin care products. The re-processed residual oil can be sold in bulk to major cosmetic companies. Alternatively, the VCO processors can convert Class B oil into a moisturising body oil that is an easy, risk-free product to make at home or village level.</p> <p>Because of the presence of water in creams and lotions, preservatives are needed to prolong the product shelf-life. Sometimes, these may be difficult to obtain.</p>
5) Herbal soap	<p>Coconut oil is an excellent raw material for making soaps as it provides the lathering and active cleaning properties that other oils cannot. In the last five years, the use of herbal soaps has gained worldwide popularity, so conversion of the residual oil into herbal soaps offers good marketing prospects.</p> <p>Philippine-made herbal soap prices range in price from USD0.80 to \$2.00 per 135 g bar depending its therapeutic effect. Pacific and Thai herbal soaps are often sold at higher prices.</p>
6) Raw material for biodiesel production	<p>Biodiesel is gaining popularity as a fuel additive and fuel enhancer to support the Clean Air Act of the Philippines.</p> <p>As the quality of Class B oil is still much higher than that of copra-derived crude coconut oil, it is an excellent raw material for small-scale processing into biodiesel. However, the economics of using this oil for biodiesel production has to be studied and compared with the income obtained.</p>

Source: Revised excerpt from Bawalan, D. 2005, *GTZ Mission Report*

Simple methods for preparing coconut oil-based aromatherapy and massage oils are given in Annex 4 page 103. Adapted formulations for some skin care products that do not need chemical preservatives are also found in Annex 4. Both are excerpts from Bawalan, D., 2005. *Final Mission Report on Coconut Processing*. Thailand.

Search the Internet for information on methods and uses.

Coconut husk, fibre and shell

Coconut fibre, husk and shells may be used in many ways to produce value-added, for example, coir, rope, mats, coco-peat for potting mixtures, shells for charcoal and ornaments. Shells may also be used to fire coconut dryers and husks can be returned to the field as organic mulch to supply nutrients around trees.



From curd to soap

Training at Chumphon teaches staff how to make by-products from residual oil. Some of the TISTR soaps and oil are shown in the photo below.





Chapter 6

Economic analysis

	Units	Unit cost USD
Motorised grater (1/2 HP)	1	154.55
Bridge press	1	690.91
Gravity type filter assembly	2	72.73
Flexible reboiler assembly	1	109.09
Semi-expendable tools and utilities which is assumed in the calculated cost to be replaced every year		
Fermenting plastic container	18	1.82

Do I have enough money to buy this equipment?

How long before I get my money back?

The profitability of any processing venture is highly dependent on the country, the location of the VCO operation and availability of equipment and raw materials.

Economic analysis

To provide indicative data on the profitability of micro-scale VCO processing, a cost and return analysis was done using the Modified Natural Fermentation Method based on a 350 nuts/day processing capacity in a coconut producing community in the Philippines.

Cost and return analysis — VCO production

The 350 nuts/day capacity used in the calculation, is the maximum capacity in an eight-hour day that can be processed with a bridge press fabricated in the Philippines, if coconut milk extraction is done in two passes³. There is a limit to upscaling the size of a bridge press since a balance has to be made between capacity and milk extraction efficiency. Other data used in the calculation were gathered on a mission for the German Development Cooperation Agency (GTZ) in July 2005.

Oil recovery is increased by about 17% if the grated meat is double-pressed before extracting the milk. However, double-pressing also halves the processing capacity of the bridge press. If a higher processing capacity is desired, the processor can do a single pressing of the grated meat in two eight-hour shifts per day or add another set of equipment.

Under the current marketing structure for VCO in the Philippines, a micro- or a village-scale VCO processor has the following options to sell the product.

- Sell in bulk to traders.
- Sell in bulk to repackers.
- Pack in small package sizes and wholesale to retail outlets, or direct sell.
- A combination of these options is possible.

For purposes of clarification, the following definitions are applied.

Trader — a person or a company who buys in bulk from producers, exports the VCO or supplies the VCO to retailers.

Repacker — a person or a company who buys in bulk from producers, repacks the product in small sizes under their own brand name, and sells to retailers.

³ Capacity is based on the performance evaluation on similar equipment by the National Coconut Research Center, Leyte State University, Baybay, Leyte, Philippines under the guidance of Prof. Dr Roberto Guarte, Dean of the College of Engineering and Agro-Industries.

Scenarios

Three case scenarios are considered.

- Case 1: All Class A VCO products sold in bulk at the current traders buying price of USD2.40/L (Php 132/L).
- Case 2: All Class A VCO products sold in bulk to re-packers at USD3.50 (Php 192.50 /L).
- Case 3: Half of Class A VCO sold in bulk to traders at USD2.40/L and half sold in the retail market at USD8.00/L.

In all cases, it is assumed that the residual oil (Class B) is sold in bulk at USD1.70/L. As well as the prices mentioned above, the basic assumptions in Table 15 are used.

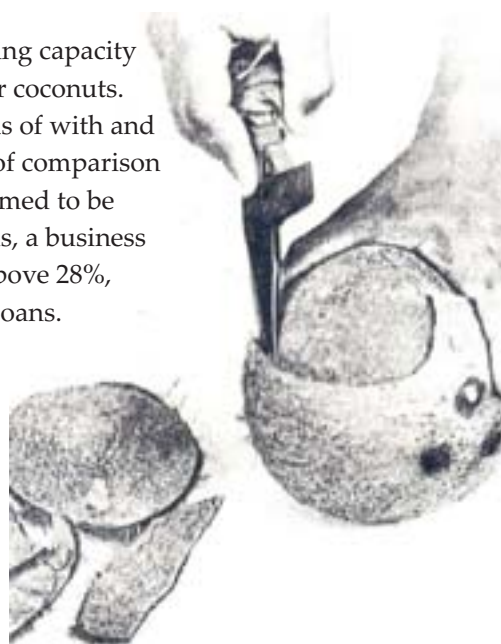
Table 15. Basic assumptions for selling residual oil (Class B)

Exchange rate	USD1.00 = Php55.00
Wages for equipment operators	USD2.91/day
Wages for unskilled workers	USD2.73/day
Salary of production supervisor	USD150.00/month
Cost of electricity	USD0.27/kw-hr
Pre-operating expense	USD910 (for training personnel and government registration fees)
Quality control expenditure	USD440.00/yr
Admin & marketing cost	2% of gross sales
Fringe benefits	15% of salaries and wages
Number of plant workers	6

The Modified Natural Fermentation Method, using listed equipment, has the lowest labour requirement with the least energy input.

The working capital is calculated based on a seven-day inventory of raw material at a buying price of USD0.09 per nut; a 90 day inventory of packaging material and labels as applicable, one month direct labour cost and a seven-day finished goods inventory.

Sensitivity analyses on the specified processing capacity defined three case scenarios at different prices for coconuts. The Return on Investment (ROI) under conditions of with and without taxes are calculated and used as a basis of comparison and a measure of profitability. Income tax is assumed to be 35% of the net profit. Under Philippine conditions, a business enterprise is considered profitable if the ROI is above 28%, which is the current interest rate on commercial loans.



Source: Hagenmaier, R.D. 1980 Coconut Aqueous Processing

Summary of calculations

Cost (in USDollars)

350 nuts/day processing capacity; processed by Natural Fermentation Method

	Case 1 Bulk sale to trader	Case 2 Bulk sale to repacker	Case 3 50 % Bulk sale to trader, 50% Retail
No. of nuts processed/day	350	350	350
Operating days/year	300	300	300
Effective production days/year	250	250	250
Raw material cost \$/nut	0.09	0.09	0.09
Production cost			
Class A VCO (\$/L)	2.60	2.60	2.84
Class B VCO (assumed by-product; no cost)			
Assumed selling price \$/L			
Class A bulk	2.40	3.50	2.40
retail			8.00
Class B bulk	1.70	1.70	1.70
Building cost (80 m2)	5,091	5,091	5,091
Fixed capital investment	6,373	6,373	6,373
Working capital and pre-op.	2,158	2,375	3,323
Total investment	8,531	8,748	9,695
Total revenue	18,727	26,486	38,477
Total fixed cost	5,429	5,429	5,429
Raw material	7,875	7,875	7,875
Packaging	369	369	2,068
Direct labour	4,455	4,455	4,455
Light and power	179	179	179
TOTAL variable cost	12,877	12,877	14,576
TOTAL production cost	18,306	18,306	20,006
GROSS profit	421	8,180	18,471
Admin & marketing cost (2% of gross sales)	375	530	770
WITHOUT TAX			
NET PROFIT	46	7,650	17,702
RETURN ON INVESTMENT (ROI) %	54%	87%	182%
WITH TAX			
Income Tax (35% of net profit before tax)	16	2,677	6,196
NET PROFIT (after tax)	30	4,972	11,506
RETURN ON INVESTMENT (after tax)	35%	56%	118%

Higher profits from pre-packaged retail products involve additional risk. However, returns on investment are very attractive with a short payback period of about one year.



Remember
Quality, Price and Continuity of Supply are
essential in marketing VCO.

Sensitivity analysis

350 nuts/day processing capacity, double-pressing

	Price of nut USD/100 pieces				
	5.00	6.00	7.00	9.00	11.00
PRODUCTION COST					
Case 1: bulk sale \$2.40/L (trader)	2.10	2.22	2.35	2.60	
Case 2: bulk sale \$3.50/L (repacker)			2.35	2.60	2.84
Case 3: 50% to trader; 50 % retail \$8.00/L	2.34	2.46	2.59	2.84	3.08
GROSS PROFIT					
Case 1: bulk sale \$2.40/L (trader)	3,921	3,046	2,171	421	
Case 2: bulk sale \$3.50/L (repacker)			9,930	8,180	6,430
Case 3: 50% to trader; 50% retail \$8.00/L	21,971	21,096	20,221	18,471	16,721
RETURN ON INVESTMENT (without tax)	%	%	%	%	%
Case 1: bulk sale \$2.40/litre (trader)	42	32	21	0.54	
Case 2: bulk sale \$3.50/L (repacker)			108	87	67
Case 3: 50 % to trader; 50 % retail \$8.00/L	221	211	202	183	164
RETURN ON INVESTMENT (with tax) %	%	%	%	%	%
Case 1: bulk sale \$2.40/L (trader)	27	21	14	0.35	
Case 2: bulk sale at \$3.50/L (repacker)			70	57	44
Case 3: 50 % to trader; 50 % retail \$8.00/L	144	137	131	119	106
PAYBACK PERIOD (years)					
Case 1: bulk sale \$2.40/L (trader)			3.71	11.84	
Case 2: bulk sale \$3.50/L (repacker)			0.93	1.13	
Case 3: 50 % to trader; 50 % retail \$8.00/L			0.51	0.56	

Results and discussion

Results of analysis revealed the following.

- The operation will not be profitable at the specified processing capacity of 350 nuts/8 hr day if the price is USD0.09/nut and if the VCO is sold in bulk to traders at USD2.40/L. In Case 1 (350 nuts per day capacity), the operation can only be profitable when the price/nut is reduced to USD0.06 if no tax is paid, or USD0.05/nut if tax is paid (tax rate 35% of profit).
- The operation is very profitable even if the price is increased to USD0.11/nut and 35% tax is paid, if the Class A VCO is sold in bulk to repackers at USD3.50/L.

The most profitable operation is Case 3 where 50% of Class A VCO is sold in bulk to traders at USD2.40/L and 50% sold to retailers at USD8.00/L. However, this involves higher working capital because of higher packaging cost, higher marketing costs and higher risks in cash flow since the turn-over is not as fast as selling in bulk. In most cases, retail selling means selling the product on consignment. If the turn-over is low then the cash

The most profitable operation is Case 3 where 50% of Class A VCO is sold in bulk to traders at USD2.40/L and 50% sold to retailers at USD8.00/L



This manual provides these standard guidelines and Critical Control Points.

In Thailand, graters are about one-third of the prices quoted here and stainless steel containers, strainers etc., are about half the price quoted here.

flow and working capital of the operation are compromised. Payback period at a processing capacity of 350 nuts/day, price of nuts at USD0.09/nut and a VCO selling price of USD3.50/L (Case 2) is 1.13 years.

Selling in bulk to traders at USD2.40/L can also be profitable if VCO is produced by individual farmers at home, processing their own coconuts and using family labour where there are no overhead costs as in an established VCO processing facility. This model is common in Luzon, Philippines, where traders have their own group of farmer producers. However, this system has a higher risk in terms of maintaining the quality of the product. The risk can be greatly reduced if the farmer-producer follows a strict, standardised procedure manual where all Critical Control Points in VCO processing are observed.

Equipment costs

Below is a list of approximate prices of the necessary equipment for setting up a 350 nut/day unit for VCO processing.

	Units	Unit cost USD
Motorised grater (1/2 HP)	1	154.55
Bridge press	1	690.91
Gravity type filter assembly	2	72.73
Flexible reboiler assembly	1	109.09
Semi-expendable tools and utilities which is assumed in the calculated cost to be replaced every year		
Fermenting plastic container	18	1.82
Stainless steel stock pot (4 sets at 4 assorted sizes per set)	4	18.18
Charcoal stove with housing	1	63.64
Assorted stainless steel strainers		72.73
Ladles and other accessories		
Plastic pails (24 L)	6	5.45
Plastic container with cover (400 L)	2	10.00
Stainless steel basin (60 cm dia)	2	13.64



Chapter 7

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Asian and Pacific Coconut Community (APCC)
website: WWW.apcc.org.sg

Recipes and further information on by-products can be found here. WWW.eaudrey.com