NEW TECHNOLOGIES ON THE PRODUCTION OF VIRGIN COCONUT OIL AND THEIR APPLICABILITY TO INTEGRATED COCONUT PROCESSING MODULES

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Abstract

The increasing number of published books, literatures, results of medical researches and internet information extolling the beneficial effects of coconut oil to the human body led to the development of a "niche" and very high value market for a special type of coconut oil which is processed differently from the traditionally known refined, bleached and deodorized (RBD) coconut oil. From a much maligned substance in the 80's which has been claimed by American Soybean Association as causing heart disease and atherosclerosis, this high quality version of coconut oil which is now generally referred to as virgin coconut oil has resurrected its reputation and made a dramatic turn-around in the world market as a functional food that not only nourishes but also heals. Dubbed as the 'healthiest oil on earth", virgin coconut oil (VCO) is processed from the fresh and mature kernel of the coconut and its derivatives coconut milk and coconut milk residue. The paper presents salient information on the 8 different processes for producing VCO (4 from fresh kernel, 3 from coconut milk and 1 process from coconut milk residue), the advantages and disadvantages of each process, the quality control requirements and critical control points to be followed to insure the production of high quality VCO, the applicable scale of operation for each process and the required machineries and equipment. The sensory evaluation attributes to assess the quality of VCO in the absence of laboratory analysis are also discussed. In addition, it clarifies some points with regards to the "heat or no heat" controversy surrounding the production of VCO. The concept of integrated coconut processing module is introduced and differentiated to the general norm of integrated coconut processing per se..Likewise, the applicability of VCO processing technologies to integrated coconut processing modules is discussed.

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1. Introduction

The increasing number of published books, literatures, results of medical researches and internet information extolling the beneficial effects of coconut oil to the human body led to the development of a "niche" and very high value market for a special type of coconut oil which is processed differently from the traditionally known refined, bleached and deodorized (RBD) coconut oil. From a much maligned substance in the 80's which has been claimed by American Soybean Association as causing heart disease and atherosclerosis, this high quality version of coconut oil which is now generally referred to as virgin coconut oil has resurrected its reputation and made a dramatic turn-around in the world market as a functional food that not only nourishes but also heals. Dubbed as "the healthiest oil on earth" by Dr. Bruce Fife, a certified American nutritionist, and author of the "Healing Miracles of Coconut Oil", "Coconut Cures" and other books on coconut, virgin coconut oil (VCO) is obtained from the fresh and mature kernel of coconut by mechanical or natural means with or without the application of heat which does not lead to alteration of the oil and its properties. Virgin coconut oil is suitable for human consumption in its natural state immediately after extraction and filtration.

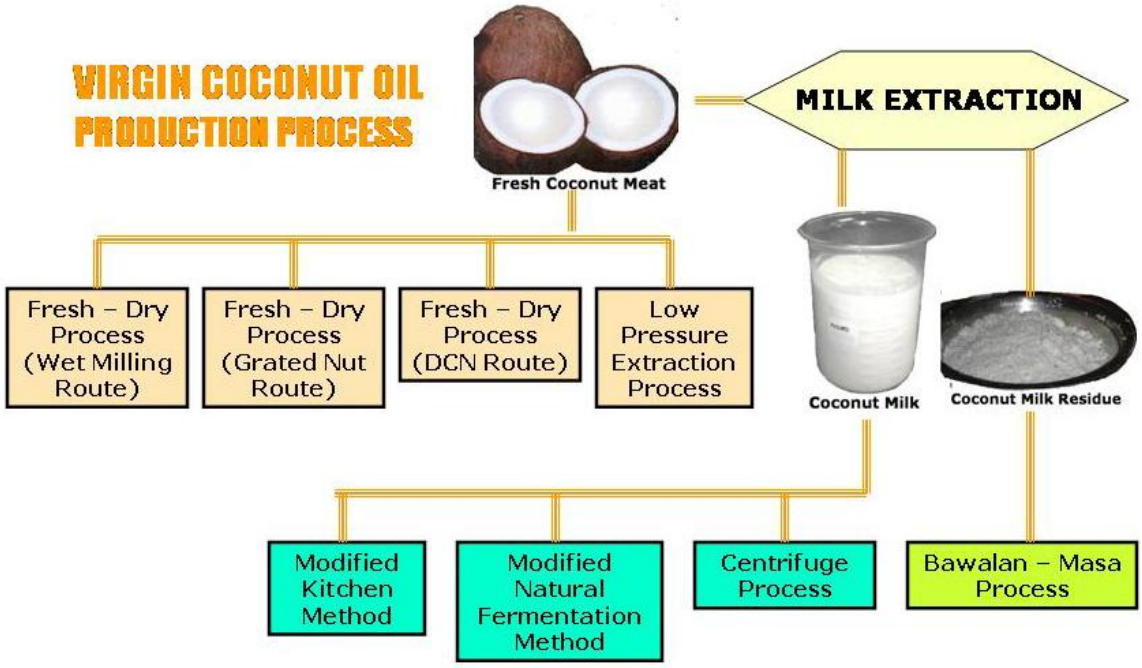
It is the purest form of coconut oil, water white in color, contains natural Vitamin E and which has not undergone any hydrolytic and atmospheric oxidation as attested by its very low free fatty acid content (even without refining) and low peroxide value. It has a fresh coconut scent which could be mild to intense depending on the process used.

Among the plant derived vegetable, seed and nut oils, VCO is quite unique in the sense that it is the only oil with a multi-functional uses. This is the only oil in which you can ingest as a food supplement or functional food, you can use for cooking and other food preparations or you can put on the hair and skin as a moisturizer and conditioner. Because of its hypoallergenic properties, it can also be used as major ingredient in skin care products or as carrier oil in aromatherapy and massage oils. The utilization of virgin coconut oil appears to be endless because aside from the above mentioned uses, it can also be utilized in all applications in which the copra derived RBD oil is traditionally used such as a substitute for the expensive butterfat in filled milk, filled cheese and ice cream, provision of lubricating action in dressings or leavening effect in baked item, raw material for the production of coco methyl ester as substitute fuel or additive to diesel and others. In addition, aside from the growth of VCO industry in the food supplements or nutraceutical market, the VCO-based products industry (e.g. skin and hair care products) is also growing.

2. VCO Production Processes

VCO can be produced either from the fresh comminuted coconut meat/kernel or coconut milk or coconut milk residue. This is schematically shown in Figure 1, which also shows which processes will have coconut flour as a co-product. The choice of the technology to be adopted greatly depends on the scale of operation, the degree of mechanization that is desired, the amount of investment available and most of all on the demand of the prospective buyer. VCO produced from each process exhibits different organoleptic characteristics such that the process used in producing VCO can be identified by sensory evaluation.

Figure 1: Schematic Diagram for producing VCO



2.1. Production Processes from Coconut Meat

a. Fresh Dry Process, Wet Milling Route - involves de-shelling the meat either manually or by de-shelling machine, splitting and slicing the de-shelled meat, washing, grinding or wet milling, drying the milled coconut meat and then extracting the oil using a specially designed screw type press to produce virgin coconut oil and food grade full protein, medium fat coconut flakes. The flakes are further grinded to produce coconut flour with testa.

b. Fresh-Dry Process, Desiccated Coconut (DCN) Route - involves undergoing all processes necessary for the production of desiccated coconut (de-shelling, paring, washing, grinding, blanching and drying) except sulfite treatment and then extracting the oil using a specially designed screw type press to produce virgin coconut oil and food grade full protein, medium fat coconut flakes. The flakes are further grinded to produce coconut flour. Desiccated coconut products which did not pass the quality standards for color and microbial content can be further processed to produce virgin coconut oil and aflatoxin-free coconut flakes for animal feeds.

This process is particularly useful to desiccated coconut processors wherein DCN which did not pass the stringent quality standard for the product can still be converted into high value virgin coconut oil and coconut flour or aflatoxin-free high grade animal feed.

c. Fresh-Dry Process, Grated Coconut Route - involves splitting the nut, grating, blanching and drying the coconut meat and then extracting the oil using a specially designed screw type press to produce virgin coconut oil and food grade full protein, medium fat coconut flakes. The flakes can be further grinded to produce coconut flour. This is similar to the DCN Route except that this requires fewer process step and equipment.

It should be noted that in the different routes/version of the fresh-dry process, the basic difference is just in the preparation of the fresh coconut meat before drying. After drying, they all follow the same extraction process using the same operating conditions as well as the post processing of the oil and resulting coconut flakes.

d. Low Pressure Oil Extraction or Intermediate Moisture Content Method - involves splitting the nut, grating the meat to fine particles, drying it to a moisture content of about 10 – 12 % and extracting the oil using a manually operated bridge press. Inasmuch as it is very difficult to manually determine dried grated coconut at 10 – 12 %, what is being done is to dry a portion of the coconut meat to bone dry state and then mixed freshly grated coconut meat at a specific proportion to get the right moisture content. The Direct Micro Extraction (DME) process developed by Dr. Dan Etherington of Australia which is being used in South Pacific also works on a similar principle except that it differs in the type of manually operated press being used for oil extraction and the manner by which the grated coconut meat is prepared prior to oil extraction.

2.2. Production Processes from Coconut Milk

Before starting with any process to recover VCO from coconut milk, a pre-processing of nuts is required for the extraction of coconut milk. This involves splitting the nut, grating the meat to fine particles, extracting the coconut milk with or without addition of water depending on the manner, by which the extraction is done, either manual or the use of manually operated milk press (hydraulic or vertical screw type) or motorized screw type milk extractor. The type of coconut milk extraction method or equipment to be adopted is dependent on the scale of operation. Likewise, the number of milk extraction done and the type of hydrating liquid to be used (tap or purified water or coconut water) depends on the preference of the processor and the type of equipment used for milk extraction.

a. Traditional Wet Process/Modified Kitchen Method - involves gradually heating the coconut milk mixture (1st and 2nd extract) until all the water has been evaporated to produce the virgin coconut oil and proteinaceous residue or "latik". One variation of the traditional wet process is allowing the milk to stand for 3 hours, then removing the coco skim milk (watery portion) that settles at the bottom and gradually heating the resulting cream to recover the oil. In this manner, process time to recover the oil is greatly reduced. The latik obtained from the modified kitchen method can be eaten as is or added to rice cakes or can be used as meat extender. However, if the settling time exceeded 3 hours, the latik already tastes sour and no longer palatable.

b. Modified Natural Fermentation Process - involves allowing the milk to stand for 16 – 24 hours depending on the ambient condition in the area. Then the fermented coco skim milk (watery portion) is decanted, the oil that separated out is filtered and the fermented curd which still contains part of the oil is gradually heated to further recover some oil. Fermentation is generally done using a transparent plastic container to see clearly the separation of the layers.

Generally, 5 layers in a fermenting container can be seen. The first layer in the bottom comprises of solid gummy materials. The second layer is the watery phase which essentially is fermented coco skim milk. In terms of relative volume, this is the biggest. The third layer is the solid fermented curd which still entrained some oil. The fourth layer (second layer from the top) is the separated white coconut oil (main product). The fifth layer from the bottom or top layer is another solid fermented curd with some entrained oil.

c. Centrifuge Process – involves subjecting the coconut milk through a mechanical phase separation process through the use of centrifuge. Coco skim milk (watery phase) is separated first from the cream (oily phase) and the gums with the use of centrifuge. The resulting cream after the skim milk was separated is then subjected to vacuum evaporation and pass through a centrifuge again to obtain the virgin oil. Centrifuge process is done under a medium scale plant operation inasmuch as investment costs for the centrifuge equipment is very high.

Another version of the centrifuge process which was reported in the APCC Cocoinfo International and being used by a producer in Sulawesi involves blast freezing the coconut milk to a temperature of -5 ^{0}C, crushing the solidified milk and passing the liquefied crushed milk through the centrifuge to separate the water from the oil. The recovered oil is then subjected to vacuum drying. Compared to the centrifuge process described above, this version is much more energy intensive.

2.3 Production Process from Coconut Milk Residue

Coconut residue is a by-product of the coconut milk, nata de coco and coconut jam production processes. It is also a by-product of the VCO production processes which are based on coconut milk. It represents approximately 25- 50 % of the weight of freshly grated meat on a wet basis depending on the coconut milk extraction process that is used. It still retains about 35 - 40 % of the original oil content of the fresh coconut meat. It has a low market value and is normally sold as animal feed. In some cases, it is just being thrown away. There are still some questions whether the white coconut oil obtained from coconut milk residue can still be qualified to the label "virgin". It is the opinion of the author that the oil obtained from the coconut milk residue is still entitled to the label "virgin" because it satisfies all the criteria attributed to virgin oil. In terms of quality, it also more than passes the Philippine National Standard for VCO.

a. Bawalan - Masa Process - the production process was developed by Engr. Divina D. Bawalan, former Senior Science Research Specialist, Product Development Department (PDD), Philippine Coconut Authority (PCA) together with Ms. Dina B. Masa, Manager, PDD - PCA using the coconut milk residue from a coconut milk manufacturing plant as starting material. It involves blanchng the residue, drying at a specific moisture content level and subsequently defatting the residue under

controlled conditions using a specially designed equipment to produce virgin coconut oil and low fat, high fiber coconut flakes. The flakes are further grinded to produce coconut residue flour. The technology was adopted for commercialization last April 1, 2002 by Sirawan Foods Corporation through a technology transfer agreement with PCA. It won second prize in the Most Oustanding Creative Research (Likha Award) category during the 1998 National Inventors Week and has a patent pending with the Philippine Intellectual Property Office.

2.4. Comparative Analysis of Different Processes for Producing Virgin Coconut Oil

Type of Process	Quality of Oil and Recovery	Advantages and Limitations
1. Fresh – Dry Process (Wet Milling Route)	FFA - 0.05 – 0.08 % M.C - 0.07 - 0.1 % Color - water clear Oil recovery - 600 kgs per ton (1000 kgs) of dried milled coconut meat	• With the use of proper equipment, has the highest oil extraction efficiency among the VCO processes available. • Produces full protein, medium fat coconut flour as a co-product • Long shelf-life of oil – 1 yr and above • Uses mechanical type of equipment to produce the oil • Can be produced under small to medium scale plant operation
2. Fresh – Dry Process (Dessicated Coconut Route)	FFA - 0.05 – 0.08 % M.C - 0.07 - 0.1 % Color - water clear Oil recovery - 580 kgs per ton (1000 kgs) of desiccated coconut	• Produces full protein, medium fat coconut flour without testa as a co-product • Long shelf-life of oil – 1 yr and above • Uses mechanical type of equipment to produce the oil • High investment cost, medium scale plant operation
3. Fresh – Dry Process (Grated Coconut Route)	FFA - 0.05 - 0.08 % Moisture – 0.07 -0.1 % Color - water white Oil recovery - 300 kgs per ton of fresh grated meat	• Produces full protein, medium fat coconut flour without testa as a co-product • Long shelf-life of oil – 1 yr and above • Uses mechanical type of equipment to produce the oil • Can be done under small scale plant operation

4. Low Pressure Method	FFA - 0.1 - 0.2 % Moisture – 0.17 % and below* Color - water clear Oil recovery - 25 kgs per 100 kgs of grated coconut meat * Moisture content of final product is highly dependent on the skill of the operator doing the drying process and preparing the grated meat prior to extraction.	• Uses manually operated equipment to produce the oil • Produces a semi-dry coconut residue that has to be further dried or processed to have market value. • Shelf – life of oil can be very short if milled or grated coconut meat is not properly prepared prior to oil extraction. Oil drying is recommended to insure long shelf -life
5. Traditional Wet or Modified Kitchen Process	FFA - 0.06 – 0.2 Moisture – 0.07 – 0.14 Color - water clear to pale yellow depending on the heating process Oil recovery - 16.5 kgs per 100 kgs of grated coconut meat	• Very low investment cost. • Can be produced on a home scale operation using ordinary kitchen utensils.. • Produces a wet coconut residue that has to be further dried or processed to have market value. • Produces a by-product (proteinaceous residue) which does not have commercial value at present. • Oil gets rancid after 5 days if oil is not properly heated to dryness.
6. Modified Natural Fermentation Process	FFA - 0. 1- 0.2 % M.C.–0.12 % & below Color - water clear Oil recovery - 34 liters per 100 liters of coconut milk (*about 19 kgs oil per 100 kgs of grated meat*)	• Can be produced on a home scale operation using ordinary kitchen utensils or on small-medium scale operation using semi-mechanized equipment. • Disposal of fermented skim milk could be a big problem if done on medium scale plant operation. • Oil produced has a faint sour smell which can be removed by a proper post processing.
7. Centrifuge Process	FFA - 0.04 – 0.08 % Moisture – 0.1 % and below Color – water clear	• Produces the best quality coconut oil with sweet coconut aroma if done in a two-stage centrifuge process.

	Oil recovery – about 28 liters oil per 100 liters of coconut milk	• Can only be applied in a medium scale operation as investment cost is very high. • Optimization of the process is still required to improve oil recovery rate. Current oil recovery rates are much lower than the modified fermentation process. • Further processing of the coco skim milk into health beverage and the sapal generated into coconut flour can improve profitability
8. Bawalan –Masa Process	FFA - 0.05 –0.08 % Moisture – 0.07 – 0.12 % Color - water clear Oil recovery - 170 kgs per ton (1000 kgs) of wet residue	• Further recovery of high value oil from residue makes coconut milk processing more profitable. • Long shelf-life of oil – 1 year and above. • Produces low fat high fiber coconut flour as a by-product • Requires mechanical type of equipment to produce the oil • Production process has to be attached or integrated to an existing coconut milk processing plant

Among the VCO processing technologies, the natural fermentation method has the least labor requirement and the least energy input. However, if fermentation process is not properly controlled, then it produces VCO with a sour smell and relatively higher free fatty acid content. Precise control on the maturity of the coconuts and the ambient conditions in the fermentation area is necessary to obtain good oil recovery. On the other hand, the modified kitchen method produces VCO with an intense coconut aroma or scent. However, it has the lowest oil recovery among the available technologies inasmuch as a lot of oil remains entrained in the proteinaceous residue or "latik". In addition, it requires precise temperature control and timing during the heating process to prevent the oil from turning yellow. The highest oil recovery can be obtained from the fresh-dry process wet milling route but this could be applied only for small to medium scale operation because of the need to invest in a conveyor type dryer and an expeller with a built-in cooling system.

3. Quality Standard and Critical Control Points in VCO Processing

3.1 Basic Criteria and Quality Standard

One may ask " HOW DO YOU KNOW IF THE COCONUT OIL IS REALLY A VIRGIN?" Well, the answer to this is if the oil satisfies the basic criteria and the quality control parameters attributed to virgin oil.

Internet research revealed the following basic criteria for any plant derived vegetable or seed or nut oil to be entitled to the label "virgin":

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

In the Philippines which pioneered the commercialization and export of VCO, the quality standard for the said product is set forth in the Philippine National Standard for VCO (PNS/BAFPS 22.2004/ICS 67.2000.10). It officially defines *virgin coconut oil as an oil obtained* ***from the fresh and mature kernel (meat) of the coconut by mechanical or natural means, with or without the use of heat,*** *which does not lead to the alteration of the nature of the oil and without undergoing chemical refining, bleaching and deodorization. VCO 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.*

Aside from the levels of fatty acid composition which is set forth in FAO Codex Alimentarius Commission's Standard for edible coconut oil which should be satisfied, the following quality parameters/standards have to be met.

Color, Odor and Taste	- VCO shall be colorless, sediment free, with natural fresh coconut scent and free from rancid odors or tastes.
Moisture and volatile content, %, max	- 0.20
Free fatty acids (FFA) expressed as lauric acid, %, max.	- 0.20
Peroxide value, meq/kg oil, max.	- 3.0
Food additives	- None permitted
Contaminants:	
Matter volatile at 105°C, %, max.	- 0.20
Heavy Metal, mg/kg	
Iron (Fe)	- 5.0
Copper (Cu)	- 0.40
Lead (Pb)	- 0.10
Arsenic (As)	- 0.10

Likewise, it is recommended that the VCO shall be processed in accordance with the appropriate Sections of the General Principle of Food Hygiene recommended by the Codex Alimentarius Commission (CAC/RCP 1-1969, Rev.3-1997).

As mentioned before, there are 8 different processes for producing VCO. The VCO produced from each process has distinct sensory characteristics aside from the usual quality parameters attributed to coconut oil. In the absence of a laboratory analysis report, the quality of VCO can be assessed through sensory evaluation by testing the following attributes:

a. Color - VCO has a water clear appearance. Based on the studies done under the RP-UK Aflatoxin Reduction in Copra Project, the color of the oil is either brought by contaminants in the oil (as in tapahan drying of copra), high temperature processing and microbial contamination on the coconut meat prior to oil extraction. Yellow or pink or red orange colored coconut oil can be obtained depending on the type of microorganisms that contaminated it. **Coconut oil in its purest form is water clear in appearance. If the coconut oil does not exhibit a water clear appearance, then it could no longer be considered as virgin.**

b. Smell - a good quality VCO does not have any rancid smell. It has a sweet coconut scent or aroma which could range from mild to intense depending on the process used.

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

3.2. Critical Control Points in VCO Processing

a. Critical Control Points Common to All Processes

To insure that only high quality VCO will be produced, the following critical control measures should be applied in all of the processes that will be presented and discussed in this VCO manual. Critical control points specific to a particular process will be presented in the technology sheet for the said process.

1) Receipt and Inspection of Nuts

Upon delivery to the plant of dehusked nuts, inspection is done on a per nut basis to segregate and reject iimmature, germinated or spoiled (with cracked shells) nuts from the good quality nuts. Only fully matured nuts (12 – 13 month old) should be processed for VCO production. As an indicator of maturity of the nut, the husk and shell is brown in color and gives sloshing sound when shaken.

Always insure that the nut while fully mature does not have “tubo” or haustorium (Figure 2). This is because the oil content of the kernel started to decline once the haustorium is formed. Aside from yield, the oil quality also deteriorates, as the haustorium grows bigger.

Figure 2: Dehusked coconut with haustorium for rejection

Proper action must be made so that nuts will not break while unloading. Likewise, exposure to sunlight of the dehusked nuts during delivery, weighing and unloading should be avoided to prevent cracking of the shell, which will lead to spoilage.

2) Storage

Dehusked nuts should be kept in clean storage spaces with cement floor, good ventilation and adequate rain/sun cover. Exposure to the sun of the dehusked nuts should be avoided at all costs. The shell of the nuts will crack after being exposed in the sun for more than one hour. The storage bins should be designed and partitioned in such as a way that the principle of first in-first out can be easily implemented. It is advisable that the pile of dehusked nuts should not be placed directly at the cement floor but in an elevated platform with slats so that the coconut water could flow down in cases some coconut breakages occur. Maximum height of pile for storage of fresh nuts in the bodega should be 1.8 meters.

Ideally, dehusked fresh coconuts should be processed within seven (7) days from the time it is harvested so the VCO processing facility should be set-up within the coconut producing areas to insure the freshness of raw material. At the same time, this would lower the transport cost for the nuts.

3) Handling of Coconut Water

Coconut water spoils and ferments very fast once the nut is opened. As you split the nut, collect the coconut water in a container and dispose properly. Part of the coconut water generated can also be converted into vinegar as another source of income.

Flush with water if coconut water got spilled on the floor. Spilled coconut water on the floor if not immediately cleaned will invite flies in the area and become a source of contamination. It will also destroy the cement surface of the floor (if there is no tiles) since fermented coconut water becomes very acidic. It also generates foul smell once fermentation started.

4) Drying and Handling of VCO Product

Please remember that water is the archenemy of oil. Presence of water in oil will make its shelf-life short i.e. water in oil will cause rancidity upon storage. To insure that the VCO produced will have a long shelf-life, it should be subjected to an oil drying process after it is recovered from coconut milk or extracted from dry grated or granulated coconut kernel. Residual moisture content is particularly critical in the VCO produced from the modified kitchen method and the modified natural fermentation process since they are falling under the general category of wet process, i.e. the oil is being recovered from coconut milk and from the low pressure extraction method since oil extraction is being done at an intermediate moisture content level.

Drying of the oil to insure that all residual moisture are removed can be done using the following methods.

- Placing the extracted oil in a double boiler and heat for about fifteen minutes or until such time that the oil has turned water clear if it appears turbid.
- Incubation or air heating the container with oil at 50 ^{0}C for 12 hours or until such time that the oil has turned water clear if it appears turbid.
- Vacuum drying

An improvised double boiler can be made by placing a stainless steel mixing bowl or basin in a fitted pot or pan with water. The oil is placed in the SS mixing bowl or basin over the pot or pan with water so heating is regulated. Once the water in the pot or pan starts to boil, reduce the flame to the lowest possible setting such that the temperature of the hot water will just be sustained.

Vacuum drying is the most effective way of drying oil without the risk of the color turning to yellow but the investment cost is high so it will not be viable for micro-scale processing involving one processor. It could be viable by having a vacuum dryer in a centrally located area where various processors can bring in their raw VCO to dry under a toll processing scheme.

Insure that the water content of the oil is down to 0.1% and that any process container or packaging material to be used for VCO are thoroughly cleaned and dried. In addition, NEVER HEAT oil directly in a pot or pan as this will cause the oil to turn yellow.

b. Critical Control Points Common to Modified Kitchen Method, Natural Fermentation and Centrifuge Process

1) Handling of Coconut Milk

Coconut milk is a low acid food. At the same time, it has high moisture content with protein and other nutrients. As such, it is very susceptible to microbial contamination and spoils very easily. Under this condition, grating of fresh coconut kernel and subsequent extraction of coconut milk should be done in a clean

surrounding and under very strict sanitary conditions. The following control measures have to be applied at all times:

- Always insure that grating of kernel and subsequent coconut milk extraction is done under sanitary conditions by observing personal hygiene especially washing hands with soap and water before doing any preparation work, wearing the necessary attire/uniform with hair cover, cleaning all utensils to be used and keeping the work area clean. Ring or rings in the finger should be removed when directly handling grated coconut meat.
- Insure that all materials, utensils or equipment that will be used in extracting and holding coconut milk are thoroughly cleaned and rinsed with hot water. It should be free from any soap residues.
- Water to be used as diluent or rehydrating agent for the second milk extraction should be of high quality, free from microbial contamination and from too much mineral content. Purified or demineralized water should preferably be used. Coconut water can also be used as diluent but specific handling procedure has to be done (i.e. filtering and immediate placement in a refrigerator or ice box while waiting for the grating and first milk extraction to be finished.). Otherwise, microbial contamination will occur.

2) Critical Control Points Specific to Modified Kitchen Method

Aside from the critical control points discussed above, heating of the coconut milk or cream is the major critical step in the Modified Kitchen Method as this will determine whether the oil that will be recovered will be water clear or yellow which will not make the recovered oil to be classified as "virgin"

The following control measures should be observed at all times to insure that only water clear oil will be recovered:

- Heating should be done in such a way that the coconut cream in the pan will just simmer and not boil.
- Do not allow the proteinaceous residue or "latik" to turn brown as this will give a yellow colored coconut oil which will no longer pass the virgin label. Once the oil separates out from the latik, take the oil out. After the oil that separated out has been taken, toast the latik to further recover the oil which is entrained in the latik. However, this type of oil will already be yellow and just suitable for skin care products.
- Heat the cream at medium heat at the initial stage until the coco cream is near boiling. Then reduce the heating to low until the "latik" coagulates and the coconut oil separates out. Heating the coco cream should be accompanied with constant stirring to disperse the heat absorbed

3**) Critical Control Points Specific to Natural Fermentation Method**

Aside from critical points discussed above, settling and subsequent fermentation of coconut milk is the most critical step in the 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 the oil to separate. There are cases in which no oil is being separated at all even after 24 hours settling. There are also cases when the coconut milk mixture that is left to settle for 16 -24 hours will generate big bubbles, overflow in the fermenting container with no oil being separated. To insure that good quality VCO will be produced, the following measures should be done:

- Maintain a fermentation temperature of 35 – 40 ^{0}C in the area where the fermenting container with coconut milk will be placed. Relative humidity condition within the area should also be maintained at 75 % and below. One way of doing this is to have a properly designed fermentation cabinet with electric bulbs placed in strategic position that could raise the temperature inside when needed by just flicking the switch. A small electric heater with built-in thermostat control can also be installed in the fermentation cabinet. Under this condition, fermentation time of 16 hours give a relatively good yield of good quality VCO.

- The major cause of the "bubbling over the container" problem as mentioned above is contamination either through soap residues on the fermenting container or invasion of different types of microorganism. Hence, strict sanitary measures have to be observed at all times.

  Autjor's *Note: If this problem occurs, the immediate action is to put the mixture in the evaporating pan and apply the modified kitchen method so that oil can be still recovered instead of wasting the whole batch. However, the coconut oil that will be recovered is already considered class B VCO and should just be used for making herbal soap and skin care products.*

- The natural fermentation method is very sensitive to the maturity of the nuts and the freshness of the nuts. Immature nuts contain a higher percentage of protein which makes the protein in coconut milk much more difficult to break to release the oil. Likewise, the longer the coconuts are stored, the higher is the risk for spoilage and the higher is the risk for contamination. Hence, to insure that the oil will naturally separate from the coconut milk upon settling for 16 – 24 hours, only newly harvested fully mature coconuts should be processed.

If proper operating conditions and sanitary precautions are strictly followed, five distinct layers can be seen in the fermenting container after settling for sixteen hours. The bottom layer is made of gummy material. The next layer from the bottom is the watery portion which is actually a fermented skim milk. The skim milk recovered here is no longer fit for human consumption and has to be properly discarded. After the layer of skim milk is a solid layer composed of spent fermented curd. The next layer to this going to the top is the separated oil for recovery as VCO. The top most layer is again fermented curd. Fermented curd still contains entrained oil.

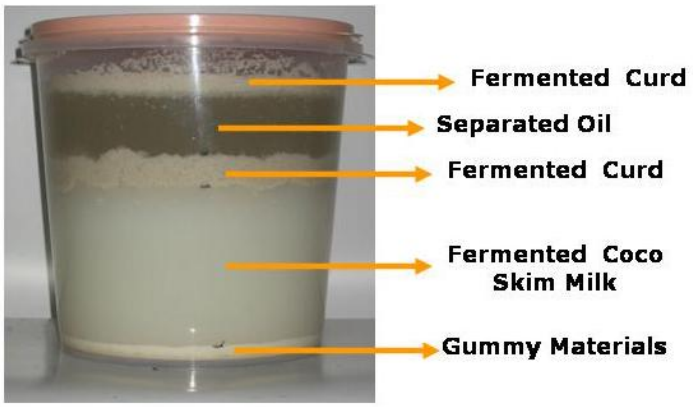


Figure 3 : Different Layers of Fermented Coconut Milk

c. Critical Control Points Common to Low Pressure Extraction Method and High Pressure Expeller Process

Low pressure extraction method and high pressure expeller method belongs to the general category of fresh-dry process for VCO production wherein the VCO is obtained by drying first the fresh grated or comminuted coconut kernel and then pressing the dried kernel to separate the oil. Hence, in both processes, the most critical step is in the drying of the meat. The following critical control measures have to be observed when preparing the coconut kernel for subsequent oil extraction.

- Drying of the coconut kernel/meat should be done within four (4) hours of opening the nut. Delay in drying will allow bacterial contamination on the fresh meat and will result in a yellow colored oil.

- Dry the grated or granulated coconut kernel at a temperature of 70 – 75 ^{0}C using an indirect "hot air" dryer, either steam heated or biomass fired. If the drying temperature is too low, there is the strong probability that bacterial contamination will occur on the grated or comminuted coconut kernel. This will result in yellow colored oil. On the other hand, if the drying temperature is too high, there is a strong tendency that the grated or comminuted kernel will be burned which will also result in a yellow colored coconut oil.

- Under condition of low humidity and hot midday temperature, solar drying of the grated meat can also be done. A well-designed solar dryer normally can generate a drying temperature of about 70 ^{0}C which is just about right for the intended purpose. Solar and not sundrying is done to prevent the grated meat from being contaminated with dust and insects.

- In using a direct contact dryer similar to the one being used in the South Pacific for the Direct Micro Expelling (DME) process, constant turning of the grated kernel is required to prevent it from getting scorched or burned which will result in yellow colored oil.

1) Critical Control Points Specific to Low Pressure Oil Extraction Method

Aside from the critical points discussed above, the most critical step in low pressure oil extraction method is in getting the grated or grinded coconut meat dried to a moisture content within the range of 10 – 12% since this has been found to be the optimum range where oil recovery and quality will be good. If the moisture content of the meat is too low, no oil will be extracted inasmuch as the bridge press can only generate about 400 psi pressure. However, if the moisture content is too high, what will come out of the press is a turbid coconut oil or a mixture of oil and coconut milk. It should be noted that the moisture content of coconut meat varies according to maturity of the nut when harvested, the variety of the coconut and the length of time that the nut has been stored before processing. Likewise, the performance of dryers used for micro and village scale operation varies with the design and the heating medium. Hence, it takes a lot of exposure and skills for an operator of a specific type of dryer to determine at what point the drying of coconut meat will be stopped to get moisture contents within the range of 10 – 12 %.

2) Critical Control Points Specific to High Pressure Expeller Process

Aside from considering the critical control measures discussed special attention should be given in the oil extraction step because this is the most critical part of the high pressure expeller process in terms of oil extraction efficiency and product quality.

Oil extraction efficiency in high pressure expellers are 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 - 4 %. Likewise, the dried granulated meat is being heated and fed while still warm to make the oil flow out easily during the extraction process. This is the reason why the standard Anderson expellers which is generally used in the coconut oil milling industry in the Philippines has built-in conditioner – cookers to adjust the moisture content and temperature of the milled copra. Adjustments in the choke clearance are made to get the maximum oil yield possible. The thickness of the pressed cake coming out of the expeller gives an indication of the oil extraction efficiency in the expeller, i.e. experienced operators know whether oil extraction rate is at the optimum level by looking at the thickness of the pressed cake. Corresponding adjustments in the choke clearance is normally made if the pressed cake is not at a thickness of 1 mm and below. It is advisable to granulate the coconut kernel to a particle size of 3mm thickness since very thin particles as in grated or sliced or shredded coconut meat tends to slide out of the choke thereby reducing the amount of oil obtained from it.

As mentioned before, expellers for VCO production requires a built-in cooling system for the wormshaft to insure that the temperature will not go to high levels as high pressure is developed during the extraction operation. This is to prevent the oil from turning yellow. For expellers without cooling system, one way of reducing the temperature inside the expeller is to adjust the "choke" to a wider clearance and to have the feed material at higher moisture content. However, this method sacrifices the oil extraction efficiency which reduces considerably the profitability in VCO operation.

4. Misconceptions in VCO Processing

4.1. Process Temperature

One of the biggest misconception in VCO processing is that the use of heat will make coconut oil lose the attributes of being "virgin" oil. A lot of people think and a lot of VCO producers claim that coconut oil should be processed without any heat to retain its virgin quality. The VCO which is processed without heat is being claimed by their producers to be the best and being priced higher notwithstanding its quality and sensory characteristics. Admittedly, the VCO processed without heat has a relatively higher Vitamin E than the VCO processed with heat but in terms of value, the Vitamin E content of coconut oil is very little (36 mg/kg) for it to be considered a deciding factor in the grading of VCO. Vitamin E is also lost when the oil is exposed to sunlight

It should be emphasized that the main reason why virgin coconut oil is being bought at a much higher price than any other edible oils is because of the presence of high percentage of medium chain fatty acids (MCFA) particularly lauric fatty acid which has been shown to have anti-microbial properties, promote weight loss, boost immune system and other health benefits. Information on the stability of different nutrients to temperature, light, acid and other factors showed that essential fatty acids are not affected by temperature as long as the smoke point of the oil is not reached. It is the vitamins which are very susceptible to increases in temperature. The first clinical trial on the application of coconut oil as a possible cure for HIV/AIDS done in 1999 at the San Lazaro Hospital in Manila, Philippines actually used RBD coconut cooking oil (Minola brand) and good results were also obtained. At that time, VCO is not yet known in the commercial market. **Therefore, VCO extraction at higher temperature as long as it does not discolor the oil is permissible and does not diminish the health benefits that can be obtained from it**. It should be noted that the VCO standard stipulates that VCO should be colorless. This is in itself is a self-checking mechanism on how high the process temperature should be because too high process temperature will discolor the oil.

If the process temperature will be a limiting factor to qualify for the label "virgin" in coconut oil, the processes that will only qualify for producing VCO are the centrifuge process and fermentation process. There are so many variations of the natural fermentation process such that in some cases, the quality of the oil produced will not pass the quality standard for VCO particularly in terms of free fatty acid content.

Further, it should be noted that in the listed basic criteria for an oil to qualify for the label "virgin" as discussed above, the process temperature is not a requirement. Therefore, coconut oil which is extracted by means of drying the fresh meat/kernel under sanitary conditions and immediately extracting the oil after drying (i.e. not passing the copra stage) using an expeller can also qualify for the label "virgin".

4.2. "Extra Virgin" and "Cold Pressed" Label for VCO

A lot of VCO producers in different coconut producing countries who are selling on the retail market are placing "extra virgin" and "cold pressed" in their label without actually understanding what the said label means or entails. There are even pale yellow colored coconut oil that the author encountered with a label "extra virgin VCO".

To gain a full understanding of the terminologies involved, a literature and internet research was conducted which revealed the following:

a. The term "extra virgin" is exclusive to olive oil. However, the term "virgin " can be applied to olive oil as well as other types of oil provided the criteria discussed in Item 3.1 are satisfied. The main reason for the "extra virgin" label being exclusive to olive oil is because when the fresh olives are pressed, what is coming out can be called "olive oil juice" since this is essentially a mixture of olive oil and water which upon settling or centrifugal separation, the olive oil can already be recovered. On the other hand, when fresh coconut kernel/meat is pressed, what comes out is coconut milk, which is an emulsion of oil and water stabilized by protein. To recover the coconut oil, the said protein bond has to be broken either by heating, or by natural or biological fermentation or by enzymatic action or some other means.

b. Information from internet websites gave conflicting information on what really is a "cold pressed" oil. A lot of websites mentioned that the term "cold pressed" does not have any legal definition in several countries like United Kingdom and the United States. Instead, it is just a marketing strategy because for an oil to be efficiently extracted from its plant-based source (seeds, nuts, etc.), it has to be heated to a certain extent to allow the oil to flow freely. Likewise, only seeds or nuts or any other plant source with oil content above 30 % can be extracted by pressing. It was also mentioned that most plant-based oil cannot be produced in big/commercial quantities if only cold pressing will be used. In most websites, the term "cold pressed" is associated with olives for reasons stated in item 1) above. On the other hand, some websites mentioned that the term "cold pressed" is associated with an oil that has been extracted/processed at a temperature below 122 ^{0}F or 50 ^{0}C. Therefore, under this condition, coconut oil which is produced by drying the fresh comminuted meat and subsequently extracting the oil using high pressure expellers will not qualify for the label "cold pressed" since temperatures higher than 50 ^{0}C are generated inside the expellers but it will qualify to the label "virgin". However, it was noted that some manufacturers are placing the term "cold pressed" in their labels although their process is done at temperatures higher than 50 ^{0}C. Only VCO produced using the modified natural fermentation process and the centrifuge process with vacuum evaporation can be entitled to the label "virgin and cold pressed"

The only major difference that the writer can discern between a “cold pressed” VCO and an “expeller pressed” or heat processed VCO is that the “cold pressed” or low temperature - processed VCO does not leave an oily after taste in the mouth when ingested. Likewise, the VCO processed at low temperatures also solidifies much faster and liquefies much slower than the expeller pressed VCO. However, this factor will go under the so called “customer preference”. In other words, let the customer decide which type of oil they prefer to buy.

4.3. Testa or Brown Skin of Coconut Kernel

Another big misconception in VCO processing is that if the brown skin or testa of the coconut kernel is not removed, it will discolor the VCO. Hence, majority of VCO producers make it a point to remove the testa prior to extraction of the oil. This is not true at all. The author has done countless production trials where the brown skin is included and the resulting coconut oil is still water clear. The color of the coconut oil is normally caused by microbial action on improperly handled fresh kernel and too high temperature used in processing. Removing the testa strips the VCO of linoleic acid, an essential fatty acid required by the body at a maximum level of 3.5 % of total fat intake. In addition, the total oil yield on a per nut basis is reduced because in the process of removing the testa, a portion of the white kernel is also being removed.

5. Integrated Processing Module Concept

It is a well-known fact that to be globally competitive, one must be able to produce good quality products at the least cost and at the least waste of materials. This can be done by producing more value-added products from a single raw material at the least input. Coconut, given its versatility as a raw material fits well the above mentioned strategy.

Everyone recognizes the fact that the profitability in a coconut processing operation can be greatly improved if the generated by-products in a particular operation will be further processed into value-added products instead of wasting them. While a lot of full-integrated coconut processing projects have already been proposed and studied in the Philippines, none has been translated so far into successfully operating plant. This is because the proposals were all hinged on utilizing all parts of the coconut without considering the constraints in terms of economies of scale and available equipment which are specific to each processing technology that will be integrated in the operation. Hence, the concept of integrated coconut processing module concept is being introduced.

It is different from the integrated processing concept that has been proposed before in the sense that it does not recommend per se the processing of all parts of the coconut fruit in one continuous operation which is difficult because of lack of equipment with synchronized processing capacities. Rather, it will improve the economic viability in coconut processing operation by combining the production of three (3) or more related coconut products in one processing set-up considering either of the following three aspects; a) the maximization of raw material or further processing of generated by-products; b) maximization of time through proper production scheduling to get

around the constraints and inefficiencies of batch type processing or c) maximization of equipment utilization through the use of multi-functional equipment for greater flexibility in product processing or d) combination of two or all aspects whichever is more appropriate in a given market condition. In other words, each product identified to be included in the integrated module will be processed separately based on its identified economies of scale and will just share in plant personnel and appropriate equipment if applicable. One advantage of the integrated process module concept is that expansion to a higher scale of operation can be easily done by just adding a similar module of the same product mix or integrating another product which complements the existing product mix or by adding a module of different product mix which is complementary to the existing module. In other words, the key elements that should be considered in designing a coconut processing module is complementation of raw material use, production scheduling and equipment usage.

6. Applicability of VCO Processing Technologies in Integrated Coconut Processing Modules

The choice for the principal product in an integrated coconut-processing module is always guided by the market demand and the value of the product (i.e. which product will bring the biggest profit to the enterprise). Since its introduction in the world market in 2001, VCO emerged as the highest valued coconut product in the world now with an average Philippine export price of US $ 3,225.00/MT (2003-2007). Likewise, because of its versatility and multi-functional uses as mentioned before, the demand for the product is increasing. Hence, it can be considered as a principal product in an integrated coconut-processing module.

The choice of VCO processing technology to be adapted is greatly hinged on the scale of operation, amount of investment that one is willing to put into it and the sensory attributes of the VCO as demanded by the buyer. The investment requirement in turn is greatly dependent on the type of equipment needed to produce the product. For instance, the VCO with the best quality and sensory attributes is the one produced using the centrifuge process. However, it has to be produced at a higher scale of operation because of high investment cost. Listed below is a comparative matrix of selected VCO process technology, the applicable process capacity, the type of products generated and the major equipment required.

VCO Process Technology	Type of Products and Kernel By-Products Generated	Major Equipment Required
1. Fresh-Dry Process, (5,000 – 10,000 nuts per day capacity)	a) Expeller Pressed VCO b.) Full Protein Coconut Flour Note: Coconut flour is now also considered as a health product because of its high dietary fiber content. Philippine export price for coconut flour is about US $ 600/MT	De-shelling Machine Paring Machine Mechanical Shredder or Grinder Steam Boiler Mechanical Dryer High Pressure Expeller with water cooled wormshaft Plate and Frame Filter Press Coconut Flour Grinder

2. Low Pressure Oil Extraction Process (200 - 1,000 nuts/day capacity)	a.) Class A VCO b) Semi-Dry Residue (need to be dried or further processed to have economic value)	Coconut Grater or Shredder Biomass (Shell or Husk) Fired Indirect Type Dryer Bridge Press or DME Press Settling tanks with conical bottom
3. Modified Natural Fermentation Process (200 – 3,000 nuts per day capacity	a) Class A VCO b) Class B VCO c) Wet Residue (need to be dried or further processed to have economic value)	Coconut Grater or Shredder Coconut Milk Extractor Fermenting Containers Gravity Filter
4. Centrifuge Process (10,000 – 20,000 nuts per day process capacity)	a. Premium Grade VCO b. Residue to be further processed into Low Fat DCN c. Coco Skim Milk which could be further processed into nutritious beverage	De-shelling Machine Paring Machine Mechanical Shredder or Grinder Coconut Milk Extractor Centrifuge Vacuum Evaporator Mechanical Dryer Steam Boiler
5. Centrifuge Process in tandem with Bawalan-Masa Process (10,000 – 20,000 nuts per day process capacity)	a. Premium Grade VCO b. Residue to be further processed into VCO and coconut flour c. Coco Skim Milk which could be further processed into nutritious beverage	De-shelling Machine Paring Machine Mechanical Shredder or Grinder Coconut Milk Extractor Centrifuge Vacuum Evaporator Mechanical Dryer Steam Boiler High Pressure Expeller with water cooled wormshaft Plate and Frame Filter Press Coconut Flour Grinder

With VCO as a principal product in an integrated processing module, some attention will have to be focused as well in the generated non-kernel by-products such as coconut water and coconut shell. The choice of the VCO technology to be used will also define how the coconut shell and water can be utilized. If the fresh-dry process will be adopted in the module, then the coconut shell can either be used as fuel in the steam boiler or it can be processed in a separate area into charcoal. Part of the coconut water generated can be converted into coconut water vinegar and the rest have to be

disposed properly. On the other hand, if the centrifuge process will be adopted, coconut shell can also be used as fuel for steam boiler and the coconut water can be further processed into coconut water beverage as an additional product line either by mixing it with coconut milk or coco skim milk to enhance its protein content and lend flavor. If the modified fermentation process will be adopted, then coconut water can be used as coconut milk diluent to facilitate the removal of coconut gums and enhance fermentation. The coconut shell can be converted shell buttons, fashion accessories and other handicrafts.

7. Final Remarks

The fast developing and high value niche market for virgin coconut oil offers a good prospect for the improvement of the life of the farmer. Inasmuch as virgin coconut oil can also be produced on a micro and village scale of operation, it creates a situation where coconut farmers can directly participate and get a bigger share of the profit of the industry instead of being a mere producer of copra. This is already being enjoyed by groups of coconut farmers in the Philippines who produce virgin coconut oil for traders and exporters who either repack for the domestic market or export the product to the United States and Canada.

The development of the high value market for VCO also offers a lot more options and flexibility for processors to earn higher income from coconut since different process technologies and a range of process equipment are available to suit specific scales of operation. This is the only coconut product that can be produced profitably from micro scale to big commercial plant operation with the proper choice of technology to be applied. Likewise, VCO's multi-functional uses insure that there will always be a good market for the product.

8. References

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