CLEANER PRODUCTION IN THE MANUFACTURING OF VIRGIN COCONUT OIL

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Introduction

Virgin Coconut Oil (VCO) is an unrefined premium grade oil extracted from fresh coconut meat without the use of chemicals and high heating. The crystal clear oil produced has light viscosity, rich in vitamin E and antioxidant and still retains the natural coconut scent and flavor. Due to high content of vitamin E and antioxidant the oil is very stable and can have very long shelf life.

VCO is composed predominantly of medium- and short-chain fatty acids that have different effect on the body than the long-chain fatty acids found typically in animal fat or other vegetable oils. Medium-chain fatty acids (MCFA) in foods are broken down and used predominantly for energy production and thus seldom end up as body fat or as deposits in arteries or anywhere else. The MCFA in VCO consists of lauric acid, caprylic acid, and capric acid in addition to other beneficial fatty acids. When oil is consumed the triglycerides break apart into diglycerides, monoglycerides, and free fatty acids. The monoglycerides of lauric acid and capric acid (monolaurin and monocaprin) and their free fatty acids have very active antimicrobial properties (attacking viruses, bacteria, and other pathogens) and can build the body's immune system.

VCO differs from most commercial grade coconut oils that are made from copra. It is unrefined. Copra is basically the dried kernel (meat) of the coconut. It can be made by smoke drying, sun drying, or kiln drying, or a combination of these three. If standard copra is used as a starting material, the unrefined coconut oil extracted from copra is not suitable for consumption and must be purified. This is because the way most copra is dried is very unsanitary. Most of the copra is dried under the sun in the open air, where it is exposed to insects and molds. The standard end product made from copra is Refined Bleached Deodorized (RBD) coconut oil. Both high heat and chemicals (e.g. solvent extractions, phosphoric acid) are used in this method.

One of the main differences between VCO and refined coconut oils is the scent, taste and color. VCO is crystal clear and retains the fresh scent and taste of coconuts, whereas the copra-based refined coconut oils is yellowish or gray and have no taste due to the refining process. However, the most important different in RBD oil is the formation of toxic chemicals of trans fatty acids from the normal unsaturated fatty acids due to high temperature exposure (more than 200°C) for extended periods of time during refining process.

VCO has been used for many applications. As a medicine, it is traditionally used to treat a variety of conditions such as burns, wounds, ulcers, kidney stones, and choleric dysentery. In modern application, VCO has been used to prevent and treat heart disease and AIDS. As food, VCO is a nutritional oil and energy source, very easily digested and gives flavor and taste to finished products. As cooking oil, it is ideal for use, having a high resistance to heat (stable to oxidation). Due to high content of vitamin E and antioxidant the oil is very stable and can have shelf life up to 3 years. As salad oil, VCO is also ideal for use, given the natural and health-treating benefits provided by its essential ingredients. As a massage oil and body lotion, it leaves skin soft and smooth, relieving dry skin itchiness and other skin diseases, making the skin supple.

Although the manufacturing of VCO is not considered to be an environmentally hazardous industry, like other food industries it can cause organic pollution if designed and operated with insufficient attention to the environment. The environmental aspects common to this industry include high water consumption, generation of high organic content of wastewater, and generation of solid wastes and sludge.

Cleaner Production (CP) is the latest integrated approach of environmental management in industries. Prior to this approach, waste management was carried out through end-of-pipe (EOP) technologies. The EOP deals with the treatment of wastes after generated in order to detoxify the wastes for safe disposal, which means expense for industry. CP, on the contrary, is a process-orientated and preventative approach to environmental management. CP focuses on reducing resource consumption and avoiding the generation of wastes and pollutants. CP not only provides improved environmental performance but also, efficiency, financial savings and increased competitiveness in a market where consumers are more environmentally aware. Therefore CP approach is considered as a win-win solution for industry in managing its environmental problems.

This paper illustrates the extent to which environmental improvements are possible through identification of some cleaner production opportunities. This is conducted by analyzing the entire system of VCO manufacturing, including raw materials and auxiliary materials, processing steps and procedures, and products design.

Manufacturing of VC

Good quality VCO will depend very much on the quality of coconut. The optimum age of coconut for making VCO is about 12 months. The coconut must be processed as fresh as possible after harvest. To produce a liter of VCO some 15-17 coconuts will be needed.

There are two main processes of manufacturing VCO:

Dry Process

This is carried out by quick drying of grated fresh coconut meat which is then followed by pressing out the oil by mechanical means. Depending on its production capacity, several types of dryer can be used, such as tray dryer, rotating basket dryer, and fluidized bed dryer. Drying is effected by introducing hot filtered air, which must be controlled to maintain the coconut meat temperature about 50°C. The dried coconut meat is then pressed using hydraulic or expeller type of mechanical press to extract the oil. This type of process will also result in pressed cake (similar to desiccated coconut) as a by-product (Figure 1).

Wet Process

This is carried out by extracting the coconut milk from fresh coconut meat followed by demulsifying the milk to separate the oil from the water phase. The coconut meat is first shredded or grated and then pressed by hydraulic or screw press to get the coconut milk. The oil is extracted from the milk by various means, such as centrifugation, fermentation, enzymes, boiling or refrigeration, and alteration of emulsion phase composition (Figure 2).

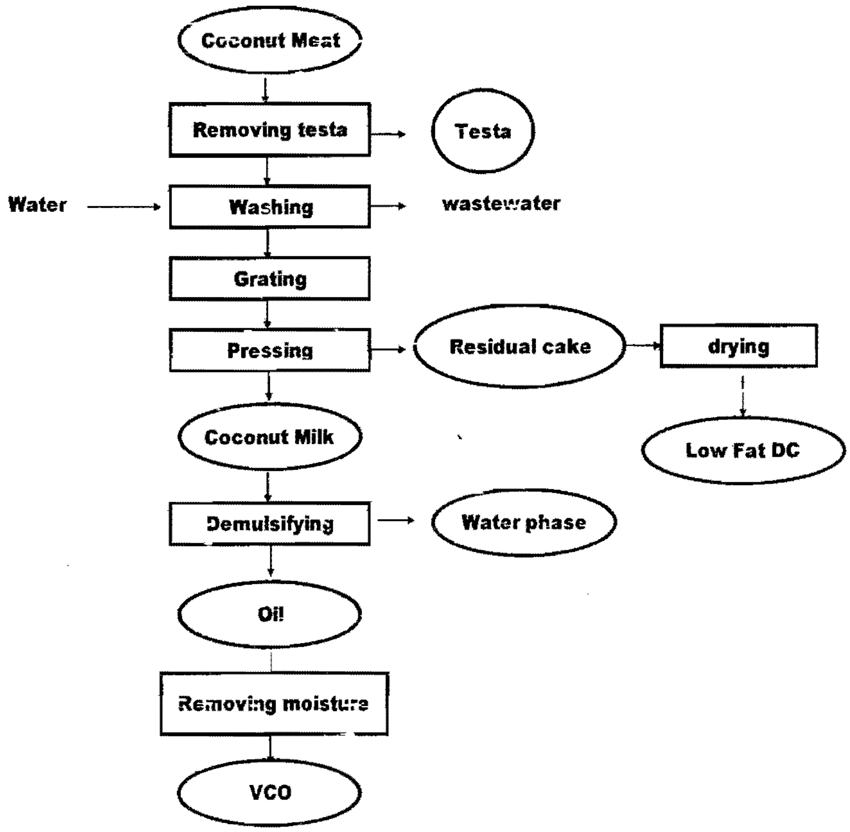

Figure 1. Process flow diagram of dry process VCO

Using high speed centrifugal separator, the pure oil can be separated from the water phase of coconut milk or coconut cream emulsion in very short time. In fermentation process, the coconut milk is left fermented for 24-36 hours, during which the water separates from the oil. The oil is then slightly heated for a short time to remove moisture, and filtered from the curds. The introduction of enzymes can speed up the settling/fermentation process and improve the extraction rate. The result is a clear coconut oil that retains the distinct scent and taste of coconuts. The boiling technique introduces heat to break the emulsion and extract the oil. This can take several hours to remove the moisture and normally produce oil with yellowish color.

Among the processing methods described above, the manufacturing of VCO using wet process via centrifugation offers many benefits such as:

- Avoidance of drying of the coconut meat.
- Avoidance of heat and prolonged settling during oil extraction.
- Reduction of processing time, and thus increased capacity.
- Reduction of potential microbial contamination due to minimum amount of manual steps.

- Production of not only oil, but also low fat desiccated coconut and coconut protein concentrate.
- One critical aspect of the production of VCO regardless of the extraction method used is the need to reduce the final moisture content of the oil to 0.1% or less. This is necessary to prevent the oil from becoming rancid and to prolong the oil's shelf life. This further removal of moisture can be carried out by direct heating or indirect heating using steam-jacketed kettles, exposure to hot air, clarification using a series of settling and decanting steps, and vacuum drying/evaporation. The use of vacuum will give advantage since removal of moisture can be effected even in low drying/evaporation temperature (less than 50°C). On the contrary, the direct heating usually result in relatively higher moisture content and often give the oil roasted and smoky flavor. Table 1 shows the quality standard of VCO developed by Asian Pacific Coconut Community (APCC).

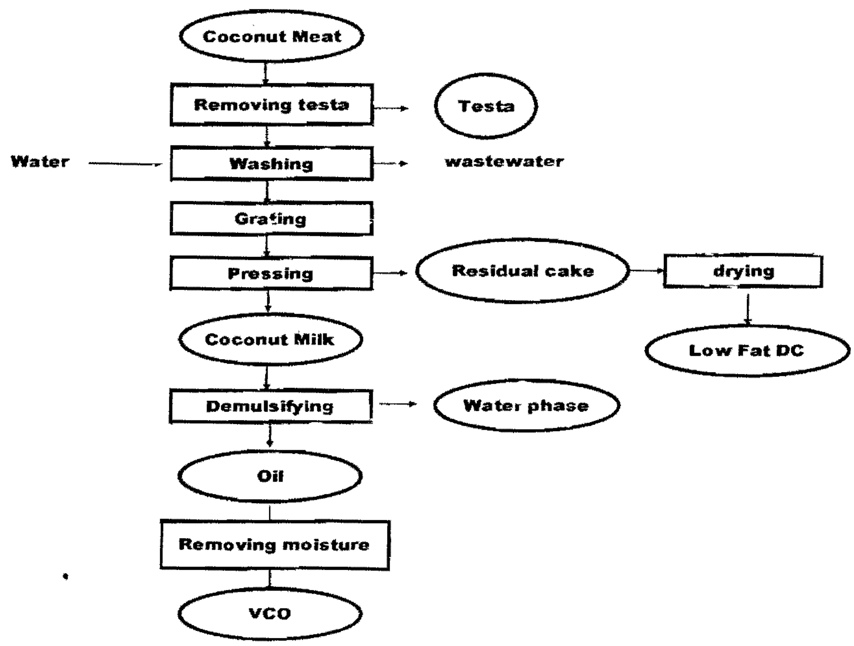

Figure 2. Process flow diagram of wet process VCO

Cleaner Production Approach

In Cleaner Production approach, there are two measures which lead to the reduction to the lowest amount possible of waste materials, namely waste avoidance and waste utilization. In the avoidance strategy the understanding of the type of waste generation is of utmost interest. In any industrial production raw materials is converted into goods. Beside raw materials auxiliary materials are used that are not part of the final product. These materials, in addition to their products or by products, can reappear as production residues or as waste (Figure 3).

Table 1. Quality standard of VCO

Characteristics	Value	Unit
Identity characteristics		
- Relative density	0.915-0.920	
- Refractive index, 40°C	1.4480-1.4492	
- Moisture, max	0.1-0.5	%
- Insoluble impurities, max	0.05	%
- Saponification value, min	250-260	
- Iodine value	4.1-11	
- Unsaponificable matter, max	0.2-0.5	%
- Specific gravity	0.915-0.920	
- Acid value, max	0.5	
- Polenske value, min	13	
Fatty acids compositions		
C 6:0	0.4 - 0.6	%
C 8:0	5.0 - 10.0	%
C 10:0	4.5 - 8.0	%
C 12:0	43.0 - 53.0	%
Characteristics	Value	Unit
C 14:0	16.0 - 21.0	%
C 16:0	7.5 - 10.0	%
C 18:0	2.0 - 4.0	%
C 18:1	5.0 - 10.0	%
C 18:2	1.0 - 2.5	%
C 18:3 – C 24:1	< 0.5	%
Quality characteristics		
- Colour	water clean	
- Free Fatty Acid	≤ 0.5	%
- Peroxide Value	≤ 3	meq/kg oil
- Total Plate Count	< 10	cfu
- Odor and taste	Free from foreign and rancid odor and taste	
Contaminants		
- Matter volatile at 105oC	0.2	%
- Iron	5	mg/kg
- Copper	0.4	mg/kg
- Lead	0.1	mg/kg
- Arsenic	0.1	mg/kg

Figure 3 indicates that there are 5 types of waste generation, namely:

1. Yield losses; full conversion of raw materials to the final products is not possible, also due to non optimum process conditions.
2. Raw and auxiliary materials; are not part of products and by the end of manufacturing process they are found in wastewater, emission or solid waste.

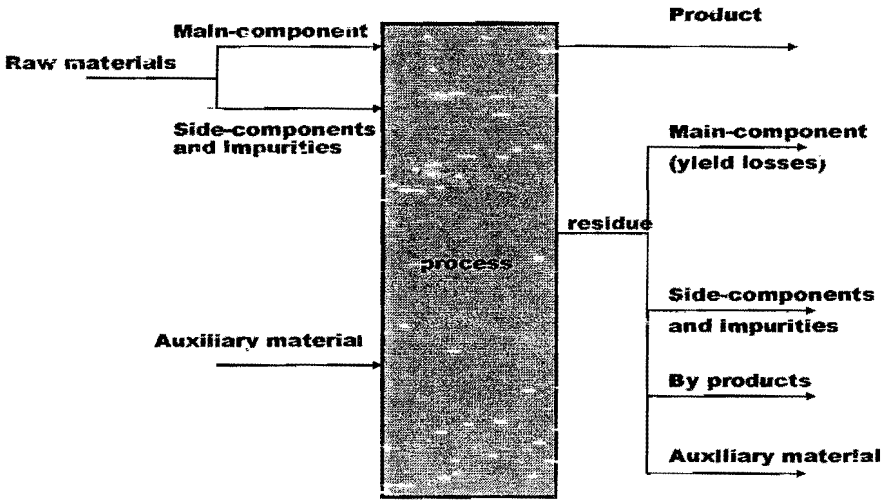

Figure 3. Types of waste generation

3. Side reactions; by products synthesized from raw and auxiliary materials in side reactions are often useless.
4. By-products and impurities; material components not intended for conversion into final product must be separated during process and are discharged to wastewater, emission, or solid waste.
5. Products; the product itself can become waste.

There are three types of measures to reduce waste generation (Figure 4), namely:

1. Technical changes to the process, alternative processes.
2. Exchange of raw and auxiliary materials.
3. Closure of material cycles.

Several audit methodologies for implementation of CP in industries have been developed. However they have something in common. Among the important audit steps involved are analyzing the process steps (including preparation of process flowchart, making material and energy balance, process review to identify waste causes), generating waste minimization opportunities, and selecting waste minimization solutions based usually on technical feasibility, financial viability, and environmental considerations.

From the observation during industrial visits in several small-scale as well as large-scale VCO manufacturing industries (especially those using dry process and centrifugal separation) some opportunities for CP implementation are identified and summarized in Table 2. Opportunities for CP Implementation in VCO Manufacturing

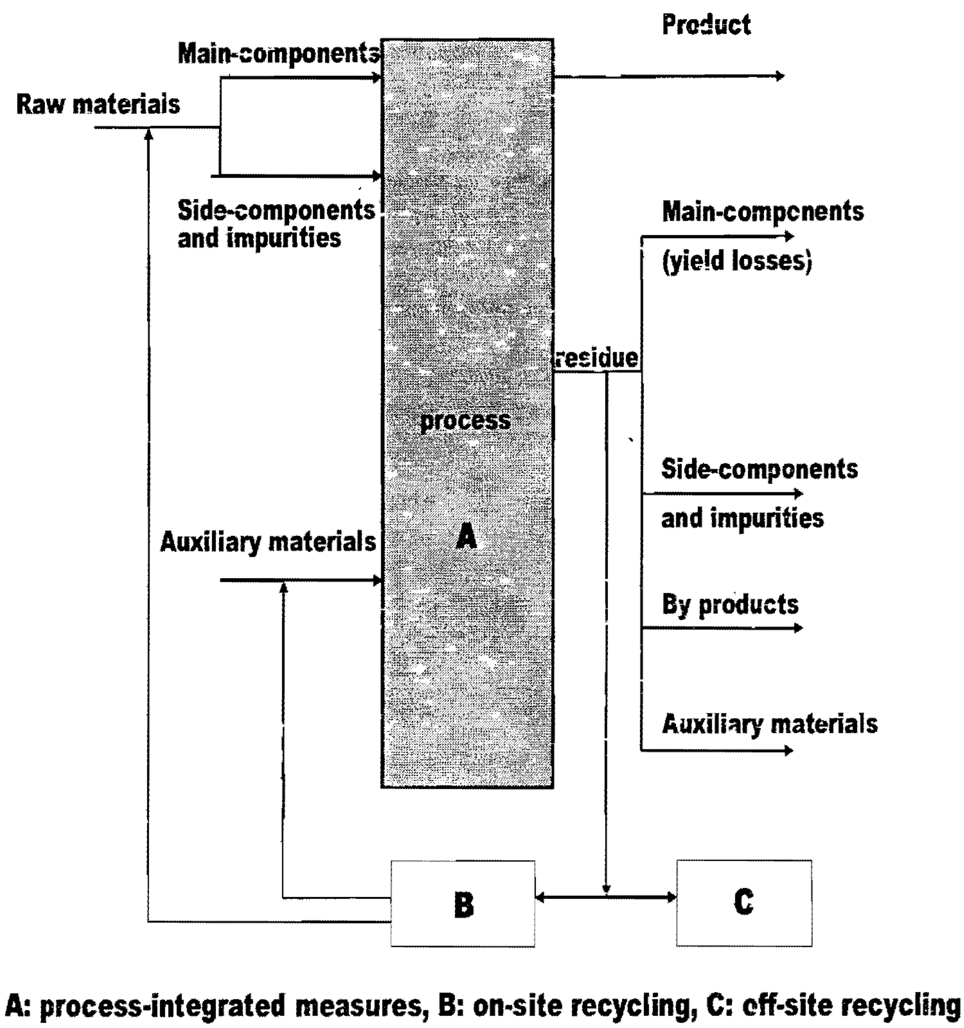

Figure 4. Waste minimization measures

Conclusions

The approach of Cleaner Production in industries is becoming increasingly important. Cleaner Production focuses on reducing resource consumption and avoiding the generation of wastes and pollutants. Cleaner Production not only provides improved environmental performance but also efficiency, financial savings and increased competitiveness in a market where consumers are more environmentally aware. The potential implementation of CP in the manufacturing of VCO has been addressed, especially focuses on two most common processing technology, namely dry process and wet process via centrifugation technique.

Table 2. Identification of critical process steps, CP strategies and opportunities

No	Process Step	CP Strategy	CP Opportunity
1	Coconut receiving and material warehouse	Good housekeeping	Establish clear criteria for purchased coconut, such as age of harvest, freshness, no physical defect, etc.
			Implement strict inspection of incoming coconut
			Implement incentive system for performing supplier
			Implement FIFO system in material warehouse
			Maintain optimum storage conditions, such as temperature, good ventilation
		Substitution of materials	Use type of coconut which gives higher oil yield, or organic-certified if market need it
2	Removing coconut shell, coconut water and testa	Modification of technology	Use of safe deshelling machine to minimize work accident
		Internal/external recycling	Utilization of collected coconut water for making nata de coco, vinegar, etc.
			Utilization of collected coconut shell for making charcoal, activated carbon, shell dust, or fed on boiler furnace
			Screw or hydraulic pressing of testa to recover the oil
3	Washing coconut meat and transfer	Modification of technology	Use of counter current washing technique instead of co-current or single cascade to minimize water usage

The critical manufacturing process steps have been identified and some possible options for implementing CP strategies, such as good housekeeping, substitution of materials, modification of technology, product modification and internal/external recycling have been illustrated. As already become a standard procedure for CP assessment methodology, these options of course still have to be evaluated for their feasibility (in terms of technical, financial, and environmental) prior to implementation. For doing this, collecting and establishing the existing data of process performance, benchmarking to similar industry and Best Available Technology, as well as analyzing and estimating the benefits of the proposed options have to be conducted.

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