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Process Design of the Production of Virgin Coconut Oil (VCO) Using Combined Low-Pressure Oil Extraction Method and Modified Kitchen Method

L.D. Pestaño[1], C.D. Diaz[2], M. Tamaki[2] and L.O. Timbre[2*]
[1]Ph.D. Professor, Chemical Engineering Department,
Faculty of Engineering, University of Santo Tomas, Manila, Philippines.
[2]BS ChE Student, Chemical Engineering Department,

(Corresponding author: L.O. Timbre)*
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ABSTRACT: Virgin coconut oil (VCO) is the most valued coconut-based product globally; thus, the production of VCO adds more profit than producing copra alone. This research aims to design a process to produce VCO involving the combined low-pressure oil extraction method and modified kitchen method applicable to a small-medium scale coconut community or farm in the Philippines. Preparation of raw materials includes splitting, grating of coconut meat and milk extraction. The VCO processing technology employs two assembly lines: (1) the fresh-wet process through modified kitchen method that consumes the extracted coconut milk; and (2) the fresh-dry process through low-pressure oil extraction method that utilizes the coconut meat residue or *sapal*. The Low-pressure oil extraction method combined with modified kitchen method was developed based on the review of VCO processing technologies that was conducted involving the two methods. Both assembly lines are expected to produce VCO that will qualify in the Asian and Pacific Coconut Community (APCC) standard for VCO. A conceptual design for the integrated method applicable to a small-medium scale coconut community or farm in the Philippines was developed that will yield 25% and 16.5% VCO for the low-pressure oil extraction method and modified kitchen method, respectively. The weight of all recovered materials and utilization of wastes in the VCO processing technology to produce value-added commodities were accounted for. This review of the combined VCO processing techniques will benefit coconut farmers and their families by providing additional income in their livelihood as they venture into an improved VCO processing.

Keywords: Copra, low-pressure oil extraction, modified kitchen method, *sinusinu*, small-medium scale, virgin coconut oil

Abbreviations: RCO, Refined Coconut Oil; RBD, Refined, Bleached, and Deodorized; VCO, Virgin Coconut Oil; PCA, Philippine Coconut Authority; ACOP, Asia-Pacific Ocean Cooperation Project; DA, Department of Agriculture; APCC, Asian and Pacific Coconut Community; FFA, Free Fatty Acids; PV, Peroxide Value; SV, Saponification Value; IV, Iodine Value; MIV, Moisture Impurities and Volatile Matter

I. INTRODUCTION

Coconut oil was derived from dried coconut (*Cocos nucifera*) meat kernels, also known as copra. Coconut oil belongs to the lauric oil group, which is a category of vegetable oil. There are several methods used in producing coconut oil, and these include wet and dry processing. The dry process is the prevalent method of extracting coconut oil [1]. A refined commercial coconut oil (RCO) is extracted from copra and undergoes an industrial process by washing, bleaching, and decolorization (RBD) [2]. On the other hand, virgin coconut oil (VCO) comes from fresh coconut meats that undergo physical processes. In contrast with RCO, the process does not require chemical refinement [3]. The method includes extracting fresh coconut milk by inducing heat [4].

The Philippines, compared to Southeast Asian competitors such as Indonesia, has been keeping in the lead in VCO production. Today, the Philippine Coconut Authority (PCA) reported a production capacity of 2931 MT. According to ACOP Inc., its affiliates can generate 50,000 L of VCO using a cold press [5]. VCO is currently produced mostly by small-medium scale businesses in the Philippines, with few caterings to the export market. It may be produced without any special equipment, and the raw material is coconut meat [6].A shorter period is required to achieve an increased production while also ensuring the quality of VCO, which depends on different factors relating to the condition of the raw material, processing method, packaging, and storage condition [4].

Researchers developed several VCO processes depending on the production capacity, availability, and cost that satisfy the highest efficiency. Bawalan and Chapman [7] classified these two methods into two types: dry process and wet process. Production of VCO under wet and dry processing methods are applicable at a small-medium scale setting with capacities of 5,000-10,000 nuts/day [8]. The dry process method involves the coconut meat kernels subjected to different operations such as low-pressure oil extraction, high-pressure extraction, and fresh-dry centrifuge. In contrast, the wet process method includes coconut milk and kernels under methods such as natural fermentation, fresh-wet centrifuge, and modified kitchen [7]. The researchers use the combination of dry and wet processing methods: low-pressure oil extraction method and modified kitchen method.

VCO is the most valued coconut-based product globally [9]; thus, the production of VCO adds more profit than producing copra alone. This review of the combined techniques for VCO processing will benefit coconut farmers as well as their families. This will provide additional income to improve the cost of living as they venture into an improved VCO processing.

Furthermore, researchers recommend VCO as a potential antiviral agent against coronavirus disease 2019 (COVID-19) [2]. Also, it is said to have a variety of health benefits such as skincare, haircare, stress relief, weight loss, cholesterol level maintenance, immunomodulatory effects, cardiovascular uses, and, more recently, Alzheimer’s disease are among them [10].According to Babu *et al.* [11], VCO shows potential cardio protective effects due to its medium-chain fatty acids content, which is known for high antioxidant properties.

This research intends to design a processing technology that combines low-pressure oil extraction method and modified kitchen method to produce VCO in a small-medium scale setting. The VCO to be produced using the integrated approach would qualify the standards set by the Department of Agriculture (DA) and the Philippine Coconut Authority (PCA).

The specific objectives are:

- To conduct a review of the VCO production technologies that utilize the combined low-pressure oil extraction method and modified kitchen method.
- To determine the total weight of recovered materials and coconut wastes and investigate the possible utilization of these wastes to produce value-added commodities.
- To develop a conceptual design of the production of VCO that applies to a small-medium scale coconut community or farm in the Philippines.

The combined process is designed for a small-medium scale set-up as one of the technologies undergoes the fresh-dry process. It works on the premise that oil from seeds or nuts can be extracted using low pressure at roughly 460 psi if the moisture percentage of the material is between 10% and 13% [12].

II. MATERIALS AND METHODS

A. Process description

The VCO processing technology will use 6,000 matured de-husked nuts per day which is ideal for small-medium scale setting. The VCO process will employ two assembly lines: VCO extraction through fresh-dry process by the low-pressure oil extraction method, which can be done in a typical coconut farm in the Philippines and through fresh-wet process by the modified kitchen method, done in the convenience of the homes of its populaces.

B. Preparation of raw materials

Fresh and matured de-husked coconuts of 10 to 12 months of age will be utilized. Place the nuts in large rice sacks and bring them to an area for splitting and grating.

Collection of coconut water. Make a hole in one of the “eyes” of the nut, as shown in Fig. 1 since it is the area where the thinnest shell is located. Using a hammer and a clean nail, puncture a hole to create an orifice and let the coconut water to drain. Collect the coconut water using clean plastic containers and store it in a refrigerator [13].

Fig. 1. The coconut’s “eye” [13].

Splitting. As shown in Fig. 2, hold the nut with one hand and apply a force using a large kitchen knife until the nut is completely split into half [13].

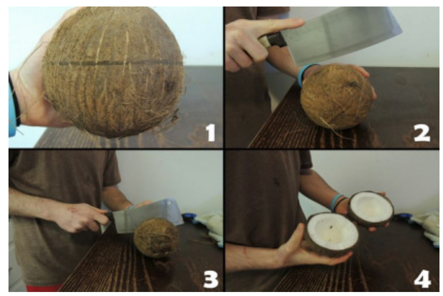

Fig. 2. Steps in splitting coconut [14].

Grating of coconut meat. Hold the de-husked coconut and subject the whole white coconut meat portion to the scraping tool in a circular motion (See Fig. 3) to comminute the meat into fine particles. Collect the grated coconut meat in clean large plastic pails and put the coconut shells in large plastic bags.

Fig. 3. Grating of coconut meat [15].

Coconut milk extraction. The coconut milk can be extracted by hand or by a manual hydraulic jack. Mix the grated coconut with water, which creates a milky heterogeneous mixture. Several sources claim that the ideal ratio of water to grated coconut is 1:1 to create the desired consistency of coconut milk [16].

Extraction of coconut milk by hand. Place the grated coconut mixture in cheesecloth bags as shown in Fig. 4. Squeeze the cheesecloth bags containing the grated coconut mixture to extract the coconut milk. Collect the extracted coconut milk and coconut meat residue (*sapal*) separately in clean large transparent plastic containers.

Fig. 4. Hand squeezing of coconut milk using a cheesecloth [17].

Extraction of coconut milk by manual hydraulic jack. Place the cheesecloth bag containing the grated coconut mixture at the center of a manually operated hydraulic jack and extract the coconut milk according to the jack's operating procedure as shown in Fig. 5. Collect the coconut milk and grated coconut meat residue separately in clean large transparent plastic containers.

Fig. 5. Extraction of coconut milk using a manual hydraulic jack [17].

C. VCO processing methods

The collected coconut milk will undergo modified kitchen method while the collected *sapal* will be subjected to low-pressure oil extraction method.

D. Modified kitchen method

Settling. Let the coconut milk settle for exactly 2 hours in a chilled refrigerator about 0°C to 4°C [17]. The coconut milk extract should appear separated into two phases: the coconut cream layer and the coconut skim milk layer as shown in Fig. 6. Using a ladle, scoop the coconut cream (oily phase) from the top. Put the cream in clean medium plastic containers and store the skim milk in the refrigerator.

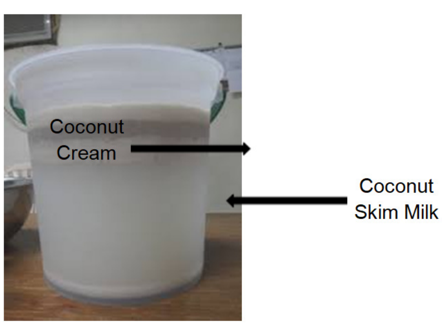

Fig. 6. Separated coconut cream and skim milk [17].

Slow heating. Heat the coconut cream in a casserole pan. For the first hour, set the stove between medium to high until the temperature reaches 90°C. For the succeeding hours, heating will be done at a temperature not higher than 80°C until the coconut cream starts to form the coagulated protein (*sinusinu*) [17] (See Fig. 7). At this point, lower the temperature setting at 60°C. Use a kitchen thermometer to control all the temperatures precisely. Continuously stir the mixture to prevent the oil from turning yellowish in color.

Fig. 7. Separation of oil from the coagulated protein (*sinusinu*) [17].

Filtering. Filter the oil-*sinusinu* mixture to eliminate the adhering fine particles, leaving a colorless oil. Put a muslin cloth into a strainer and pour the oil-*sinusinu* mixture over the cloth (Fig. 8). Commercially available muslin cloth can be bought in fabric stores in the market and are commonly 90 x 100 cm in dimension [18]. Collect the filtered coconut oil in clean transparent medium plastic containers. Remove the *sinusinu* from the muslin cloth then manually squeeze the cloth to collect the absorbed coconut oil [17]. Collect the *sinusinu* residue in large plastic bags.

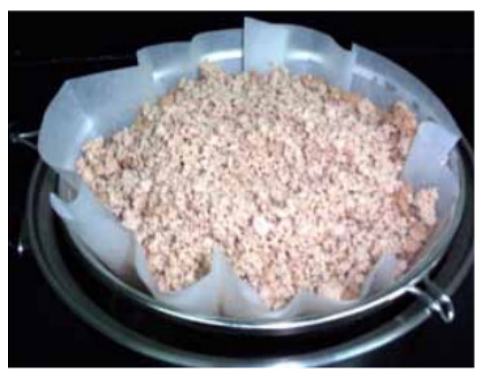

Fig. 8. Separation of *sinusinu* from VCO [17].

Oil drying. Oil drying will be done through a double boiler process [17]. Submerge a stainless-steel mixing bowl inside a pot with half full of water. Put the coconut oil in the mixing bowl. Reduce the setting of the stove to low once the water starts to boil. The coconut oil should not be heated directly in the pot to prevent the temperature from exceeding 65°C since this will make the coconut oil yellowish in color [17]. Collect the final colorless VCO from the mixing bowl in large clean plastic containers with a cover. Label the containers with VCO.

Fig. 9. Double boiler setup [17].

E. Low-pressure oil extraction

Drying. Pre-heat the electric tray dryer at 70°C for about 30 minutes [12]. Spread the *sapal* uniformly over the surface of 16 × 32 × 1 ¼ in. trays. Load batches of trays containing *sapal* into the pre-heated electric dryer. Dry the *sapal* at a temperature of 70°C for 29.7 minutes reaching 11% moisture content, to attain an optimum oil recovery [12, 17], as shown in Fig. 10. Place the dried *sapal* in clean cheesecloth bags.

Fig. 10. Drying *sapal* using tray dryer [17].

Manual pressing. Position the packed dried *sapal* in the pressing area of the hydraulic manual press [17]. Prepare clean plastic containers with a lid under the pressing area of the hydraulic manual press. Move the pump operating lever at the side in an alternating push-and-pull motion to compress the dried *sapal*.

Fig. 11. Manual pressing of *sapal* [17].

Release the lever until all the crude coconut oil has been extracted from the *sapal*, as shown in Fig. 11. Collect the spent dried *sapal* in clean large plastic bags. Set aside the crude coconut oil for settling.

Settling. Let the extracted crude coconut oil stand for seven days to settle the fine particles adhered to the crude coconut oil. Allot another seven days to settle the crude coconut oil [17]. Decant the final VCO to clean plastic containers and collect the fine particles in plastic bags for disposal for the 2 intervals. Cover and label the containers.

F. Collection of wastes and disposal

Dispose the coconut shells by selling them to charcoal, plywood, or handicraft manufacturers. Store the collected coconut water in a refrigerator for consumption purposes or this can be converted to a high-energy drink that can be sold to consumers [19]. Wash the cheesecloth bags and muslin cloth fabrics after the processes and reuse them again for another batch of operation. Refrigerate the coconut skim milkfor a maximum of two hours for consumption purposes.

Set aside the *sinusinu* to use as a rice cake topping or a meat-based food extender, decreasing the cost of the meal without sacrificing its nutritional value.

Set aside the spent dried *sapal* meat since this can be used in different applications such as a healthy snack food, a meat extender, and an organic fertilizer.

G. Quality testing

The obtained VCO from the modified kitchen method will be tested for different parameters such as iodine value, peroxide value, saponification value, moisture content, and free fatty acids (FFA). The VCO samples will be brought to the Philippine Coconut Authority (PCA) for the testing of said parameters.

H.Mass balance

A mass balance of all the process units is executed to account for the mass of various streams entering and leaving each process. 6000 nuts per day was used as the basis for a small-medium scale setting in coconut farms. All percentage compositions are per weight. The calculated amounts from the mass balances are used as basis to determine the desired yield and productivity.

III. RESULTS AND DISCUSSION

A. Process design of the VCO processing

After the procurement of fresh and matured de-husked coconuts, the preparation of raw materials will be done that includes: (1) collection of coconut water; (2) splitting; and (3) grating of coconut meat; and (4) milk extraction that will produce coconut milk and coconut meat residue (*sapal*). Coconut water and coconut shells are waste products that can be converted into value-added commodities.

The VCO processing technology employs two assembly lines: (1) the fresh-wet process by the modified kitchen method that will consume the extracted coconut milk; and (2) the fresh-dry process by the low-pressure oil extraction method that utilizes the sapal. The major product of both assembly lines is the VCO. Shown above in Fig. 12 is the flowchart of the integrated modified kitchen method and low-pressure oil extraction method for the production of VCO.

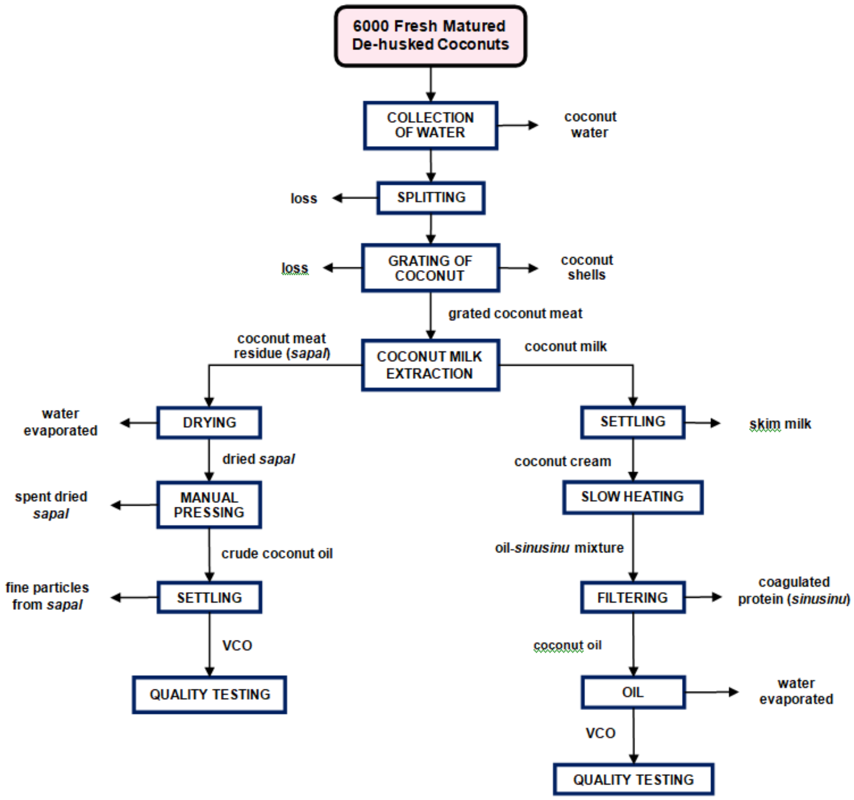

Fig. 12. Flowchart of the integrated modified kitchen method and low-pressure oil extraction method for the production of VCO.

B. Quantitative flow diagram

The researchers were able to determine the average weight of the following quantities: 520.07 g coconut water; 312.21 g coconut shell; and 517.27 g grated coconut meat per nut. The average composition of a nut for an average weight of 1374.01 g were computed as 22.72% shell, 37.85% water, 37.65% flesh, and 1.78% that corresponds to losses in handling [12].

For an input of 222 kg fresh grated coconut meat, 85 kg milk was extracted through manual pressing with 130 kg coconut residue (*sapal*) and 7 kg losses [8]. The researchers were able to calculate the following percentage composition: 38.29% coconut milk, 58.56% grated coconut meat residue, and 3.15% loss.

The weight of dried *sapal with* 10-12% moisture, spent dried *sapal*, *sinusinu,* and VCO per input of *sapal*and grated coconut meat is shown in Table 1 [8,16]. Coconut milk is composed of coconut cream and skim milk. The composition of coconut cream consists of 74.6% moisture, 20% fat, and 5.4% non-fat solids [20]. Using Equation (1), the mass of coconut cream can be determined from the fat content of the coconut cream and recovery of VCO.

$$\text{kg coconut cream} = \frac{\%\text{VCO recovery} * \text{ kg coconut milk}}{\%\text{ fat in coconut cream}} \quad (1)\ [20]$$

An experiment by Hundana*et al.*[21],used the modified kitchen method where after slow heating and filtration process of coconut cream, the weight of *sinusinu* was determined. Furthermore, according to Bawalan [17], for the modified kitchen method, 16.5 kg VCO per 100 kg grated coconut meat was recovered. From the data, other recovered materials were determined. The recovery of materials for low-pressure oil extraction method and modified kitchen method is shown in the Table 1.

Table 1: Recovery of materials for low-pressure oil extraction method and modified kitchen method.

	Input	Output
Low-Pressure Oil Extraction Method [8]	130 kg *sapal*	89 kg dried *sapal*
	89 kg dried *sapal*	21 kg spent dried *sapal*
	100 kg grated coconut meat	25 kg VCO
Modified Kitchen Method [17, 21]	1125 kg grated coconut meat	162 g *sinusinu*
	100 kg grated coconut meat	16.5 kg VCO

Using the data above from different VCO technology studies, Fig. 13 below shows the quantitative flow diagram (QFD) for the production of VCO. The QFD indicates that for 6000 fresh mature de-husked coconuts per day will be collected, the total weight of the nuts is 8244.06 kg and contains 3120.42 kg water, 709.04 kg coconut shell, 3103.62 kg grated coconut meat, and 97.86 kg losses. The obtained grated coconut is extracted producing coconut milk. The coconut milk will undergo the modified kitchen method while the extracted coconut meat residue (*sapal*) will be sent to the low-pressure oil extraction method assembly line.

From 1188.32 kg coconut milk, 207.956 kg coconut skim milk and 980.37 kg coconut cream are produced. The obtained coconut cream is sent to a slow heating process resulting in a 980.37 kg oil-*sinusinu* mixture. The product mixture is filtered producing 446.92 kg *sinusinu* and 533.45 kg coconut oil. The obtained coconut oil evaporated 21.35 kg of residual moisture and produced the final product, 512.10 kg VCO.

On the other hand, the *sapal* weighing 1817.435 kg is subjected to drying: evaporating 573.19 kg of water and producing 1244.24 kg dried *sapal*. The obtained dried *sepal* is sent to manual pressing, producing 950.66 kg crude coconut oil and 293.59 kg spent dried *sapal*. The obtained crude coconut oil is subjected to settling, collecting 174.75 kg fine particles and the final product, 775.91 kg VCO.

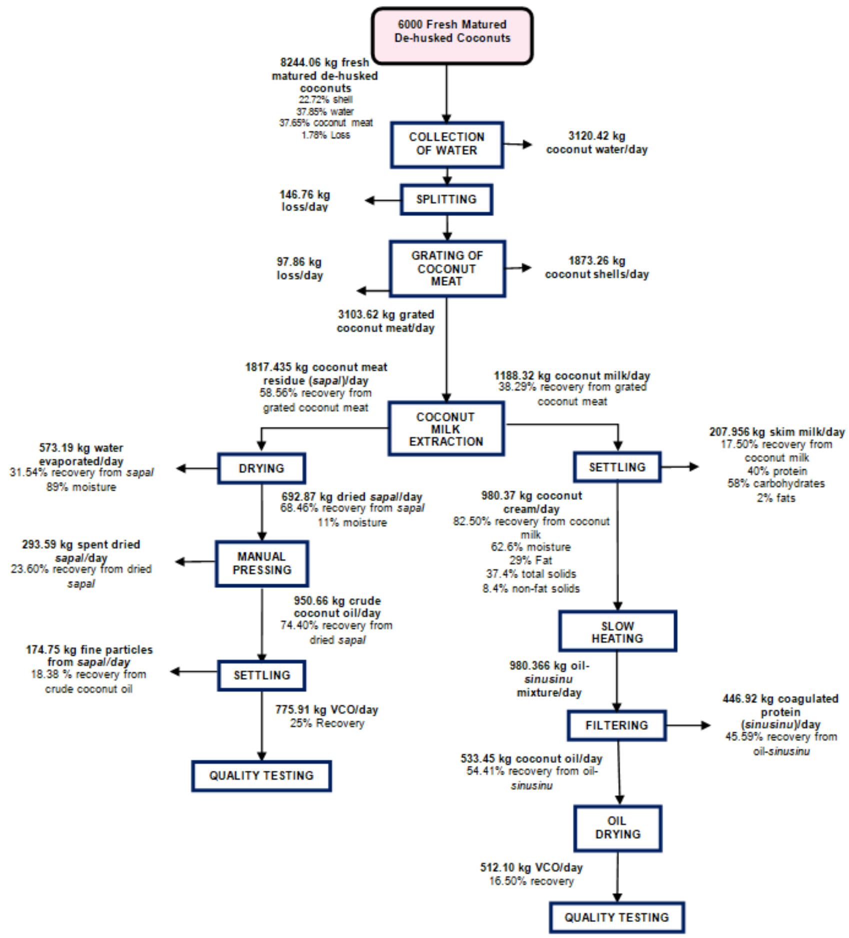

Fig. 13. Quantitative flow diagram for the production of VCO through a combination of low-pressure oil extraction method and modified kitchen method.

C. Review of VCO technology

The modified kitchen method and low-pressure oil extraction method have several recommendations as described by the authors. In the milk extraction process, the ideal ratio of water to grated coconut is 1:1 in order to create coconut milk [15].

For the modified kitchen method, it is highly recommended to subject the VCO to an oil drying process due to its initially high moisture content [17]. The presence of water in VCO will make the oil spoiled. According to Bawalan [17], the allowable moisture content of oil should not exceed 0.1% for the VCO to have a longer shelf-life. Additionally, for slow heating, reduce the setting of the stove to low once the pot-filled water starts to boil. The oil shall not be heated directly in the pot to prevent the temperature from exceeding 65°C since this will make the oil yellowish in color [17].

A study reported the importance of drying for the low-pressure oil extraction method. The optimum oil recovery for low-pressure oil extraction is attainable when the dried grated kernel's moisture content is 11% before extraction [17]. No oil can be extracted when the moisture content is much lower than 11%, while the oil tends to mix with the coconut milk when the moisture content is much higher than 11% [7]. Since it is required to reach a 10–12% range of moisture content, it is necessary to do a material balance computation to determine the kernel's final weight when its moisture content reduces to 11%. Additionally, the moisture content of the dried kernel is usually determined by feel and greatly depends on the skill of the operator doing the drying process and preparing the grated kernel prior to extraction [17].

Quality testing. The Asian Pacific Coconut Community (APCC) and Codex Alimentarius have standardized quality control criteria for physical, chemical, and microbiological characteristics of VCO, as seen in Table 2 [22]. A VCO that meets APCC's interim standard indicates that the oil is produced by natural means and there are no alterations in its properties. Conforming to the Codex Standard for Coconut Oil implies that “virgin oils” are suitable for human consumption and purification can be done by water-washing, settling, filtering, and centrifugation to remove undesired components and extend shelf life [23].

The three scientific journals for the production of VCO through the modified kitchen and low-pressure oil extraction method by Achinewhu *et al.* [24], Sedode [25], and Afiq *et al.* [26], showed the quality testing results for physicochemical properties such as the Iodine Value, FFA, Peroxide Value, Saponification Value, and Moisture Content. The data were investigated and compared from the required values based on the Asian and Pacific Coconut Community (APCC) Standard for VCO, shown in Table 2.

Table 2: Quality testing results for the two VCO processing technologies.

Parameter	Asian and Pacific Coconut Community (APCC) Standard for VCO [22]	Modified Kitchen Method		Low-Pressure Oil Extraction
		Achinewhu*et al.*[24]	Sedode[25]	Afiq*et al.* [26]
Iodine Value (g/100g)	4.1-11	6.05 ± 0.071	5.88	4.18 ± 0.04
FFA (%)	0.2	0.051 ± 0.005	0.14	0.46 ± 0.01
Peroxide Value (MEq/kg)	3	1.288 ± 0.105	0.74	N/A
Saponification Value (mg kOH/g)	250-260	259.40 ± 0.566	N/A	258.42 ± 1.41
Moisture Content (%)	0.1	0.055 ± 0.07	0.02	0.04
Oil Recovery (%)	-	58.00 ± 0.001	18.89	88.35 ± 5.96

For the study of Achinewhu *et al.* [24], the Peroxide Value (PV) of the oil samples for the Hot-Pressed Method, also known as the modified kitchen method, is lower than the APCC of <3.00 mEq/kg. Low PV of the extracted VCO is due to the freshness of the mature coconut copra used. Also, this indicated that the samples are highly stable against oxidative rancidity [24]. The Saponification Value (SV) of the VCO extracted is within the standard limit for VCO, as recommended by APCC. High SV gives an indicator for the suitability of vegetable oil for industrial application [24]. Moisture impurities and volatile matter (MIV) in the samples are below APCC setstandard of <0.2% [24]. MIV are important determinants of oil quality [24]. It is best to maintain the moisture level low as it extends the shelf life by preventing oxidation and rancidity. Hydrolytic rancidity of vegetable oils and fats is increased by high moisture content [24]. The Iodine Value (IV) of the samples is within the standard limit as recommended by the APCC. The low IV of coconut oil is an indication that the oil is rich in saturated fatty acids [22]. The Free Fatty Acid (FFA) of the samples is lower than the APCC standard. Low FFA in the oil sample is an indication of good storage stability [24].

A study by Sedode [25] determined the quality of several VCO processing techniques, one of which is the modified kitchen method. The determined value for Iodine is lower than the standard values based on APCC. This indicated a high value of unsaturated fat in the VCO [25]. On the other hand, the %FFA, peroxide value, and moisture content qualified in the ranges and minimum values of the APCC standard for VCO.

The physicochemical properties of VCO extracted from various processing methods, including the fresh-dry low-pressure oil extraction method, were analyzed in a study by Afiq *et al.* [26]. Iodine Value was found to affect the overall quality parameters of VCO, such as the shelf life, appearance, taste, and smell. A low IV indicates that it is unlikely for VCO to become rancid from lipid oxidation [26]. The drying time for *sapal* prior to oil extraction can also affect the %FFA of VCO. A longer drying time leads to an increase in % FFA, causing more time for the process of rancidity to occur [26].

IV. CONCLUSION

The process for the production of VCO that employs a combined low-pressure oil extraction method and modified kitchen method was developed based on the review of VCO processing technologies that was conducted involving the two methods. Both assembly lines are expected to produce VCO that will qualify in the Asian and Pacific Coconut Community (APCC) Standard for VCO. A conceptual design for the integrated method that is applicable to a small-medium scale coconut community or farm in the Philippines was developed that will yield 25% and 16.5% VCO for the low-pressure oil extraction method and modified kitchen method, respectively. The weight of all recovered materials and wastes in the VCO processing technology and the utilization of wastes to produce value-added commodities were accounted for.

V. FUTURE SCOPE

Virgin coconut oil could be used as potential antiviral agent against COVID-19 and have a variety of health benefits. Venturing to an improved VCO processing technology through the combined low-pressure oil extraction method and modified kitchen method in a small-medium scale setting, this could increase the production of VCO and will benefit coconut farmers in providing them additional income to their families.

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Conflict of Interest. The authors declare no conflict of interest.

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