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Production of virgin coconut oil from desiccated coconut

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Abstract

Virgin Coconut Oil (VCO) is a high-value product with diverse food, cosmetic, and nutraceutical applications. Its production presents a significant economic opportunity for coconut cultivators. However, prevailing local production methods often yield a product that fails to comply with national and international quality standards, diminishing its commercial value and restricting market access. This report details a standardized process for producing VCO on a household scale using the dry-pressing method. The investigation demonstrates that oil produced via this methodology consistently meets the quality parameters stipulated by the Asian and Pacific Coconut Community (APCC) standards. The adoption of this process has the potential to enhance the economic value and marketability of locally produced Virgin Coconut Oil.

Keywords: Virgin coconut oil, dry-pressing method, desiccated coconut, APCC standards (Asian and Pacific Coconut Community), CODEX

1. Introduction

Virgin Coconut Oil (VCO) is a clear, sediment-free oil with a natural coconut aroma, devoid of any rancid or sour smells.[1] Unlike some other oils, VCO is primarily composed of medium-chain triglycerides of saturated fatty acids (about 90-95%).[2] Due to their short chain length, the fatty acid radicals in coconut oil are easily absorbed into cells and immediately converted into energy, which means VCO is more digestible than other types of triglycerides.[3]

VCO is extracted from fresh coconut meat (12-13 months old) using various extraction methods, which depend on the desired quality, production scale, and cost.[4],[5] There are generally two main

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methods for producing VCO: fresh wet and fresh dry.[6] VCO obtained through the fresh wet method,[7],[8],[9],[10],[11],[12] via coconut milk, is of high quality. It is light, easily absorbed by the skin, and contains antioxidant compounds. The extraction equipment is also simple. However, the yield of VCO from this method is not high (17-30%) [13],[14], or it requires the use of special, rare enzymes to achieve a higher yield (65-83%).[15],[16],[17] In the fresh dry method,[7],[18],[19],[20] VCO is obtained directly from desiccated coconut. The resulting VCO often contains natural gums and has a distinctive coconut meat aroma. This method offers a higher yield (around 60%), but it is more expensive due to the need to invest in production machinery and equipment.

The information presented suggests that the fresh dry method for producing coconut oil has more advantages, including a better yield, making it more economical and easier to implement.

2. Experimental Method

2.1. Drying of fresh coconut kernel

Fresh coconut kernel purchased from the market was dried to a specific moisture content using an electric stove and a non-stick pan. The stove's temperature was set to around 70 °C. The coconut meat was continuously stirred in the pan until the desired moisture content was reached. Specifically, 714.87 g of fresh coconut meat was roasted at approximately 65-70 °C for about 75 minutes, yielding 401.63 g of dried coconut meat with a moisture content of about 4.5%.

2.2. Extracting virgin coconut oil from desiccated coconut

The desiccated coconut from the previous drying step was fed into a Lalifa 08NC press to extract the oil. During pressing, the temperature was maintained below 90 °C. If this temperature is exceeded, the oil will turn yellow and will no longer be virgin. The oil obtained from this stage still contains solid impurities (coconut residue) and is therefore filtered through a Celite filter aid layer to obtain a clear oil. Specifically, 401.63 g of dried coconut meat with a 4.5% moisture content was pressed with a Lalifa 08NC machine, yielding 259.22 g (64.5% yield) of oil still mixed with coconut residue. After filtering with 50 g of Celite filter aid powder, 250.81 g (62.5% yield) of a clear, colorless oil was obtained. The mass of the coconut residue after oil separation was 140.58 g.

2.3. Determine the moisture content of the obtained VCO [21]

Place a weighing bottle (with its mass already recorded) containing 10.000 ± 0.001 g of the VCO oil sample into a drying oven and dry it at 103 ± 2 °C for 1 hour. Afterward, cool it to room temperature in a desiccator and weigh it precisely to 0.001 g. Repeat the process, but reduce the drying time to 30 minutes each time, until the mass loss between two consecutive weighings does not exceed 4 mg.

3. Results and discussion

3.1. Yield and moisture content of the obtained VCO with different types of desiccated coconut at varying moisture levels

Applying the desiccated coconut pressing procedure from section 2.1 and 2.2 in the experimental part to different types of desiccated coconut with varying moisture levels yielded Virgin Coconut Oil (VCO) at corresponding yields (Table 1). The results show that as the moisture content of the desiccated coconut increases, the VCO yield decreases. The highest yield was achieved when the desiccated coconut had a moisture content of 4.5% (Figure 1).

This outcome may seem counter-intuitive, but it can be explained by the fact that if the desiccated coconut's moisture content is higher than 4.5%, the oil extraction process is not optimal. The resulting oil contains a large amount of residual desiccated coconut, which negatively affects the overall VCO yield. This is further evidenced by the increase in the mass of the coconut residue as the moisture content of the desiccated coconut increases (m_{bd} increases as the moisture content of the desiccated coconut increases).

Conversely, when the desiccated coconut's moisture is below 4.5% (around 2.6%), the pressing process becomes very difficult and often causes the press screw to jam.

Furthermore, the VCO obtained from desiccated coconut samples with a moisture content higher than 6.2% (Table 2) has a higher moisture content, exceeding the APCC standard (which sets the maximum moisture content for VCO at 0.1%). This moisture standard is crucial because the water content in VCO directly impacts its quality and shelf life. High moisture content can cause the oil to turn rancid and significantly shorten its shelf life. This is why the moisture content in the oil should be reduced as much as possible, ideally not exceeding 0.1%.

Table 1. VCO yield based on desiccated coconut moisture.

	Desiccated coconut moisture						
	3%	**4%**	**6%**	**8%**	**10%**	**12%**	**14%**
m_0 (g)	714.78	714.87	714.72	715.10	715.98	713.36	715.78
m_1 (g)	383.41	383.46	383.38	383.58	384.05	382.65	383.94
m_2 (g)	393.74	401.63	408.53	418.64	429.29	435.28	447.26
A (%)	2.6	4.5	6.2	8.4	10.5	12.1	14.2
m_{d1} (g)	–[a]	259.22	244.44	235.42	227.70	219.17	192.62
H_1 (%)		64.5	59.8	56.2	53.0	50.4	43.1
m_{d2} (g)		250.81	232.92	224.37	220.35	207.52	180.54
H_2 (%)		62.5	57.0	53.59	51.3	47.8	40.4
m_{bd} (g)		140.58	161.84	181.27	199.82	214.05	252.48

[a]: VCO was not produced under these experiment condition; where: m_0: Initial mass of coconut meat (g); m_1: Estimate mass of desiccated coconut with 0% moisture (g); m_2: mass of coconut meat after drying (g); A: Actual moisture content of coconut meat after drying (%); m_{d1}: Mass of VCO pressed out without filtering (g); m_{d2}: Mass of VCO pressed out after filtration (g); H_1: Unfiltered VCO yield (%); H_2: Filtered VCO yield (%); m_{bd}: Coconut pulp mass after pressing (g)

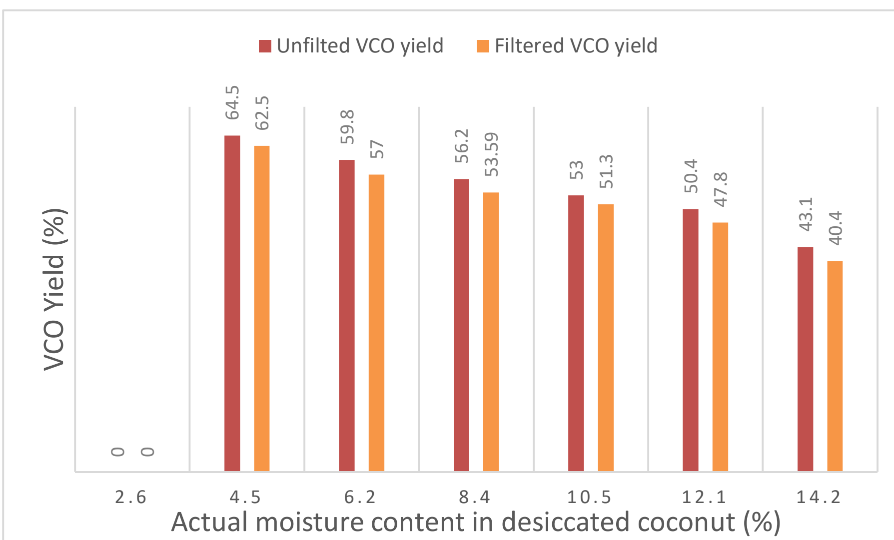

Figure 1. VCO yield based on desiccated coconut moisture.

According to the data in Table 1 and Table 2, the moisture of VCO1 (0.087%) is significantly lower than the APCC limit (0.1%) and is comparable to the RBD CNO (0.098%). While it is higher than the Commercial VCO (0.021%), it still meets the strict quality requirements without requiring an industrial drying stage.

We selected oil samples VCO1, VCO2, VCO3, VCO4, and VCO5 for further testing of other parameters, as their moisture content is the closest to the required standard.

Table 2. Moisture content analysis: In-housed produced vs. two commercial VCOs.

Oil samples (A%)	m_0 (g)	m'_0 (g)	m_1 (g)	m_2 (g)	W (%)
VCO1 (4.5%)	17.9114	10.0033	27.9147	27.9060	0.087
VCO2 (6.2%)	20.3243	10.0037	30.3280	30.3178	0.102
VCO3 (8.4%)	18.0677	10.0037	28.0714	28.0586	0.128
VCO4 (10.5%)	15.1050	10.0058	25.1108	25.0961	0.147
VCO5 (12.1%)	20.1975	10.0014	30.1989	30.1821	0.168
VCO6 (14.2%)	18.3420	10.0081	28.3501	28.3289	0.212
Commercial VCOs					
Commercial VCO	21.1643	10.0073	31.1716	31.1695	0.021
RBD CNO	17.9370	10.0068	27.9438	27.9340	0.098

Where: A: Actual moisture content of desiccated coconut (%); m_0: mass of tare (g); m'_0: Initial mass of oil sample (g); m_1: Tare and oil sample mass (g); m_2: Tare and oil sample mass after drying (g); W: VCO moisture (%)

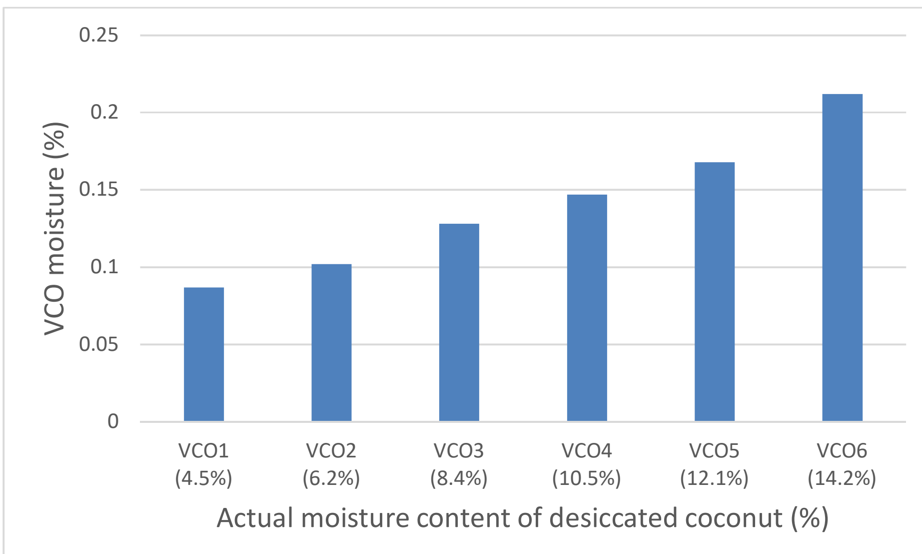

Figure 2. Moisture of filtered VCO based on initial desiccated coconut moisture.

3.2. Free fatty acid

The free fatty acid (FFA) in each VCO sample was determined three times for repeatability and reliability. The results (Table 3) were presented as the average value of the data obtained. The mean and standard deviation were calculated by using MS-Excel.

Based on the APCC standard, the maximum limit for FFA is ≤ 0.1% for Refined, Bleached, and Deodorized Coconut Oil (RBD CNO) and ≤ 0.2% for Virgin Coconut Oil (VCO). The Codex standard sets a maximum limit of 0.3%.

Our in-house produced VCO samples ranged from 0.07% to 0.22% FFA. In contrast, the commercial VCO sample had an FFA of 0.093%. VCO1 achieved the lowest FFA value (0.072%) among all samples, including the Commercial VCO (0.093%) and RBD CNO (0.082%), indicating excellent prevention of hydrolytic rancidity during our standardized lab-scale process.

There is a clear correlation between the moisture content of the coconut oil and its FFA percentage: the higher the moisture content, the higher the FFA. This is because moisture facilitates the hydrolysis of triglycerides into free fatty acids.

It is worth noting that in the production of RBD CNO, chemical treatments are used to remove any remaining free fatty acids, water, and microbial or enzymatic residues.

According to the APCC standard, all the samples are acceptable except for the VCO5 sample, which exceeds the 0.2% limit.

Table 3. FFA results of samples.

Sample	Free fatty acid (%)			
	Trial 1	**Trial 2**	**Trial 3**	**Result**
VCO1	0.073	0.073	0.070	0.072 ± 0.002
VCO2	0.114	0.114	0.110	0.113 ± 0.002
VCO3	0.135	0.135	0.140	0.137 ± 0.003
VCO4	0.187	0.187	0.190	0.188± 0.002
VCO5	0.218	0.218	0.220	0.219 ± 0.001
RBD CNO	0.083	0.083	0.080	0.082 ± 0.002
Commercial VCO	0.094	0.094	0.090	0.093 ± 0.002
APCC [a]	≤ 0.1 (Refined Oil)			
	≤ 0.2 (Virgin Oil)			
CODEX [b]	≤ 0.3			

[a]*The Asian Pacific Coconut Community standard;* [22] [b]*Codex standard* [23]

3.3. Saponification value

The saponification value (SV) of each oil sample was determined three times for repeatability and reliability. The results (Table 4) were presented as the average value of the data obtained. The mean and standard deviation were calculated using MS-Excel.

Table 4. SV results of oil samples.

Sample	Saponification value (mg KOH/g oil)			
	Trial 1	**Trial 2**	**Trial 3**	**Result**
VCO1	262	262	261	262 ± 1
VCO2	256	255	256	256 ± 1
VCO3	254	255	255	255 ± 1
VCO4	253	253	254	253 ± 1
VCO5	259	258	257	258 ± 1
RBD CNO	252	253	253	253 ± 1
Commercial VCO	262	261	261	261 ± 1
APCC [a]	250-260			
CODEX [b]	248-265			

[a] *The Asian Pacific Coconut Community standard;* [b] *Codex standard*

Both the APCC and Codex standards set specific ranges for the SV, which indicates the amount of potassium hydroxide (KOH) required to saponify a gram of oil. The APCC standard is 250-260 mg KOH/g oil, while the Codex standard is 248-265 mg KOH/g oil.

Our in-house produced VCO samples had a saponification value ranging from 254-262 mg KOH/g oil. The VCO1 sample and the commercial VCO sample both had the highest SV at 262 mg KOH/g oil. This high SV suggests a superior ability to make soap compared to the RBD CNO sample, which had an SV of 252 mg KOH/g oil. A higher saponification value for a triglyceride also indicates a higher concentration of medium-chain fatty acids (MCFAs) in the oil. All the tested oil samples fell within the acceptable limits of both the APCC and Codex standards.

3.4. Iodine value

The iodine value (IDV) of each oil sample was determined three times for repeatability and reliability. The result (Table 5) was presented as the average value of the data obtained. The mean and standard deviation were calculated using MS-Excel.

Table 5. IDV results of samples.

Sample	Iodine Value (g I_2/100 g oil)			
	Trial 1	**Trial 2**	**Trial 3**	**Result**
VCO1	7.54	7.55	7.55	7.55 ± 0.01
VCO2	7.49	7.50	7.50	7.50 ± 0.01
VCO3	7.61	7.61	7.59	7.60 ± 0.01
VCO4	7.53	7.53	7.54	7.53 ± 0.01
VCO5	7.58	7.58	7.57	7.58 ± 0.01
RBD CNO	7.46	7.46	7.47	7.46± 0.01
Commercial VCO	7.35	7.34	7.31	7.33 ± 0.02
APCC [a]	4.1-11.1			
CODEX [b]	6.3-10.6			

[a]*The Asian Pacific Coconut Community standard;* [b]*Codex standard*

According to the Codex and APCC standards, the acceptable iodine value (IV) for coconut oil ranges from 6.3-10.6 g I_2/100 g oil and 4.1-11.1 g I_2/100 g oil, respectively.

Our results show that the in-house produced VCO samples had an iodine value between 7.50-7.60 g I_2/100 g oil, which is slightly higher than that of the commercial VCO sample (7.34 g I_2/100 g oil) and the RBD CNO sample (7.46 g I_2/100 g oil).

The fact that the iodine values for all three types of coconut oil samples are very similar suggests that their content of unsaturated fatty acids is not significantly different. All the tested samples fall within the accepted limits of both the Codex and APCC standards for coconut oil.

3.5. Peroxide value

The peroxide value (PV) of each oil sample was determined three times for repeatability and reliability. The results (Table 6) were presented as the average value of the data obtained. The mean and standard deviation were calculated using MS-Excel.

Table 6. PV result of sample.

Sample	Peroxide value (mEq O_2/ kg oil)			
	Trial 1	Trial 2	Trial 3	Result
VCO1	1.16	0.96	1.06	1.06 ± 0.10
VCO2	1.45	1.25	1.35	1.35 ± 0.10
VCO3	1.83	1.64	1.74	1.74 ± 0.10
VCO4	2.12	2.02	2.22	2.12 ± 0.10
VCO5	2.41	2.51	2.32	2.41± 0.10
RBD CNO	0.87	0.77	0.67	0.77± 0.10
Commercial VCO	1.44	1.53	1.33	1.43 ± 0.10
APCC [a]	≤ 3			
CODEX [b]	≤ 10 (Refined Oil)			
	≤ 15 (Virgin Oil)			

[a] *The Asian Pacific Coconut Community standard;* [b]*Codex standard*

Based on the Codex standard, the maximum peroxide value (PV) is 15 mEq O_2/kg for virgin oils and 10 mEq O_2/kg for RBD (Refined, Bleached, and Deodorized) CNO. The APCC standard is stricter, recommending a maximum of 3 mEq O_2/kg for both types of oil.

Our in-housed produced VCO samples had a PV ranging from 1.1 to 2.4 mEq O_2/kg, which is slightly higher than the commercial VCO samples (1.4 mEq O_2/kg) and the RBD CNO sample (0.8 mEq O_2/kg). The low PV of the RBD CNO can be attributed to the addition of small amounts of natural antioxidants during the refining process, which helps to prevent rancidity.

All of the tested oil samples fall well within the acceptable limits of both the Codex and APCC standards.

3.6. Fatty acid components

The VCO1 sample, which was identified as the highest-efficiency coconut oil of five in-house produced samples, RBD CNO and commercial VCO was analyzed by GC-FID (Appendix 3,4,5 in the Supporting Information) and the results are presented in Table 7

Fatty acid composition is the most crucial factor for identifying different vegetable oils. For example, coconut oil is characterized by its high content of lauric acid, while olive oil is primarily composed of oleic acid.

Coconut oil is exceptionally stable against oxidation because it contains roughly 94% saturated fatty acids. Furthermore, it is the richest source of medium-chain fatty acids (MCFAs) among all vegetable oils, with these beneficial compounds making up about 62% of its total fatty acid content. Lauric acid, in particular, is the most abundant fatty acid, accounting for almost 50% of the total.

All of the tested oil samples' fatty acid compositions fell within the acceptable ranges set by both the APCC and Codex standards.

Table 7. Fatty acid components of samples.

Fatty Acid	%Fatty acid components				
	RBD CNO	VCO1	Commercial VCO	APCC [a]	CODEX [b]
C 6:0	0.65	0.64	0.64	0.10 – 0.95	ND[c]-0.7
C 8:0	8.39	8.14	8.06	4.0-10.0	4.6-10.0
C 10:0	6.38	6.49	6.38	4.0-8.0	5.0-8.0
C 12:0	48.13	48.35	48.76	45.0-56.0	45.1 - 53.2
C 14:0	17.97	17.9	18.35	16.0-21.0	16.8-21.0
C 16:0	8.56	8.48	8.5	7.5-10.2	7.5-10.2
C 18:0	3.23	2.96	3.23	2.0-4.0	2.0-4.0
C 18:1	5.57	5.61	5.16	4.5-10.0	5.0-10.0
C 18:2	0.97	1.31	0.82	0.7-2.5	1.0-2.5
C 20:0	0.09	0.09	0.09	ND-0.2	ND-0.2
C 20:1	0.03	0.04	0.03	ND-0.2	ND-0.2

[a] The Asian Pacific Coconut Community standard; [b] Codex Standard; [c] Not detected

3.7. Anticipated Challenges

Thermal Uniformity: In small-scale operations, uniform temperature distribution is achieved by mechanically or manually stirring the coconut pulp in a pan. Conversely, large-scale production involving hundreds of kilograms mandates the use of a fluidized bed or freeze-drying system. These systems are necessary to sustain a constant drying temperature of 70 °C, thereby preventing oil discoloration and avoiding unwanted fluctuations in the PV/FFA indices.

Moisture Consistency: According to research, a moisture content of 4.5% is considered the optimal standard. In large-scale processing, guaranteeing uniform moisture distribution across the entire batch to meet this specific threshold presents a substantial technical challenge in process control.

Mechanical Stress: As noted, excessively low moisture levels (e.g., 2.6%) can induce mechanical jamming within the pressing shaft. During industrial-scale production, such failures inevitably result in substantial operational disruptions and escalated maintenance expenses.

Energy Efficiency: The baseline production cost of VND 129,629/liter is predicated only on current raw material (fresh coconut meat). Moving forward, as production volume expands, optimizing the energy efficiency of the drying and pressing operations will be the decisive factor in achieving market competitiveness against established industrial alternatives.

By-product Management: The volume of coconut residue produced is significant, yielding approximately 140g per 400g of dried meat. In large-scale operations, implementing strategies to upcycle this byproduct into value-added goods—such as coconut flour or animal feed—is imperative for optimizing overall economic efficiency and profitability.

The stability of the oil recovery rate (351 g/kg fresh meat) in a larger production context depends heavily on the standardization of the raw material. By implementing rigorous screening for foreign materials and utilizing industrial-grade drying and pressing equipment, the moisture content and extraction efficiency can be controlled more precisely, ensuring consistent yields even with larger volumes of coconut meat

4. Conclusion

This study initially investigated six coconut oil samples, with comprehensive chemical profiling conducted on the five samples that met the moisture standards, focusing on key parameters including free fatty acids (FFA), iodine value, saponification value, peroxide value (PV), and fatty acid composition. The results demonstrate that Virgin Coconut Oil (VCO) produced using a standardized dry-pressing method at a household scale meets the quality standards established by the APCC and Codex. Specifically, the optimized sample (VCO1) yielded 62.5% oil with a low FFA (0.07%) and PV (1.06 mEq O_2/kg), which is comparable to commercially available and RBD coconut oils (Table 8). Based on the current lab-scale efficiency, 1 kg of fresh coconut meat can yield approximately 351 g of VCO at a production cost of 129,629 VND/liter. While these findings confirm the feasibility of high-quality small-scale production, further research is required to evaluate the long-term stability and energy efficiency of the process if moved toward larger production volumes.

This study examined the chemical properties of seven different coconut oils, including free fatty acid (FFA), iodine value, saponification value, peroxide value (PV), and fatty acid composition.

Notably, the results from our in-housed produced Virgin Coconut Oil (VCO) samples, produced with lab-scale equipment, fall within the strict standards set by the APCC and Codex for industrial-scale products.

The RBD (Refined, Bleached, and Deodorized) CNO samples showed the best quality for cooking and storage due to their low PV (0.8 mEq active O_2) and low %FFA (0.08%), along with a high percentage of lauric acid (48.35%). Heating oil during cooking increases both PV and FFA.

The VCO1 sample, which was produced in-house, demonstrated quality factors remarkably similar to both RBD CNO and commercially available VCO (Table 8). Based on the performance results, 1 kg of fresh coconut meat yields 351 g of VCO. With the market price of fresh coconut meat at 50,000 VND per kilogram, the raw material cost for producing 1 liter of VCO is estimated at 129,629 VND, based on a yield of 351 g VCO per kg of fresh coconut meat. This figure does not include additional overheads such as labor, energy consumption, equipment depreciation, or packaging, which should be considered in a full-scale commercial economic assessment. Given its comparable quality and promising production metrics, VCO1 is an excellent candidate for further research and potential development for large-scale industrial production.

Table 8. Comparative analysis of VCO1 vs. commercial samples

Parameter	VCO1 (optimized)	Commercial VCO	RBD CNO	APCC Standard
Moisture (%)	0.087	0.021	0.098	≤ 0.1
FFA (%)	0.072	0.093	0.082	≤ 0.2
Lauric acid (%)	48.35	48.76	48.13	45.0-56.0
Peroxide Value	1.06	1.43	0.77	≤ 3.0

Author Contributions

This research was a collaborative effort with distinct roles for each contributor. Hong Ngoc Thi Le and Minh Ngoc Phung were responsible for preparing the virgin coconut oil (VCO) from desiccated coconut. The analysis of the VCO's physiochemical properties was performed by Tuong Vy Le Nguyen, Tien Van Tran. Finally, Vinh Ngoc Huynh verified the analysis results, wrote and provided the final corrections for the manuscript.

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