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Research Paper

Optimization of Halal Bioadsorbent Particle Size from Pyrolysis Products of Coconut Trunk Sawdust for the Purification of Virgin Coconut Oil (VCO)

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Abstract: One of the critical challenges in the virgin coconut oil (VCO) industry is the selection of crude VCO filtration media that must be strictly guaranteed halal, since VCO is widely used as a food ingredient and for medicinal purposes. In this study, coconut trunk sawdust waste was utilized as a raw material and converted into charcoal through a pyrolysis process. The resulting charcoal was then applied as a bioadsorbent for crude VCO filtration. This article reports the effect of bioadsorbent particle size variations, specifically -/20, 20/50, 50/100, 100/140, 140/200, and 200/- mesh, to determine the optimum particle size that provides the highest VCO clarity. The experiments were conducted under constant conditions with a bioadsorbent-to-VCO ratio of 2% (g/mL) and a filtration time of 10 minutes. The optimum particle size was obtained at 50/100 mesh (200 *μ*m), which resulted in maximum VCO clarity with a turbidity value of 1.48 NTU. Based on this optimum particle size, the filtered VCO showed desirable quality parameters, including lauric acid content of 51.96%, total suspended solids of 5.77%, density of 0.95 g/mL, total plate count (TPC) <10 CFU/mL, and moisture content of 0.0235%. These characteristics meet both the Indonesian National Standard (SNI) and international standards of the Asian and Pacific Coconut Community (APCC). Moreover, the resulting VCO exhibited better clarity than commercial VCO filtered using paper or cloth media (1.59 NTU), while also ensuring halal integrity through the use of bioadsorbent derived from pyrolyzed coconut trunk sawdust.

Keywords: Halal bioadsorbent; Coconut trunk sawdust; VCO; Turbidity; Optimum particle size.

1. Introduction

Coconut trunks are widely processed into furniture, house construction timber, and various household items, with the production process generating wood waste in the form of cut pieces. In the timber industry, a significant amount of wood waste remains underutilized. Therefore, it is essential to develop and implement recycling concepts within this industry [1]. For instance, in Indonesia, approximately 6 million tons of sawmill waste are produced annually. Unfortunately, this waste often poses environmental problems, as most of it is still stockpiled, disposed of into rivers (causing water pollution), or directly burned [2].

Coconut trunk sawdust contains a fixed carbon content of approximately 18.6% (ADB) with a calorific value of around 4400 kcal/kg (ADB). In some cases, the carbon content can reach up to 48% (ADB). In addition to its use as a fuel source, coconut trunk sawdust also has potential for conversion into charcoal through the pyrolysis process, which can then be utilized as biochar [3]. Currently, only a small portion of Indonesia's biomass potential is being utilized, mainly derived from sources such as oil palm residues, rice milling waste, wood, plywood, sugar mill waste, cocoa, and other agricultural residues. One of the underutilized sources with significant potential is sawdust waste. Generally, most sawdust waste is used merely as fuel for furnaces or is burned directly without further processing, which can lead to environmental pollution. Sawdust can be processed through pyrolysis to produce charcoal—a high-carbon, environmentally friendly energy source. This charcoal can subsequently be used as an alternative energy material [4].

Biomass waste is one of the most significant sources of renewable energy, accounting for approximately 79% of the total potential; however, its utilization remains suboptimal. Biomass refers to materials derived from waste sources such as wood, agricultural residues, industrial organic waste, household waste, algae, and others. Agricultural products such as sugarcane, corn, eucalyptus, and rice generate substantial amounts of waste with great potential as energy sources [5]. One of the combustion methods that can be employed is pyrolysis. Pyrolysis is a process in which solid materials, such as biomass, thermally decompose under limited air or oxygen conditions. This process produces products such as biochar and liquid smoke [6].

Indonesia plays an important role as one of the world's major charcoal suppliers, with a substantial level of production. Charcoal is produced from various organic materials such as wood, bones, animal horns, agricultural residues, and other organic wastes [7]. The resulting charcoal possesses a high calorific value and can be used as a fuel or processed further into activated carbon. Meanwhile, the liquid smoke generated from the pyrolysis process can be utilized as an additive or preservative in food and other products [8]. The gas produced during the process can also be directly used as a fuel. Pyrolysis gas can be categorized into two types: non-condensable gases such as CO, CO_2, CH_4, and similar compounds, and condensable gases such as tar [9].

Virgin Coconut Oil (VCO) is produced from fresh coconuts without extreme heat treatment, allowing the essential components of the oil to be preserved since it is processed without chemical refining, bleaching, or deodorizing (RBD), thus maintaining its natural characteristics [10,11]. VCO is obtained from coconut milk and appears as a clear liquid with no specific taste and a distinctive coconut aroma. Its production process is relatively economical because the raw materials are easily available at an affordable price and the processing method is simple [12]. The purification of VCO can be carried out using various methods, one of which involves the use of bioadsorbents derived from biomass waste such as coconut trunk sawdust. The VCO clarification process effectively removes impurities and coloration, resulting in a clear product with a low turbidity value [12].

Turbidity refers to the degree of cloudiness or haziness in a liquid caused by the presence of suspended particles or microorganisms. It is commonly used as an indicator of water quality, where higher turbidity values correspond to lower quality. The maximum turbidity value (NTU) typically ranges from 0 to 25. Turbidity may result from suspended particles such as clay and silt, dissolved colored organic compounds, as well as plankton and other microscopic organisms [13]. The clarity or turbidity analysis of Virgin Coconut Oil (VCO) is carried out using a turbidity meter. A turbidity meter is an instrument used to measure the cloudiness of a liquid based on optical properties produced by light dispersion. It operates by comparing the intensity of light reflected or scattered by particles in the sample to that of the incident light, thereby determining the liquid's clarity [14].

The novelty of this research lies in the purification process of Virgin Coconut Oil (VCO), which utilizes biomass waste as a bioadsorbent, specifically coconut trunk sawdust. During its preparation, no chemical additives are used, making the resulting bioadsorbent environmentally friendly and ensuring its halal integrity. In contrast, previous studies employed zeolite as the purification medium for VCO. Zeolite is a hydrated aluminosilicate material with a porous structure and high specific surface area, providing great potential as an adsorbent material [15].

2. Research and Methodology

In this study, pure coconut water was used as the main raw material for producing Virgin Coconut Oil (VCO), while charcoal derived from the pyrolysis of coconut trunk sawdust was utilized as a bioadsorbent in the VCO purification process. The purification was carried out using a filtration method with a vacuum filter apparatus. The detailed arrangement of the equipment used in the VCO purification process employing the bioadsorbent from coconut trunk pyrolysis is shown in Figure 1.

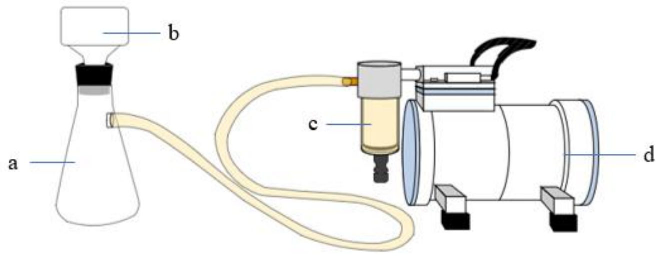

Figure 1. Vacuum Filtration Apparatus Configuration
a. 500 mL Erlenmeyer flask, b. Buchner funnel, c. Flow meter, d. Vacuum pump

In the preparation of the bioadsorbent, coconut trunk sawdust was sun-dried for three days. After drying, 1,500 grams of sawdust were weighed and placed into a pyrolysis unit operated at 400 °C for two hours. The resulting products—charcoal and liquid smoke—were then collected and weighed. The produced charcoal was subsequently sieved using several mesh size variations, ranging from 20 mesh to 200 mesh. For the production of Virgin Coconut Oil (VCO), fresh coconuts were grated, and coconut water was extracted according to the research requirements and placed in a container. The coconut milk was then obtained by pressing the grated coconut twice to maximize the yield. The extracted coconut milk was allowed to stand for approximately one hour to separate the water and pure coconut cream. The separated coconut cream was then naturally fermented for 24 hours. After fermentation, the oil layer was collected using a hose and transferred into sample bottles as Virgin Coconut Oil (VCO). In the VCO filtration process, charcoal with different mesh sizes—20, 20/50, 50/100, 100/140, 140/200, and 200 mesh—was weighed at 1 gram each. Subsequently, 50 mL of VCO was added into a 500 mL Erlenmeyer flask, homogenized for one minute, and allowed to stand for ten minutes. It was then homogenized again for 30 seconds before being poured into a Buchner funnel for filtration. The filtered VCO was collected in labeled sample bottles according to the mesh size used. Finally, the clarity of each filtered VCO sample was measured using a turbidity meter [16].

3. Results and Discussion

The bioadsorbent used in the filtration of Virgin Coconut Oil (VCO) was charcoal derived from the pyrolysis of coconut trunk sawdust biomass. The bioadsorbent was first sieved to obtain various particle sizes using a mesh screen. The turbidity data of Virgin Coconut Oil (VCO) based on different particle size variations of the sawdust-derived bioadsorbent are presented in Table 1.

Table 1. Analysis Results of Virgin Coconut Oil (VCO) Turbidity Based on Bioadsorbent Particle Size

No	*Mesh* (*range*)	Rata-rata	dp (μm) = $17771(M)^{-1},034$	Turbidity (NTU)
	Blank			4,08
0	-	10	1650	3,11
1	/20	20	800	2,47
2	20/50	35	450	2,35
3	50/100	75	200	1,48
4	100/140	120	130	1,45
5	140/200	170	100	1,50
6	200	300	50	1,35

From Table 1, it can be seen that coconut trunk sawdust is quite effective as a bioadsorbent. The table shows a decreasing trend in the turbidity of VCO as the particle size of the bioadsorbent decreases, within the size range of 1650 to 200 μm (approximately 10–75 mesh). This phenomenon can be explained by the fact that smaller particle sizes provide a larger surface area of the bioadsorbent in contact with the VCO during the filtration process, resulting in higher adsorption capacity for impurities present in the oil. This is indicated by the lower turbidity values, meaning the VCO becomes clearer [19]. The optimum particle size of the coconut sawdust bioadsorbent was found to be at 50/100 mesh, with a turbidity value of 1.48 NTU.

However, for bioadsorbent particle sizes smaller than 200 μm, or mesh sizes above 50/100 (average above 75 mesh), there was no significant decrease in turbidity observed. Therefore, the 50/100 mesh size is considered the optimum particle size for the bioadsorbent [16].

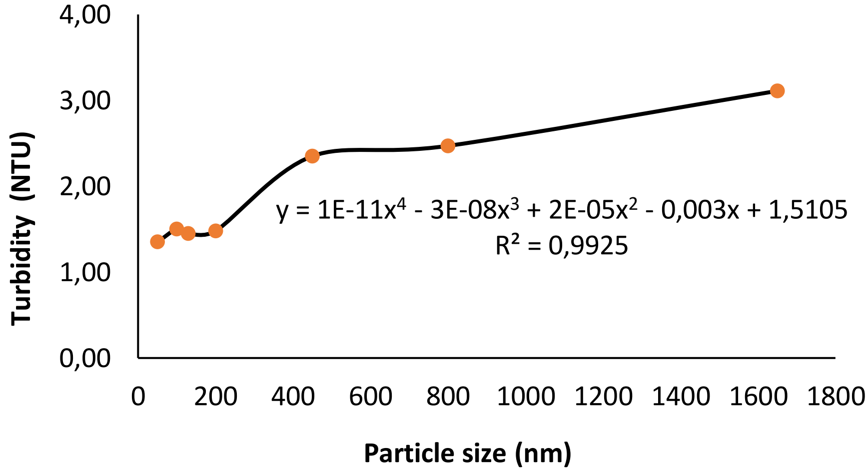

Figure 2. Graph of the Relationship Between Bioadsorbent Particle Size and Virgin Coconut Oil (VCO) Clarity

The relationship between the bioadsorbent particle size and the turbidity of VCO can be well represented by a fourth-order polynomial equation. The turbidity level of the filtered Halal Virgin Coconut Oil (VCO) as a function of the bioadsorbent particle size within the range of 50–1650 μm (or 10–300 mesh) can be adequately approximated by a fourth-order polynomial equation, as indicated by a correlation coefficient (R^2) close to 1 (R^2 = 0.9925). The corresponding polynomial equation is as follows.

y = 1E-11x4 - 3E-08x3 + 2E-05 x 2 - 0,003x + 1,5105 .... (1)

R^2 = 0,9925

Description:
y = Turbidity of Virgin Coconut Oil (NTU)
x = Particle Size (nm)
R = Correlation Coefficient

The relative comparison of turbidity values between Halal VCO/Biocharcoal, VCO AVCOAL, and crude Halal VCO can be seen in Figure 3.

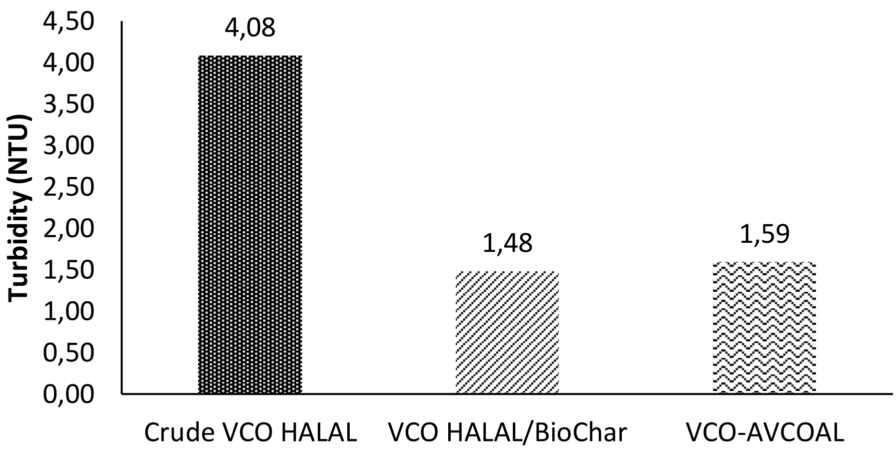

Figure 3. Comparison graph of turbidity between Halal VCO/Biocharcoal, VCO-AVCOAL, and crude Halal VCO.

As shown in Figure 3, the Virgin Coconut Oil (VCO) in this study experienced a reduction in turbidity from 4.08 NTU to 1.48 NTU after filtration using the bioadsorbent. A turbidity value of 1.48 NTU is considered quite good, as visually, VCO with turbidity below 2 NTU appears almost as clear as water.

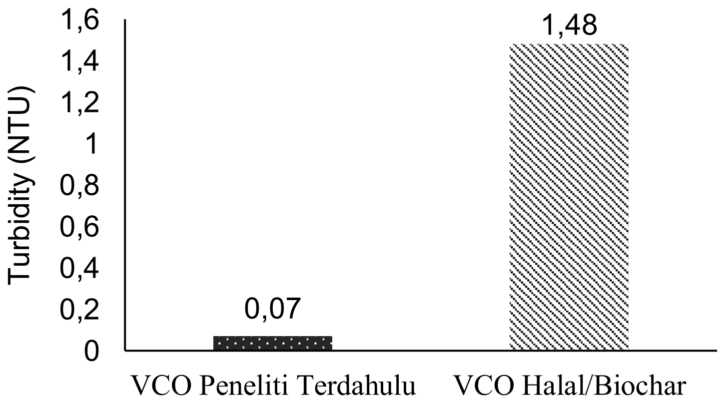

Figure 4. Comparison Graph of Turbidity Values Between Halal/Biocharcoal VCO and Turbidity Values of VCO from Previous Researchers.

Figure 4 shows that the difference in turbidity values between Halal VCO and the turbidity values obtained by previous researchers is considerably significant. In the study conducted by [17], the turbidity value of virgin coconut oil measured using a turbidity meter was 0.07 NTU, whereas in the present study, the measured turbidity value was 1.48 NTU.

The considerable difference in turbidity values of VCO is influenced by the use of inappropriate measuring instruments. Initially, turbidity measurements were carried out using a standard turbidity meter, in which the turbidity value of the VCO could not be properly detected, resulting in readings that were almost zero. In contrast, the turbidity analysis performed using a specialized turbidity meter designed for non-polar solutions or oils produced a turbidity value of 1.48 NTU. This result differed significantly from the analysis obtained using the standard turbidity meter, which is typically used for measuring water turbidity. Therefore, it can be concluded that the turbidity value of an oil is highly dependent on the type of turbidity meter used.

In this study, Virgin Coconut Oil (VCO) was produced using a fermentation method with a fermentation time of 24 hours. No chemical substances were used during the production process. The results of the characteristic analysis of Virgin Coconut Oil (VCO) are presented in Table 2.

Table 2. Results of the Virgin Coconut Oil (VCO) Characteristic Analysis

Parameter / Component	***Crude* VCO Halal**	***Crude* VCO AVCOAL**
Laurie Acid (C12:0) (%)	51,96	45,76
TS (%)	5,77	5,37
Bj (g/mL)	0,9473	0,9648
TPC (Cfu/mL)	< 10	< 10
Turbidity (NTU)	4,08	4,07
Moisture Content (%)	0,15	0,18
Moisture Content after Filtration (%)	0,0235	0,0285

Various characteristic tests were carried out on the Halal Virgin Coconut Oil (VCO). One of the analyses performed was the determination of lauric acid content in the VCO. The comparison between the lauric acid content of crude Halal VCO and crude VCO AVCOAL is presented in Figure 5.

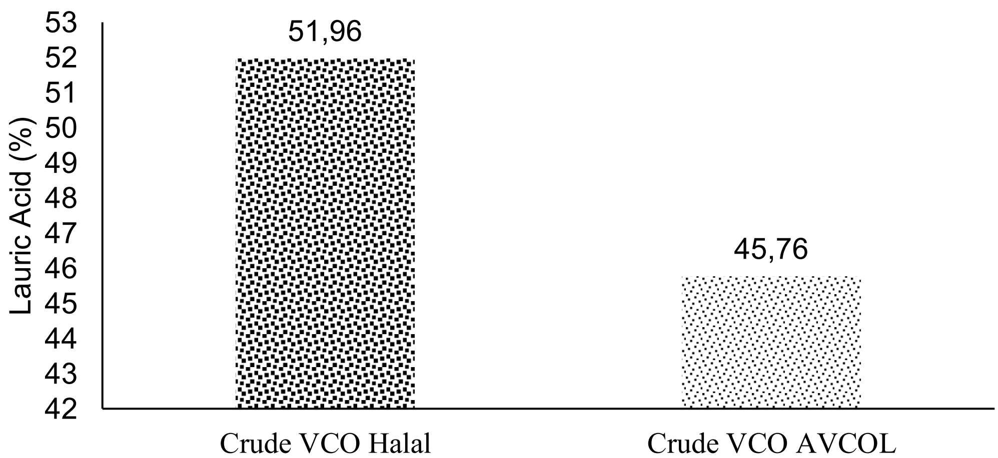

Figure 5. Comparison of Lauric Acid Content between Crude Halal VCO and Crude VCO AVCOAL

The higher the lauric acid content in the consumed food, the greater its potential health benefits [20]. Referring to this explanation, it can be stated that the quality of VCO increases in line with the higher lauric acid content present in the oil.

As shown in Figure 5, the lauric acid content of the crude Halal VCO is 51.96%, while that of the crude VCO AVCOAL is 45.76%. The quality standard for Virgin Coconut Oil (VCO) specified in SNI 7381:2008 ranges from 45.2% to 53.2%. These results indicate that the quality of the produced Virgin Coconut Oil meets the required standard.

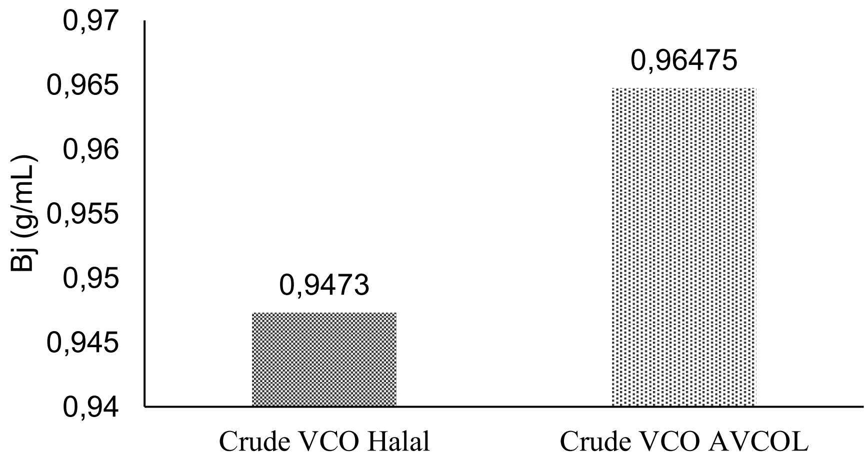

Figure 6. Comparison of Density between Crude Halal VCO and Crude VCO AVCOAL

As shown in Figure 6, the density of the crude Halal VCO is 0.9473 g/mL, while that of the crude VCO AVCOAL is 0.96475 g/mL. The quality standard required by the Asian Pacific Coconut Community (APCC) ranges from 0.915 to 0.920 g/mL. These results indicate that the quality of the Virgin Coconut Oil (VCO) produced generally complies with the APCC standard, as the difference in values is relatively small.

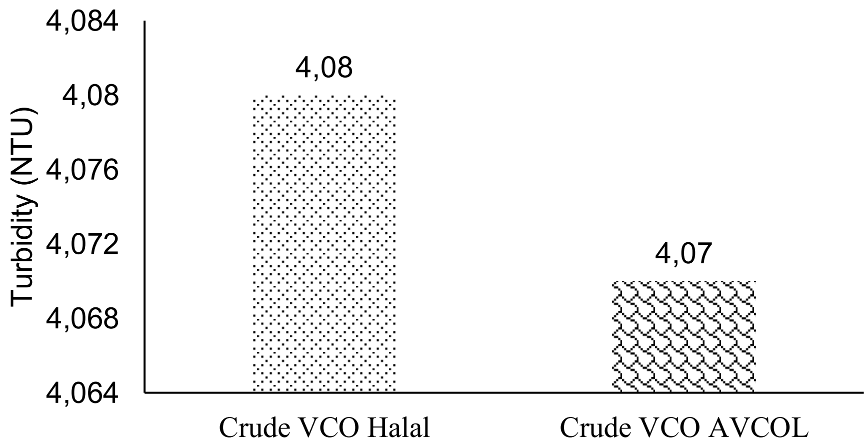

Figure 7. Comparison of Turbidity between Crude Halal VCO and Crude VCO AVCOAL

As shown in Figure 7, the turbidity of the crude Halal VCO is 4.08 NTU, while that of the crude VCO AVCOAL is 4.07 NTU. The turbidity test for Virgin Coconut Oil (VCO) has not yet been established in either the Indonesian National Standard (SNI) or international standards.

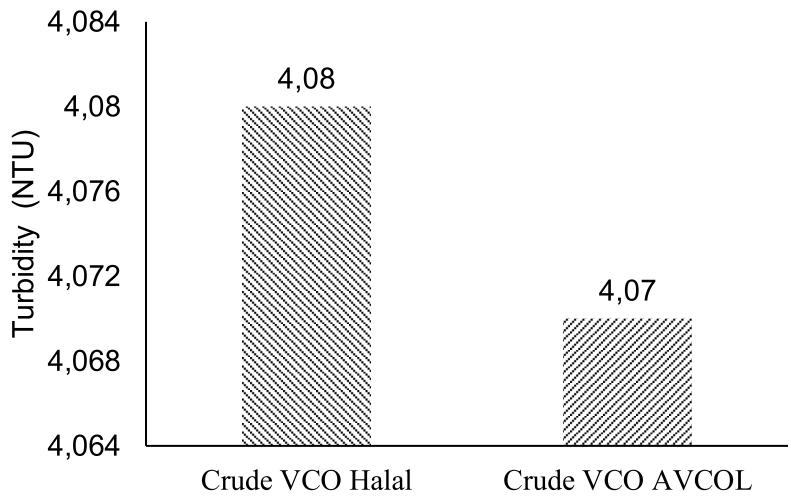

Figure 8. Comparison of Turbidity between Crude Halal VCO and Crude VCO AVCOAL

As shown in Figure 8, the turbidity of the crude Halal VCO is 4.08 NTU, while that of the crude VCO AVCOAL is 4.07 NTU. The turbidity test or turbidity parameter for Virgin Coconut Oil (VCO) has not yet been established in either the Indonesian National Standard (SNI) or international standards.

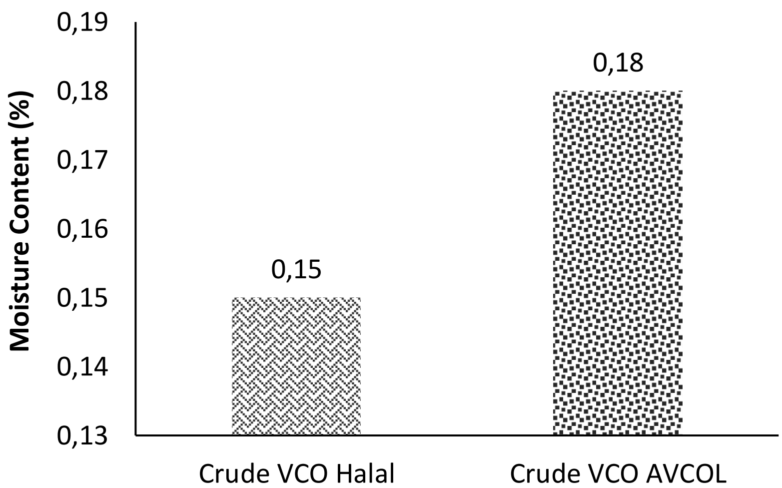

Figure 9. Comparison of Moisture Content between Crude VCO AVCOAL and Crude Halal VCO

The moisture content of VCO decreased after undergoing the heating and filtration processes. The comparison shows a significant reduction in moisture content after heating and filtration compared to the VCO before these processes. The moisture content of the crude Halal VCO was 0.15%, while the Halal/Biocharcoal VCO had a moisture content of 0.0285%. Meanwhile, the crude VCO AVCOAL had a moisture content of 0.18%, and the VCO AVCOAL was 0.0235%. The moisture content of the Halal/Biocharcoal VCO complies with both the APCC and SNI 7381 (2022) standards. According to the APCC, the maximum allowable moisture content is 0.1%, while the SNI 7381 (2022) standard sets a maximum value of 0.2%.

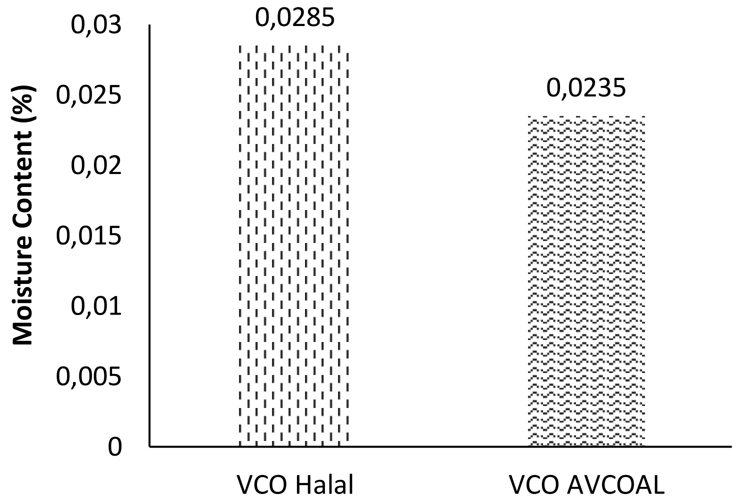

Figure 10. Comparison of Moisture Content between Halal VCO and VCO AVCOAL

4. Conclusion

Observations on the fixed variables, namely a bioadsorbent-to-VCO ratio of 2% (g/mL) and a filtration time of 10 minutes, resulted in the following conclusions:

The optimum particle size of the bioadsorbent was 50/100 mesh (200 μm), which produced a VCO clarity (turbidity) value of 1.48 NTU. Under these optimum conditions, the characteristics of the filtered VCO were as follows: lauric acid content of 1.96%, total suspended solids (TS) of 5.77%, density of 0.95 g/mL, bacterial content (total plate count, TPC) < 10 CFU/mL, and moisture content of 0.0235%.

Based on the VCO characteristics described above, the filtered VCO produced using the bioadsorbent has met both the Indonesian National Standard (SNI) and the international standard established by the Asian and Pacific Coconut Community (APCC). The filtered VCO obtained using the halal bioadsorbent shows a turbidity value of 1.48 NTU, which is relatively better compared to commercially available VCO filtered using paper or cloth, which typically exhibits a turbidity value of 1.59 NTU. In addition, the use of a halal bioadsorbent derived from the pyrolysis of coconut trunk sawdust ensures that the VCO is compliant with halal requirements.

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5. REFERENCES

[1] Aktawan, A., Maryudi., Marzun, H, M. dan Noor, S, A. (2020) "Gasifikasi Serbuk Gergaji Batang Kelapa untuk Menghasilkan Bahan Bakar Gas," Konversi, 9(1), hal. 1–6.

[2] Sahrum, R.P., Syaiful, A, Z. Dan Gazali, A. (2021) "Uji Kualitas Asap Cair Tempurung Kelapa dan Serbuk Gergaji Kayu Metode Pirolisis," Saintis, 2(2), hal. 73–78.

[3] Hamid, S., Aladin, A., Modding, B., Syarif, T., Wiyani, L. dan Arman, M. (2023) "Pengaruh Aliran Nitrogen Kontinyu ke dalam Reaktor Pirolisis Limbah Biomassa Serbuk Gergaji Batang Kelapa (*Cocos Nucifera*) terhadap Nilai Kalor," *Journal of Chemical Process Engineering*, 8(1).

[4] Hasan, S., Aladin, A., Syarif, T. dan Arman, M. (2020) “Pengaruh Penambahan Gas Nitrogen terhadap Kualitas Charcoal yang Diproduksi Secara Pirolisis dari Limbah Biomassa Serbuk Gergaji Kayu Ulin (Euxideroxylon Zwageri),” *Journal of Chemical Process Engineering*, 5(1), hal. 61–68

[5] Darajat, Z., Munira., Septiani, M. dan Aladin, A. (2021) “Pengaruh Ukuran Partikel Bahan dan Waktu Penahanan Pada Pirolisis Lambat Limbah Tongkol Jagung Menjadi Bioarang,” *Journal of Chemical Process Engineering*, 6(2), hal. 96–102

[6] Ridhuan, K. dan Irawan, D. (2019) “Pengaruh Jenis Biomassa Terhadap Karaktristik Pembakaran dan Hasil Bioarang Asap Cair dari Proses Pirolisis,” *Mechanical*, 10(1), hal. 7.

[7] Murti, B. dan Sutapa, J.P.G. (2003) “Pemanfaatan Limbah Gergajian Batang Kelapa (*Cocos Nucifera* L.) sebagai Bahan Baku Pembuatan Arang,” hal. 407–414.

[8] Aladin, A. et al. (2022) ‘*Organoleptic Observations of the Preservation of Mackerel Fish using Liquid Smoke from Coconut Shells Pyrolysis’, World Chemical Engineering Journal*, 6(1), p. 29.

[9] Ridhuan, K., Irawan, D. dan Inthifawzi, R. (2019) “Proses Pembakaran Pirolisis dengan Jenis Biomassa dan Karakteristik Asap Cair yang Dihasilkan,” Turbo : Jurnal Program Studi Teknik Mesin, 8(1), hal. 69–78.

[10] Aladin, A. et al. (2016) ‘*Grated coconut waste as heating jacket and temperature stabiliser in the production of virgin coconut oil by natural fermentation*’, ARPN *Journal of Engineering and Applied Sciences*, 11(8), pp. 5171–5176.

[11] Wiyani, L. et al. (2020) ‘*Antioxidant Activity Of Virgin Coconut Oil And Virgin Coconut Oil Emulsion’, Systematic Reviews In Pharmacy*, 11(12), pp. 973–976.

[12] Rosalin, Darma Paramita, V. dan Saleh, M. (2021) “Pemanfaatan Arang Aktif Tempurung Kelapa Sebagai Adsorben untuk Mempertahankan Mutu *Virgin Coconut Oil* (VCO),” Prosiding Seminar Nasional Fisika [Preprint].

[13] Muharni, Y. dan Hartono, N. (2021) “*An application of multiple regression for predicting Turbidity of standard water quality for industrial and household consumption,” Journal Industrial Servicess*, 7(1), hal. 8.

[14] Monica, D. (2021) “Pengukuran Nilai Kekeruhan Air PDAM Tirta Keumuening Kota Langsa,” Jurnal Hadron, 3(1), Hal. 19–22.

[15] Fatimah, F. dan Sangi, M.E.C. (2010) “Kualitas Pemurnian *Virgin Coconut Oil* (VCO) Menggunakan Beberapa Adsorben,” *Chemistry Progress*, 3(2), hal. 65–69.

[16] Ifa, L., Nurdjannah., Syarif, T. dan Darnengsih. (2021) Bioadsorben dan Aplikasinya. Diedit oleh N.M. Pratama. baru: Yayasan Pendidikan Cendikia Muslim.

[17] Somantri, F.R.R. (2016) “Pembuatan dan Analisis *Virgin Coconut Oil* yang Dihasilkan dengan Menggunakan Metode Pancingan.”

[18] Aladin, A. et al. (2023) ‘Karakterisasi *Charcoal* Hasil Pirolisis Serbuk Gergaji Batang Kelapa sebagai Bioadsorben Halal untuk Proses Penyaringan Minyak Kelapa Murni (VCO)’, 6051, pp. 104–109.

[19] Reforma, B., Ma’arif, A. and Sunardi, S. (2022) ‘Alat Pengukur Kualitas Air Bersih Berdasarkan Tingkat Kekeruhan dan Jumlah Padatan Terlarut’, Jurnal Teknologi Elektro, 13(2)

[20] Widiada, I. G. N., Suhaema and Gunarti2 (2010) 'Perbandingan Komposisi Asam Lemak *Virgin Coconut Oil* (VCO) Hasil Fermentasi Starter Ragi Roti Dengan VCO Hasil Pabrikan Serta Aktivitas Antibakterinya Pada Bakteri Penyebab Diare', Jurusan Gizi Poltekkes Kemenkes Mataram, pp. 1–9

[21] Kardiman., Ifa, L. dan Rasyid, R. (2019) 'Pembuatan Adsorben Dari Sabut Kelapa sebagai Penyerap Logam Berat Pb(II)', ILTEK, 14 (2).

[22] Pranata, D., Ardiningsih, P., Rahmalia, W., Nurlina. dan Syahbanu, Intan. (2020) 'Ekstraksi Minyak Kelapa Murni dengan Metode Pengadukan dan *Cold Pressed*', Indonesian Journal of Pure and Applied Chemistry, 3 (2).

[23] Renni, C.P., Mahatmanti, F.W. dan Widiarti, N. (2018) "Pemanfaatan Zeolit Alam Teraktivasi sebagai Adsorben Ion Logam Fe (III) dan Cr (VI)," *Indonesian Journal of Chemical Science*, 7(1), hal. 65–70.

[24] Muamar, A., Nisah, K. dan Nasution, R. (2020) "Kajian Arang Aktif Dari Limbah Pertanian Sebagai Bioadsorben Zat Warna," *Program Studi Kimia, Fakultas Sains dan Teknologi Universitas Islam Negeri Ar-Raniry*, 2(2), hal. 59–63.

[25] Rahman, A. *et al.* (2021) "Prediksi Tingkat Kekeruhan (Turbiditas) Menggunakan Citra Satelit Sentinel-2a Di Waduk Jatiluhur, Jawa Barat," *Jurnal Sumber Daya Air*, 17(2), hal. 59–68.