

Synthesis of KOH-activated carbon through sonication for adsorption in soap production from used cooking oil

Felda Mufarrihati¹, Adilah Aliyatulmuna¹, Rosanina Kartika Santana¹, and Amalia Qurrata A'yun¹

¹Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Malang, Indonesia

Abstract. Used cooking oil (UCO) is a waste generated from frying processes in both household and industrial sectors. One way to utilize UCO is by processing it into soap. However, before being used as a raw material, purification is required because UCO contains reaction products formed during frying. This study aims to purify UCO using corn cob-based activated carbon (AC), which was activated with KOH and assisted by ultrasonic irradiation, and to evaluate its feasibility as a raw material for liquid soap production. The purification process of UCO was carried out in several stages, including degumming, neutralization, and adsorption using AC. The AC was carbonized and activated with varying KOH concentrations (10% to 60%) under ultrasonic irradiation times of 20, 40, and 60 minutes, followed by characterization using FTIR, XRD, SEM, and BET. The results showed that AC prepared with 40% KOH and 40 minutes of ultrasonic irradiation exhibited the highest iodine adsorption capacity of 1065 mg/g. The purification process from degumming to adsorption successfully reduced the free fatty acid content to 0.144%, peroxide value to 9.8 meQ O₂/kg, and moisture content to 0.07%. The purified UCO was then applied as a raw material to produce high-quality liquid soap.

1 Introduction

According to Statistics Indonesia (BPS, 2025), palm cooking oil consumption in Malang reaches 0.204 L per capita per week, generating a substantial volume of used cooking oil (UCO) that poses environmental and disposal challenges. Repeated frying accelerates hydrolytic and oxidative degradation of triglycerides, resulting in the accumulation of free fatty acids (FFAs) and polar oxidation products that deteriorate oil quality. Consequently, purification is required prior to further utilization, particularly for soap production, as the Indonesian National Standard (SNI 2588:2017) limits the FFA content in liquid soap to $\leq 1\%$.

Oil purification commonly involves sequential de-gumming, neutralization, and adsorption processes. De-gumming and neutralization are effective in removing phospholipids, metal ions, and short-chain FFAs, while adsorption using activated carbon serves as a critical final step to eliminate residual polar compounds, including FFAs and peroxide species. The

¹ Corresponding author: adilah.aliyatulmuna.fmipa@um.ac.id

effectiveness of this adsorption stage is strongly governed by the physicochemical properties of the activated carbon, which are in turn determined by the activation method. Chemical activation using KOH is widely employed due to its ability to generate a higher proportion of micropores compared to NaOH or H₃PO₄ activation, thereby enhancing adsorption capacity toward small polar molecules [1].

Previous studies have demonstrated the effectiveness of KOH activation for biomass-derived carbon. Rozanna et al. (2020) reported that activation using 20% KOH at 367 °C yielded an iodine adsorption capacity of 769 mg g⁻¹ [2]. However, conventional chemical activation typically involves prolonged impregnation and thermal treatment, which may limit the penetration of the activating agent into the internal carbon matrix and result in non-uniform pore development. Such mass-transfer limitations can restrict adsorption efficiency despite relatively high chemical loading. Ultrasonic irradiation has emerged as a potential strategy to overcome these limitations by enhancing activator diffusion through cavitation phenomena. The formation and collapse of microbubbles during sonication generate localized high-energy conditions that can improve KOH impregnation, disrupt particle agglomeration, and promote more uniform pore development [3]. Nevertheless, the specific contribution of ultrasonic assistance to KOH-based activation, particularly in relation to adsorption performance for oil purification, remains insufficiently quantified. Moreover, studies that link ultrasonic-assisted activation conditions with downstream application outcomes, such as the quality of soap derived from purified oil, are still limited.

Ultrasonic irradiation has emerged as a potential strategy to overcome mass-transfer limitations during chemical activation by enhancing activator diffusion through cavitation phenomena. The formation and collapse of microbubbles generate localized high energy conditions that facilitate KOH impregnation, disrupt particle agglomeration, and promote more uniform pore development. However, the specific contribution of ultrasonic assistance in KOH-based activation, particularly in relation to adsorption performance for oil purification and its impact on downstream applications, remains insufficiently quantified [4]. In this study, activated carbon was prepared from corn cobs, a lignocellulosic biomass that can be converted into porous carbon materials with a wide range of surface areas. The quality of activated carbon is commonly evaluated using the iodine number, with the Indonesian standard specifying a minimum value of 750 mg/g (SNI 06-3730-1995). In oil purification, activated carbon removes phospholipids, free fatty acids (FFAs), and oxidized compounds through a combination of physical adsorption and interactions involving surface functional groups. The purified oil was subsequently processed into liquid soap via saponification, in which triglycerides react with KOH to form soap and glycerin, while additives such as glycerin, sorbitol, or sucrose act as humectants and Tween 80 functions as an emulsifier to stabilize the formulation. This integrated approach allows simultaneous evaluation of ultrasonic-assisted KOH activation and the performance of the resulting activated carbon in improving oil quality for downstream soap production.

2 Method

2.1 Tools and Materials

The tools used in this study include Erlenmeyer 100 mL, Erlenmeyer with a lid 100 mL, funnel, 250 mL split funnel, porcelain cup, cross, 100 mL beaker cup, 250 mL beaker glass, 1000 mL beaker glass, 10 mL measuring glass, 100 mL measuring glass, 10 mL measuring pipette, 25 mL volume pipette, suction ball, 100 mL measuring gourd, Whatman No. 42 filter paper, thermometer, spatula, stirring rod, spray bottle, 10 mL pycnometer, pipette, burette and statit, universal indicator, analytical balance (Shimadzu ATX 224), shaker, centrifuge, kiln (B-one), oven (Emmert), desiccant, magnetic stirrer, and ultrasonic bath. Ultrasonic activation was

conducted using an ultrasonic bath (GT Sonic R6) operating at a frequency of 40 kHz with an ultrasonic power of 150 W.

Characterization instruments included X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR, Shimadzu IRPrestige-21), scanning electron microscopy with energy-dispersive X-ray analysis (SEM–EDX, Zeiss Bruker), and Brunauer-Emmett-Teller (BET) surface area analyzer (Micromeritics Tristar II). The materials needed in this study include corn cob (from Grobogan, East Java), used cooking oil, KOH Merck, Na₂S₂O₃ 0.1N, 1% amylum, aquadest, technical ethanol, NaOH Merck, PP indicator, technical chloroform, technical glacial acetic acid, technical HCl 0.1N, technical HCl 1N, saturated KI solution, sucrose, tween 80, glycerin, and iodine 0.1N.

2.2 Carbonization and Carbon Activation

Corn cobs were initially subjected to carbonization at 400 °C for 10 min to promote early devolatilization while preserving reactive sites for subsequent chemical activation. After cooling to room temperature, the carbonized material was ground and sieved to 100 mesh. Chemical activation was performed using KOH solution assisted by ultrasonic irradiation. The determination of the optimum ultrasonic irradiation time was conducted at a fixed KOH concentration of 30%, with irradiation times of 20, 40, and 60 min at 60 °C. The irradiation time yielding the highest iodine adsorption capacity was selected as the optimum condition and subsequently validated at KOH concentrations of 10% and 20% to ensure consistency. Further activation experiments were carried out by varying KOH concentrations from 10% to 60% using the selected optimum irradiation time. After impregnation, the carbon was filtered, dried at 110 °C for 2 h, and thermally activated at 600 °C for 30 min. The activated carbon was then neutralized using 0.1 N HCl until neutral pH was achieved, followed by washing and drying prior to characterization [3]. All activation experiments were conducted in duplicate, and key adsorption measurements were performed in triplicate to ensure reproducibility.

2.3 Analysis of Activated Carbon

The quality of the activated carbon was evaluated by determining moisture content, ash content, and iodine adsorption capacity in accordance with SNI 06-3730-1995. Structural and surface characterizations were carried out using X-ray diffraction (XRD) to assess structural ordering, Fourier transform infrared spectroscopy (FTIR) to identify surface functional groups, scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy (SEM–EDX) to observe morphology and elemental composition, and surface area analysis (SAA, BET method) to determine specific surface area and pore characteristics.

2.4 Used Cooking Oil Purification

Used cooking oil was first filtered to remove suspended impurities and subsequently purified through sequential de-gumming, neutralization, and adsorption processes. De-gumming was carried out by heating the oil with distilled water at a 1:1 volume ratio at 110 °C to remove phospholipids and gum components. Neutralization was performed by reacting to the oil with 15% NaOH to reduce free fatty acid content. The adsorption stage was conducted by adding activated carbon at a fixed dosage of 10 weight % relative to oil mass, followed by stirring at 170 rpm for 60 min. The adsorbent dosage was kept constant to evaluate the comparative effectiveness of the activated carbon under uniform purification conditions.

2.5 Analysis of Oil

The refined oil was analyzed for moisture content, free fatty acid (FFA) content, peroxide value, and saponification number in accordance with applicable Indonesian National Standards (SNI). FTIR analysis was conducted on oil samples before and after purification to identify changes in functional groups associated with degradation and oxidation products.

2.6 Soap Production and Evaluation

Liquid soap was prepared using refined oil as the raw material. A total of 30 g of oil was reacted with a 30% KOH solution at 70-80 °C under continuous stirring until the trace phase was achieved. A sucrose solution (70%) and Tween 80 mixture (1:2 ratio) was added at a 1:1 ratio relative to oil mass, followed by the addition of 2 mL glycerin and distilled water until the desired consistency was obtained [5]. Liquid soap was evaluated based on physical characteristics, including color, odor, homogeneity, and phase separation after 24 h of storage at room temperature. The pH of the soap was measured at 25 °C using a pH meter. Soap preparation and evaluation were conducted in duplicate.

3. Results and Discussion

3.1 Carbonization and Carbon Activation

Corn cobs were used as the precursor for activated carbon preparation due to their high contents of cellulose (42%), hemicellulose (33%), and lignin (18%), which make them suitable for conversion into porous carbon materials. Chemical activation was carried out using KOH, assisted by ultrasonic irradiation, to enhance pore development and adsorption capacity. During thermal treatment at approximately 400°C, KOH reacts with the carbon matrix to form intermediate species such as K_2CO_3 , while the release of gaseous products (e.g., H_2) contribute to pore formation within the carbon structure [6]. Ultrasonic irradiation promotes activator penetration through cavitation effects, which enhance mass transfer and facilitate pore opening on the carbon surface [3]. In this study, variations in ultrasonic irradiation time (20, 40, and 60 min) and KOH concentration (10% to 60%) were investigated to identify the activation conditions that produce activated carbon with the highest adsorption performance toward polar compounds in UCO. The quality of the activated carbon was evaluated using the iodine adsorption capacity, with a minimum requirement of 750 mg/g according to SNI standards.

Table 1. Carbon Iodine Adsorption Testing

Carbon Before activation	Irradiation Time (minutes)	Adsorption of iodine (mg/g)
	-	855.067
Activate with KOH 10%	20	941.861
	40	962.743
	60	938.123
Activate with KOH 20%	20	947.050
	40	980.569
	60	944.045
Activate with KOH 30%	20	948.182
	40	998.354
	60	922.530
Activate with KOH 40%		1065.998
	40	1040.617
		1040.617

Activate with KOH 50%	40	1014.797
		1002.109
		1027.479
Activate with KOH 60%	40	961.59
		1012.2
		1012.2

As shown in **Table 1**, activated carbon prepared with ultrasonic irradiation for 40 min consistently exhibited higher iodine adsorption values compared to shorter or longer irradiation times. This result suggests that 40 min provides sufficient energy to enhance pore development, while prolonged irradiation (60 min) may adversely affect the carbon structure, resulting in reduced adsorption capacity [3]. Regarding the effect of KOH concentration, the highest iodine number (1065 mg/g) was obtained at a KOH concentration of 40%, indicating effective pore formation and a high accessible surface area. At higher KOH concentrations ($\geq 50\%$), a decrease in iodine adsorption capacity was observed, which may be associated with excessive activation leading to partial pore blockage or structural collapse during carbonization [7].

3.2 Analysis of Activated Carbon

3.2.1 Carbon Quality Testing

The quality of the activated carbon was evaluated based on moisture content, ash content, and iodine adsorption capacity. High moisture content can block pore accessibility and reduce adsorption performance. After activation, the moisture content decreased from 3.98% to 3.21%, remaining well below the SNI 06-3730-1995 limit of 15%, which indicates that KOH activation effectively promotes dehydration during thermal treatment [2]. The ash content increased from 2.96% to 3.77% after activation but remained below the maximum allowable limit of 10% specified by SNI 06-3730-1995. This increase is associated with thermal decomposition of the organic carbon matrix during activation, while thermally stable inorganic components such as silica and alkali or alkaline earth metals remain and contribute to ash formation. Despite the increase, the ash content indicates that the activated carbon maintains acceptable structural characteristics for adsorption applications [8]. The iodine adsorption test showed the optimum result at 40% KOH activation of 1065 mg/g, exceeding the minimum standard of 750 mg/g [9]. This result reflects enhanced adsorption capacity associated with the development of accessible micropores. Overall, the combined results demonstrate that KOH activation assisted by ultrasonic irradiation improves the physicochemical quality of the activated carbon, as summarized in Table 2.

Table 2 Carbon Quality

Parameters	Carbon before activation	KOH activated carbon 40%	SNI activated carbon 06-3730-1995
Moisture content (%)	3.98	3.21	Max. 15
Ash content (%)	2.96	3.77	Max. 10
Adsorption of iodine (mg/g)	734.20	1065	Min. 750

3.2.2 FTIR

The FTIR spectra indicate changes in the surface functional groups of the carbon material before and after activation. A broad absorption band at approximately 3035 cm^{-1} , attributed to -OH

stretching vibrations, was observed in the carbon prior to activation but disappeared after activation. This change suggests the reduction of hydroxyl-related functional groups because of thermal treatment during the activation process. The absence of the aliphatic –CH stretching band at 2873.94 cm^{-1} further indicates the removal of non-carbonaceous or volatile components during activation. Shifts in the carbonyl-related absorption bands from 1687.71 cm^{-1} to 1700.55 cm^{-1} and from 1578.42 cm^{-1} to 1648.21 cm^{-1} reflect changes in the chemical environment of oxygen-containing surface groups rather than the formation of new ordered structures. In addition, the shift of the band from 1220.94 cm^{-1} to 1022.34 cm^{-1} suggests a redistribution of –CO functionalities, which may be associated with ether or alcohol-type groups on the carbon surface. Overall, the FTIR results demonstrate that chemical activation modifies the surface chemistry of the carbon primarily through the reduction of thermally unstable functional groups and the alteration of oxygen-containing species, which is typical for activated carbons subjected to high-temperature treatment, as summarized in **Table 3** [10].

Table 3. Number of Waves and Functional Groups of Activated Carbon

Carbon Before Activation	Wavenumber (cm^{-1})		Function Clusters
	Carbon Activated with KOH 40%	Literature [11]	
3035.96	-	3700-3000	□OH
2873.94	-	3100-2700	□CH
1687.71	1700.55	1850-1600	C=O
1578.42	1648.21	1650-1590	C=C
1220.94	1022.34	1300-1020	□CO.

3.2.3 XRD

XRD characterization was conducted to assess the structural order of the activated carbon. The diffractograms display broad and low-intensity reflections in the ranges of $2\theta \approx 20\text{-}30^\circ$ and $40\text{-}50^\circ$, which are characteristic of predominantly amorphous carbon materials. The broad reflection centered at approximately $2\theta \approx 23^\circ$ is commonly assigned to the (002) plane of turbostratically arranged graphene layers, while the feature around $2\theta \approx 43^\circ$ corresponds to the (100) plane associated with turbostratic carbon structures. The presence of broad and weak diffraction peaks indicates limited structural ordering and a low degree of graphitization rather than the formation of well-crystallized graphite.

Such diffraction behavior reflects the development of turbostratic carbon, in which the structural ordering is intermediate between amorphous carbon and crystalline graphite. At high activation temperatures, partial rearrangement of carbon layers may occur; however, excessive thermal treatment can also disrupt graphitic ordering, resulting in irregular and highly disordered carbon structures. The absence or weak intensity of the (002) reflection further suggests randomly oriented graphene layers with poor long-range order, which is commonly associated with increased pore development and higher specific surface area. Based on the XRD results, the activated carbon can therefore be classified as predominantly amorphous with turbostratic characteristics [10]. The corresponding XRD patterns are presented in Figure 1.

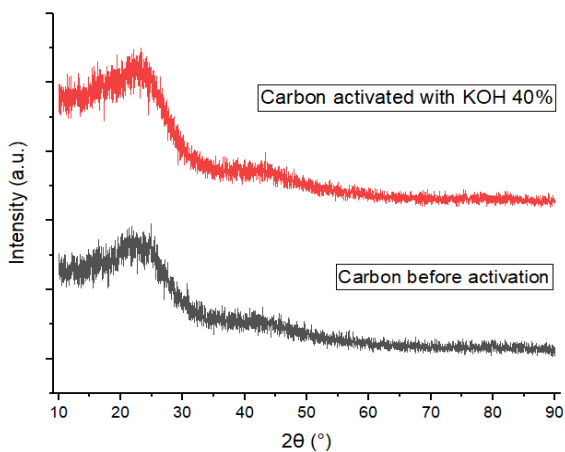


Fig. 1. XRD graph of carbon

3.2.4 SEM

Pre-activated carbon and 40% KOH-activated carbon show activated carbon morphology with porous structure at 2500x magnification, shown in **Figure 2**. When compared to carbon before activation, activated carbon has wider pores. This indicates that the carbon activation process using KOH effectively expands the pores of carbon when compared to carbon before activation.

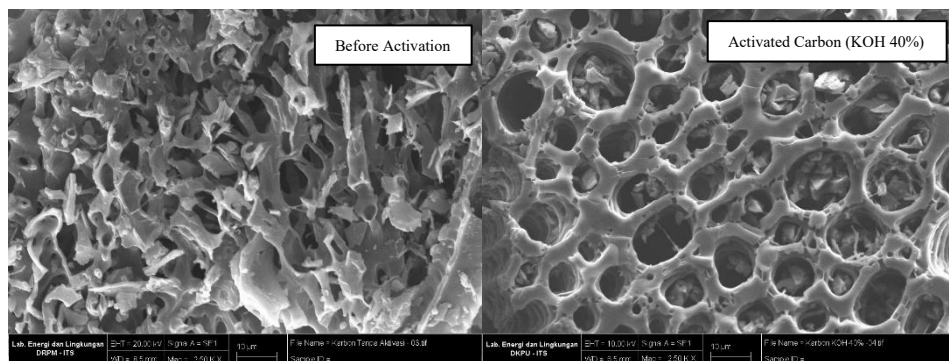


Fig. 2. Carbon Surface Morphology

Table 4. EDX Analysis Results on Corn Cob Carbon

Chemical elements	Weight percent (wt%)		Atomic percent (at%)	
	Before Activation	Activation with KOH 40%	Before Activation	Activation with KOH 40%
C	72.36	81.01	78.90	87.50
O	24.22	13.41	19.82	10.87
Fe	0.12	2.57	0.03	0.6
K	1.57	1.12	0.53	0.37
Ti	0.04	0.68	0.01	0.18
P	1.30	0.35	0.55	0.11
Ca	0.05	0.35	0.02	0.11

S	0.33	0.21	0.14	0.09
Si	0.00	0.05	0.00	0.02
Mg	0.00	0.01	0.00	0.01
Na	0.00	0.01	0.00	0.01
Al	0.00	0.00	0.00	0.00

Based on Table 4, carbon (C) is the dominant element and shows the most pronounced increase after activation. The carbon content increased from 72.36 wt% (78.90 at%) before activation to 81.01 weight% (87.50 at%) after activation with 40% KOH. This increase is accompanied by a corresponding decrease in oxygen (O) content, from 24.22 wt% and from 19.82 at% to 10.87 at%. Such changes are consistent with the thermal treatment involved in carbonization and activation, during which oxygen-containing components are partially removed, leading to enrichment of the carbon matrix [10]. The decrease in oxygen content indicates a reduction in oxygen-containing components, which is commonly observed in chemically activated carbons treated with alkaline agents such as KOH [6].

3.2.5 BET

Chemical activation using KOH significantly increased the BET surface area of the carbon from 11.166 m²/g (non-activated) to 490.789 m²/g after activation with 40% KOH. This enhancement is attributed to the interaction of KOH with the carbon matrix during pyrolysis, which promotes pore opening and the formation of new pores through combined chemical reactions and gas evolution. The substantial increase in surface area indicates that the activation conditions were effective in developing the porous structure of the carbon, in agreement with the general mechanism of alkali-activated carbon reported in the literature, according to Table 5 [12].

Table 5. Carbon Surface Area

Carbon	Surface area (m ² /g)
Carbon before activation	11.166
Carbon activation with KOH 40%	490.789

3.3 Used Cooking Oil Purification

The oil purification process consisted of sequential de-gumming, neutralization, and adsorption stages. During repeated frying, exposure of oil to moisture and oxygen promotes triglyceride hydrolysis and oxidation, leading to the formation of free fatty acids (FFAs), partial glycerides, and other polar degradation products. The de-gumming stage is intended to reduce hydrophilic impurities such as phospholipids and other polar components that can be removed through water-assisted phase separation. This treatment decreases the content of gum-forming substances that may interfere with subsequent processing steps.

Neutralization is applied to reduce FFA content through acid-base reactions with alkaline reagents, thereby lowering oil acidity and contributing to the partial removal of odor- and color-forming compounds. In this study, NaOH solution was used as the neutralizing agent to convert FFAs into soap, which can be separated from the oil phase. Following neutralization, adsorption using activated carbon was employed as a final purification step to reduce remaining polar impurities, including residual pigments, FFAs, and oxidation products such as peroxides [13]. This sequential treatment improves the chemical quality of the oil prior to further utilization.

3.4 Analysis of Oil

3.4.1 Oil Quality Testing

The free fatty acid (FFA) content decreased from 3.328% to 3.082% after the de-gumming stage, which can be associated with the partial removal of polar impurities and phospholipid-related components. A more pronounced reduction occurred during neutralization, where FFA levels decreased to 0.407% because of acid-base reactions with NaOH. Subsequent adsorption using activated carbon further reduced the FFA content to 0.144%, indicating that adsorption functions as an effective final step for removing residual acidic and polar compounds. Peroxide values showed a temporary increase during the de-gumming and neutralization stages, which is likely related to oil exposure to heat and oxygen during processing. Following adsorption, peroxide values decreased, suggesting the removal of peroxide-related oxidation products by activated carbon [14]. The moisture content increased after de-gumming due to incomplete separation of added water but subsequently decreased after heating and adsorption treatments. The saponification value of 190 mg KOH/g indicates that the triglyceride content of the purified oil remained sufficiently high for use as a raw material in soap production, as summarized in **Table 6**.

Table 6. Oil Quality

SNI 7709:2019 on palm cooking oil	FFA (%)	Peroxides number (meQ O ₂ /kg)	Moisture Content (%)
	Max. 0.3	Max. 10	Max. 0.1
UCO	3.328	9.95	0.27
De-gumming Process	3.082	11.71	0.33
Neutralization Process	0.407	13.92	0.18
Adsorption Process	0.144	9.8	0.07

3.4.2 FTIR

Table 7. Number of Waves and Function Groups of Oil

Wavenumber (cm ⁻¹)			Function Clusters
UCO	Refined Oil	Literature [11]	
3479	-	3700-3000	□OH
2922	2926	3000-2800	□CH
2852	2853	3000-2800	□CH
1745	1743	1735-1750	C=O
1463	1465	1460-1475	□CH
1166	1164	1110-1300	□CO.
		970-1200	P=O P-O-C

The FTIR spectra of the oil, as summarized in Table 7, show that the broad absorption band at 3479 cm⁻¹ observed in UCO disappeared after purification. This band is generally associated with -OH stretching vibrations and suggests a reduction of hydroxyl-containing polar components. The loss of this band is consistent with the decrease in free fatty acid and peroxide

values measured during purification, indicating the effective removal of polar oxidation products. Slight shifts in the $-\text{CH}_2$ stretching bands from 2922 and 2852 cm^{-1} to 2926 and 2853 cm^{-1} indicate minor changes in the aliphatic structure. The sharpening and slight shift of the carbonyl band from 1745 cm^{-1} to 1743 cm^{-1} suggest a reduction of secondary oxidation products such as aldehydes and ketones after adsorption. Furthermore, the decreased intensity in the $1200\text{--}970\text{ cm}^{-1}$ region indicates the reduction of phosphate-related vibrations ($\text{P}=\text{O}$ and $\text{P}-\text{O}-\text{C}$), supporting the effectiveness of the de-gumming stage in removing phospholipid-derived impurities [11].

3.4 Soap Production and Evaluated

The refined used cooking oil was subsequently employed as a raw material for soap production. Waste cooking oil contains free fatty acids and thermal-oxidation products that interfere with the saponification reaction and adversely affect the chemical properties of the final soap, making purification necessary prior to use [15]. Sequential de-gumming, neutralization, and adsorption treatments improved oil quality by progressively reducing free fatty acids and polar oxidation products. Although de-gumming and neutralization decreased FFA content, these stages were accompanied by a temporary increase in peroxide value due to thermal exposure, thereby requiring adsorption as a final treatment to remove residual oxidized compounds.

Soaps prepared from oils subjected to more advanced purification stages exhibited more favorable observable properties. Soaps produced from unrefined and de-gummed oils showed higher residual alkalinity, phase separation, and detectable rancid odor, which may indicate incomplete saponification and the presence of oxidation-related impurities. In contrast, soaps derived from adsorbed oil displayed a homogeneous structure, lower final pH (11), and no detectable rancidity. These observations are consistent with the reduction of acidic, pigmented, and polar oxidation-related compounds during the purification process. Changes observed in the FTIR spectra of the purified oil (**Table 7**), particularly in the $-\text{OH}$ stretching region, further indicate alterations in polar functional group composition following purification. The absence of phase separation and lower residual alkalinity suggests that the removal of degradation products facilitates a more uniform saponification process.

4. Conclusion

Carbon activation using KOH assisted by ultrasonic irradiation was demonstrated to be effective in enhancing the adsorption performance of activated carbon derived from the studied material. Based on the investigated parameters, the optimum activation condition was achieved at a KOH concentration of 40% and an ultrasonic irradiation time of 40 minutes, yielding an iodine adsorption capacity of 1065 mg/g . The activated carbon produced under these conditions effectively reduced free fatty acid (FFA) content and peroxide value in used cooking oil, indicating an improvement in oil quality after the adsorption process. The reduction of these quality parameters suggests a lower presence of oxidation-related compounds in the purified oil. Furthermore, the improved oil quality contributed to observable improvements in the characteristics of the liquid soap produced, particularly in terms of more stable pH values and a brighter visual appearance, compared to soap prepared from untreated UCO. These results indicate that the optimized activated carbon is suitable for application in UCO purification and subsequent soap production.

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