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Effects of Different Bleaching Conditions on Bleaching Efficiency and Physicochemical Characteristics of Cambodian Soybean Oil

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Abstract: *Soybean oil extracted from different methods contains impurities and undesirable substances such as soap residues, free fatty acids, phosphatides, trace metals, coloring pigments, and other impurities that negatively impact the soybean oil's quality including testability, appearance, smell, and shelf life. To enhance the quality of soybean oil, the removal of these undesirable substances is commonly carried out through the bleaching process, which is a crucial step in the refining process. The objective of this study was to investigate the effects of various bleaching conditions by using the activated bleaching earth on the quality of soybean oil. The different dosages of activated bleaching earth ranging from 1 to 7 wt%, the contact times ranging from 20 to 90 minutes, and the bleaching temperatures ranging from 80 to 120°C were investigated during the bleaching process with stirring at 500 rpm. The bleaching efficiency was measured using a UV-Vis spectrophotometer and the physicochemical qualities of neutralized and bleached soybean oil were also evaluated including peroxide value, acid value, iodine value, and color. The results showed that the soybean oil bleached with 5 wt% of activated bleaching earth, 60 minutes of contact time, and 110°C of bleaching temperature exhibited the highest bleaching efficiency of 75.78%. Furthermore, these refining conditions of soybean oil resulted a peroxide value of 0.95 meq O_2/kg oil, acid value of 1.31g KOH/g oil, iodine value of 132.27 g I_2/100 g oil, and color difference (ΔE) of 22.13, which stayed in the standard quality. In conclusion, it can be inferred that the optimal conditions for bleaching soybean oil are 5 wt% of activated bleaching earth at 110°C for 60 minutes. The amount of bleaching earth, as well as the bleaching time and temperature, significantly influenced the peroxide value, and color of the oil, while their impact on the acid and iodine values was comparatively lesser.*

Keywords: Activated bleaching earth; Bleaching process; Bleaching efficiency; Peroxide value; Soybean oil.

1. INTRODUCTION[1]

Soybean (Glycine max L.) is the most widely grown oilseed crop in the world. It has a moderate oil content and a high protein content that account for 20% and 40%, its total mass [1]. Crude soybean oil is extracted by various extraction methods such as solvent extraction or mechanical pressing which produces a mixture of various lipids. It contains 95-97% of triglycerides, 1.5-2.5 % of phosphatides, 1.6% of unsaponifiable matter, 0.3-0.7% of free fatty acids, and other composites [2]. In this context, it contains undesirable substances such as soap residues, free fatty acids, phosphatides, trace metals, coloring pigments, and other impurities that impact the oil's quality [3]. To improve the quality of soybean oil, the refinery process includes degumming, neutralization, bleaching, and deodorization, which have the major to remove undesirable substances that are influenced in soybean oil [4],[5]. Among these 4 stages, bleaching is the most delicate stage for removing the undesirable substances. Its primary focus to eliminate

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compounds like soaps, contaminants, oxidation products, pigments, phospholipids, and glycolipids [6]. In addition, it significantly reduces the color and decompose peroxide value [7]. The bleaching process involves bleaching agents, dosage, bleaching time, and temperature. Thus, these parameters should be adjusted to achieve the desired quality of the bleached oil.

Activated bleaching earth (ABE) is derived from montmorillonite-rich bentonite clay. It effectively removes color, spits soap, reduces free fatty acids, peroxide and oxidation products, while also promoting isomerization. Furthermore, it serves as a solid, acidic catalyst, adsorptive agent, cation exchanger, and filter aid, with a high pigment adsortption capacity [8],[9]. However, increasing clay amounts improves oil components removal but poses challenges for effective bleaching due to variations in oil composition and clay reactions. The optimal clay quantity varies depending on clay type, oil pretreatments, and desired oil grade, typically ranging from 0.1 to 2.0 wt%, or higher in special cases.

The adsorbent requires time to adsorb pigments, comtaminants, and removes moisture [10]. At short contact time for bleaching, the adsorption of the impurities may not be saturature and the different contaminants in the oil have varying degrees of attraction toward the adsorbed complicates of the adsorption process [11].

Temperature is most effective in bleaching which has an influence on processes such as hydrogenation or adsorption. Specifically, heat is effective in removing pigments. Higher temperatures improve absorption, and removing clay moisture improves color adsorption [11],[12]. To achieve optimal color removal, vacuum bleaching methods often require lower temperatures than atmospheric bleaching. Therefore, oils should be bleached at a temperature between 100-120℃ [13].

The aim of this study was to propose the bleaching conditions of neutralized soybean oil including activated bleaching earth (wt%), contact time (minutes), and temperature (℃) which influence on the physicochemical quality of soybean oil. The effect of these parameters on bleaching efficiency was investigated, and the physicochemical characteristics of soybean oil were also compared.

2. METHODOLOGY

2.1 Preparation of neutralized soybean oil

The soybean seeds were purchased from a farmer in Preah Vihear province, Cambodia. They were manually inspected for foreign materials and then ground using a ginder (SL309, CW, Thailand). The crude soybean oil was extracted by using the hydraulic press (BY-180, HENAN BEYRONG, China), degummed with phosphoric acid and neutralized by the water. The neutralized soybean oil was subsequently utilized for the bleaching process.

2.2 Chemicals

In this study, the activated bleaching earth used was produced and commercialized by Wee-rin Chemical, Thailand. The specifications of the activated bleaching earth are indicated in Table 1. The reagents used in the present study include phosphoric acid, sodium hydroxide, sodium thiosulfate, potassium iodine, phenolphthalein, and starch as an indicator (Sigma-Aldrich, USA), n-Hexane, acetic acid, cyclohexane, Wijis solution, ethyl alcohol (DAEJUNG, South Korea), and chloroform (Fisher Chemical, USA).

2.3 Bleaching procedure

The bleaching experiment was conducted using a 250 ml three-necked round-bottomed glass flask equipped with a hotplate magnetic stirrer (IKA C-MAG HS7, IKA, Germany), a thermometer, and a vacuum pump (DOA-P504-BN, GAST, China), as illustrated in Fig. 1. Varying amounts of activated bleaching earth (1-7 wt%) were added at different bleaching times (20-90 minutes) and under desired bleaching temperatures (80-120℃). This process was performed in batches with a detailed experimental design is presented in Fig. 2. After bleaching, the heating and vacuum were turned off, allowing for a fifteen-minute cooldown. The mixture was separated using a centrifuge (HERMLE Z326K, HERMLE Labortechnik GmbH, Germany) at 4,000 rpm for 30 minutes. The supernatant solution was further filtered under vacuum using filter paper (Whatman 1, Cytiva, China) to remove the adsorbent. The clarified solution was then stored in a dark glass bottle at −17℃ for subsequent analysis.

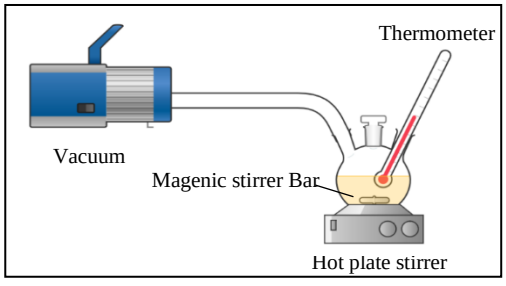

Fig. 1. Schematic diagram of the experimental setup for bleaching process

2.4 Bleaching efficiency

The bleaching efficiency (BE) was determined using a UV-Vis Spectrophotometer (G6860ACARY, Agilent Technologies). Each 0.1 g sample of soybean oil was poured into a 10 ml test tube by diluting it with 7.5 mL of petroleum ether. Next, the mixture was poured into the cuvette, and the

value of the absorbance was then measured at 445 nm wavelength [14].

$$\% \text{ BE} = \frac{A_0 - A_t}{A_0} \times 100 \qquad \text{(Eq. 1)}$$

where:
A_0= absorbance of neutralized soybean oil
A_t= absorbance of bleached soybean oil

2.5 Physicochemical analysis of soybean oil

Each sample was subjected to the analysis of its phyicochemical quality, such as peroxide value (PV), acid value (AV), iodine value (IV), and color by using the standard methods of AOCS (1990) official method [14].

2.5.1 Peroxide value

5g of the oil sample was dissolved in a 50 ml mixture of acetic acid and water (3:2 v/v) in a 250 ml conical flask. After gently swirling, 0.5 ml of saturated KI solution was added. The mixture was shaken for 1 minute, and then 30 ml of distilled water was added. This mixture was titrated with a 0.01 N sodium thiosulfate solution using 1% starch solution as an indicator. The titration continued until the dark blue color disappeared. Finally, the peroxide value was calculated using the following equation:

$$\text{PV (mg } O_2\text{/ kg oil)} = \frac{(S-B)\times M\times 1000}{W} \qquad \text{(Eq. 2)}$$

where:
B = volume of Na_2SO_3 solution for the blank (ml)
S = volume of Na_2SO_3 solution for the sample (ml)
M = molarity of Na_2SO_3 solution (0.01N)
W = oil sample weight (g)

2.5.2 Acid value

5g of the oil sample was weighed into a 250 ml Erlenmeyer flask, sealed with a glass stopper. To the flask, 80 ml of freshly neutralized hot ethyl alcohol was added, along with 0.5 ml of phenolphthalein as an indicator solution. The mixture was titrated with a 0.1N sodium hydroxide solution (KOH) until the a persistent pink color appeared for at least 30 seconds. The experiment was conducted in duplicate, and the acid value results were expressed as mg KOH/g oil, calculated using the following equation:

$$\text{AV (mg KOH/g oil)} = \frac{56.1\times V\times N}{W} \qquad \text{(Eq. 3)}$$

where:
V = volume of standard KOH used (ml)
N = normality of KOH solutoion (0.1N)
W= oil sample weight in (g)

2.5.3 Iodine value

0.1g of the oil sample was weighed into 250 ml Erlenmeyer with glass stopper. Next, 15 ml of cyclohexane-acetic acid was added into flask containing the oil sample. Then, 25 ml of wijs solution was added, and the mixture was kept in dark place for 30 minutes. Afterward, the mixture was titrated with 0.1 N of sodium thiosulphate ($Na_2S_2O_3$) using starch as an indicator solution. The titration continued until the dark blue color disappeared and calculated using the following equation:

$$\text{IV (mg } I_2\text{/100g oil)} = \frac{(B-S)\times M\times 2.69}{W} \qquad \text{(Eq. 4)}$$

where:
B = volume of Na_2SO_3 solution for the blank (ml)
S = volume of Na_2SO_3 solution for the sample (ml)
M = molarity of Na_2SO_3 solution (0.1N)
W = oil sample weight (g)

2.5.4 Color

The color of soybean oil was carried out by using chromat (CR-400, Konica Minolta, Japan) which was expressed in L^* value reprented the degree of lightness (0:back and 100: white), a^* value represented the difference between red ($+a^*$) and green ($-a^*$), and b^* value that represented by difference between yellow ($+b^*$) and blue ($-b^*$). The colorimeter was placed on 10 ml of the oil sample which was put into the plate.

2.6 Statistical analyses

The analysis of variance (ANOVA) was conducted using the standard significance value of 95% confidence interval (p<0.05). To identify significant differences between the means, the Duncan multiple range test was employed. The data were subjected to a One-Way ANOVA to compare the means of two independent groups. All experimental data were obtained through duplication.

Table 1. Components of activated bleaching earth.

Parameter	Specification
Appearance	Not agglomerate
pH (10% Supension)	2.5-3.0
% Moisture by drying at 105℃ for 3 h	13% Max
Bulk density (g/cm^3)	0.40-6.0
Free fatty (H_2SO_4)	0.60% Max
After 3% bleaching (Lovibound 5.25 inch)	30Y 12R 0.8B

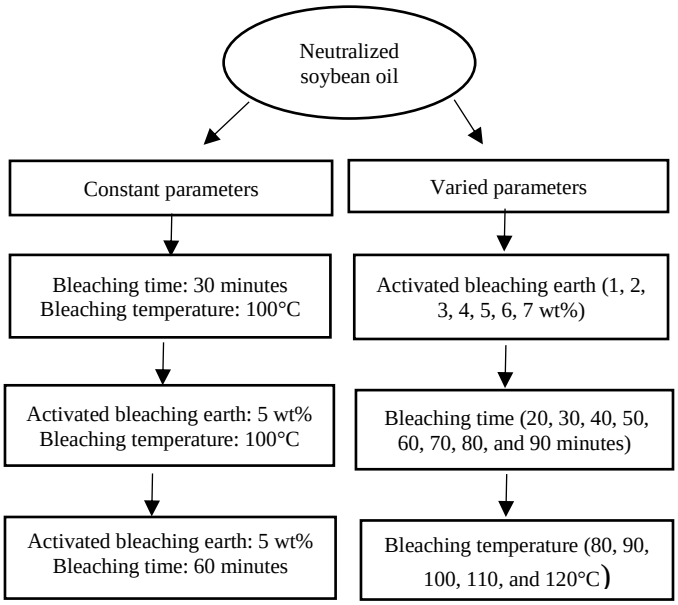

Fig. 2. Detailed experimental design of this study

3. RESULTS AND DISCUSSION

3.1 Effect of activated bleaching earth dosage on soybean oil bleaching process

Activated bleaching earth (ABE) is a highly effective bleaching agent that significantly influences bleaching capacity. In this study, we investigated the effect of different amounts of the ABE on BE of soybean oil at 100°C for 30 minutes. Based on Fig. 3, 1 to 5 wt% of ABE has a significant influence on BE (p<0.05). However, there were no significant differences on BE observed at 5 wt%, 6 wt%, and 7 wt%. The BE values for these concentrations were 69.55%, 69.63%, and 69.25% respectively, indicating consistent performance with increasing amounts of bleaching earth. It is crucial to use an appropriate amount of ABE until no further color change is observed in the soybean oil. However, higher amounts of ABE usage have increased the adsorption sites which has a positive effect on pigment adsorption and produces superior-quality bleached oil within the assessment range [15],[16]. Therefore, the concentration of 5wt% of ABE was acceptable for the investigation of higher bleaching efficiency. Ye et al. [17] recommended that the amount of bleaching clays used should be between 2-5wt% of the oil during the bleaching process.

The effect of ABE dosage on the PV of bleached soybean oil is summarized in Table 2. Results indicate that the dosage significantly affects PV (p<0.05). Using 1 to 3 wt% of ABE, PV decreases from 2.59 meq O_2/kg oil to 0.74 meq O_2/kg oil. However, there is a slight PV increase from 0.75 meq O_2/kg oil to 1.35 meq O_2/kg oil with 4 to 7 wt% dosage. Higher bleaching earth dosages might reduce natural antioxidants like tocopherols, which protect against oxidation. The bleaching with synthetic bleaching earth introduced more impurities or metals into the oil, which contacted as catalysts for oxidation [18]. According to García-Moreno et al. [16], the primary oxidation products were affected by using higher clay amount (5 wt%). Therefore, it is important to use high-quality bleaching earth with low impurity content. The bleached soybean oils had the PV values under 5 meq/kg oil which were the acceptable for refined oil.

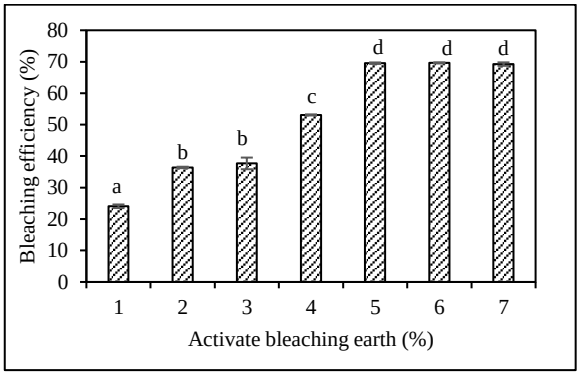

Fig. 3. Effect of activated bleaching earth dosage on the bleaching efficiency of bleached soybean oil. (^{a,b,c,d} Different letters indicate significant different differences using activated bleaching earth dosage (p<0.05)

The AV and IV of soybean oil were influenced by varying amounts of ABE, as displayed in Table 2. During the bleaching process, the AV and IV in bleached soybean oil exhibited slight fluctuations without significant differences (p>0.05). However, increasing the amounts of ABE (2-7 wt%) resulted in a rapid change, with the maximum decrease of 1.17 mg KOH/g oil observed at 5 wt%. They did not show significant differences after bleaching with different dosages of bleaching earth. This suggests that the effect of bleaching earth on the hydrolysis or oxidation of fatty acids is not as strong as other factors such as temperature, moisture, and pretreatment [18]. Furthermore, they were already low or stable before bleaching, due to the quality of the crude oil or the previous refining steps. The acid activation produces acidic surfaces which were more easily broken down into free fatty acids in the oil, and iodine content was stable throughout the refining process [19],[20].

The color index, represented by L* for lightness, a* for red or green, b* for yellow or blue, and ΔE for color variation, is used to describe the color of soybean oil. The impact of different amounts of ABE on the color of soybean oil present in Table 3. The color (L*, a*, and b*) remained consistent as the dosage of bleaching earth increased from 5 to 7 wt%. The a* and b* values indicated a reduction towards green and yellow when using 1 to 4 wt% of bleaching earth. However, when the dosage of bleaching earth was increased from 5 to 7 wt%, particularly ΔE values were 21.63, 21.73, and 21.58,

respectively. This demonstrates that the color of soybean oil is influenced by the dosage of the ABE. Gómez-Polo et al. [21] showed that the higher a* value indicated a reduced level of green, while the higher b* value indicated an increased level of yellow, it can be seen that the amount of the ABE had a significant effect on the color of soybean oil. The ABE dosage and soybean oil color help the industry keep getting better, improving how they make soybean oil, and making the products more competitive in the market.

Table 2. Effect of activated bleaching earth dosage on the physicochemical quality of soybean oil

Activated bleaching earth (%)	Peroxide Value (meq O_2/Kg oil)	Acid Value (g KOH/g oil)	Iodine Value (g I_2/g oil)
NS	5.07±0.01^{d}	1.29±0.07^{c}	127.38±3.52^{a}
1	2.59±0.14^{c}	1.36±0.01^{b}	140.75±2.39^{a,b}
2	1.35±0.07^{b}	1.30±0.02^{a,b}	137.47±2.49^{b,c,d}
3	0.79±0.06^{a}	1.26±0.02^{a,b}	135.54±2.37^{c,d}
4	0.79±0.06^{a}	1.24±0.02^{a,b}	132.94±0.61^{c,d}
5	1.29±0.13^{b}	1.17±0.04^{a}	127.04±0.64^{a,b,c}
6	1.60±0.35^{b}	1.26±0.02^{a,b}	138.60±0.65^{c,d}
7	1.50±0.21^{b}	1.29±0.00^{a,b}	143.73±4.94 ^{c}

NS means neutralized soybean oil, ^{a,b,s,d} Different letters in the column indicate significant difference (p<0.05).

Table 3. Effect of activated bleaching earth dosage on color of neutralized and bleached soybean oil

Activated bleaching earth (%)	CIELAB Color			
	L*	a*	b*	ΔE
NS	32.53±0.11^{c}	-5.85±0.01 ^{a}	18.75±0.44^{e}	_
1	31.20±0.59^{a}	-1.92±0.09^{b}	7.68±0.59^{d}	11.84±0.65^{a}
2	31.28±0.16^{a}	-0.81±0.07^{c}	3.79±0.23^{c}	15.84±0.49^{b}
3	31.24±0.48^{a}	-0.19±0.12^{d}	1.94±0.41^{b}	17.79±0.58^{c}
4	31.72±0.14^{a,b}	-0.03±0.02^{e}	1.54±0.11^{b}	18.19±0.41^{c}
5	32.32±0.44^{b,c}	0.69±0.07^{f}	-1.86±0.24^{a}	21.63±0.49^{d}
6	31.95±0.08^{b,c}	0.86±0.05^{g}	-1.91±0.15^{a}	21.73±0.57^{d}
7	32.17±0.27^{b,c}	0.74±0.01^{f,g}	-1.79±0.22^{a}	21.58±0.47^{d}

NS means neutralized soybean oil, ^{a,b,c,d,e,f,g} The data with different letters in superscript differ significantly (p<0.05).

3.2 Effect of different bleaching times on soybean oil bleaching process

This study investigated the effect of time on BE of soybean oil by using 5 wt% of activated bleaching earth at 100℃ for different durations from 20-90 minutes. The effect of different bleaching times on BE is shown in Fig. 4. Based on the results, the BE reached to 75.32% at 60 minutes and the maximum 75.36% at 70 minutes of bleaching time The time from 70-90 minutes was likely stable due to the saturation and the depletion of its bleaching ability. However, it declined slightly (72.14% at 80 minutes) and increased slowly (74.35% at 90 minutes). For the stabilization of BE after 60 minutes of bleaching is that the bleaching earth may reach its maximum adsorption capacity, such that no more color pigments or impurities can be removed from the oil. This depended on the quality and quantity of the bleaching earth, as well as the initial color and impurities content of the oil and it may reach an equilibrium state, where the rate of adsorption and desorption of color pigments and impurities are equal [22],[23]. According to Aly [18], the percentage of removal value (%) remained for 60-70 minutes. The optimal point that investigated bleaching efficiency was at a different value in the bleaching time required to bleach soybean oil 75 -85 minutes [24]. According to García-Moreno et al. [16], their study was also obtained at 130℃, 5 wt% of ABE, and 60 minutes. Thus, the optimum of soybean oil's bleaching time was 60 minutes.

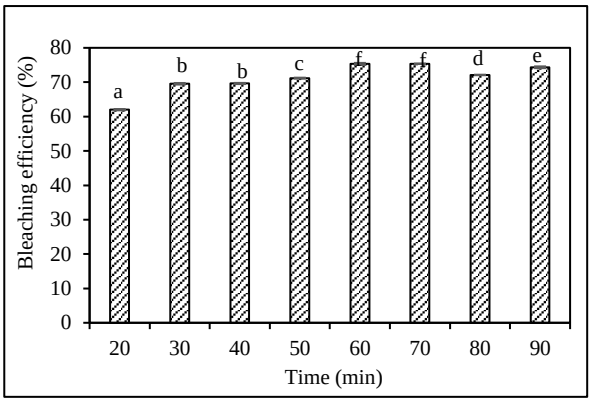

Fig. 4. Effect of different bleaching times on bleaching efficiency of bleached soybean oil. (^{a,b,c,d,f}Different letters indicate significant differences at time bleaching (p<0.05)

The effect of different bleaching times on the peroxide value of bleached soybean oil is shown in Table 4. After bleaching, PV showed a significant difference (p<0.05) in bleaching time. PV was decreased steadily from 1.50 to 1.25 meq O_2/kg oil by using 20–40 minutes of bleaching time. This bleaching may remove some of the peroxides or their precursor by adsorption or decomposition. It stayed steady when using bleaching time (50–70 minutes) at 1.35 meq O_2/kg oil. However, it increased slightly when using 80–90 minutes. At 50-70 minutes of bleaching, the bleaching earth may reach a balance between removing and introducing peroxides. This may depend on the temperature and moisture conditions of the bleaching process, as well as the type and acidity of the bleaching earth [23]. The bleaching time 80-90 minutes, the bleaching earth may lose its activity or efficiency. Additionally, after 40 minutes of bleaching, the ABE may have to reach saturation, it has absorbed as many impurities as possible and could no longer effectively remove any more time. According to Tai & Lin [25], the soy oil continued oxidation after 45 minutes of bleaching time, thus the peroxides value increased slightly. The bleaching time of 60 minutes is significantly effective to remove pereoxide value [26]. The peroxide value of bleached soybean oils was

below 5 meq O_2/kg oil, a contact time of 60 minutes was acceptable for soybean oil quality.

The effectiveness of contact time on AV and IV in bleached soybean oil are shown in Table 4. The results illustrated that the AV and IV were not significantly different (p>0.05) in the bleaching time of soybean oil. Therefore, bleaching time does not affect both parameters.

The effect of bleaching time on the color of neutralized and bleached soybean oil is displayed in Table 5. This demonstrated that the L*, a*, and b* at 100°C using 5 wt% of ABE were significantly different (p<0.05). The ΔE showed the difference color of of neutralized and bleached soybean oil . The ΔE value shows a profound influence of bleaching time on bleached soybean oil. Based on the result, ΔE value were between from 21.16 and 23.24 which were more dissimilar color of neutralized soybean oil. According to Xu et al. [27], ΔE value above 10 indicates significant differences in the oil colors between the various sample conditions.These indicated that bleaching times were important enhancing the color stability of soybean oil. The rang of ΔE value were the potential impact of bleaching time as a factor influencing the overall color characteristic of soybean oil, thereby offering valuable insights for optimizing the bleaching process.

Table 4. Effect of different bleaching times on the physicochemical quality of soybean oil

Bleaching time (mins)	Peroxide Value meq O_2/Kg oil	Acid Value g KOH/g oil	Iodine Value g I_2/g oil
NS	5.07±0.01^{d}	1.29±0.08^{a}	127.38±3.52^{a,b}
20	1.5±0.01^{b,c}	1.20±0.04^{a}	133.17±1.89^{a,b}
30	1.19±0.13^{a}	1.26±0.04^{a}	132.55±0.64^{a,b}
40	1.25±0.07^{a}	1.26±0.04^{a}	125.72±2.18^{a}
50	1.35±0.07^{a,b}	1.29±0.00^{a}	137.36±4.27^{b}
60	1.35±0.07^{a,b}	1.23±0.08^{a}	137.81±3.93^{b}
70	1.35±0.07^{a,b}	1.26±0.04^{a}	134.36±0.73^{a,b}
80	1.55±0.08^{c}	1.23±0.00^{a}	136.38±5.37^{b}
90	1.60 ±0.00^{c}	1.26±0.04^{a}	135.58±8.82^{a,b}

NS means neutralized soybean oil,^{a,b,c,d} Different letters in the column indicate significant difference (p<0.05).

Table 5. Effect of different bleaching times on color of neutralized and bleached soybean oil

Time (mins)	CIELAB Color			
	L*	a*	b*	ΔE
NS	32.53±0.11^{b,c}	-5.85±0.01^{a}	18.75±0.44^{d}	
20	32.47±0.28^{b,c}	0.61±0.05^{d,e}	-1.58±0.16^{b}	21.33±0.49^{a}
30	32.32±0.44^{b,c}	0.69±0.07^{e}	-1.86±0.24^{b}	21.63±0.49^{a}
40	32.33±0.32^{b,c}	0.53±0.03^{c,d}	-1.54±0.20^{b}	21.28±0.35^{a}
50	32.81±0.33^{c}	0.85 ±0.04^{f}	-3.5±0.28^{a}	23.24±0.57^{b}
60	32.11±0.05^{a,b}	0.61±0.03^{d,e}	-1.43±0.08^{b,c}	21.20±0.44^{a}
70	32.21±0.38^{b,c}	0.79 ±0.06^{f}	-3.02±0.54^{a}	22.76±0.94^{b}
80	31.53±0.40^{a}	0.41 ±0.07^{b}	-0.87±0.24^{c}	20.62±0.58^{a}
90	31.52±0.39^{a}	0.50±0.03^{c}	-1.41±0.54^{b,c}	21.16±0.93^{a}

NS means neutralized soybean oil, $^{a, b, c, d, e, f}$ The data with different letters in column differ significantly (p<0.05).

3.3 Effect of different bleaching temperatures on soybean oil bleaching process

The effective temperature of oil was required in the bleaching process by using 5 wt% for 60 minutes and various bleaching temperatures. Fig. 5 showed the effects of bleaching temperature on BE of bleached soybean oil. Based on the result, the BEs were significantly different when subjected to different temperatures (p<0.05). The BE increased steadily with bleaching temperature from 80 to 100°C. It may have higher adsorption capacity and activities at higher temperature, as the pores and surface area of the bleaching earth increase. The BE remained stable at bleaching temperatures of 100°C and 110°C which were performed at 75.32% and 75.78%. The increasing adsorption rate with increasing temperature may be due to a reduction in the viscosity of crude soybean oil molecules which leads a greater ability to be adsorbed [18]. According to Abedi et al. [28], the recommended temperature range for oil bleaching is between 85-120°C, depending on the oil type and clay activity.

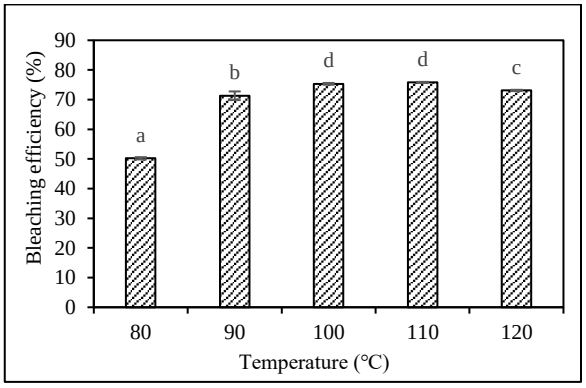

Fig.5. Effect of different bleaching temperatures on bleaching efficiency of bleached soybean oil. (^{a,b,c,d,f}different letters indicate significant differences (p<0.05)

In unsaturated fats and oils, the PV is the initial evidence of oxidative rancidification. It identifies the amount of oxidation that an unsaturated fat or oil has experienced. The effective PV at the various temperatures was determined as described in Table 6. The results indicated a significant difference (p<0.05). At lower temperatures (80-90°C), the bleaching process may proceed at a slower rate which allows for more effective removal of impurities and less exposure of the oil to oxygen. This can lead to a decrease in PV as the oxidation of the oil is inhibited and it was reduced to 0.80 meq O_2/ kg oil at 100°C. However, at a temperature of 100°C, the bleaching process may proceed at a faster rate leading to increasing PV. At even higher temperatures of 110 and 120 °C, the bleaching process any be more effective due to the increased rate of adsorption of impurities by the ABE. It can lead to a decrease in PV as the oxidative stability of the oil improves. According to Wang & Lin [29], the optimum

bleaching temperature of 110℃ was found with several oils studied. The hydroperoxide breakdown during bleaching can be destroyed in the final refining stage of deodorization [6]. The AV and IV at different temperatures are indicated in Table 6. The results showed that they were not significantly different (p>0.05). The most important alterations are saponified with sodium hydroxide and separated in soap stock after the neutralization process which was 1.29 mg KOH/ g oil. The lack of significant differences in AV and IV of the oil after the bleaching process could be due to the fact that the process is designed to remove impurities and undesirable components from the oil. Moreover, the ABE used in this process is selective and mainly adsorbs impurities such as pigments, phospholipids, and oxidation products. In general, high IV has lower oxidative stability and more double bonds than low IV of oil. According to Sánchez-Machado et al. [30], this content was stable throughout the refining process and was not significantly different between treatments. And Henache et al. [31] showed that free fatty acids, iodine, and saponification values remained unchanged.

Table 6. Effect of different bleaching temperatures on the physicochemical quality of soybean oil

Bleaching temperature (℃)	Peroxide Value (meq O_2/Kg oil)	Acid Value (g KOH/g oil)	Iodine Value (g I_2/g oil)
NS	5.07±0.01^{d}	1.29±0.08^{a,b}	127.38±3.52^{a}
80	1.30±0.01^{c}	1.23±0.07^{a}	136.97±0.36^{b}
90	0.8±0.14^{a,b}	1.29±0.01^{a,b}	138.14±1.39^{b}
100	1.35±0.06^{c}	1.23±0.07^{a,b}	137.81±3.93^{b}
110	0.95±0.07^{b}	1.31±0.03^{a,b}	132.27±2.83^{a,b}
120	0.75±0.07^{a}	1.40±0.08^{b}	131.60±2.35^{a,b}

NS means neutralized soybean oil,^{a,b,s,d} The data with different letters in column differ significantly (p<0.05).

The effect of bleaching temperature on the color of neutralized and bleached soybean oil is presented in Table 7. The higher L* value generally showed a decreasing trend since the bleaching temperature reached 100°C, but it slightly increased above 100°C.

Table 7. Effect of bleaching temperatures on the color of neutralized and bleached soybean oil

Bleaching temperature (℃)	CIELAB Color			
	L*	a*	b*	ΔE
NS	32.53±0.11^{a}	-5.85±0.01^{a}	18.75±0.44^{d}	_
80	32.10±0.54^{a}	0.83±0.04^{c}	-1.93±0.27^{b,c}	21.74±0.68^{a,b}
90	32.17±0.37^{a}	0.82±0.07^{c}	-2.19±0.36^{b}	21.98±0.78^{a,b}
100	32.11±0.05^{a}	0.61±0.03^{b}	-1.43±0.08^{c}	21.20±0.44^{a}
110	32.36 ±0.37^{a}	0.78 ±0.93^{c}	-2.36±0.32^{b}	22.13±0.77^{a,b}
120	32.81±0.49^{a}	0.98±0.05^{d}	-3.28±0.36^{a}	23.07±0.72^{b}

NS means neutralized soybean oil, ^{a,b,c,d,} the data with different letters in superscript differ significantly (p<0.05).

Furthermore, the color-difference index ΔE was over 10 between neutralized soybean oil and bleaching temperature (80–120°C). Moreover, the bleaching temperature of 110°C had the effect on decoloring. The temperature was around 100°C, and 110°C being the most typical during the edible bleaching process that may be regarded as the standard bleaching temperature [3].

4. Conclusions

In this study, the activated bleaching earth dosage, contact time, and temperature significantly affected on the bleaching process of soybean oil, resulting in different bleaching efficiencies. Their effects on acid value and iodine value were not slightly different. The fluctuations or changes in peroxide, and color values were likely caused by the bleaching agent, and the vacuum applied in the bleaching process. Among all conditions studied, the bleaching efficiency in the bleaching process ranged from 24.07% to 75.78%. The bleached soybean oil at 5 wt% for 60 minutes at 110°C was selected for its higher bleaching efficiency. For its physicochemical quality, the PV, IV, and ΔE were 0.95 meq O_2/kg oil, 132.27 g I_2/100 g oil, and 22.13, respectively. These resulted in slight differences in the physicochemical quality of neutralized and bleached soybean oil, and they fit into the quality standards recommended for bleached oils and are adopted by edible oil refinery factories. It should be noted that these optimum conditions should be further tested with different bleaching earth properties and mixing speeds.

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