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A Comparative Determination of the Physicochemical Properties of the Crude and Refined Products of Palm oil and Soybean oil

Akintomiwa Olumide ESAN[1]*, Ibidotun Theophilus OLAWORE[2], Grace Ibukunoluwa FAYOKUN[1], Samuel Adeyeoba ADEREMI[1], Deborah Adejoke BADMUS[1], Funmilayo Yetunde OLUSHOLA[1], Samuel Sodienye URANTA[1]

[1]*Department of Pure and Applied Chemistry, Ladoke Akintola University of Technology, P.M.B. 4000, Ogbomoso, Oyo State, Nigeria.*

[2]*Department of Chemistry, Ahmadu Bello University Zaria, Nigeria*

aoesan@lautech.edu.ng, ibidotunolawoore@gmail.com, graceibukunoluwa@gmail.com, hirewamiri@gmail.com, badmusdeborah9@gmail.com, olusholafunmilayo0212@gmail.com, sodiuranta@gmail.com

*Correspondence: aoesan@lautech.edu.ng; Tel.: +2348034397212

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Abstract**:** *This study compared the physicochemical properties of crude and refined palm oil and soybean oil. Key parameters such as acid value, peroxide value, saponification value, free fatty acid, and iodine value were analysed. Crude palm oil exhibited higher acid and saponification values, while refined oils showed improved stability and reduced free fatty acids. Refining reduced oxidation susceptibility in soybean oil but increased the peroxide value in palm oil. The results revealed significant changes in oil quality post-refinement, impacting nutritional and industrial applications. These findings highlight the critical role of refining in improving oil quality and safety for industrial applications. However, the effects of refining vary depending on the oil type.*

Keywords: Physicochemical properties, crude and refined oils, palm oil, soybean oil and oil quality analysis.

1. INTRODUCTION

Vegetable oils are essential dietary and industrial resources, providing both nutritional and functional value in food processing, cosmetics, pharmaceuticals, and biofuel industries [1]. Palm oil and soybean oil are two of the most widely used and produced vegetable oils, and they are also very important from an economic and nutritional standpoint [2]. *Elaeis guineensis* fruits are used to make palm oil, which is mostly produced in tropical areas and has a high yield rate, making it a cost-effective option in international oil markets [3]. Glycine max seeds are used to make soybean oil, which is produced in large quantities in temperate regions and prized for having a comparatively high unsaturated fatty acid content. The distinct physical and chemical properties of both crude and refined oils affect their quality, shelf life, and uses [4]. Degumming, neutralization, bleaching, and deodorization are examples of refinement procedures that aim to remove impurities, improve stability, and enhance sensory qualities [5]. However, refining also alters the physicochemical characteristics, which may have an impact on the oxidative stability and nutritional value of the oils [6].

Important markers of quality, purity, and safety are the physicochemical characteristics of oils, such as their free fatty acid (FFA) content, peroxide value, iodine value, and saponification value [7]. Peroxide values show the degree of oxidation, while high FFA levels can indicate hydrolytic degradation [8]. These factors impact the oil's shelf life and suitability for industrial or consumer use [9]. It is essential for producers' consumers and regulators to comprehend how refining alters these qualities [10]. Furthermore, there is an increasing need for oils that strike a balance between stability and nutritional value as a result of consumers increased awareness of food quality and its effects on health. This is particularly relevant in developing countries where people frequently consume crude oils directly, while refined oils are typically preferred in developed markets due to their stability, odour, and appearance [11].

Therefore, assessing how refining affects palm and soybean oils provides important insight into how processing affects oil properties and health attributes. Determining and contrasting the physicochemical characteristics of crude and refined palm and soybean oils while examining how refinement processes change their quality indicators is the aim of this study. The data from this study will be used to inform consumer decisions, direct industry practices, and support regulatory standards for the extraction and processing of oil.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Reagents and Chemical used

All reagents and chemical used in this research were of analytical grade and purchased from Lab-trade, a Nigerian company which sells Sigma Aldrich Chemical Co. (St. Louis, MO, United States of America).

2.1.2 Sample Collection

The crude oil samples were collected from a local producer in Modakeke, Osun State, Nigeria while the refined oil samples were purchased from two different industry in Sagamu, Ogun State, Nigeria.

2.2 Methods

2.2.1 Determination of free fatty acid value

The procedure outlined by Febrianto *et al.* (2019) was used in determining the free fatty acid value [12]. Five thousand grams of the oil samples were weighed and put into a 250 millilitre Erlenmeyer, previously considered empty weight. 40 °C was reached after adding 50 ml of 96% ethanol. Following cooling, two drops of phenolphthalein indicator were added to the oil. It is not lost for 30 seconds after titration with 0.1M NaOH to create a pink solution. The titrant's volume was noted. For every sample, there were three titrations. Equation (1) was used to determine each sample's free fatty acid value.

$$\% \text{ Free fatty acid} = \frac{V \times N \times BM}{m \times 1000} \quad (1)$$

where: V = volume NaOH titration (mL), N = Normality of NaOH, BM = molecular weight fatty acid (gram) and m = Mass of oil sample.

2.2.2 Determination of Acid Value

Using the procedure outlined by Esan *et al.* (2024), the acid value was calculated [8]. 100 ml of ethanol was added to each 1 g oil sample, which was then weighed and dissolved in the flask. A 0.1N potassium hydroxide solution (KOH) was used to titrate two drops of phenolphthalein indicator to the pink end point, which lasted for fifteen minutes. It was noted how much the titrant was. Each sample underwent three iterations of the titration. Equation (2) was used to determine each sample's acid value.

$$\text{Acid value} = \frac{56.1 \times v \times c}{m} \quad (2)$$

where: 56.1 = Equivalent weight of KOH, V = Volume in ml of standard volumetric KOH, C = Concentration in KOH (0.1N) and m = Mass in grams of the oil sample.

2.2.3 Determination of Iodine Value

The iodine value was determined using the Hanus iodine solution method Hilp (2002) [13], which is described as follows: Weigh 0.25 g oil into a 500 ml conical flask and distillate in 10 ml chloroform. Using a measuring cylinder, add 25 ml Hanus iodine solution and let it stand in dark for 30 minutes, shaking occasionally for an accurate result. Add 10 ml 15% KI solution, shake thoroughly, and add 100 ml fresh boiled and cooled H_2O. Titrate iodine with standard 0.1N $Na_2S_2O_3$, adding it gradually, with constant shaking, until yellow solution turns almost colourless. Add 0.5 ml starch indicator and continue titrate until blue completely disappears towards the end of reaction and shake violently, so that any iodine remaining in solution in chloroform may be absorbed by KI solution. The black test was carried out in addition to the sample determination. Each sample underwent two titrations, and the iodine value was calculated using Equation (3).

$$\text{Iodine value} = \frac{(B-S) \times N \times 12.69}{Wt.of\ sample} \quad (3)$$

where: B = volume in ml of blank solution, S = volume in ml of standard $Na_2S_2O_3$ and N = Normality of $Na_2S_2O_3$.

2.2.4 Determination of Saponification Value

The method outlined by Triyasmono *et al.* (2022) approach was used to calculate the saponification value [14]. 5g of the oil sample was weighed into 50 ml of alcoholic hydroxide (KOH + ethanol) in a round-bottom flask. Using aluminium foil as a catalyst, the first 50ml of the distillation was discarded. For the same predetermined amount of time, reflux the samples. Add a few drops of the indicator phenolphthalein, then use 0.5N HCL to titrate. The disappearance of the pink colour indicates the saponification value. The blank determination procedure was carried out in the same way. Equation (4) was used to determine the saponification value for each sample.

$$\text{Saponification value} = \frac{28.05 \times (Vb-Vs)}{Ws} \quad (4)$$

where: V_b = Volume in ml of standard HCL solution used for blank test, V_s = Volume in ml of standard HCL solution used for sample and W_s = Weight of sample

2.2.5 Determination of Peroxide Value

The methodology outlined by Esan *et al.* (2024) was used to calculate the peroxide value [8]. A conical flask containing 10–12 g of oil sample was filled with 30 ml of a solvent mixture of glacial acetic acid and chloroform. After a vigorous shake, clockwise and counterclockwise, 1 ml of saturated KI was added. After adding 30 ml of distilled water and vigorously shaking it for a minute, 0.5 ml of starch indicator was added, and the mixture was titrated using a 0.01N $Na_2S_2O_3$ solution. Shake vigorously until the black colour turns white to initiate the reaction. Alongside the oil samples, a blank was made. Each sample's peroxide value was determined using Equation (5).

$$\text{Peroxide value} = \frac{V \times N \times 1000}{Ws} \quad (5)$$

where: V = Volume in ml of standard $Na_2S_2O_3$, N = Normality of $Na_2S_2O_3$ and Ws is the weight of oil.

3. RESULTS AND DISCUSSION

Edible oils, such as palm and soybean oils, are crucial in food, cosmetics, and biodiesel industries. Their physicochemical properties, including acid value, peroxide value, saponification value, free fatty acid (FFA) content, and iodine value, determine quality, stability, and application [15]. Acid value reflects oil stability, peroxide value indicates oxidation levels, and saponification value is vital for soap and biodiesel production. FFA content impacts shelf life, while iodine value measures unsaturation, influencing reactivity [8, 16]. Understanding these parameters in crude and refined oils aids quality assessment and industrial suitability. Tables 1 and 2 highlight the differences in these properties for palm and soybean oils.

The acid value, which measures the free fatty acid content, is significantly higher in crude palm oil (10.66±0.56 mgKOH/g) than in refined palm oil (5.24±0.49 mgKOH/g). This reduction during refining is attributed to the neutralization step, which removes free fatty acids, thereby improving the oil's quality and stability for culinary and industrial applications [17]. In contrast, soybean oil shows a slight increase in acid value after refining (from 4.68±0.49 mgKOH/g to 6.29±0.43 mgKOH/g), likely due to oxidative degradation of triglycerides at high processing temperatures, generating additional free acids [18]. These findings highlight how refining impacts the chemical characteristics of oils and reveal differences in how palm and soybean oils respond to processing. The results also align with Tsado *et al.* (2018), who analyzed the fatty acid profile of Blighia sapida fruit oil extract [19].

The peroxide value (PV) results show contrasting trends between the oils. For palm oil, the PV increases significantly from 2.73±0.07 Meq/kg in the crude form to 6.73±0.13 Meq/kg in the refined state. This increase is likely due to oxidative stress induced by heat treatment during deodorization, which forms peroxides as primary oxidation products [20]. On the other hand, soybean oil demonstrates a slight decrease in PV during refining, with values dropping from 2.49±0.09 Meq/kg to 2.18±0.09 Meq/kg. The relative stability of soybean oil's PV suggests that it may undergo a less aggressive refining process or possesses inherent oxidative stability due to its composition. These findings highlight the trade-off in refining, where impurities and rancidity-inducing compounds are removed at the cost of introducing oxidation stress. The results is also with Wazed *et al.* (2023) study, who evaluate the physicochemical parameters of edible oils at room temperature and after heating at high temperature [21].

The saponification value shows a substantial decrease in both oils following refining, indicating the removal of high-molecular-weight triglycerides and complex lipids [22]. Crude palm oil exhibits a saponification value of 259.03±0.61 mgKOH/g, which reduces to 161.28±0.44 mgKOH/g in the refined product. Similarly, crude soybean oil's saponification value decreases from 224.85±1.00 mgKOH/g to 168.59±1.38 mgKOH/g. This reduction signifies that refining simplifies the lipid composition, which is beneficial for certain industrial uses, such as soap manufacturing and biodiesel production, where consistent molecular properties are essential [23]. The results also align with Esan *et al.* (2024) study, who Characterize Palm fatty acid distillate and soybean deodorized distillate for biodiesel production [8].

The free fatty acid (FFA) content is a key determinant of oil quality and storage potential [24]. In crude palm oil, the FFA content is relatively high at 0.85±0.01%, but it decreases significantly to 0.06± 0.01% in the refined product. This dramatic reduction underscores the efficacy of refining in improving the oil's quality and usability for consumption and industrial processing. Crude soybean oil, which starts with a low FFA content of 0.07± 0.03%, exhibits an even further reduction to 0.01±0.01% after refining, reflecting its already high quality and oxidative stability compared to palm oil.

The iodine value, which reflects the degree of unsaturation in the oil [25], increases in refined palm oil, rising from 8.12±3.08 gI_2/100g in the crude form to 16.8±0.86 gI_2/100g. This shift suggests a compositional change favoring unsaturated fatty acids due to the removal of more saturated fractions during refining. In contrast, soybean oil, naturally richer in unsaturated fatty acids, shows only a slight increase in iodine value, from 31.47±1.02 gI_2/100g to 32.74±0.59 gI_2/100g. These findings emphasize the intrinsic differences between the two oils, with soybean oil being more suited for applications requiring high unsaturation levels, such as margarine production and bio-lubricants.

The observed variations between crude and refined products are attributed to the refining process, which involves degumming, neutralization, bleaching, and deodorization [26]. These steps are designed to remove impurities and improve quality but also alter the chemical composition and stability of the oils. The changes in peroxide value and acid value highlight the trade-offs of refining, where stability and usability improve at the expense of increased oxidative degradation in some cases.

Table 1: Physicochemical parameters of crude palm oil and refined palm oil and refined soybean oil

Parameters	Crude Palm Oil	Refined Palm oil
Acid Value (mgKOH/g)	10.66 ± 0.56	5.24 ± 0.49
Peroxide value (Meq/kg)	2.73 ± 0.07	6.73 ± 0.13
Saponification Value (mgKOH/g)	259.03 ± 0.61	161.28 ± 0.44
Free Fatty Acid (%)	0.85 ± 0.01	0.06 ± 0.01
Iodine Value (gI_2/100g)	8.12 ± 3.08	16.8 ± 0.86

Table 2: Physicochemical parameters of crude soybean oil and refined soybean oil

Parameters	Crude Soybean oil	Refined Soybean oil
Acid Value (mgKOH/g)	4.68 ± 0.49	6.29 ± 0.43
Peroxide value (Meq/kg)	2.49 ± 0.09	2.18 ± 0.09

Parameters	Crude Soybean oil	Refined Soybean oil
Saponification Value (mgKOH/g)	224.85 ±1.00	168.59 ± 1.38
Free Fatty Acid (%)	0.07 ± 0.03	0.01 ± 0.01
Iodine Value (gI_2/100g)	31.47 ± 1.02	32.74 ± 0.59

4. CONCLUSION

This study highlights the significant impacts of refining on the physicochemical properties of crude and refined palm and soybean oils, emphasizing the need to optimize refining processes to enhance oil stability, quality, and nutritional value while minimizing oxidative damage. The findings provide valuable benchmarks for the edible oil industry, aiding informed decisions by producers and consumers. It is recommended that refining techniques focus on preserving essential bioactive components and improving functionality. Further research into innovative refining methods is encouraged to develop oils with superior stability, functionality, and health benefits.

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