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Effect of Variety on the Quality Parameters of Crude Soybean Oil

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Abstract The main objective of this study was to evaluate the effect of seed variety on soybean oil quality and quantity. Soybean oil was extracted from four different varieties obtained from three locations in Nigeria namely; Benue, Bauchi and Kaduna States. The soybean seeds were sorted, cracked, conditioned, flaked and pressed to obtain the oil. The oil was further treated with 2% distilled water to obtain the degummed oil. The oil samples were investigated for their physical, chemical and mineral contents. The physical parameters showed that the oil yield ranged between 22.79 and 24.79%, specific gravity was from 0.91 to 0.93, density 0.92 to 0.94g/m^3, refractive index 1.46 to 1.47 and smoke point 230.50 to 233.50°C. Chemical analysis result showed that free fatty acid ranged from 0.28 to 0.29% with sample B (spotted variegated variety) as the lowest, peroxide value 1.77 to 1.88 meq/kg with sample D (black variety) having the highest value, saponification value ranged between 194.12 and 194.88 mgKOH/g, iodine value ranged from 104.83 to105.07mg/100g while phosphatide ranged from 2.65 to 3.10 with sample D (black colour) having the highest value. All the chemical parameters showed no significant differences ($p<0.05$) except peroxide and phosphatide values. The mineral composition of the oil samples showed that Calcium ranged from 3.33 to 3.66mg/kg, Iron was from 0.23 to 0.27mg/kg, Magnesium 0.73 to 0.75mg/kg while Manganese ranged from 0.005 to 0.010mg/kg. The study revealed that soybean variety had an effect on the oil yield, specific gravity, density, color intensity, peroxide value and calcium content of the oil samples. The refractive index, peroxide value, saponification value, iodine value and iron content of the oil samples were within the permissible limits stipulated by CODEX (1999) and the National Agency for Food and Drug Administration and Control (NAFDAC) (2019). These quality indicators are important parameters for choosing soybean variety for industrial and domestic oil production.

Keywords: *soybean, varieties, soybean oil, chemical, mineral, quality*

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1. Introduction

Soybean (*Glycine Max L*) is an annual herbaceous legume crop of the pea family *leguminesae*. Soybean oil is a vegetable oil extracted from the seeds of the soybean plant and is rich in omega-3 and omega-6 fatty acids [1]. It is also highly digestible, odourless and colourless, which does not coalesce easily. It is one of the most common vegetable cooking oil used presently [2,3]. Soybean oil is valued for its affordability, high smoke point and health benefit. It often has a dark yellow or faint green colour, which can be used for baking, cooking and frying.

There are different unit operations/processes employed in the extraction of oil from soybean seeds, which are the solvent and mechanical extraction. The solvent extraction method recovers about 95 – 98% of the oil while mechanical extraction removes only about 75 – 80% of the oil in soybean seeds.

Crude edible vegetable oils are usually known as unrefined and unprocessed oils extracted from vegetables (seeds), which are rich sources of unsaturated triacylglycerols. Triacylglycerols provide energy, maintain muscle activity, insulates the body, and aid in the absorption of vitamins while protecting the organs from injury. Most edible oils are extracted from plants through a combination of mechanical and solvent extraction process [4].

Oil obtained through this process is termed crude because of its high content of impurities, which are categorized into two major parts namely; soluble and insoluble impurities. Visible impurities such as seed fragments, fibers are known as insoluble impurities, while others such as free fatty acid, ketones, tocopherols, phytosterols, phospholipids, proteins, pigments and resins are soluble impurities [5].

Most of these impurities have unfavourable effects on the flavour, odour, appearance, and shelf life of the vegetable oil. Due to these effects, the removal of these impurities is necessary in order to maintain the nutritional quality and shelf life of the oil. Most of the impurities are removed from crude vegetable oil by chemical, mechanical and physical refining processes respectively. In order to convert the crude vegetable oil to refined oil, it must undergo further processing such as degumming, bleaching, deodorization and fractionation [6].

Phospholipids or gums are one of the major soluble impurities, which pose many problems to the processing and storage of crude vegetable oils. The presence of phospholipids in oils beyond 30ppm causes higher oil loss during neutralization, inefficient bleaching and darkening of the oil at high temperature during deodorization [6]. Phospholipids are removed from oil during refining by a process known as degumming.

Degumming is an important preliminary step in oil refining process, because it involves the removal of phospholipids along with other unwanted minor compounds without destroying the beneficial ones [7]. Gums tend to produce high refining losses, foaming, settling during storage, and undesirable characteristics in the final product such as unpalatable and dark coloured oil [8]. Degumming plays a critical role in the refining process of crude vegetable oil, as inefficiency during this process would affect other refining processes and the quality, shelf-life and storage of the finished product [9].

Quality and stability are the major important factors in the production, acceptance and marketing of vegetable oil products. The impurities present in crude oils depend largely on the seed quality, extraction method, processing conditions during extraction and refining of crude vegetable oil [10]. Varieties of soybean seed have shown differences in size and color. Previous studies by Anwar *et al.*, [11,12] have reported inter-varietal variations in the chemical composition of oils from the seed of okra and winter melon**.** Soybean variety has also been reported to affect the quality characteristics of soybean products [13]. The yield and quality characteristics of soybean oil may not vary only among different species and agro-climatic location but also among different varieties or cultivars of the same species [14]. The differences in colour and chemical composition of soybean varieties available in Nigeria may have an effect on the quality of oil extracted from the different varieties. Thus the objective of the study is to evaluate the effect of variety on the quality parameters of soybean oil.

2. Materials and Methods

2.1. Materials

The different varieties of soybean seeds used for this study were bought from Benue, Bauchi and Kaduna States of Nigeria.

Plate 1. Soybean (*Glycine max* (*L*) varieties (A- light brown colour, B - Spotted variegated colour, C- off white colour, D - Black colour)

2.2. Methods

2.2.1. Extraction of Soybean Oil

The extraction process was carried out at the Food Extraction Plant, Phinomar Nigeria Limited, Enugu-Ngwo, Enugu State. The analysis was carried out at Energy Research Center, University of Nigeria Nsukka (UNN). The method of Bargale *et al.*, [15] was used for oil extraction. The soybean seeds were cleaned and then de-hulled using a high-temperature de-huller. They were then conditioned and flaked. The flakes were then fed into the extruder (Model-10 DOX) dry expander, Anderson International Corporation, Cleveland, OH) and were allowed to attain a maximum temperature of 150°C at a retention time of 20s. The oil was then extracted using a screw press and the crude soybean oil was obtained.

2.2.2. Degumming of Crude Soybean Oil

The crude soybean oil was degummed using water degumming process. The method described by Andrew [16] was modified and used for the degumming of the crude soybean oil. Crude soybean oil was heated up to a temperature of 90°C. Distilled water (2% v/v) was added to the crude soybean oil and agitated using a high shear mixer for about 20 minutes and heated during mixing to a temperature of 70°C. The mixture was then centrifuged at 7000 rpm for 10 min to separate the oil from the precipitated gum after which the two products were dried at 150°C for 10 minutes and stored for further processing.

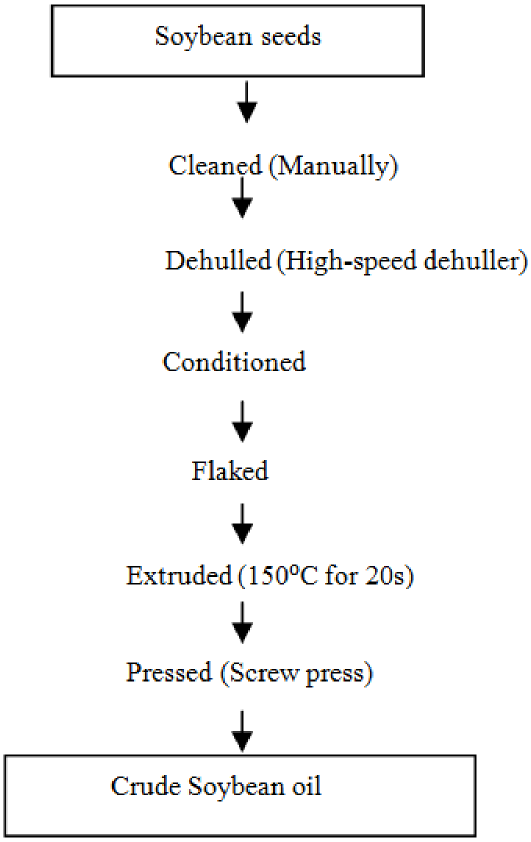

Figure 1. Extraction of Crude Soybean Oil [15]

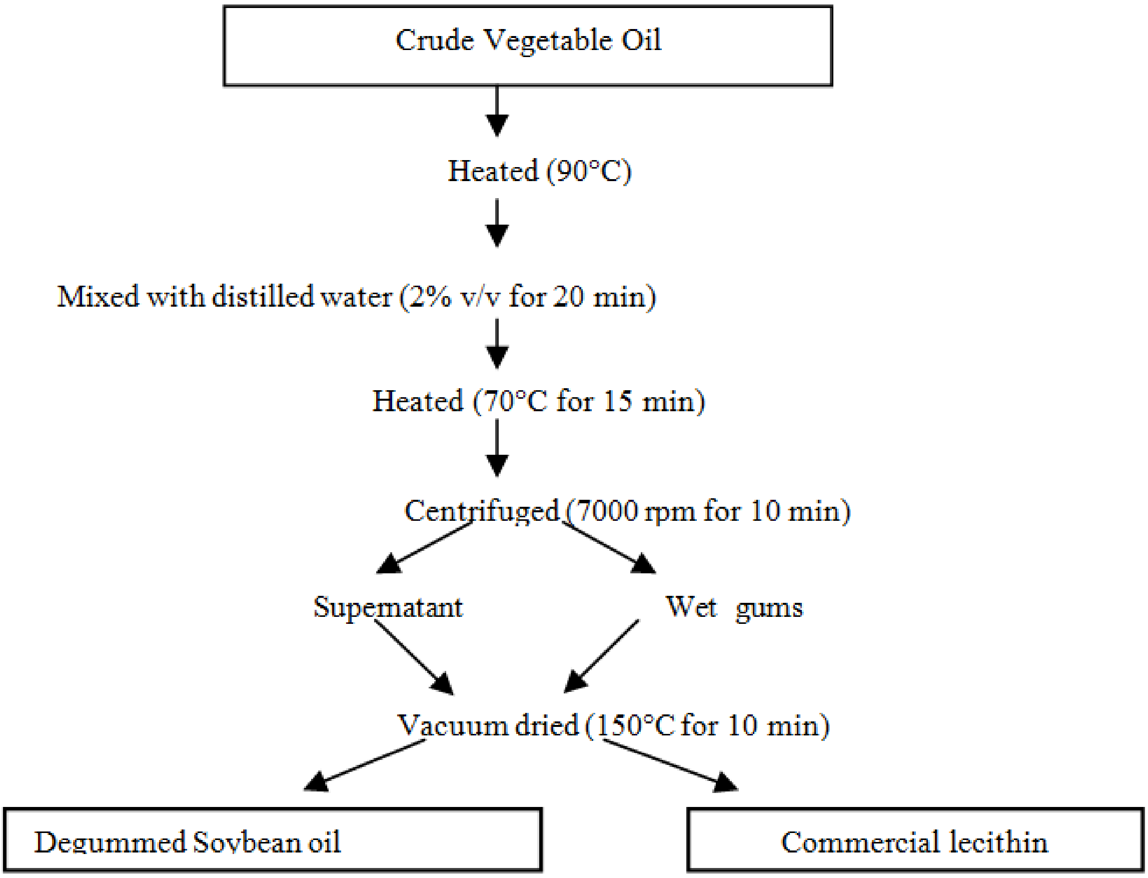

Figure 2. Water degumming process [16] (Adapted)

2.2.3. Determination of Physicochemical Properties

The physicochemical properties such as specific gravity, density, refractive index, free fatty acid (FFA), Peroxide value (PV), saponification value and iodine value of the oil samples were determined using the method of AOAC [17]. Phosphatide content of the oil samples were determined as described by Tosi *et al*., [18]. The color intensity of the oil samples were determined using a Lovibond Tintometer as units of red, yellow and blue according to the [19]. Density of the oil samples were measured by a Relative Density (R.D) bottle at what temperature 25°C while refractive index was determined using an Abbey Refractometer Model 2WAJ (Wincom, China).

2.2.4. Determination of Mineral composition

Mineral content of the oil samples were determined according to the method of Allen [20] as described by Prasad, *et al.*, [21]. The Oil samples were wet digested with a mixture of perchloric ($HClO_4$), nitric (HNO_3) and sulfuric (H_2SO_4) acids. The digest was used for the estimation of the mineral content of the samples at different wavelengths and standards appropriate for each of the elements determined. The concentration of minerals in the oil samples were determined using an Atomic Absorption Spectrophotometer (AAS) (model 5100 PCAAS, Perkin Elmer, USA).

2.3. Statistical Analysis

The oil samples were analyzed in duplicates and the data generated was subjected to statistical analysis of variance (ANOVA) using SPSS version 20. Differences between sample means were considered statistically different at $p< 0.05$.

3. Results

The physical properties of oils produced from different varieties of soybean seeds are presented in Table 1. Oil yield of the samples ranged from 22.79 to 24.79% with sample A (light brown color) having the lowest and sample D (the black variety) the highest. Specific gravity of oil ranged from 0.91 to 0.93 while density ranged from 0.92 to 0.94g/ml with the light brown variety as the highest in both cases. Refractive index ranged from 1.46 in samples A and D to 1.47 in samples B and C, while Smoke point ranged from 229.50 in sample B to 233.50 in samples A and D. The colour intensity of the oil samples ranged from 6/30/2 in sample C to 7/30/8 in sample D.

Table 1. Physical Properties of Soybean Oil from four varieties

Sample	Oil yield (%)	Specific gravity	Density at 25°C (g/m^3)	Refractive index	Smoke point (°C)	Color (R/Y/B)
A	22.79^b±0.01	0.93^a± 0.004	0.94^a±0.004	1.46^a± 0.00	233.50^a± 2.12	7/30/5
B	22.87^b±0.01	0.91^b± 0.001	0.92^b±0.001	1.47^a± 0.00	229.50^a± 0.71	7/30/4
C	24.76^a±0.06	0.91^b± 0.003	0.92^b±0.003	1.47^a± 0.00	230.50^a± 0.71	6/30/2
D	24.79^a±0.02	0.92^{ab}±0.003	0.93^{ab}±0.003	1.46^a± 0.01	233.50^a± 0.71	7/30/8

Values are means of duplicate determination ±SD. Means having the same letter within a column are not significantly different ($p< 0.05$).
Key: A = light brown colour, B = spotted/variegated colour, C = off white colour, D = black colour, R = red, Y= yellow, B= blue

The result of the chemical properties of degummed soybean oils is presented in Table 2. The Free Fatty Acid content of the oil samples ranged from 0.28 in sample B to 0.29% in samples A, C and D while the peroxide value ranged from 1.77 in A to 1.88meq/kg in sample D. The Saponification value ranged from 194.12 to 194.88 mgKOH/g with sample A having the highest and sample C the lowest while the Iodine value ranged from 104.83 in sample B to 104.97mg/100g in sample C. The Phosphatide content ranged from 2.65 to 3.30% in samples C and D respectively.

Table 2. Chemical properties of Soybean Oil from four varieties

Sample	FFA (%)	Peroxide value (meq/kg)	Saponification value (MgKOH/g)	Iodine value (gI/100g)	Phosphatide (%)
A	0.29^a±0.01	1.77^d± 0.01	194.88^a± 0.03	104.96^a±0.09	3.10^{ab}±0.14
B	0.28^a± 0.00	1.78^c± 0.00	194.46^a± 0.34	104.83^a±0.03	2.75^b±0.07
C	0.29^a± 0.01	1.80^b± 0.00	194.12^a± 0.34	104.97^a±0.16	2.65^b±0.07
D	0.29^a± 0.00	1.88a± 0.01	194.87^a± 0.09	105.07^a±0.01	3.30^a±0.14

Values are means of duplicate determination ±SD. Means having the same letter within a column are not significantly different ($p< 0.05$).
Key: A = light brown colour, B = spotted/variegated colour, C = off white colour, D = black colour.

Table 3. Mineral Composition of Soybean Oil from four varieties (mg/kg)

Sample	Calcium	Iron	Magnesium	Manganese
A	3.66^a± 0.01	0.23^a± 0.02	0.73^a± 0.02	0.005^a± 0.01
B	3.46^{ab}± 0.15	0.24^a± 0.03	0.74^a± 0.03	0.010^a± 0.00
C	3.33^b± 0.00	0.24^a± 0.01	0.74^a± 0.02	0.005^a± 0.01
D	3.35^b± 0.00	0.27^a± 0.00	0.75^a± 0.00	0.010^a± 0.00

Values are means of duplicate determination ±SD. Means having the same letter within a column are not significantly different ($p< 0.05$).
Key: A = light brown colour, B = spotted/variegated colour, C = off white colour, D = black colour.

Mineral composition of Soybean oil from four varieties

The chemical compositions of soybean oils are presented in Table 3. The Calcium content ranged from 3.33 in sample C to 3.66mg/kg in sample A while Iron ranged from 0.23 to 0.27mg/kg with sample A having the least and sample D having the highest. Magnesium ranged from 0.73 to 0.75 mg/kg in samples A and D respectively while the Manganese content of the oil samples ranged from 0.005mg/kg in samples A and C to 0.010mg/kg in samples B and C.

4. Discussion

4.1. Physical Properties of Soybean Oil

The percentage oil yield is one of the factors for consideration in the choice of soybean variety for industrial processing of oil. The percentage oil yield (22.79 to 24.79%) from the different soybean varieties investigated in the present study differed significantly ($p>0.05$) implying variations in oil yield among the soybean varieties. The values obtained for oil yield in the present study are higher than 15.85 – 19.49% oil yield of different varieties of soybean reported by Anwar *et al.*, *[14]*.

Specific gravity is the weight of oil compared with that of water. There was a significant difference ($p> 0.05$) in the specific gravity of the oil samples which ranged from 0.91 to 0.93. The values obtained are in agreement with previous studies by Alemayhu *et al.*, [22] who reported a specific gravity of 0.929 for soybean oil and Chompoo *et al.*, [23] who reported values of 0.921 and 0.923 for palm oil.

Density is an important factor that influences oil absorption [24]. The density of the oil samples were significantly different ($P> 0.05$). Sample A (light brown colour) had the highest density of 0.94g/m^3 which may be attributed to varietal difference. The values obtained in this study are higher than previous studies by Sahasrabudhe *et al.*, [25] who reported the density of soybean oil at room temperature as 0.9157g/m^3 and Tulcan *et al.*, [26] who reported values of 0.922 and 0.920 g/m^3 as the density of soybean oil at 15°C and 20°C respectively.

Refractive index is an important test for uniformity of the composition of oils. It gives an index of the molecular weight, fatty acid chain length, degree of unsaturation and degree of conjugation [27]. The Refractive index of the oil samples were not significantly different ($P < 0.05$) and ranged between 1.46 and 1.47 with samples B (spotted/variegated colour) and C (off white colour) having the highest values. The values are slightly lower than (1.489) reported for soybean oil by Alemayhu *et al.*, [22] but are within the range (1.466 -1.470) for soybean oil reported by Gunstone [28]. The higher refractive index of samples B (spotted/variegated colour) and C (off-white colour) could be attributed to higher degree of unsaturation in these samples. The values obtained in the present study are within the range (1.466-1.470) specified by the National Agency for Food and Drug Administration and Control (NAFDAC) [29].

The Smoke point gives an indication of the thermal stability of the free fatty acids in oils. The smoke point is the temperature at which cooking oils breakdown to fatty acids and glycerol which further degrades to acreolein the component of the bluish flame [30]. The smoke point of the oil samples were not significantly different ($p<0.05$). The values obtained in the present study (229.50 to 233.50°C) are higher than the value reported for soybean oil (224.33°C) by Mengistie *et al.*, [31]. The values are also higher than the minimum temperature of 200°C recommended by the Standard Organization of Nigeria [32]. The high smoke point of the oil samples indicates that the oils were properly refined, can resist ignition at high temperatures and are suitable for frying.

The intensity of the colour of vegetable oils gives an indication of the level of refining and is linked with the presence of different pigments [14]. The values for the colour of the oil samples revealed that sample C (off white colour) had the least colour intensity and is the most suitable for domestic use. The higher colour intensity of the other samples may be attributed to higher concentration of carotenoids and other red pigments present in the oil samples due to varietal differences. Vegetable oils with low color values are better for edible and domestic applications [14].

4.2. Chemical Properties of Soybean Oil

Free fatty acids are one of the impurities in crude oils which shorten their shelf life by stimulating oxidative rancidity and also darkening of the oils [23]. The free fatty acid content of the oil samples in the study ranged from 0.28 to 0.29 and did not differ significantly ($p<0.05$). The values obtained are lower than the maximum allowable limit of 0.6% stipulated by Codex Alimentarius International Food Standards (CODEX) [33]. Oils with lower content of free fatty acids are less prone to hydrolytic rancidity.

The peroxide value reflects the content of oxygen as peroxide in the form of hydro peroxides caused by primary oxidation [34]. The peroxide value could be used to assess the quality and stability of fats and oils as it determines the extent to which oil has undergone rancidity [35]. There was a significant difference ($p> 0.05$) in the peroxide value of the oil samples (1.77 to 1.88meq/Kg). The difference in peroxide values of the oil samples could be attributed to the effect of soybean variety on the oil samples. The peroxide values of the oil samples in the present study are lower than the maximum permissible limit of 10meq/Kg specified by the Standard Organization of Nigeria [32]. High peroxide values in oils indicate a higher susceptibility of the oils to oxidative rancidity.

Saponification value is an index of the average molecular mass of the fatty acids present in an oil sample [35]. The values obtained for the saponification value of the oil samples (194.12 to 194.88mgKOH/g) were not significantly different ($p<0.05$) and are within the range (177 to 196mgKOH/g) reported by Adeniyi *et al.*, [36]. The high saponification values of the oil samples suggest the presence of high proportion of unsaturated fatty acids and also an indication that the oils could be used in the production of soaps and shampoos.

Iodine value is a measure of the degree of unsaturation in vegetable oils and reflects the susceptibility of the oil to oxidation [37]. There was no significant difference ($p<0.05$) in the iodine value of the oil samples (104.83 to 105.07gI/100g). The values obtained are within the range (86-107g I/100g) reported for peanut oil by Johnson *et al.*, [38]. The values obtained in the present study are lower than the maximum range of 124 to 139gI/100g recommended by CODEX [33] The high iodine values in the oil samples indicate the presence of high fraction of unsaturated fatty acids in the oil samples.

Phosphatides are one of the contaminants that affect the physicochemical, sensory characteristics and storage stability of crude oils [39]. The process of degumming is used to reduce the phosphatides in vegetable oils [40]. The phosphatide content of the oil samples differed significantly ($p > 0.05$) among the varieties of soybean. The values obtained in the present study (2.65 to 3.30%) are within the range of 1.1 to 3.2% reported as the phosphatide content of soybean oil by O'Brien [41]. The phosphatides present in the oil samples might consist mainly of non-hydratable phosphatides as the water degumming process employed in this study was capable of removing hydratable phosphatides from vegetable oils.

4.3. Mineral Composition of Soybean Oil

Minerals are important in nutrition because of their health benefits. However large concentrations of some of these minerals could accumulate in tissues and become harmful to humans [42]. Thus assessing the mineral composition of vegetable oils is important due to their metabolic role in human diet as well as for detecting adulteration and oil characterization [43].

The mineral composition of the oil samples differed significantly ($p>0.05$) in their calcium content while iron, magnesium and manganese contents were not significantly different ($p<0.05$). The calcium content of the oil samples ranged from 3.33 to 3.66mg/kg. The calcium content of the oil samples are lower than 17.72mg/kg reported by Lamas *et al.*, [44] for sunflower oil. High content of calcium in crude vegetable oils suppresses the hydration of phospholipids thus reducing the efficiency of degumming and refining processes [43].

Iron plays a vital part in human health as it is required for the formation of red blood cells and cellular metabolism [45]. The requirement for iron is in small concentration and at higher concentrations it could become toxic. High concentrations of iron in refined vegetable oils adversely affects the colour intensity of the oils [46] and increase the rate of oxidation [47]. The iron content of the soybean oil samples (0.23 to 0.27mg/kg) in this study are in agreement with the findings of Aluyor *et al.*, [47] who reported iron content of 0.3109 mg/kg for refined groundnut. The values are also lower than the maximum level (1-1.5 mg/kg) of iron in vegetable oils recommended by CODEX [48]. The low content of iron in the oil samples indicates adequate processing and a reduced tendency for oxidation to occur in the oil samples during storage. Oils with high concentration of iron when exposed to light undergo reactions that catalyze oxidation [42].

The presence of magnesium in crude oils affects the process of refining. The result obtained for the magnesium content (0.73 to 0.75mg/kg) of the oil samples in the present study did not differ significantly ($p<0.05$). The similarities in the magnesium content of the oil samples despite the different varieties of soybean used for oil extraction might be attributed to the refining process. The use of appropriate technology in oil production effectively removes excessive concentrations of minerals present in the raw material [42].

Manganese is one of the minerals capable of increasing the rate of oil oxidation at high concentration [49]. The manganese content (0.005 to 0.010mg/kg) of the oil samples in this study are lower than the findings of Szyczewski *et al.*, [42] who reported manganese content of 0.15 mg/kg in refined soybean oil. The result of the present study is in agreement with the findings of Alrajhi and Idriss [50] who reported a range of 0.001 to 0.128mg/kg of manganese in some edible vegetable oils.

5. Conclusion

The study showed that the different soybean varieties can be used for oil extraction; however the off-white and black variety had higher oil yield than the other varieties. The result of the physical, chemical and mineral composition of the oil samples showed that soybean variety had an effect on the density, colour intensity, phosphatide and calcium content of the oil samples. The refractive index, saponification value, iodine value and iron content of the oil samples were within the permissible limits stipulated by CODEX [32] and the National Agency for Food and Drug Administration and Control (NAFDAC) [28]. The study has revealed that varietal differences in soybean seeds affect the quality of the soybean oil. However, with appropriate processing method, quality oil can be produced from the four varieties of soybean studied.

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