

Evaluation of Physicochemical Parameters of Unbranded Palm Oil Samples Purchased from Important Markets in Lagos, Nigeria

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Abstract

Background: The evaluation of the physicochemical properties of palm oil is a reliable means of ascertaining its quality and suitability for certain applications. **Aim:** This study was therefore carried out to examine the physicochemical parameters of sixty (60) unbranded palm oil samples collected from major markets in Lagos, Nigeria. **Method:** Nine physicochemical parameters such as viscosity, specific gravity, moisture content, refractive index, impurity level, acid value, iodine value, peroxide value and saponification value were analyzed in this study employing standard laboratory methods. **Results:** The results obtained from the properties analyzed for all the samples had the following ranges: Moisture contents (0.199 ± 0.19 %- 6.209 ± 3.83 %), specific gravities (0.91 ± 0.004 - 0.916 ± 0.002), refractive indices ($1.46 \pm 2.34E-16$ OBx- 1.454 ± 0.019 OBx), viscosities (23.536 ± 15.37 cP- 672.486 ± 1836.06 cP), impurity levels (0.145 ± 0.06 %- 15.618 ± 4.39 %), acid values (3.6634 ± 0.950 %- 5.4471 ± 2.80 %), iodine values (45.533 ± 1.79 Wijs- 98.974 ± 22.50 Wijs), free fatty acid value (1.8317 ± 0.48 %- 2.72355 ± 1.40 %), peroxide values (1.968 ± 2.81 meq/kg- 17.826 ± 17.09 meq/kg) and saponification values (121.483 ± 44.56 mg KOH/g- 200.559 ± 9.82 mg KOH/g). P-value of 0.74237 obtained for all the parameters were more than the traditional p-value of 0.05 showing that there is no notable difference between the values of the physicochemical parameters of all the palm oil samples. The refractive index and specific gravity values for all the samples agrees the Standard Organization of Nigeria (SON) limit. However, the other parameters analyzed exceeded the standard set by SON and was associated with the primitive processing techniques, poor storage practice, the usage of bad palm fruits, climatic and soil conditions. **Conclusion:** There should therefore be adequate sensitization of palm oil traders and manufacturers along with enforcement to ensure best practices are employed during processing, transportation, and storage of the palm oil products.

Keywords: Palm oil, physicochemical, limit, adulteration, food quality

1. Introduction

Palm oil is derived from oil palm tree fruits and is widely produced for various purposes. Palm oil contains fatty acids, esterified with glycerol, Myristic, palmitic, stearic, Oleic, linoleic acids are common type of fatty acids found in palm oil (Prada et al., 2011). Tocopherols, tocotrienols and carotenoids are some of the other components found in palm oil (Yi et al., 2011). β -carotenes are good sources of vitamin A and visual disorders could occur when this nutrient is lacking. The β -carotene level in palm oil is 15 times higher than in carrot and 300 times more than in tomato, making palm oil a major source of the nutrient (Souganidis et al., 2013). Tocopherols and tocotrienols are members of the vitamin E family which is beneficial to the human reproductive system (Ahsan et al., 2015). Also, palm oil has been proven to be effective in reducing cancer risk, cholesterol levels, boosting brain health, improving skin and hair health, and inhibiting the progression of heart disease (Shimizu et al., 2012; Mukherjee and Mitra, 2009).

These properties, make it suitable for many important foods and non-foods uses (Pande et al., 2012) such as cooking, production of soaps production of detergents, pharmaceutical products, cosmetics and oleochemical products among others (Yeong et al., 2012) and has led to a high consumption rate in Nigeria. Nigeria, being the



most populous black country in the world, is the biggest consumer of palm oil in Africa. About 1.34 million metric tons of palm oil was used up by the nation in 2018 (Shahbandeh, 2021). The high demand for palm oil coupled with inadequate monitoring by the regulatory bodies, makes this product prone to adulteration by unscrupulous producers and marketers in Nigeria. Incidences of adulteration of palm oil and arrest related to such crimes have been reported (Okogeri, 2013; Azubuike, 2020; Akinfenwa, 2018; Okeke, 2018). In addition to adulterations, the quality of the oil can also be adversely affected by traditional processing techniques (Amata and Ozuor 2013), poor storage practices (Onyeka et al., 2005), climatic and soil conditions, and usage of unhealthy palm fruits (Godswill et al., 2017).

The evaluation of the physicochemical parameters of palm oil is a reliable means of ascertaining its quality and suitability for certain applications (Aremu et al., 2018). Otunola et al. (2009), Kenechi et al. (2017), Akinola et al. (2010) and Enyoh et al. (2017) all used physicochemical properties to access its quality of palm oil. However, they accessed palm oils from within and outside Nigeria but not in Lagos. Only Adebayo-Oyetero et al. (2019) studied physicochemical parameters of palm oil samples from within a small part of Lagos- The Lagos mainland, leaving out parameters like viscosity among others. Since the over 10 % percent of Nigeria’s population resides in Lagos, Nigeria’s industrial capital (Fatunsin et al.,2019), it is important to ensure quality of food consumed by its inhabitants meet standards. This study was therefore carried out to examine the quality of unbranded palm oil samples sold in Lagos markets and to evaluate the level of their compliance with standards.

2. Materials and Methods

2.1 Sample Collection

Samples of unbranded palm oil were obtained from six markets in and around Lagos, Southwestern Nigeria. Sampled markets include Ayobo, ItaFaji, Bariga, Ikorodu, Lambe and Aguda markets. A total number of sixty (60) samples, ten (10) from each market were obtained. The samples were purchased in plastic bottles, labelled, and stored in a cupboard to avoid exposure to sunlight till ready for use.

2.2 Reagents Used and Their Sources

All the solvents and reagents used were of analytical grade, and they include n-Hexane (99.5%), Hydrochloric Acid (36.5%), Iodine Monochloride (95%), Potassium Hydrogen Phthalate (96.1%), Sodium Carbonate (99.99%), Sodium Thiosulphate (99%), Potassium Hydroxide (99%) and Sodium Hydroxide (99%) which were purchased from Merck, Germany. Chloroform (99%), Glacial Acetic Acid (99.4%), Magnesium Acetate (98.5%) and Potassium Iodide (99%), And Ethanol (95%) Phenolphthalein and Soluble Starch were purchased from Loba Chemie, India. Methyl Orange.

2.3 Physicochemical Parameter Determination

Nine physicochemical properties were evaluated in this study namely, viscosity, specific gravity, moisture content, refractive index and impurity level as well as the acid, iodine, peroxide and saponification values of the oil samples.

2.3.1 Acid value

For each sample, 0.1 g of oil was measured into a 250 mL conical flask, followed by the addition 50 mL of freshly neutralized hot ethanol and 1 mL of phenolphthalein indicator. The mixture was heated in a water bath for 5 minutes at around 40 °C, then titrated against (0.1 N) potassium hydroxide solution while still hot until the yellow colour changed to golden yellow (JOCS, 2013). The acid value was obtained from the average titre by applying the equation I below:

$$\text{Acid Value} = \frac{56.1VN}{W} \dots\dots\dots I$$

Where; V = Volume in mL of KOH consumed for titration, N = Normality of the base used, W = mass of oil sample. The acid value was used to determine the free fatty acid. (Patterson, 2011)



2.3.2 Saponification value (SV)

In a 250 mL conical flask, 2 g of each oil sample was weighed, and 25 mL alcoholic potassium hydroxide (KOH) was added. (Abdullah *et al.*, 2013). The mixture was then refluxed till every trace of the oil disappeared (between 1 and 2 hours). The excess KOH was then titrated in the presence of the phenolphthalein indicator, against 0.5 N standard hydrochloric acid till a colorless end point was achieved. The same procedure was then applied on a blank. Saponification value for the samples were calculated with the formula (II):

$$\text{Saponification value} = \frac{56.1 \times N \times (B-S)}{W} \dots\dots\dots\text{II}$$

Where; B- Volume of standardized hydrochloric acid used for the blank titration, N - Normality of standardized hydrochloric acid, S - Volume of standardized hydrochloric acid used up for the sample titration, W - Weight of the oil sample.

2.3.3 Iodine value (IV)

This was obtained for each sample following standard methods (AOCS, 2016). Briefly, 20 mL Glacial Acetic Acid, 25 mL Wijs solution (solution of Iodine Monochloride in Glacial Acetic Acid), and 10 mL Magnesium acetate, which worked as the catalyst, were added to around 0.25-0.26 g of the oil in a 250 mL conical flask. The mixture was well stirred, covered and left in a light-tight cupboard for 5 minutes. Then 15 mL of already prepared 10 % potassium iodide was added to the mixture. After 10 minutes the reaction was ended by adding 50 mL of distilled water. The mixture was titrated against standardized 0.1 N sodium thiosulphate with starch as indicator till a colorless end point was obtained. A blank sample was also titrated. The iodine value was then generated from the titers by applying the equation (III):

$$\text{Iodine Value} = \frac{12.69 \times N \times (B-S)}{W} \dots\dots\dots\text{III}$$

Where B - Volume of standardized Sodium thiosulphate consumed for the blank titration, N - Normality of standardized Sodium thiosulphate, S - Volume of standardized Sodium thiosulphate required for the sample titration, W- Weight of the oil sample.

2.3.4 Peroxide Value (PV)

This procedure was determined following the procedures established by the Food Safety and Standard Authority of India (FSSAI, 2016). Five grams of each of the oil samples was weighed into a 250 mL conical flask, after which 25 mL of 3:2 glacial acetic acid, chloroform combination, and 1 mL of saturated potassium iodide solution were added to each sample. The mixture was stirred and placed in the dark for an hour, after which 75 mL of distilled water was added. The mixture was then titrated using starch as indicator from blue-black to a colorless end point against a 0.01 N standardized sodium thiosulphate solution. The peroxide value each sample was calculated with the formula (IV);

$$\text{Peroxide value} = \frac{S \times N \times 1000}{W} \dots\dots\dots\text{IV}$$

Where S = Thiosulphate volume used up in sample titration, W = weight of the sample, N = normality of standardized thiosulphate

2.3.5 Moisture content

Gravimetric method was employed to determine the moisture content of the palm oil samples (JOCS, 2013). About 5.9-6 g of each palm oil sample was weighed into the previously dried, cooled and weighed crucibles. The samples in the crucible were and heated for 1 hour at 105 ± 1 °C, after which it was cooled in a desiccator and weighed. The heating and cooling continued until This process was repeated until steady weight was achieved in all the samples. The moisture content of the samples was calculated using the formula in equation V:

$$\text{Moisture Content}\% = \frac{W_2 - W_f}{W_2 - W_1} \times 100 \dots\dots\dots\text{V}$$

Where: W_2 = Weight of crucible with the oil sample before heating, W_1 = Weight of crucible only, W_f = Weight of crucible with the oil sample after final heating.

2.3.6 Impurity determination



Palm oil impurities were obtained by the gravimetric method (AOCS, 2016). In a conical flask, 2 g of oil was weighed, and 20 mL of n-hexane were added. The mixture was allowed to settle for 30 minutes at 30°C before being filtered using a Whatman filter paper. The residue on the filter was washed with 10 mL of n-hexane and oven-dried till constant weight at 105 °C. The amount of impurity was calculated using the formula in equation VI below:

$$\text{Impurity}\% = \frac{W_2 - W_1}{W} \times 100 \dots\dots\dots \text{VI}$$

Where; W_2 = Weight of filter paper + impurity, W_1 = Weight of filter paper, W = Weight of sample

2.3.7 Viscosity

The Brookfield viscosimeter-DV2T was used to determine the viscosity of the oil samples. (FSSAI, 2016). The viscometer was first calibrated using water as the sample at 26 -28 °C. For each sample, 200 mL of the oil was measured into a 250 mL beaker and the rotating spindle of the viscometer was immersed in it. The viscosities of the samples were then read from the monitor of the viscometer. A correlation factor of 0.86 was applied to the viscosity measurements for each of the oil samples as recommended by the manufacturer.

2.3.8 Refractive Index

The hand-held refractometer was employed for the determination of the refractive index (AOAC, 2012). Prior to sampled analyses it was calibrated using water as the sample at a temperature of 20 °C. For each sample, a drop of the oil was applied to the measuring surface just beneath the viewpoint illuminator and the refractive index was recorded.

2.3.9 Specific Gravity

The analysis was done using a graduated density bottle. The empty density bottle was weighed with its lid on and recorded. The density bottle was then filled with water, covered with the lid, weighed, and recorded. This served as the reference. For each sample, the density bottle was then filled with oil, covered with the lid, weighed, and recorded. This method was used to compute the specific gravity of all the oil samples using the formula in equation VII below;

$$\text{Specific Gravity} = \frac{\text{Density of the sample}}{\text{Density of water}} = \frac{W_2 - W_1}{W_3 - W_1} \dots\dots\dots \text{VII}$$

Where: W_1 = Weight of the Density Bottle, W_2 = Weight Density Bottle + Water, W_3 = Weight of Density Bottle + Oil Sample

2.4 Statistical analysis

The mean, standard deviation, ANOVA test, and correlation matrix were used to analyze the data obtained from the physico-chemical examination of palm oil samples.

3 Results

3.1 Physicochemical parameters of palm oil samples

The oils samples were analyzed for their various parameters and the results are as shown in Table 1.0. The ranges of the physicochemical properties obtained from the analyses are as follows: moisture contents (0.199 ± 0.19 % - 6.209 ± 3.83 %), specific gravities (0.91 ± 0.004 - 0.916 ± 0.002), refractive indices ($1.46 \pm 2.34E-16$ °Bx - 1.454 ± 0.019 °Bx), viscosities (23.536 ± 15.37 cP - 672.486 ± 1836.06 cP), impurity levels (0.145 ± 0.06 % - 15.618 ± 4.39 %), acid values (3.6634 ± 0.950 % - 5.4471 ± 2.80 %), iodine values (45.533 ± 1.79 Wijs - 98.974 ± 22.50 Wijs), free fatty acid value (1.8317 ± 0.48 % - 2.72355 ± 1.40 %), peroxide values (1.968 ± 2.81 meq/kg - 17.826 ± 17.09 meq/kg) and saponification values (121.483 ± 44.56 mg KOH/g - 200.559 ± 9.82 mg KOH/g).

High moisture content indicates an increased risk of spoiling and rancidity, as well as a shorter shelf life due to microorganisms and fungi growth (Rawat, 2015). High moisture content however makes the palm oil suitable for industrial applications such as in soap and detergent manufacturing as well as for culinary use such as baking and frying (Birnin-Yauri & Garba, 2011). Sample moisture levels ranged from 0.199 0.19 % to 6.209 3.83 % (Table



1.0). Palm oil from Aguda market had the lowest moisture content while palm oil from Ita Faji market had the highest. The moisture content values obtained for palm oil from Ayobo and Aguda markets agrees with the 0.29% recommended for fresh oil by SON (2000). Moisture content of palm oil is a factor of the efficiency of the final extraction and clarification processes (Echioda *et al.*, 2018). However, the 0.205 ± 0.29 % obtained for Aguda market had correlation with the value obtained by Ngando *et al.*, (2011) for crude palm oil sold in Cameroon. Lower moisture content can be achieved by heating the oil, which reduces the viscosity (Aremu *et al.*, 2015).

The viscosity of the palm oil samples across the six markets are as presented in Table 1.0. The increase in unsaturation of fatty acids reduces viscosity (Kim *et al.*, 2010) and oils with lower viscosity are more suitable for consumption (Hasan *et al.*, 2016). The viscosity of samples ranged from 23.536 ± 15.37 cP to 672.486 ± 1836.06 cP. Palm oil samples from Aguda market were the most viscous. High viscosity is often associated with mechanically extracted palm oil (Yahaya *et al.*, 2012). Nevertheless, the 50.624 ± 27.29 cP obtained for the various brands of vegetable oils available in Ilorin metropolis.

The specific gravity of the samples ranged from 0.91 ± 0.004 (Lambe market) to 0.916 ± 0.002 (Ayobo market). High specific gravity indicates susceptibility to spoilage and adulteration (Kenechi *et al.*, 2017). All the palm oil samples in this study complied with the standard values (0.897 to 0.907) set by SON (2002). Akinola *et al.* (2010) and Enyoh *et al.* (2017) obtained similar specific gravity values in comparison with those obtained from this study. The refractive indices of the oil samples are shown in table 1.0 below. The refractive index is a measure of how much light deviates in direction when moving through media of different densities, and is an indicator of the purity of oil. Higher refractive index correlates to higher adulteration and spoilage due to oxidation (Sarkar *et al.*, 2015). The refractive indices of the palm oil samples varied from $1.46 \pm 2.34E-16^{\circ}Bx$ to $1.454 \pm 0.019^{\circ}Bx$ while limit by SON is 1.453-1.459 $^{\circ}Bx$. The samples complied with limit. This values show that the oil samples are free from adulteration. The refractive indices in this study were similar to the values in Enyoh *et al.* (2017) for palm oil collected from processing factories in Imo state, Nigeria.

A range of 0.145 ± 0.06 % (Aguda Market) to 15.618 ± 4.39 % (Ikorodu Market) was obtained for impurities in this study. The values obtained are all higher than the SON limit of 0.05 %. Odoh *et al.* (2017) in their study also had an impurity level higher than the standard ranging between 0.28 to 0.44 %, but lower than most of the oil samples in this study. High impurity levels in palm oil are likely due to the use of traditional extraction methods and can be reduced by subjecting it to further processing thereby increasing the quality of the oil (Ohimain *et al.*, 2013). High amount of insoluble impurity is associated with increased oxidation of fatty acids and carbohydrates which makes the oil less suitable for consumption (Babayana *et al.*, 2016).

Iodine value shows the level of saturation and stability of an oil sample (Hasan *et al.*, 2016; He *et al.*, 2010). Degradation of vegetable oils is often linked with low iodine values while higher iodine values result in rapid oxidation of the oil (Chebe *et al.*, 2016). Thus, the iodine value of oils should not be too low nor too high. The palm oil samples studied had iodine values within the range of 45.533 ± 1.79 Wijs to 98.974 ± 22.50 Wijs. Only palm oil samples collected from Aguda and ItaFaji Markets fell within acceptable levels as stipulated by SON (2000). Palm oil samples from other markets had higher iodine values suggesting high susceptibility to oxidation. Otunola *et al.* (2009), in their study, obtained iodine values between 82 ± 0.32 Wj's and 119.4 ± 0.1 Wj's which is similar to the values reported for samples from Lambe and Ayobo markets.

The acid values for the palm oil samples analyzed are presented Table 1. Acid value of oil is a function of the free fatty acid value. High levels of free fatty acids cause lipid oxidation, which lowers the oil's quality. (Akinola *et al.*, 2010). In this study, acid values obtained ranged between 3.6634 ± 0.95 and 5.4471 ± 2.80 % with samples from Ikorodu market recording the highest acid value. There is no limit for acid value in the SON standard. However, a limit value of 3.6% has been set by SON for free fatty acid in (SON, 2002). Free Fatty acid is about half the acid value of oils [22]. In this study the free fatty acid varied between 1.8317 ± 0.48 % and 2.7236 ± 1.40 %. Hasan *et al.* (2016) in their study of various oils from smallholders in Bangladeshi obtained a value of 0.094 % as the average

acid value for palm oil. The marked contrast between the value obtained by Hasan *et al.* (2016) and those reported in this study is possibly due to difference in climatic conditions under which the palm trees were cultivated, with the weather in Bangladeshi being more suitable for the growth of palm trees.

Peroxide values of palm oil samples from major markets in Lagos are shown in Table 1. High peroxide value in palm oil is responsible for primary oxidative reactions during storage and it causes rancidity (Onyeka *et al.*, 2005). The peroxide values obtained ranged from 1.968 ± 2.81 meq/kg to 17.826 ± 17.09 meq/kg. The highest value recorded was for samples from Ayobo market and they were the only set of samples which exceeded the limit of 10 meq/Kg set by SON (2002). The high peroxide values for the palm oil samples from Ayobo market indicate the commencement of primary lipid oxidation. For palm oil samples from local industries in Imo state, Nigeria, Enyoh *et al.* (2017) reported a mean peroxide value of 17.75 meq/Kg, which was close to 17.826 ± 17.09 meq/Kg for oil samples from Ayobo Market.

Saponification values of palm oil samples assessed are presented in the Table 1. The suitability of a sample an oil sample for soap making is indicated by saponification value (Agbaire, 2012). The palm oil samples analyzed in this study had a saponification value range of $121.48 \pm 44.56 - 200.56 \pm 9.82$ mgKOH/g. Palm oil samples obtained from Ayobo and ItaFaji markets had the highest saponification values and were the only set of samples with saponification values within the limit (195-205mgKOH/g) set by SON (2002). This also implies that the palm oil samples from these markets are most ideal for soap production. Samples from Lambe, Ikorodu, Aguda and Bariga markets had SV values lower than those reported by Udensi and Iroegbu (2007) and Agbaire (2012) in their respective assessments.

Table 1.0: Physicochemical parameters of palm oil samples purchased from six markets in Lagos and its environs.

S/N	MARKET	LAMBE	AYOBO	ITA FAJI	IKORODU	AGUDA	BARIGA	SON limits
1	Saponification Value (mgKOH/g)	150.199 ± 38.13	198.276 ± 8.85	200.559 ± 9.82	121.483 ± 44.56	143.964 ± 65.61	174.786 ± 60.18	195-205
2	Iodine Value (Wijs)	98.974 ± 22.50	97.757 ± 40.00	57.766 ± 36.04	76.54 ± 17.27	45.533 ± 1.79	71.8747 ± 35.02	45-55
3	Peroxide Value (meq/kg)	2.81 ± 2.52	17.826 ± 17.09	2.935 ± 0.97	1.968 ± 2.81	3.425 ± 2.52	2.159 ± 2.92	10
4	Acid Value %	4.9729 ± 8.59	3.8067 ± 19.22	4.2399 ± 22.65	5.4471 ± 28.01	4.8555 ± 20.36	3.6634 ± 9.50	7.0%
5	Free Fatty acid %	2.4864 ± 0.43	1.9034 ± 0.96	2.1199 ± 1.14	2.72355 ± 1.40	2.4278 ± 1.02	1.8317 ± 0.48	3.5
5	Refractive Index (°Bx)	1.46 ± 2.34E-16	1.457 ± 0.0048	1.46 ± 2.34E-16	1.46 ± 2.34E-16	1.454 ± 0.019	1.46 ± 2.34E-16	1.453-1.459
6	Impurity Determination (%)	11.509 ± 1.98	0.145 ± 0.06	6.777 ± 2.67	15.618 ± 4.39	0.121 ± 0.27	0.122 ± 0.04	0.02%
7	Specific gravity	0.91 ± 0.004	0.921 ± 0.009	0.913 ± 0.014	0.916 ± 0.002	0.913 ± 0.004	0.914 ± 0.003	0.898-0.907
8	Viscosity (cP)	25.3 ± 32.53	23.536 ± 15.37	50.624 ± 27.29	42.246 ± 36.61	672.486 ± 1836.06	35.388 ± 34.00	NIL
9	Moisture Content (%)	2.095 ± 1.81	0.199 ± 0.19	6.209 ± 3.83	1.164 ± 1.33	0.205 ± 0.29	1.458 ± 1.03	0.20

3.10 Relationship Between the Physicochemical Parameters of the Palm Oil Samples Obtained From Six Markets In Lagos and Environs

One way ANOVA was used to compare the physicochemical properties of the palm oil samples from Lambe, Ita Faji (Lagos Island), Ikorodu, Aguda, Bariga and Ayobo markets using Excel 2007 and the results are shown in



Tables 2A & 2B. P-value of 0.725024 was obtained for all the parameters which is more than the traditional p-value of 0.05. The p-value was associated with F-value of 2.408514. This result demonstrates that the values of the physicochemical parameters of all palm oil samples are not significantly different. This indicates that the palm oil samples were likely produced from the similar sources or under identical conditions.

Table 2A: Single Factor ANOVA for the comparison of the physicochemical parameters of the palm oil samples obtained from the different markets

SUMMARY				
<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
LAMBE	10	300.7163	30.07163	2681.252
AYOBO	10	345.8271	34.58271	4200.336
ITA FAJI	10	333.6028	33.36028	3901.451
IKORODU	10	269.5657	26.95657	1713.762
AGUDA	10	875.3843	87.53843	44272.31
BARIGA	10	293.6568	29.36568	3152.394

Table 2B: Single Factor ANOVA for the comparison of the physicochemical parameters of the palm oil samples obtained from the different markets (Continued)

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	27145.42	5	5429.083	0.54362	0.74237	2.38607
Within Groups	539293.5	54	9986.917			
Total	566438.9	59				

Table 3.0: Correlation coefficient (r) among physicochemical parameters of the palm oil samples purchased from the different markets

M.C.: Moisture Content, S.G.: Specific Gravity, I.D.: Impurity Values Determined, A.V.: Acid Value, F.F.A.: Free Fatty acid, P.V.: Peroxide Value, I.V.: Iodine Value, S.V.: Saponification Value

The results of matrix correlation of the parameters acquired from the examination of the palm oil samples are shown

	M.C.	Viscosity	S.G.	I.D.	R.I.	A.V.	F.F.A.	P.V.	I.V.	S.V.
M.C.	1									
Viscosity	-0.341	1								
S.G.	-0.401	-0.206	1							
I.D.	0.263	-0.397	-0.302	1						
R.I.	0.539	-0.867	-0.224	0.595	1					
A.V.	-0.098	0.255	-0.375	0.774	-0.008	1				
F.F.A.	-0.099	0.255	-0.375	0.774	-0.009	1	1			
P.V.	-0.359	-0.161	0.825	-0.438	-0.351	-0.458	-0.476	1		
I.V.	-0.243	-0.699	0.287	0.267	0.397	-0.085	-0.085	0.492	1	
S.V.	0.442	-0.323	0.323	-0.564	0.064	-0.860	-0.859	0.531	0.092	1

in Table 3.0. A Pearson correlation of .90 to 1.00 (-.90 to -1.00), .70 to .90 (-.70 to -.90), .50 to .70 (-.50 to -.70), and .00 to .30 (.00 to -.30) indicates very high positive (negative) correlation, high positive (negative) correlation, moderate positive (negative) correlation, low positive (negative) correlation and negligible correlation respectively (Mukaka, 2012). Thus, high negative correlations were observed between refractive index and viscosity, saponification value and acid value, saponification value and free fatty acid value while high positive correlation were observed between impurity and acid value, impurity and free fatty acid, peroxide value and specific gravity, and free fatty acid and acid value as shown in Table 3. The strong positive correlation between impurity level and acid value, between impurity level and free fatty acid and between free fatty acid and acid value is because free fatty acids are major contributors to the acid value and also the major impurity in palm oil samples (Mancini *et al.*,



2015). The high positive correlation between the peroxide and the specific gravity values may be because both parameters indicates the susceptibility of palm oil to spoilage and rancidity (Kenechi *et al.*, 2017).

4 Conclusion

This study shows that palm oil products sold in different markets in Lagos, Nigeria, has a wide range of physicochemical properties, indicating its stability, appropriateness, and quality. The palm oil samples from Bariga market showed the best physicochemical properties of all the markets studied. The refractive index and specific gravity values for all the samples fell within the SON limit signifying that the oil samples were not contaminated. However, the other parameters for all the samples analyzed exceeded the standard set by SON, and this is likely due to primitive processing techniques, poor storage practice, climatic and soil conditions, and the usage of bad palm fruits. It is therefore recommended that adequate sensitization and enforcement is done by the various regulatory agencies to ensure that oil palm processing factories employ safe and effective techniques in their palm oil production process. Awareness must also be carried out among palm oil sellers on appropriate means of transportation and storage of the oil to avoid contamination and possible degradations.

Compliance with Ethical Standards

Conflict of interest: On behalf of all authors, the corresponding author states that no conflict of interest.

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