International Journal of Advanced Chemistry, 12 (2) (2024) 71-76

International Journal of Advanced Chemistry

Website: www.sciencepubco.com/index.php/IJAC

Research paper

Comparative analysis of the physicochemical properties and trace metal content of palm oil, from selected markets in Jos south and Jos north LGA, Plateau state, Nigeria

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Abstract

The quality of palm oil samples collected from three different markets in Jos South and Jos North Local Government Area of Plateau State were analyzed and evaluated using standard analytical laboratory procedures. The relative ranges of the physicochemical values obtained were as follows; Moisture Content (MC): 0.56 - 1.89, Iodine value (IV); 51.88 - 55.57 g I2/100g, Peroxide Value (PV): 0.98 - 4.16 mEq02/kg, Saponification Values (SV): 198.46 - 201.54 mgKOH/g, Acid Value (AV): 9.93 - 57.65, and Refractive Index (RI), 1.4576 - 1.4580. The moisture content, iodin value, pH values and acid values were found to exceed the Standard Organization of Nigeria (SON) permissible limits of moisture content (0.29 mgKOH/g), iodine value (45 - 53 mg I2/100g), pH (5 - 7 mg/L), and acid value (0.7 max mg/L) for edible oils respectively while the refractive index, saponification values, peroxide values falls within the SON allowable limits of refractive index (1.4612-1.4707 mg/L), saponification value (195-205 mgKOH/g) and peroxide value (10 mEq02/kg) respectively . The amounts of trace metals (Cu, Zn, Fe, Pb and Cd) determined in the palm oil using the atomic absorption spectrophotometer ranged from Cu(0.34 - 0.52 mg/l), Zn(1.58 - 2.33 mg/l), Fe(19.18 - 26.74 mg/l), Pb(2.87 - 4.06 mg/l) and Cd(1.58 - 2.24 mg/l). However, the levels of Zn, Fe, Pb and Cd exceeded the WHO/FAO recommended values of (1.50, 1.00, 0.05 and 0.02 mg/L) respectively while only Cu concentration was below the WHO/FAO limits of 2.00 mg/L for trace metals in edible palm oil. Consequently, the results of this study shows that the palm oil consumed from these selected markets does not meet the standard quality specification for edible palm oils and hence can post significant health threat to consumers. Therefore, food regulatory agencies should strengthen their surveillance to promote food and health safety of the populace.

Keywords: *Physicochemical Properties; Palm Oil; Trace Element; Adulteration Atomic Absorption Spectrophotometer.*

1. Introduction

Palm oil (Red Oil) which is orange-red to brownish or yellowish-red in colour is usually extracted from the mesocarp of fruits of palm oil tree (Elaeis guineas) (Akinola et al., 2010; Orji and Mbata, 2008). The palm oil is naturally composed of fatty acids and esterifies with glycerol just like ordinary fat (Ichu and Nwakanma, 2020) with the fatty acids composed of saturated and unsaturated aliphatic carboxylic acids with carbon chain lengths in the range of C_6 up to C_{24} (e.g CH_3 $(CH_2)_{14}$ COOH). The substance derived its name from the 16-carbon member-ring saturated fatty acid, which is the palmitic acid found in palm oil (Abdulkadir and Jimoh, 2013; Faessler, 2004).
Industrial processes; such as degumming, neutralisation with sodium hydroxide, bleaching, deodorizing, dewaxing and fractionation are used to refine palm oil to obtained a bright coloured fats, ice cream, bakery fats as well as cooking oils (Cahoon et al., 2009). The essentiality of making a good quality palm oil as part of our daily diet cannot be over emphasized as its rich in carotene and can replace cod liver for correcting vitamin A deficiency (Akannu et al., 2005; Adelaja, 2006; Oyuntibu et al., 2009). Palm oil is a major vegetable oil patronized and consumed worldwide today, accounting for 33% of total oils consumed globally and closely followed by soya oil with 31%. Statistics show that world palm oil consumption has more than doubled in the past decades, shifting from 16.7 million tons in 1997/98 to over 40 million tons in 2007/08 and this figure was estimated to surpass 70 million tons as of 2020 (Giguere et al., 2006).
Stringent observations and research have revealed that most of the oils and fats available in the markets are adulterated in one way or the other for the sole interest of maximizing volume and profit (Okogeri, 2013). This adulteration practice is achieved using of unripe fruits, or the use of tallow already affected with some bacteria, the use of substandard processing methods, or a combination of different oil plant fruits or animal fats as the case may be; which consequently reduces the palm oil quality and causes a great detriment to the health of the consumer populace (Turner, 2010). This study significantly exposed the quality state of palm oil samples available from different markets in Jos and the adulteration and safety levels. Therefore, this research aims to determine the physicochemical properties and trace metal content of palm oil and compare the results with standard recommended values for oil safety and consumer health safety.

2. Materials and methods

2.1. Sample collection

Nine palm oil samples were purchased from three different markets in Jos North and South Local Government Area of Plateau State, Nigeria. These sampling marketplaces include Faringada, Terminus and Bukuru markets. The samples were collected in a polyvinylchloride screw capped container filled to the brim and firmly locked. The samples were taken to the laboratory for immediate analysis. All chemicals and reagents used were of analytical grade obtained from Grand Cereals and Oil Mills Limited, Jos and from the chemical store, Department of Chemistry, University of Jos, Nigeria.

2.2. Methods

2.2.1. Physicochemical analysis

2.2.1.1. Determination of moisture content

The weight of an empty dry metallic crucible was weighed and recorded as W_1 (g) and then 1.0 g of the sample was weighed and recorded as W_2 (g). The sample was oven dried at 105 ^oC for 1 hour. The sample was removed from the oven and kept in a desiccator to cool, reweighed and recorded as W_3 (g). The moisture content of the oil was calculated using the formula below (SON, 2000);

$$\text{Moisture Conent (MC)} = \frac{(W1+W2)-W3}{W2} \times 100\%$$

Where; W_1 = Weight of the empty and dry crucible
W_2 = Weight of sample + crucible
W_3 = Weight of sample after drying

2.2.1.2. Determination of refractive index

The refractive index of vegetable oil can be determined by calculation using the formula below (SON, 2000).

$$\text{Refractive Index (RI)} = 0.0001171 \times \text{Iodine value} + 1.4515$$

2.2.1.3. Determination of saponification value

Exactly 2.0 g of the palm oil sample was weighed into a 250 cm^3 conical flask and 25 cm^3 of alcoholic potassium hydroxide was measured and pipette into the flask. The conical flask was connected with a reflux condenser and boils until the fat is completely saponified for about 60 minutes and allowed to cool. A few drops of phenolphthalein indicator were added until the mixture turned pink. It was then titrated with 0.5 M HCl. The saponification value was calculated using the formula: (Klaus, 2005).

$$\text{Saponification Value (SV)} = \frac{(B-S)\times N \times 56.10}{W}$$

Where; B is the volume required to titrate the blank sample.
S is the volume required to titrate the sample.
N is the molarity of the acid.
56.1 is the equivalent weight of KOH.
W is the weight of the sample in grams.

2.2.1.4. Determination of peroxide value

Exactly 5.0 g of the oil sample was weighed into a beaker and 30 cm^3 of glacial acetic acid plus chloroform was added in the ratio of 3:2, after which 0.5 cm3 of saturated potassium iodide was followed by 30 cm^3 of water. Then 0.5 $cm^3$of starch indicator was then added which gave the mixture a black coloration. The mixture was thoroughly stirred and titrated against $Na_2S_2O_3.5H_2O$ (Sodium thiosulphate) given a clear mixture. The peroxide value was calculated using the formula below (I.U.P.A.C, 1987; Nielsen, 2002)

$$\text{Peroxide Value (PV)} = \frac{(TV-B)\times N}{Wt} \times 1000$$

Where: TV is the titre value of $Na_2S_2O_3$ used
B is blank which is 0.1
N is the normality of $Na_2S_2O_3$

2.2.1.5. Determination of iodine value

A palm oil sample (0.2 g) was dissolved in 15 cm^3 of CCl_4 (Carbon tetrachloride) in a conical flask and 25 cm^3 of WIJ'S solution was then added after which the conical flask was closed with a ground stopper and mixed. It was then allowed to stand for an hour at room temperature away from light. Then 20 cm^3 of 10% aqueous Potassium Iodide KI solution and 150 cm^3 of H_2O were added to the mixture. The resultant solution was then titrated with an accurately standardized thiosulphate solution (0.1 M) in the presence of starch to a blue end point. The iodine value was calculated using the formula below (A.O.A.C., 1990; Nielsen, 2002).

$$\text{Iodine Value (V)} = \frac{(B-S)\times N\times 12.692}{\text{Weight of sample}}$$

Where: B is blank titre
S is the sample titre
N is the normality of $Na_2S_2O_3$

2.2.1.6. Determination of acid value

A Palm oil sample (1.0 g) was placed in a 25 cm^3 neutralized methylated spirit and the resultant solution was titrated with 0.1 M KOH, using a phenolphthalein indicator (3 drops). The titration continued, until a pink coloured solution was obtained, indicating the end point. The acid value was calculated using the formula below; (Kardash and Tur'yan, 2005).

$$\text{Acid Value (AV)} = \frac{T \times N \times 56.1}{\text{Weight of sample}}$$

Where: N is the normality of standard KOH (0.1M)
V is the volume of KOH in ml
56.1 is the molar mass of potassium hydroxide

2.2.1.7. Determination of ph

A pH meter was inserted into the oil sample and left for 30 sec after which the reading on the pH meter was recorded (Nordstrom and Alpers, 2005).

2.2.1.8. Digestion of palm oil sample

Approximately 1.0 cm^3 of the palm oil sample was digested with a mixture of 30 cm^3 conc. HCl and 10 cm^3 conc. HNO_3 and heated for 2 hours at 100 ^{0}C. After cooling, the mixture was filtered and made up to 50 cm^3 volumes with de-ionized waters (Adepoju-Bello et al., 2012).

2.2.1.9. Determination of trace metals

The digested samples were determined using the atomic absorption spectrophotometer (AAS) after the sample was aspirated into the flame of the AAS. The absorbance read and the concentration of trace metals was obtained through a calibration curve and reported in mg/l.

3. Results and discussions

3.1. Moisture content

Moisture content is the amount or quantity of water contained in a material, moisture content is used in a wide range of scientific and technical areas and is expressed as a ratio that can range from 0 (completely dry) to the value of the material porosity at saturation. The moisture content obtained for palm oil samples from Farin-Gada, Terminus and Bukuru markets was found to be 1.89 ± 0.07 mg/l, 0.56 ± 0.10 mg/l and 1.00 ± 0.07 mg/l respectively (Table 1). From the result obtained the moisture content of all the oils is above the SON standard permissible limits of 0.29 mg/l for edible oil. High moisture content reduces the quality of palm oil and changes the colour of the oil.

3.2. Refractive index

The Refractive index is the extent of refraction of light that occurs when light passes from one medium to another. This helps in the determination of impurities in palm oil. The refractive index of the palm oil obtained from Farin-Gada, Terminus and Bukuru markets were found to be 1.4576 ± 0.10 mg/l, 1.4580 ± 0.170 mg/l and 1.4577±0.07 mg/l respectively as shown in (Table 1). The result obtained indicates the refractive index of the palm oils samples to below the SON standard recommended level of 1.4612-1.4707 mg/l for edible oil. This implies the palm oil samples have little or no impurities in them.

3.3. Saponification value

The saponification value represents the number of milligrams of potassium hydroxide required to saponify 1.0 g of fat. It is a measure of the average weight (or chain length) of all the fatty acids present and also used in checking edible oil adulteration. The saponification values for the various palm oil samples obtained from Farin-Gada, Terminus and Bukuru markets were found to be 199.53± 0.07 mg/l, 201.54± 0.14 mg/l and 198.46± 0.17 mg/l respectively as presented in (Table 1). The result of saponification values of the oils is within the SON standard of edible oil of 195-205 mg/l. This implies that, the sampled palm oil has little or no adulterants in them.

3.4. Peroxide value

The peroxide value is the amount of peroxide oxygen per one kilogram of fat or oil, the peroxide index is an indication of the amount of hydroperoxide present in edible oil. Peroxide value gives the initial rancidity in unsaturated fat and oil. The peroxide values for the different palm oil samples from Farin-Gada, Terminus and Bukuru markets were found to be 4.16 ± 0.10 mg/l, 0.98 ± 0.07 mg/l and 1.85 ± 0.10 mg/l respectively (Table 1). However, the results obtained for the peroxide values in the oils samples are below the SON standard of 10 mg/l for edible oil. Thus, the lower the peroxide content, the better the palm oil preservation feature.

3.5. Iodine value

The iodine value represents the mass of iodine in grams consumed in 100 grams of a chemical substance. The iodine number is often used to determine the degree of unsaturation in fatty acids. The higher the iodine number the more the C=C bond is present in the oil. The Iodine

Value of the palm oil samples obtained from Farin-Gada, Terminus and Bukuru markets were found to be 51.88± 0.14 mg/l, 55.57± 0.10 mg/l and 53.12± 0.14 mg/l respectively (Table 1). Therefore, these results obtained were found to be above the SON standard recommended value of 45-53 mg/l for edible oil except for the sample from Farin Gada, which is below the standard. The higher the iodine value, the more reactive, less stable and more likely it is prompt to oxidation.

3.6. Acid value

The acid value is the mass of potassium hydroxide (KOH) in milligrams required to neutralize one gram of a chemical substance. It is primarily an indicator of free fatty acid and can be elevated if the oil is not properly produced or has undergone oxidative degradation. The acid value for the various palm oils obtained from Farin-Gada, Terminus and Bukuru markets were found to be 57.65± 0.10 mg/l, 9.93± 0.07 mg/l and 32.30± 0.10 mg/l respectively as shown in Table 1. The results show that the acid value of the oils samples falls above the SON standard olrant limits of 0.7 max mg/l for edible oil and making it acidic for consumption. High acidic value reduces the quality of palm oil and makes it a potential health threat.

3.8. pH value

The pH value is the degree of acidity or alkalinity of a substance. In this case of oil, it tells if the oil is safe for consumption. The pH value of the palm oil samples obtained from the Farin-Gada, Terminus and Bukuru markets were found to be 4.09 ± 0.10 mg/l, 3.99 ± 0.10 mg/l and 4.15 ± 0.07 mg/l respectively (Table 1). The pH value of the oil samples falls below the SON standard for edible oil of 5-7 mg/l making it acidic for consumption. A lower pH value shows that the oil is acidic and can threaten consumers' health.
The results of the Physicochemical properties of Palm Oil samples are presented in table 1.

Table 1: Physicochemical Properties of Palm Oil Samples

Parameter \ Sampling Site	Farin Gada	Terminus	Bukuru	SON (2000)
Moisture content (%) (105 ºC for 1hr)	1.89 ± 0.07	0.56 ± 0.10	1.00 ± 0.07	0.29
Refractive index at 25 ºC	1.4576 ± 0.10	1.4580±0.17	1.4577±0.07	1.4612 - 1.4707
Saponification value (mgKOH/gm)	199.53 ± 0.07	201.54 ±0.14	198.46±0.17	195 – 205
Peroxide value ($mEq0_2$/Kg)	4.16 ± 0.10	0.98 ± 0.07	1.85 ± 0.10	10 max
Iodine value (gI_2/100g)	51.88 ± 0.14	55.57± 0.10	53.12± 0.14	45-53
Acid value (mg/KOH/g)	57.65 ± 0.10	9.93 ± 0.07	32.30 ± 0.10	0.7max
pH	4.09 ± 0.10	3.99 ± 0.10	4.15 ± 0.07	5-7

The value is given as mean ± standard deviation, n=3.

3.9. Trace element concentrations

3.9.1. Copper

Copper is an essential element that plays an essential role in the biological systems, such as the prevention of cell structure damage, maintenance of blood vessels, skin and epithelial cell skeletal minimization, and cross-linking of collagen fibrils by copper-containing enzyme, thereby enhancing the mechanical strength of the protein and forming flexible connective tissue. The concentration of Copper (Cu) in the palm oil samples was found to be, 0.3497± 0.10 mg/l for Farin-Gada market, 0.3497± 0.07mg/l for Terminus market and 0.5245 ± 0.10mg/l for Bukuru market as shown in Table 2. The concentration of copper in the different oil samples was below the WHO/FAO acceptable limits of 2.00 mg/l for copper. A deficiency of copper leads to fatigue, weak and brittle bones, problems with memory and learning, increased cold sensitivity, premature gray hair and vision loss.

3.9.2. Iron

Iron plays an essential role in the body including biochemical/metabolic processes, oxygen transport, deoxyribonucleic acid, and synthesis. The concentration of Iron (Fe) was found to be, Farin Gada (22.093 ±0.07 mg/l), Terminus (19.186 ±0.10 mg/l) and Bukuru (26.744 ±0.07 mg/l) as presented in Table 2. The concentration of iron in the three oil samples is above the WHO/FAO acceptable limits of 1.00 mg/l for iron. Excess iron in the body leads to nausea, vomiting, diarrhea and stomach pain.

3.9.3. Zinc

Zinc is an essential metal that is required by the body, it plays a vital role such as wound healing, cell growth, protein synthesis, growth and development, DNA synthesis and immune, The concentration of Zinc (Zn) was found to be, Farin Gada (2.3321 ±0.14 mg/l), Terminus (2.2388±0.17 mg/l) and Bukuru (1.5858 ±0.14 mg/l) as shown in Table 2. The amount of Zn in the three oil samples is above the WHO/FAO acceptable limits of 1.50 mg/l for zinc. Excess zinc leads to headaches, stomach cramps, diarrhea, loss of appetite and vomiting.

3.9.4. Lead

Lead is the second most toxic metal after Arsenic, although earlier literature did not focus on the biological importance of Pb, recent finding, suggests that traces of Pb is important for enzyme activities and cellular systems, especially during cell development, hematopoiesis and reproduction. Lead gets into food through atmospheric dust, automobile exhaust, and polluted food and water and these are the key pathways for human exposure to lead. The concentration of Lead (Pb) was found to be; Farin Gada (2.8736 ±0.10 mg/l), Terminus (4.0230 ±0.07 mg/l) and Bukuru (4.0230 ±0.10 mg/l) as shown in Table 2. The concentration of lead from the three different markets is above the WHO/FAO acceptable limits of 0.05 mg/l for lead. Excess lead damages the nervous system and interface with the function of biological enzymes causing neurological disorder such as brain damage, behavioral problem and cancer.

3.9.5. Cadmium

Cadmium is a metal with high toxicity, which can be used in the manufacture of batteries and so much more, health benefits of cadmium are yet to be known. Food grown in contaminated soils with high levels of cadmium and contact with them, cigarette smoke contains high levels of cadmium and this can also get into food from the atmosphere through the exposure of the food substance. The concentration of Cadmium (Cd) was found to be; Farin gada (1.58±0.14 mg/l), Terminus (1.92±0.10 mg/l) and Bukuru (2.24 ±0.14 mg/l) as shown in Table 2. The concentration of cadmium from the three markets is above the WHO/FAO acceptable limits of 0.02 mg/l for cadmium. Excess cadmium leads to cough, anemia, kidney failure and cancer.
The concentration of Zn, Fe, Pb and Cd in the palm oil samples were found to be higher than the WHO/FAO acceptable limits for consumption, these makes the palm oil from these markets dangerous for consumption.
In this study, Cu, Zn, Fe, Pb and Cd concentrations were all determined in the three palm oil samples and the results of the trace metal concentration are shown table 2.

Table 2: Trace Metal Concentration (Mg/L) in Palm from Three Different Markets in Jos North and Jos South LGA

Element Sampling Site	Cu	Zn	Fe	Pb	Cd
Farin-Gada	0.38±0.10	2.33±0.14	22.09±0.07	2.87±0.10	1.58±0.14
Terminus	0.34±0.07	2.28±0.17	19.18±0.10	4.02±0.07	1.92±0.10
Bukuru	0.52±0.10	1.58±0.14	26.74±0.07	4.06±0.10	2.24±0.14
WHO/FAO (2010)	2.00	1.50	1.00	0.05	0.02

The value is given as mean ± standard deviation, n=3.
In summary, the level of trace metals in palm oil obtained from the three different markets occurred in the following sequences Fe>Pb>Zn>Cd>Cu as presented in fig 1.

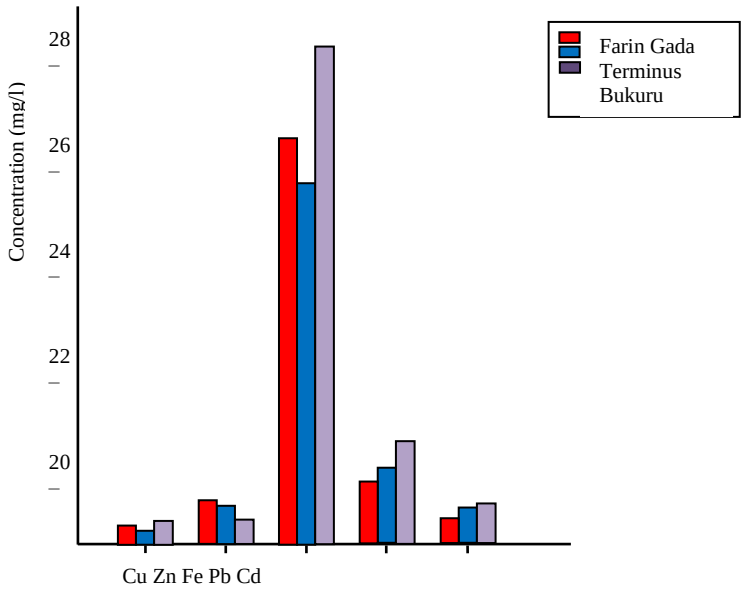

Fig. 1: Comparison in Concentration of Trace Elements (Mg/L) in Palm Oil from Three Different Markets in Jos South and Jos North LGA

4. Conclusion

The analysis of the analytical results shows that the physicochemical properties; moisture content, iodine value, acid value and pH values exceeded the SON standard values for edible oils. Trace metal concentration revealed that, the levels of zinc, iron, lead and cadmium exceeded the WHO/FAO safety limits of trace metal in palm oil. This may be due to adulteration or decomposition or the exposure of this oils to environmental pollution agents.

5. Recommendation

It is recommended that regulatory bodies like the National Food and Drugs Administration and Control (NAFDAC), Standard Organization of Nigeria (SON) and other food quality regulatory bodies in the country should give routine checking on fats and oils products within the country to ascertain their quality status before they are sent to the market to promote the safety of food materials and health safety.

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