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Physicochemical analysis of Crude Palm Oil purchased from Selected Markets in Three Different Local Government Areas in Lagos State

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Abstract
Crude Palm oil has been an essential constituent of human diet in many homes in Nigeria and it is essential in human nutrition but can be contaminated by environmental contaminants such as microorganisms and heavy metals. This study was carried out to determine the physicochemical properties of crude palm oil purchased from three local government local markets in Lagos state, Nigeria and to determine some selected toxic and trace heavy metals present in the crude palm oil. The palm oil samples were subjected to acid digestion process before analysis. Physicochemical parameters of the crude palm oil samples were measured and the digested oil samples were analysed for heavy metals using inductively coupled plasma-optical emission spectroscopy (ICP-OES) analytical technique. The results of the physiochemical parameters are: moisture content ranges from 0.10% - 0.26%, peroxide value ranges from 8.00 - 8.40 mEq.O2/kg, and saponification values ranges from 195.17mg/KOH/g - 202.37mg/KOH/g which are all within the limits recommended by the World Health organization (WHO). The pH of the samples were generally acidic (4.2, 4.5 and 5.0) and the free fatty acid values ranged from 10.44% - 12.70% which exceeds WHO recommendations of 5%. The result shows that toxic metals such as cadmium, lead and arsenic are present in the palm oil samples at high concentrations above WHO standard limits which pose serious risks to human health. In conclusion the result shows that the palm oil samples are rich in micronutrients/trace metals such as Fe, Na, Ni, Co, Mn, Zn, Mo, Cr, and Cu which are important for human good health.

Keywords: *Palm oil, physicochemical analysis, digestion, heavy metals, inductively coupled plasma optical emission spectroscopy*

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I. Introduction

Palm oil is an edible vegetable oil derived from the mesocarp (reddish pulp) of the fruit of the oil palms. Oil palm (Elaesis guineensis) belongs to the Palmae family and is indigenous to West Africa. The palm oil is produced from the fleshy part of the fruit of the palm tree (Gourichon, 2013; Tan et al., 2009; Japir et al., 2017). Crude palm oil is a mixture of saturated, unsaturated and polyunsaturated fatty acids which depend on the presence and number of double bonds as it contains large proportion of the saturated fatty acids (Minh, 2006). Crude palm oil consists mainly of glycerides and small quantities of non-glyceride components which include free fatty acids (FFA), moisture, trace metals and impurities and minor components, such as the carotenoid and vitamin E. Palm oil derives its deep red colour from its high carotenoid content and the major component of its triglycerides is the palmitic acid which is a saturated, unsaturated and polyunsaturated fatty acid. Palm oil has been part of human diet for many years now and is known to be an essential constituent of diet in many homes in Nigeria (White, 2000). Palm oil is an important source of food and a major source of lipid and it has been known to be one of the most important vegetable oils due to its unique characteristics, particularly its potential health benefits. Palm oil is one of the most important vegetable oils have numerous advantages of properties, some of which are high oxidation stability, fatty acid composition, and its good plasticity at room temperature. Although, palm oil is essential in human nutrition and medicinal treatment and it can be contaminated by environmental pollutants such as microorganisms and heavy metals. Contamination of diets including palm oil with heavy metals could result from different sources such as industrial waste, acidic rain breaking down soils and food chain. The presence of these toxic metals may appear harmless in minute quantities, however, their accumulation over time poses potential health risk to human who regularly consume palm oil contaminated with toxic metals. Besides possible contamination from heavy metals, palm oil is subject to deterioration due to microbial infestation thereby leading to alteration in some of the physiochemical parameters such as free fatty acid and this could also have harmful effects to human health.). Most food products processed using crude palm oil have longer shelf life than those processed using other vegetable oils because crude palm oil contains higher amounts of unsaturated fatty acids such as oleic acid which is responsible for its oxidative stability. Crude palm oil consists of a balanced fatty acid composition i.e. 50% saturated and 50% unsaturated fatty acid which makes it one of the most unique vegetable oils (Mba et al., 2015). Crude Palm oil is composed of fatty acids esterified with glycerol, and its quality is affected by reactions which cause the breakdown of the esterified fatty acids and formation of free fatty acids (Akinola et al., 2010). Free Fatty Acid (FFA) amount is also known as the Acid Value (AV) content of the palm oil and is one of the relevant standards for determination of the quality of crude palm oil. The level of FFA is an essential indicator of quality for selling palm oil especially in export and domestic industrial markets. High level of FFA will yield high rancidity in crude palm oil which indicates poor product quality which causes significant losses during refining process. However, low level of FFA value ($\leq$ 5%) in crude palm oil is classified as high quality product which produces good physico-chemical properties of crude palm oil products and could be useful for industrial applications (O'Brien, 2010; Ugonna et al., 2020). A Review of the Health Implications of Heavy Metals in Food Chain in Nigeria. The Scientific World Journal, https://doi.org/10.1155/2020/6594109). The quality assessment of crude palm oil for household consumption is basically organoleptic because buyers taste, smell and assess colour of palm oil to determine its quality (ref). The quality of crude palm oil is then categorised based on its FFA level as high quality (1-5%), good quality (5-10%) and poor quality (above 10%) which makes it unhealthy for human consumption (Ngando Ebongue et al., 2008); Japir et al., 2017). (TAMSI-DMSI, (2010); Codex Alimentarius Commission. (2005). Adjei-Nsiah et al., 2012 reported that the FFAs content of good quality crude palm oil should not exceed 5% (TAMSI-DMSI, (2010). Crude palm oil needs to be processed to remove undesirable components such as FFA, odors, colors, phospholipids, and oxidation products (Albert et al., 2011; Azmi et al. 2015, Hambali et al. 2019). Palm oil vitamin E has been extensively studied for its nutritional and health properties including antioxidant activities, cholesterol lowering, anti-cancer effects and protection against atherosclerosis (O callighan 2014; Prashanth et al., 2015). Its high content in pro vitamin A carotenoids makes crude palm oil to constitute an important food that could be used to prevent vitamin A deficiency. The carotenoids, tocopherols and tocotrienols maintain the stability and quality of palm oil and also act as biological antioxidants (Wu & Ng, 2007). Carotenoids are responsible for the diversity of color in nature. Alpha-carotene, β-carotene, and cryptoxanthin have demonstrated pro vitamin A activity. Beta-carotene is the most potent pro vitamin A carotenoid. Vitamin A is necessary for vision, growth, cellular differentiation and other physiologic functions (Hendler & Rorvik, 2008). Heavy metal refers to the metal whose specific gravity is greater than 5 and density is greater than $4.5g/cm^3$. It also refers to a metal whose atomic weight is greater than $5.5g/dm^3$. Heavy metals are naturally occurring elements that are found throughout the earth's crust. Heavy metals are group of metals and metalloids that have relatively high density and are toxic at part per billion (ppb) levels. Heavy metals are naturally occurring elements that comprise of essential metals (Cu, Fe, Ni and Zn) and non-essential metals (Cd, Al, and Pb). The main threats to human health from heavy metals are associated with exposure to Cadmium (Cd), Lead (Pb), Mercury (Hg), and Arsenic (As) (Odika et al., 2020). The sources of heavy metals in the environment could be natural or anthropogenic. Heavy metals including metalloids such as arsenic are widely utilized to sustain the living standards of the modern world. Human activities such as industrial, mining, and agricultural processes has led to a widespread distribution of heavy metals in the ecosystem, posing risks to human health (Liu et al. 2015). These heavy metals have the ability to disrupt metabolic processes and genetic structure, while others affects embryonic or foetal development. However, these metals are known to be non-biodegradable and have the tendency to accumulate in living beings. Heavy metals make their way into different environmental media such as soil, water, rock, and sediment from which we grow most of our food. Due to their bioaccumulation, non-degradability, and the excessive amounts in which they exist, and the heavy metals contaminate the food chain and have become a major source of toxicity to human beings and the entire ecological function. Heavy metals easily enter humans, plants, and animals by inhalation, dermal absorption, or ingestion, which are biomagnified through the food chain to pose a serious risk to food safety and human health (Zang et al. 2017). The ways in which palm oil are stored in Nigeria are in lacquered metal cans, tanks, plastics, bottles etc. Some of these containers are made up of materials which enable deterioration such as lead additives used in plastics as well as iron in metal cans (Adetola et al., 2016). Heavy metals are environmental pollutants which can bioaccumulate in plants from contaminated environment (Izah and Aigberua, 2017). Some heavy metals are required in trace concentration and they are essential heavy metals. Heavy metals can be toxic when taken into the body above recommended level (Izah and Srivastav, 2015).

II. Materials And Methods

2.1 STUDY AREA

Palm oil was purchased from three different local government areas in Lagos state, Nigeria namely: Alimosho, Badagry and Ojo. Lagos state is located in south western region in Nigeria.

Alimosho (A) is a local government area is geographically located on the western section of Lagos State and the largest local government area in Lagos with a population of 1,288,714 inhabitants, according to the 2006 census captured. It has a total population of 9,113,605 and an estimate of 17,552,940 for the state. The study area lies between the latitude 6°27' 14''N and longitude 3°23' 40''E with an area size of 3,577km². The area lies between the coordinates of 6°36'38''N and 3°17'45''E.

Badagry (B) is a local government area is geographically located on the northern section of Lagos State and between the city of Lagos shares border with a country called Republic of Benin at Seme border. The study area lies between the coordinates of 6°25'N 2°53'E with an area size of 441km² and a population of 241,093 according to the 2006 captured census figure. The major economic activities in Badagry include fishing, trading and tourism.

Ojo (C) is a local government area and a town in Lagos state, Nigeria. Ojo is geographically located on the eastern section of the Trans-West African Coastal Highway, about 37km west of Lagos. It has an area of 182km² and a population of 609,173 as recorded by 2006 captured census figure. The coordinates of the study area is 6°28'N and 3°11'E. It has some major markets some of which include: Alaba international market, the old Lagos international trade fair complex and Iyana-Iba market.

Fig. 1: Map of Lagos state, Nigeria showing the three local government areas

2.2 Sampling

The samples of crude palm oil. palm oil samples used for the study were purchased from markets of three local government areas in Lagos State, Nigeria. The crude palm oil samples were collected in plastic containers and stored in a refrigerator until they are required for physicochemical analysis for some parameters such as: pH, moisture content, free fatty acid, peroxide value, iodine value, saponification value, and toxic and trace heavy metals.

2.3 Chemicals

All solvents and chemicals were used as received, and they include hydrochloric acid, nitric acid, hydrfluoric acid, sulphuric acid, phelphthalein, sodium thiosulphate. Perchloric acid, ethanol, acetic acid, chloroform, potassium hydroxide, sodium hydroxide, potassium iodide, and wij's solution which were purchased from TUNNEX and MACDONALD chemical companies..

2.4 Physicochemical Parameters

2.4.1 Determination of pH

The pH was determined using JENWAY 3510 pH METER as it was calibrated using buffer 4, buffer 7 and buffer 9 by dissolving a capsule each buffer in 100 mL of distilled water respectively. The pH electrode was inserted into the palm oil and the reading was taken and recorded. The process was repeated twice and the readings were taken and recorded.

2.4.2 Determination of moisture content

The moisture content was determined by using the gravimetric method. According to Enyoh et al. (2017), the aluminum dishes were washed thoroughly and dried in the oven, then cooled in the desiccator before they were weighed. 5 gram of crude palm oil was poured into previously weighed dishes. Then placed in an oven at 105°C for 2 hours until all the water is driven off record and weigh the result and continue the procedure until a constant weight is obtained. The moisture dishes were cooled in a desiccator. The difference in weight is the amount of moisture in the crude palm oil was calculated.

The moisture in the palm oil is calculated as:

$$\% \text{ Moisture} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Where:

W_1 = Initial weight of empty crucible

W_2= Weight of crucible + sample before drying

2.4.3 Determination of free fatty acid

Free fatty acids (FFA) content was analyzed by using titrimetric method. 5g of the oil sample was weighed and poured in a dried conical flask. About 25 mL of absolute ethanol and 2-3 drops of phenolphthalein indicator was added. The mixture was to heating with constant shaking in a water bath until the content of the flask starts boiling. Allow the mixtue to cool and titrated with 0.1N sodium hydroxide until a pink endpoint was obtained which persisted for at least 15 seconds. This procedure was repeated for all the samples.

The FFA was calculated as:

$$\text{FFA} = \frac{\text{V (ml of titrant) x (N of titrant) x (256 g/mol)}}{\text{10 x W (Weight of sample in gram)}}$$

V = volume of NaOH

N = Normality of NaOH

W_3= Final weight of crucible + sample after drying

2.4.4 Determination of Iodine Value

Iodine value was determined using Wijs Method according to Chebet et al., 2016; Abdullah et al., 2013.by weighing 5 g of oil sample into a clean conical flask and dissolved with 20 mL of chloroform to dissolve the oil sample and swirl the mixture for some minutes. About 25 ml of Wijs reagent was added to the mixture in the flask using a measuring cylinder in a fume chamber. The mixture in the flask was swirled vigorously for adequate mixing before the flask was then kept in a dark for 1 hour. At the end of this period, 20 ml of 10% aqueous potassium iodide and 100 ml of water was added using a measuring cylinder. Excess iodine liberated was titrated with 0.1M sodium thiosulphate solution using 1% starch as indicator. The same procedure was applied for the blank test. The Iodine Value (I.V) is given by the expression;

$$\text{Iodine Value (IV)} = 12.69\ \frac{C\ (V1 - V2)}{M}$$

Where C = concentration of sodium thiosulphate

V1 = volume of sodium thiosulphate used for blank

V2 = volume of sodium thiosulphate used for determination

M = mass of sample

12.69= Constant.

2.4.5 Determination of saponification value

2 g of crude palm oil was weighed accurately and put into a conical flask containing 25 mL of 0.5 M alcoholic KOH. Heat was applied while swirling to saponify the fat. The warm mixture was then titrated against 0.5N HCl in the presence of phenolphthalein (1%). A blank titration was also carried out.

The saponification value was calculated using:

$$\text{Saponification value} = \frac{(V_b - V_s) \text{ X (N) of titrant X } 56.1}{\text{Sample weight (g)}}$$

Where:

V_b = mL of blank

Vs = mL of titrant

2.4.6 Determination of peroxide value

Peroxide value was determined by weighing 5 g of oil sample into a clean conical flask. 10ml of chloroform was added and the oil was dissolved by swirling. 15 mL of glacial acetic acid and 1ml of freshly prepared saturated potassium iodide solution were added. The flask with stopper was shaken for one minute and placed in the dark for one minute. 25 mL distilled water was added and 0.5 mL starch solution was added as indicator before titrating with 0.01 N solution of sodium thiosulphate ($Na_2S_2O_3$) shaking vigorously until the blue grey colour disappeared in the aqueous layer (upper layer) and a milky colour appeared. The procedure was repeated for blank ((Prasanth Kumar and Gopala Krishna, 2015).

$$\text{Peroxide value (mEq/kg)} = \frac{(V - V_0) \times (N) \times (F) \times 1000}{\text{Mass (g)}}$$

Where:
V = Titre volume for sample
V_0 = Titre volume of blank
F = Factor of 0.01N sodium thiosulphate
N = Normality of sodium thiosulphate ($Na_2S_2O_3$).

2.4.7 Total Acid Digestion

All the samples were digested using the same method. 2g sample was weighed and transferred quantitatively into a 250 ml conical flask and thereafter digested with 10 ml of the digestion acid mixture (ratio 1:2:2 of perchloric, nitric and sulphuric acids) with heating on a hot plate in a fume hood until evolution of white fumes. The digest was allowed to cool and 50 ml of distilled water was added to bring the metals into solution and filtered using ashless Whatman filter paper into a 100 ml calibrated volumetric flask and made up to mark with distilled water. The acid mixture, 10 ml, was also digested following the same procedure and was used as blank. The samples were analyzed for heavy metals using inductively coupled plasma. Total acid digestion is a test that involves contacting palm oil samples with concentrated acids to release all constituents into solution and then determine the total elemental composition of the sample.

2.4.8 Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES).

Inductively coupled plasma optical emission spectroscopy (ICP-OES) analytical technique was used to determine toxic and trace elements, and these elements were analysed using ICP-OES (Variance Liberty II).

Procedure

Digested crude palm oil solution samples were filtered with 0.45 µm membrane filters to remove suspended solids and diluted accurately with de-mineralized water to obtain EC values between the ranges of 50-100 µS/cm. The instrument was calibrated before it was used for cation analysis and the accuracy of the instrument was checked using certified standards. The reproducibility of the instrument was determined by running the samples in triplicate. Inductive coupled plasma optical emission spectroscopy (ICP-OES) is an analytical technique used for the detection of chemical elements. It is a type of emission spectroscopy that uses the inductively coupled plasma to produce excited atoms and ions that emit electromagnetic radiation at wavelengths of characteristic element. The intensity of this emission is indicative of the concentration of the element within the sample. Liquid samples was injected into a radio frequency (RF) induced argon plasma using one of a variety of nebulizers or sample introduction techniques. The sample mist reaching the plasma is quickly dried, vaporized, and energized through collisional excitation at high temperature. The atomic emission emanating from the plasma is viewed in either a radial or axial configuration, connected with a lens or mirror, and imaged onto the entrance slit of a wavelength selection device. Single-element measurements can be performed cost-effectively with a simple monochromator–photomultiplier tube (PMT) combination, and simultaneous multi-element determinations are performed for up to 70 elements with the combination of a polychromator and an array detector.

III. Results And Discussion

3.1 Physicochemical Parameters

The results of some physicochemical parameters of the crude palm oil analysed is presented in Table 1. All the samples are acidic with pH ranging from 4.2, 4.5 and 5.0 for Alimosho, Badagry and Ojo respectively. The moisture content for the samples from the areas is very low with 0.10%, 0.12% and 0.26% for Alimosho, Badagry, and Ojo respectively. Free fatty acid, moisture, peroxide value, iodine value and saponification value plays important role in assessing quality as well as the health effect of the crude palm oil. The FFA is high with which range from 10.44% to 12.70%, is above 5% the recommended value for quality palm oil (Japir et al., 2017).), moisture of the samples ranges from 0.1% to 0.26% which is very low and it indicate that all the samples slightly hydrolyzed, The iodine value of the oil samples ranges from 51.73 to 53.34 showed some degree of unsaturation higher than some reported in the literature. According to Edem, 2002; and O'Brien, 2010 reported that crude palm oil with iodine value range of 51-58/100 g oil is classified as saturated oil. The IV results of CPO samples used for this study are classified as saturated oil with iodine value (IV) range of 51–58 g/100 g oil. However, previous study have shown that the crude palm oils with a wider IV range of 46–63 g/100 g oil have been reported. These types of palm oil may be mixtures of oils from different species of oil palm tree or oil mixed with various proportions of palm stearin (Edem, 2002; Elias; O'Brien, 2010). Saponification values for crude palm oil samples range from 195.17 to 202.37 Mg/KOH/G and it is good for soap making and the peroxide value ranges from 8.00 to 8.4 (Meq.O2/Kg) which is low.

Table 2: Physico-Chemical Parameters of Crude Palm Oil Samples (n = 3)

S/ N	Parameters	ALIMOSHO (A)	BADAGRY (B)	OJO (C)	WHO
1	pH	4.2	4.5	5.0	
2	Moisture Content (%)	0.10	0.12	0.26	0.29
3	Free Fatty Acid (%)	10.44	12.70	12.10	5
4	Iodine Value	53.34	51.73	53.16	
5	Saponification Value Mg/KOH/G	196.40	202.37	195.17	195 - 205
6	Peroxide Value (Meq.O2/Kg)	8.00	8.40	8.15	10

3.2 HEAVY METALS

The heavy metals detected in the crude palm oil samples could have adverse effects on the health of man the final consumer of the oil.

3.2.1 Toxic Metals

Figure 2 revealed that palm oil purchased from the three market locations Metals such as cobalt (Co), copper (Cu), chromium (Cr), iron (Fe), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se) and zinc (Zn) are essential nutrients that are required for various biochemical and physiological functions. Inadequate supply of these micro-nutrients results in a variety of deficiency diseases or syndromes contained toxic metal such as Cadmium, Lead and Arsenic. The concentrations of Cadmium in the oil samples from Alimosho, Badagry, and Ojo local government areas are 0.99, 0.65 and 0.51 mg/L respectively. The highest concentration of Cd was observed in the palm oil from Alimosho and the lowest from Ojo. Cadmium is known to exert serious adverse effects on man such as prostate cancer, and could also cause kidney, liver, lungs and bone damage. (Odika et al., 2020).

The concentration of Pb range from 0.59-0.93 mg/L and palm oil from Alimosho having the highest value of 0.93 mg/L. Lead has harmful effects in man even at very low concentration and there is no known safe exposure level (K. Asemave; B.A. Anhwange 2012). Exposure to Pb is harmful to vulnerable populations, including infants, young children, pregnant women and their feotuses as it may result in possible neurological damage to feotus. Lead is toxic to both the central and peripheral nervous systems, inducing other effects like weight loss, hypertension, fatigue, headache, miscarriages, irritability, constipation, stillbirths, and renal tumors.

The concentrations of Arsenic (As) found in the oil samples are 0.76, 0.74 and 0.70 mg/L in palm oil samples from Alimosho, Badagry and Ojo respectively which shows high concentration in Alimosho and least in Ojo samples. Exposure to Arsenic may lead to progressive peripheral and central nervous changes such as numbness and tingling.ure 2 revealed that the palm oil from Alimosho have the highest concentration for all three toxic metals identified i.e. (Cd- 0.99 mg/L, Pb- 0.93 mg/L, As- 0.76 mg/L). This high concentration could be as a result of environmental pollution which was caused by high population density, rapid industrial growth and high urbanizing activities of man in the area.

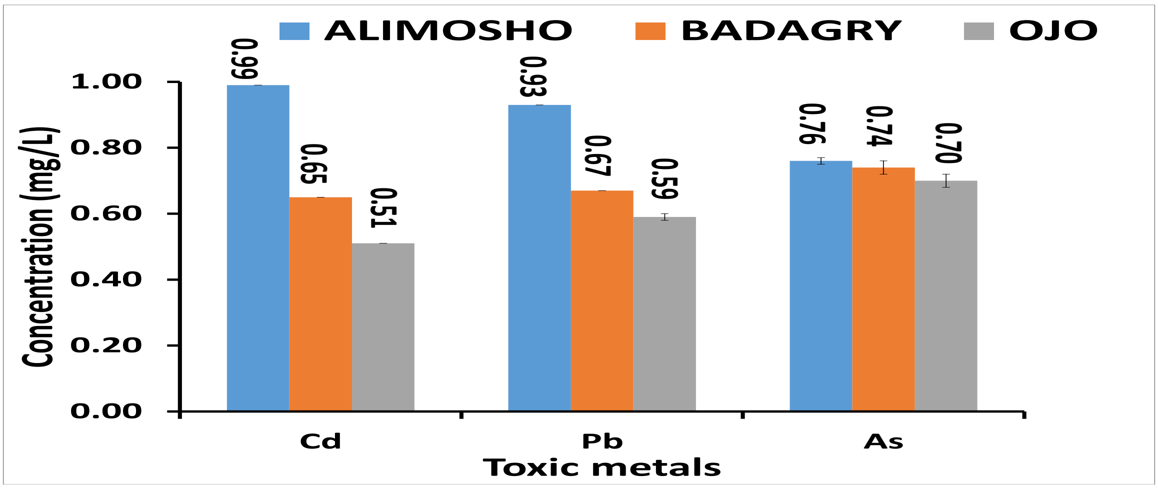

Fig 2: Concentration of toxic metals in palm oil samples from three market locations (n = 3)

3.2.2 Trace Metals

Figure 3 revealed that palm oil samples purchased from three market locations contained trace metals such as Fe, Na, Ni, Co, and Mn.

The concentration of iron (Fe) in the oil samples purchased from three locations is 5.57, 5.10, and 5.14mg/L for Alimosho, Badagry, and Ojo respectively. It has been reported that adequate Fe in a diet is imperative for diminishing the incidence of anemia (Stoltzfus, 2003). Although, the concentration of Fe is the highest amongst the metals in the entire palm oil samples, and it is also an essential nutrient of blood and skeleton.

The concentration of sodium (Na) ranged from 3.71-3.85 mg/L with Alimosho having the highest concentration. Na is necessary in the body to maintain balance in physical fluid systems and is also required for the operation of nerves and muscles, but high-sodium diets are linked to a number of health problems including damage to the kidneys and increase in the possibilities of hypertension.

Nickel (Ni) has been considered as a possible essential trace mineral for many decades. Deficiency and excess ingestion of food containing high level of Ni content could cause adverse health effects in humans. The concentration of Ni in the oil samples ranged from 0.82-1.57 mg/L.

Cobalt (Co) is another essential mineral that is required in the body. The concentrations of Co in the palm oil samples are 1.44, 0.83 and 0.82 mg/L for Alimosho, Badagry, and Ojo respectively.

Manganese (Mn) concentration ranged from 1.05-1.50mg/L for palm oil samples from the three locations. Mn plays vital roles in the body such as activation of enzyme. 2 – 5 mg of Mn is required by the body daily and deficiency of Mn can result in severe skeletal and reproductive abnormalities.

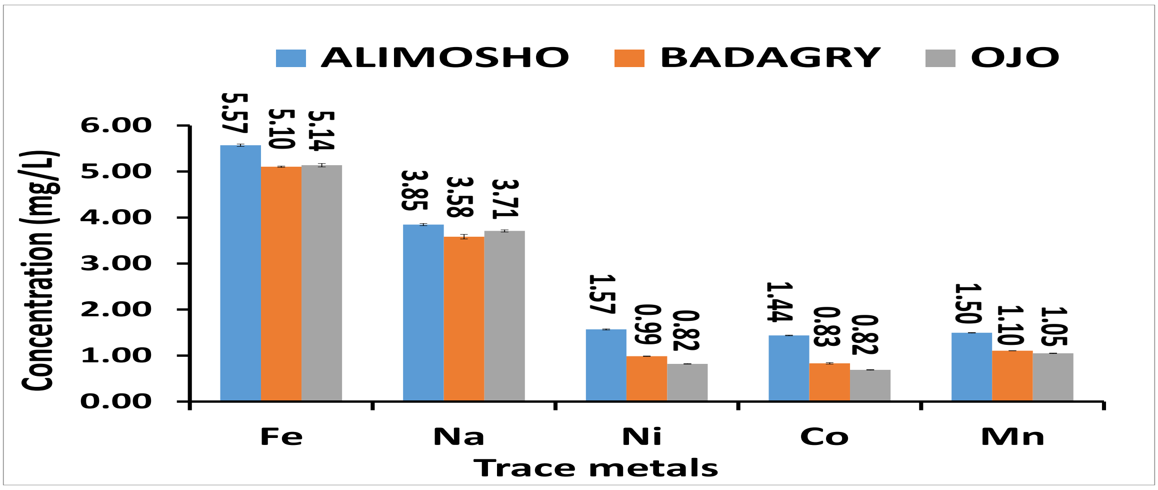

Fig 3: Concentration of trace metals in palm oil samples purchased from three market locations (n = 3)

Figure 4 presents the remaining trace metals such as Zn, Na, Mo, Cr, and Cu. Chromium (Cr) in the palm oil samples analysed and their concentrations are 1.09, 0.93 and 0.82mg/L for samples purchased from Alimosho, Badagry, and Ojo respectively. Trivalent Cr is an essential nutrient for man as it is involved in glucose tolerance. Adequate Cr nutrition may reduce risk factors associated with cardiovascular disease as well as diabetes mellitus, though hexavalent chromium is in contrast very toxic.

The concentration of Copper (Cu) in palm oil samples from Alimosho, Badagry, and Ojo were determined to be 0.93, 0.67, 0.53mg/L respectively. Copper concentration was determined and found to be the highest in Alimosho and Ojo the lowest.

Molybdenum (Mo) is an essential mineral needed by the body to stay healthy and the concentrations are 1.11, 1.01 and 0.99 mg/L for samples purchased from Alimosho, Badagry, and Ojo respectively.

The concentration of Zinc (Zn) ranged from 0.71-1.15 mg/L in the palm oil samples and zinc is required in the diet because it exhibits a wide range of biological functions such as components of enzymatic and redox systems. Symptoms of zinc deficiencies include tastelessness and loss of appetite. Zn concentration is highest in Alimosho and lowest in Ojo.

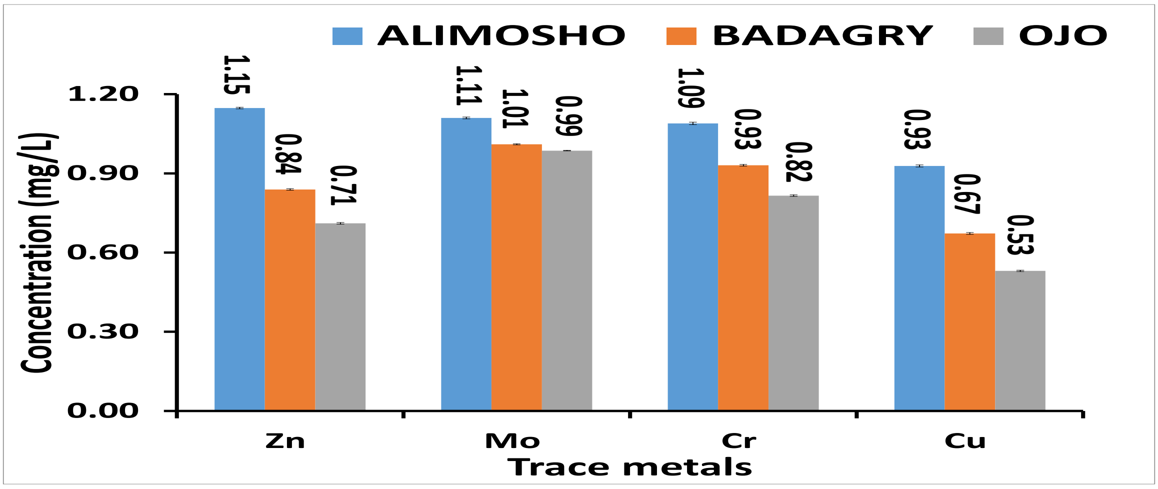

Fig 4: Concentration of trace metals in palm oil samples purchased from three market locations (n = 3)

IV. Discussion

The peroxide value determines the extent to which the oil has undergone rancidity, thus it could be used as an indication of the quality and stability of fats and oils. The peroxide value obtained from the palm oil samples range from 8.00 - 8.40 mEq.O2/kg which is comparable with the standard value of 10 mEq.O2/kg specified by the World Health organization (WHO). The free fatty acid (FFA) values obtained from the oil samples range from 10.44% - 12.70% thus, exceeding WHO recommendation of 5% free fatty acid as palmitic acid limit. The high values of the free fatty acid obtained may be due to poor handling techniques and exposure to heat and sunlight. The palm oil is not highly unsaturated because the iodine value ranged from 51.73-53.34. The moisture content of the palm oil samples ranged from 0.10% to 0.26% which is within the recommended standard of 0.29% for fresh oil by WHO. The low moisture content obtained will encourage the storage stability of the palm oil samples. The saponification values obtained ranged from 195.17mg/KOH/g to 202.37mg/KOH/g and these values are within the recommended range of 195-205 mg/KOH/g for edible palm oils as specified by the World Health organization (WHO). These values are indication that the oils are well suited for soap making. The pH of all the samples was acidic which can be attributed to the presence of high FFA. Metals such as cobalt (Co), copper (Cu), chromium (Cr), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), and zinc (Zn) are essential nutrients that are required for various biochemical and physiological functions. Inadequate supply of these micro-nutrients results in a variety of deficiency diseases or syndromes.

V. Conclusion

This study shows that the peroxide values, moisture content and saponification values of the palm oil samples are within the limits recommended by the World Health organization (WHO). However, the free fatty acid values of the palm oil samples were higher than that of the (WHO) recommendations which can be attributed to over-ripening of palm fruits, poor handling during harvesting, and environmental factors to which the oil is exposed to after processing such as display of palm oil in open market under sunlight and ultra violet radiation. This study reveals that toxic metals such as cadmium, lead and Arsenic were present in the palm oil samples at high concentration, above World Health Organization standard of 0.05, 0.1, and 0.1 mg/L for Cd, Pb and As respectively. The result also revealed that the palm oil samples are very rich in micronutrients/trace metals such as Fe, Na, Ni, Co, Mn, Zn, Mo, Cr, and Cu which are important for good health. The research study concluded that there is need for improved processing, good handling and storage practices that would ensure high quality of palm oil sold in the markets.
From the study, the following recommendations were made:

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