World Journal of Advanced Research and Reviews

eISSN: 2581-9615 CODEN (USA): WJARAI

Cross Ref DOI: 10.30574/wjarr

Journal homepage: https://wjarr.com/

(Research Article)

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Physico-Chemical and Safety Evaluation of Palm Oil Processed, Sold and Consumed in Afikpo North and South, Ebonyi State, Nigeria

Chidimma Emmanuel Ominyi [1,*] and Pius Uluocha Isaac [2]

[1] *Department of Science Laboratory Technology, Akanu Ibiam Federal Polytechnic, Unwana, Nigeria.*
[2] *Department of Food Technology, Akanu Ibiam Federal Polytechnic, Unwana, Nigeria.*

World Journal of Advanced Research and Reviews, 2024, 23(01), 2111–2121

Publication history: Received on 01June 2024; revised on 15 July 2024; accepted on 17 July 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.23.1.2082

Abstract

This study investigates the quality and safety of palm oil produced, marketed, and consumed in the Afikpo North and South Local Governent Area (LGA) of Ebonyi State, Nigeria. This research aimed at characterizing the physicochemical properties of palm oil and assess its compliance with standards. Parameters such as Free fatty acids (FFA), Iodine values (IV), Peroxide values (PV), Saponification values (SV), Moisture contents (MC), Impurity contents (IC) were meticulously analyzed. Results indicate that all the samples evaluated had their values within CODEX Alimenterium and Standards Organisation of Nigeria (SON) standards, implying that the samples are of good qualities, safe and suitable for home and industrial purposes. The research contributes to the understanding of quality of palm oils produced, marketed and consumed in Afikpo North and South LGA of Ebonyi State, Nigeria and emphasized the need for stringent quality control measures to safeguard consumers' health. It provides a foundation for policymakers and stakeholders in the palm oil industry to implement strategies that enhance the quality and safety of palm oil in Nigeria.

Keywords: CODEX Alimenterium; SON; Quality; Palm Oil; Physicochemical; Afikpo; Safety**.**

1. Introduction

Oil palm (*Elaeis guineensis)* Jacq, (*Arecaceae*) is a perennial, *monocotyledonous, monoecious* tropical crop mainly grown exclusively by seeds for the oils from the palm fruit and palm kernel (Muniran *et al.,* 2008; Mgbeze and Iserhienrhien, 2014). It is thought to have its origin in Africa (Obahiagbon, 2012). It has an extended stout single stem of about 20 to 30m high, terminating in a crown of about 20 to 100 leaves (Dransfield *et al*., 2005). Different parts of the plant have been utilized ethno-medicinally for several therapeutic purposes (Ekwenye and Ijeoma, 2005).

Palm oil is an edible oil referred to by FAO/WHO Codex alimentarius as being derived from the fleshy mesocarp of the oil palm (*Elaeis guineensis*) fruits (FAO/WHO, 2013). Palm oil is the most commonly used vegetable oil in Nigeria (Enyoh *et al*.,2017a). Palm oil is an orange-red to brownish or yellowish-red coloured liquid substance extracted from fleshy mesocarp of palm fruits (Enyoh *et al*.,2017a). Palm oil is an extract from the pulp or mesocarp of the fruits also known as crude palm oil (CPO) (Agbaire,2012). It is called crude palm oil because the extract has not gone through any refining processes (Ihekoronye and Ngoddy, 1985). Crude palm oil consists of glycerides (tri, di and mono) of fatty acids like other vegetable oil from other sources (Chabiri *et al*., 2009). CPO contains other lipids such as phosphates, unsaponifiable constituents and free fatty acids (FFA) (Chabiri *et al.,* 2009) . CPO is an orange red to brownish or yellow-red coloured semi-solid at room temperature and is highly saturated (Akinola *et al.*, 2010). CPO is insoluble in universal solvent like water and soluble in inorganic solvents like trichloromethane and alcohol (Chabiri *et al*.,2009).

*Corresponding author: Chidimma Emmanuel Ominyi; Email: emmabenominyi@gmail.com

Crude palm oil is refined to obtain a light yellow to orange red coloured palm oil (Madubuike *et al*.,2015). The yellow to orange red colour of palm oil is due to the fat soluble carotenoids in terms of retinol which are responsible for the high vitamin A content (Ugwu *et al.,* 2002). Industrially, palm oil could be refined to give a light product which could be used in the manufacturing of margarine, biscuits, ice cream, shortenings, cooking fats as well as cooking oils (Madubuike *et al.,* 2015).

The physicochemical quality and safety evaluation of crude palm oil (CPO) is essential in determining its applications domestically or industrially (Ihekoronye and Ngoddy, 1985; Okachalu *et al.*, 2011). In Afikpo North (Ehugbo) and South (Edda) Local Government Areas of Ebonyi State, traditional, smallholders and semi-mechanized palm oil processors dominates the business accounting for majority of palm oil sold and consumed in these area. Small holder and semi-mechanized processors maintained low level of hygiene in the oil processing mills and this may result to poor physicochemical and safety qualities of crude oil palm (Okachalu *et al*., 2011; Ohimain and Izah, 2003). The physicochemical and safety qualities of CPO are influenced by deteriorations due to microbial infection that occurred in the palm fruits through bruises before processing (Chabiri *et al*., 2009). The poor processing and storage methods, storage facilities as well as involvement of untrained skilled men in the palm oil processing mills affects the physicochemical and safety qualities of palm oil in Afikpo North and South. The physicochemical and safety qualities of palm oil could be affected by various factors ranging from improper post harvest handling, processing, storage methods and personnel (Agbaire, 2012). Recently, there has been wide spread speculations that palm oil is adulterated in order to increase profit margin (Agbaire, 2012). CPO that has been intentionally degraded does not only affects the physicochemical qualities of palm oil but also has implications for human health when consumed (Frank *et al.*,2013; Macarthur *et al*.,2021). These often manifest in the taste and smell of the CPO over a period of time, thereby increasing its rancidity. The rancidity of CPO could be associated with free fatty acid (FFA) increase due to atmospheric oxidation (Chabiri *et al*., 2009). The parameters affecting the quality of CPO include FFA, peroxide value, iodine value, saponification value, moisture content ,impurity level, etc (Onwuka and Akaerue,2006; Udensi and Iroegbu, 2007; Akubor and Ogu, 2012; Enemuor *et al*.,2012).

The various methods for palm oil processing have been compiled in a bulletin by Food and Agriculture Organization (Poku, 2002) of the United Nations. The compilation explained that batch processes is often employed by small-scale facilities, which process two or less tones of fresh fruit bunch per hour. The small scale factories make use of manual skilled labourers. On the other hand, large-scale plants process more than ten and often up to sixty tones of fresh fruit bunches per hour (Enyoh *et al.,* 2017a). The level of oil extraction varies wildly, mainly due to the different methods. In Imo State, Nigeria, in the traditional/local channel most of the palm oil is produced by women using manual traditional method namely mortar and pestle. Oil extracted usually reaches only 25% of the available oil in the fruit (Enyoh *et al.,* 2017b). The major processing activities irrespective of kind of processing that could affect the quality of CPO produced include bruises during transportation, fermentation prior to threshing, clarification and storage (Ohimain *et al.,* 2013). Structurally, each fruit has an outer skin. Beneath, is a layer of fibrous pulp called the mesocarp, which is rich in palm oil and contains 50 to 55% oil. The seed or nut is inside the mesocarp. The nut consists of an outer hard black shell and an inner kernel which is rich in oil, called palm kernel oil. This is the second type of oil produced from the oil palm fruit. The colour is usually pale yellow (the oil is more liquid than palm oil hence it is composed of mainly unsaturated fatty acids primarily lauric acid) while palm oil is orange to reddish of the fruit mainly after due processing and extraction (Ihekoronye and Ngoddy, 1985).

There are little or no published research on the physicochemical and safety qualities of crude palm oil processed, sold and consumed by the indigenous people of Afikpo North (Ehugbo) and South (Edda) Local Government Areas of Ebonyi State, Nigeria. Given the fact that most of the CPO consumed in these areas were either processed by semi-trained or untrained skilled men and women, whose only qualifications are their knowledge of using traditional techniques or semi-mechanised techniques to produce palm oil without in depth knowledge on palm oil quality control. One will assume that the quality and safety of this product which is locally processed and openly sold in local markets may be compromised as consumption of poor quality palm oil is unsafe and can be detrimental to public health. Quality and safety of palm oil has dominated the public discourse in recent times as a results of increase in knowledge and desire for oil worth the value for their monies. Given the above facts, issues bordering on the quality and safety of palm oil processed, sold and consumed in Afikpo North and South attracted the attention of these researchers to secure public health and fair trade around the study area and beyond. Therefore, the need to evaluate the physicochemical and safety qualities (free fatty acid, iodine value, peroxide value, saponification value, moisture and impurity content) of palm oil processed, sold and consumed by the indigenous people of Ehugbo and Edda as well as other people resident in Afikpo and Edda regions of Ebonyi State, Nigeria.

The objective of this study seeks to evaluate the physicochemical and safety qualities of palm oil processed, sold and consumed in Afikpo (Ehugbo) and South (Edda) Local Government Areas of Ebonyi State,, Nigeria.

1.1. Study area

Both Afikpo North and South are situated in a tropical region characterized by a transitional area between open grassland and tropical forest. This environment is conducive for the cultivation of oil palm trees, which are the source of the palm oil studied. The climate marked by significant rainfall and warm temperatures, influences the quality and yield of palm oil.

Afikpo North Local Government Area, now known as Afikpo is located in Ebonyi State, 5°53'N latitude and 7°56'E longitude, South East of Nigeria and has a population estimated at 156,611 according to the Nigerian 2006 Census. Afikpo South Local Government Area, now known as Edda is also located in Ebonyi State, 5°56'N latitude and 7°52'E longitude, South East region of Nigeria and has a population estimated at 157,072 according to the Nigerian 2006 Census. The coordinates indicate that these areas are located near the equator, which provides a consistent amount of sunlight throughout the year, beneficial for the growth of oil palm trees.

2. Materials and methods

Palm oil samples were collected from six major palm oil processing mills (Uji) and six major markets (Ahia ogo) in Afikpo North (Ehugbo) and South (Edda), Ebonyi State, Nigeria, namely; Uji Amangbala (Afikpo), Uji Ndemiyi (Unwana), Uji Poperi (Amasiri), Uji Ekoli (Edda), Uji Ufueseni (Edda), Uji Etiti (Edda), Eke market (Afikpo), Ahia Orie (Amasiri), Ahia Ogo (Unwana), Orie market (Ahia Ogo Nguzu Edda) , Ahia Eke (Oso Edda) and Ahia Afor (Owutu Edda). This sampling was carried out between October and December, 2023. Samples were collected into 1000ml pre-labeled sealable bottles, transported and stored at room temperature in the Food Chemistry Laboratory, Department of Food Technology, Akanu Ibiam Federal Polytechnic, Unwana, before analysis.

2.1. Physicochemical and Safety Analysis of Palm Oil

Physicochemical and safety analysis of various palm oil samples which include; free fatty acid (FFA), iodine value (IV), peroxide value (PV), saponification value (SV),moisture content (MC) and impurity content (IC) were carried out using different standard methods of analysis.. The entire chemicals used were of analytical grade.

2.2. Determination of Free Fatty Acid (FFA) Content

Determination of free fatty acid (FFA) content was determined by titrating the alcoholic solution of the oil sample with a 0.1N NaOH using three drops 1% phenolphthalein solution as an indicator, as described by Agbaire (2012), and Onyemachi and Isaac, (2015) with slight modifications. The FFA content was then expressed as percentage of palmitic acid being the major fatty acid in palm oil.

$$\text{Free Fatty Acid(mgKOH/g)} = \frac{\text{Titre value(ml)} \times 5.61 \times 0.1\text{N}}{\text{W}}$$

Where; Titre value = Volume of 0.1N sodium hydroxide used (ml)

5.61 = Conversion factor for free fatty acid

0.1N = Normality of sodium hydroxide used

2.3. Determination of Iodine Value

The iodine value of the various oil samples was determined using the method described by Akinola *et al*., (2010) with some modifications using Wij's solution.

$$\text{Iodine value } (\text{I}_2/100\text{g}) = \frac{(\text{b}-\text{a})\times 1.269}{\text{W}}$$

Where b = Volume of thiosulphate used for blank titration (ml)

a = Volume of thiosulphate used for test sample titration (ml)

W = Weight of oil sample used (g)

1.269 = Conversion factor iodine value

2.4. Determination of Saponification Value

Saponification value of the oil sample was determined by the method described by Onwuka, (2015) and Enyoh *et al.*, (2017a) with slight modifications. Alcoholic potassium hydroxide refluxed and titrated with 0.5N hydrochloric acid using three drops phenolphthalein (1%) solution.

$$\text{Saponification value} = \frac{(\text{b} - \text{a}) \times 28.05}{\text{Weight of sample used}}$$

Where b = Volume of 0.5N hydrochloric acid used for the blank sample (ml)

a = Volume of 0.5N hydrochloric acid used for the test sample (ml)

W = Weight of the oil sample used (g)

28.05 = Conversion factor for saponification value

2.5. Determination of Peroxide Value

Peroxide value of palm oil sample was determined according to method described by Akinola *et al.*, (2010) and Enyoh *et al.*, (2017a) with slight modifications. The peroxide value was determined by titrating chloroform/glacial acetic acid / saturated potassium iodide solution of the oil sample and sodium thiosulphate using three drops of 1% starch solution as indicator.

$$\text{Peroxide value (mEq/kg)} = \frac{(\text{V} - \text{Vo})\text{T} \times 10^3}{\text{M}}$$

Where V = Volume of thiosuphate used for sample titration (ml)

Vo = Volume of thiosulphate used for blank titration (ml)

T = Normality of Sodium thiosulphate used

M = Weight of sample used

Determination of Moisture Content

Moisture content of the oil sample was determined by the method described by Onyemachi and Isaac (2015) and Onwuka (2015) with slight modifications. The moisture content was assayed gravimetrically by oven drying the sample to a constant weight at 105°C.

$$\text{Moisture content(\%)} = \frac{W_2 - W_3}{W_2 - W_1} \times \frac{100}{1}$$

Where W_1= Weight of empty crucible

W_2= Weight of empty crucible and palm oil sample before drying
W_3= Weight of empty crucible and palm oil sample after drying

2.6. Determination of Impurity Content

The percentage impurity content of the oil samples were determined as described by Ngando *et al.,* (2011) with slight modifications. The oil samples were mixed with excess hexane then filtered. The residue on the filter paper was then washed with hexane and oven dried to a constant weight at 105°C.

$$\text{Impurity content(\%)} = \frac{\text{A} \times 100}{\text{AB} \times 1}$$

Where A= Weight of residues after drying (g)

AB= Weight of sample before treatment (g)

2.7. Statistical Analysis

All analytical determinations were performed at least in triplicate. Values of different parameters were expressed as the mean ± standard deviation (M ± S.D.). Genstat 2013 statistical soft ware version 19.2 was used to analyse the data by using ANOVA for multiple mean comparisons. Results for all the parameters were compared to CODEX, (2015) and SON, (2000) standards.

3. Results and discussion

Table 1 Physico-Chemical and Safety Qualities of Palm Oil Processed in Afikpo North (Ehugbo) and South (Edda) Local Government Areas of Ebonyi State, Nigeria**.**

Samples	FFA (mgKOH/g)	Iodine Value (I_2/100g)	Peroxide Value (mEq/Kg)	Saponification Value (mgKOH/g)	Moisture Content (%)	Impurity Content (%)
POUNUA	2.34^{ia}±0.04	3.85^{a}±0.04	10.43^{a}±0.09	200.34^{e}±0.03	0.26^{a}± 0.01	0.05^{a}±0.01
POUEE	2.05^{b}±0.03	2.46^{b}±0.03	7.63^{b}±0.02	200.49^{d}±0.03	0.25^{ab}±0.01	0.04^{ab}±0.00
POUPAA	1.84^{c}±0.04	2.27^{c}±0.02	6.83^{c}±0.03	200.91^{c}±0.12	0.25^{ab}± 0.01	0.04^{ab}±0.00
POUUE	1.64^{d}±0.03	1.96^{d}±0.02	6.50^{d}±0.02	200.93^{c}±0.04	0.23^{c} ± 0.01	0.03^{b}±0.01
POUEAE	1.24^{e}±0.03	1.36^{e}±0.04	6.12^{e}±0.03	201.87^{b}±0.05	0.24^{b}± 0.01	0.04^{ab}±0.00
POUAA	0.72^{f}±0.04	0.92^{d}±0.02	5.28^{f}±0.03	204.41^{a}±0.09	0.23^{c}± 0.01	0.03^{b}±0.01
LSD	0.03	0.02	0.05	0.07	0.01	0.00
Codex	10	50-55	10	195-209	0.02-0.05	0.02 – 0.05
Standard SON	3-5	45-53	10	195-205	0.02 -0.05	0.02 – 0.05

Values are means ± standard deviation of triplicate readings. Values with different lowercase superscript in the same column are significantly different (P<0.05). POUNUA = Palm Oil Processed at Uji (Mill) Ndemiyi, Unwana, Afikpo; POUEE = Palm Oil Processed at Uji (Mill), Ekoli, Edda; POUPAA= Palm Oil Processed at Uji (Mill) Poperi, Amasiri, Afikpo;POUUE = Palm Oil Processed at Uji (Mill) Ufueseni, Edda; POUEAE = Palm Oil Processed at Uji (Mill) Etiti/Amoso, Edda and POUAA = Palm Oil Processed at Uji (Mill) Amangbala, Afikpo

3.1. Free Fatty Acid (FFA)

Table1, showed that the free fatty acid content of palm oil processed and sampled from six major mills (Uji) across Afikpo North and North ranged from 0.72-2.34mgKOH/g which is lower than the permissible limits of 3.5mgKOH/g and 10mgKOH/g recommended by SON, (2000) and CODEX, (2015). The results obtained in this table were lower when compared with 2.73 – 2.83mgKOH/g (Agbaire, 2012), 9.08 -12.07mgKOH/g (Macarthur *et al.*, 2021) and 10.38 - 18.80mgKOH/g (Enyoh *et al.*, 2017b). The FFA of the samples increased in this order: POUAA > POUEAE > POUUE > POUPAA > POUEE > POUNUA. Palm oil sampled from POUNUA had the lowest FFA (0.73mgKOH/g) while sample POUNUA had the highest FFA (2.34mgKOH/g).The values obtained for FFA were all found to be below 4 mgKOH/g being the maximum limit for edible vegetable oil (Jabar *et al.,* 2016). The low FFA in this result revealed that palm oil processed across Afikpo North and South are of good grade and safe for consumption. The measure of the FFA in oils is the acid value (Agbaire, 2012). Fatty acid is an indication of edibility of vegetable oil and its suitability for industrial use (Abayeh *et al.,* 2011). Fatty acids are usually in the triglyceride form but during processing they tend to get hydrolyzed into free fatty acids (Macarthur *et al.*, 2021; Enyoh *et al.*, 2017a). This mean that higher acid values will cause higher FFA thereby decreasing the oil quality and safety vise versa lower acid value will cause lower FFA hence increasing the palm oil quality and safety (Agbaire, 2012; Enyoh *et al.*, 2017b).

3.2. Iodine Value (IV)

Results in table1 revealed that the iodine values (IV) of palm oil samples processed in six major mills (Uji) across Afikpo North and South ranged from 0.92-3.85 I_2/100g which are far less than the 45-53 I_2/100g and 50-55 I_2/100g respective permissible limits for SON and CODEX. The results indicated that sample POUAA had the lowest IV (0.92 I_2/100g) while sample POUNUA had the highest IV (3.85 I_2/100g). IV is the measure of the level of unsaturation in oil samples (AOCS, 2004). IV in the oil samples processed in six major mills across Afikpo North and South is higher than 0.48 – 2.84 I_2/100g reported by Enyoh *et al.,* 2017a but lower than 52.55-53.64 I_2/100g (Agbaire, 2012) and 43.50-46.92 I_2/100g (Macarthur *et al.,* 2021). The IV in this study increased in the following order: POUAA > POUEAE > POUUE > POUPAA > POUEE > POUNUA. IV is a measure of the level of unsaturation in palm oil and a useful tool or index of detecting adulteration of oils (Enyoh *et al.,*2017a).It is also used to categorize oil into non-drying (30-80 I_2/100 g), semi-drying (80-120 I_2/100 g) and drying (above 120 I_2/100 g) oil (Abayeh *et al.,* 2011). Therefore, these showed that the absence of unsaturation and susceptible oxidative rancidity suggests that the oil samples studied has high storability and adulteration free.

3.3. Peroxide Value (PV)

The peroxide values (PV) of palm oil samples as shown in table 1 ranged from 5.28-10.43mEq/kg. The PV of samples POUAA. POUEAE, POUUE and POUEE ranged from5.28-7.63mEq/kg which are within the permissible limit of 10mEq/kg (SON, 2000; CODEX, 2015) while sample POUNUA had 10.43mEq/kg slightly above the recommended safe limit. The PV results obtained in this study were almost in the same range with 7.08-8.38mEq/kg (Agbaire, 2012) while higher values 11.27 - 12.93mEq/kg and 14.10 – 24.80mEq/kg were reported by Macathur *et al*., (2021) and Enyoh *et al*. (2017b). The PV of samples studied were in this increasing order: POUAA > POUEAE > POUUE > POUPAA >POUEE > POUNUA. Peroxide value in palm oils is used to determine the degree of oil oxidation during storage and the freshness of the lipid matrix, it indicates early stage of rancidity under mild conditions (Ekwu and Nwagu, 2004; Nwanekezi and Onyeagba,2007; Agbaire, 2012). Peroxide value is also an indication of quality, safety and stability of fats and oils (Ekwu and Nwagu, 2004).

3.4. Saponification Value (SV)

The saponification values (SV) as seen in table1 ranged from 200.34 - 204.41mgKOH/g. Sample POUNUA had the lowest value 200.34mgKOH/g while sample POUAA had the highest value 204.41mgKOH/g. Values obtained in table1 increased in the following order: POUNUA > POUEE > POUPAA > POUUE > POUEAE > POUAA. These values are within the recommended standards of 195-209mgKOH/g for palm oils (SON, 2000; CODEX, 2015). The values obtained in this study are slightly higher than 192.49 - 202.73mgKOH/g (Agbaire, 2012; Macarthur *et al*., 2021; Enyoh *et al*., 2017b) but lower than 205.68 - 211.57mgKOH/g (Macathur *et al.,*2021). The values obtained in this study showed that the samples are suitable for soap making. Saponification value is a tool used to measure molecular weights of triglycerides in oils (Agbaire, 2012). The smaller the saponification value, the larger the average molecular weight of the triacylglycerols present in the oil and vise versa (Eromosele and Catharine, 1993).

3.5. Moisture Content (MC)

The moisture content of the samples studied ranged from 0.23-0.26% as shown in table1. Samples POUAA and POUUE had the lowest moisture content while sample POUNUA had the highest value of 0.26%. The moisture content in this study increased in the following order: POUAA and POUUE (0.23%) > POUEAE (0.24%) > POUPAA and POUEE (0.25%) > POUNUA (0.26%). The moisture contents obtained in table1 were within the acceptable standard limits (0.25 – 0.29%) for palm oils (SON, 2000; CODEX 2015). Enyoh *et al.,* (2017b) reported higher values (0.26 – 0.86%) while Agbaire, (2012) reported lower values (0.14 – 0.17%) when compared with values in table1. Moisture content of palm oils is an important parameter in accessing the quality and safety of an oil sample (Agbaire, 2012; Enyoh *et al*., 2017b). The moisture content of any food is an index of it's water activity (aw) (Fraziar and Westoff, 1978). Higher moisture content is an indication of ease of spoilage and rancidity as well as short shelf life (Enyoh *et al*., 2017a). The lower moisture contents obtained in oil samples studied will encourage the storage stability. Moisture content of palm oil is dependent on the efficiency of the final extraction and clarification process (Orji and Mbata, 2008).

3.6. Impurity Content (IC)

Table1 showed the impurity content of the various palm oil samples studied which ranged from 0.03 – 0.05%. Samples POUAA and POUUE had the lowest impurity content, followed closely by samples POUEAE,POUPAA and POUEE with 0.04% while sample POUNUA had the highest impurity content of 0.05% . The impurity contents are represented in the following increasing order: POUAA and POUUE (0.03%) > POUEAE, POUPAA and POUEE (0.04%) > POUNUA (0.05%). All values obtained are within the recommended permissible limits (SON, 2000; CODEX, 2015). The values obtained in this study are lower than values 0.11 – 0.14% reported by Agbaire, (2012). Impurity level of palm oils is directly dependent on the efficiency of the final extraction and clarification procedures (Orji and Mbata, 2008). Low impurity level is an index of good quality production procedures (Agbaire, 2012).

Table 2 Physico-Chemical and Safety Qualities of Palm Oils Sold in Different Markets and Consumed in Afikpo North (Ehugbo) and South (Edda) Local Government Area of Ebonyi State, Nigeria**.**

Samples	Free Fatty Acid (mgKOH/g)	Iodine Value (I_2/100g)	Peroxide Value (MEq/Kg)	Saponification Value (MgKOH/g)	Moisture Content (%)	Impurity Content (%)
POOMNE	4.19^{a}±0.03	4.43^{a}±0.02	9.28^{a}±0.09	197.08^{d}±0.04	0.24^{ab}± 0.01	0.05^{a}±0.01
POOMAA	4.10^{b}±0.03	4.21^{b}±0.05	9.23^{a}±0.05	197.06^{d}±0.03	0.25^{a}±0.00	0.04^{ab}±0.01
POEMOE	3.68^{c}±0.04	3.96^{c}±0.02	9.11^{b}±0.02	197.51^{c}±0.06	0.24^{b}± 0.00	0.03^{b}±0.01
POEMA	3.59^{d}±0.04	3.83^{d}±0.01	9.08^{b}±0.02	198.14^{b}±0.03	0.24^{b} ± 0.00	0.03^{b}±0.01
POAOUA	3.24^{e}±0.02	3.39^{f}±0.03	8.74^{c}±0.02	200.30^{a}±0.01	0.25^{a}± 0.01	0.04^{ab}±0.01
POAMOE	3.18^{f}±0.05	3.47^{e}±0.04	8.71^{c}±0.02	200.29^{a}±0.02	0.24^{b}± 0.00	0.04^{ab}±0.01
LSD	0.03	0.03	0.03	0.03	0.01	0.00
Codex	10	50-55	10	195-209	0.02 - 0.05	0.02 -0.05
SON	3-5	45-53	10	195-205	0.02 – 0.05	0.02 – 0.05

Values are means ± standard deviation of triplicate readings. Values with different lowercase superscript in the same column are significantly different (*P<0.05)*. POOMNE = Palm Oil Sold at Orie Market, Nguzu Edda, POOMAA = Palm Oil Sold at Orie Market,Amasiri, Afikpo, POEMOE = Palm Oil Sold at Eke Market, Oso Edda,POEMA = Palm Oil Sold at Eke Market, Afikpo, POAOUA = Palm Oil Sold atAhia Ogo, Unwana, Afikpo and POAMOE = Palm Oil Sold at Afor Market,Owutu Edda.

3.7. Free Fatty Acid (FFA)

The results in table2, revealed free fatty acid (FFA) content of palm oils sold in six (6) major local markets across Afikpo North and South of Ebonyi State, Nigeria. The FFA ranged from 3.18 – 4.19mgKOH/g. The FFA contents of the various oil samples are within the standard permissible limits of 3.5mgKOH/g and 10mgKOH/g (SON, 2000) and (CODEX, 2015). There are significant differences among the various samples (*P*<0.05) with sample POOMNE having the highest FFA value 4.19% while sample POAMOE had the lowest value 3.18mgKOH/g. The FFA contents of the oil samples increased in the following order: POAMOE (3.18%) >PAOOUA (3.24%) > POEMA (3.59%) > POEMOE (3.68%) > POOMAA (4.10%) > POOMNE (4.19%).The FFA obtained in this study were higher than 2.73 – 2.89mgKOH/g contents of palm oil sold in Aba, Umuahia and Umuopara of Abia State (Udensi and Iroegbu,2007) but lower than 8.60–8.91mgKOH/g contents of palm oils sold in some selected markets in Aba, Calabar, Lagos and Kano, Nigeria (Henshaw *et al*.,2022). The FFA values of palm oils can be affected by the duration of storage of the fruits used to process the palm oil, the length of storage of palm oil, the storage containers and the storage conditions after processing (Ihekoronye and Ngoddy, 1985; Agbaire, 2012; Henshaw *et al.*, 2022).High FFA values in palm oils could be as a results of exposure to temperatures above normal room temperature at the stores (Ekwenye and Ijeoma,2005). It may also be due to decomposition of triglycerides by fungi and other microorganisms and may be accelerated by exposure of palm oil to heat and sunlight (Hiol *et al*.,1999; Houria *et al*., 2002; Okechalu *et al*., 2011).

3.8. Iodine Value (IV)

Iodine value (IV) results as shown in table2 ranged from 3.39 – 4.43I_2/100g. The results obtained showed significant difference (*P*<0.05) among the various samples studied, where sample POOMNE had the highest IV (4.43I_2/100g) while sample POAOUA had the least value (3.39I_2/100g). The iodine value obtained in this study were below 45-53I_2/100g and 50-55I_2/100g recommended by SON, (2000) and CODEX, (2015). These low IV values suggests that the various palm oil samples has low level of unsaturation and might not be susceptible to oxidation (Enyoh *et al.*, 2017a).The iodine value ranking increased in this order: POAOUA (3.39I_2/100g) > POAMOE (3.47I_2/100g)> POEMA (3.83I_2/100g) > POEMOE (3.96I_2/100g) > POOMAA (4.21I_2/100g) > POOMNE (4.43I_2/100g). The value obtained from this study were higher than 0.48-2.84I_2/100g reported by Enyoh *et al.*, (2017b) but lower than 33.24I_2/100g and 52.55-53.66I_2/100g reported by Akinyere *et al.*, (2011) and Agbaire, (2012). Iodine values are tool for measuring levels of unsaturation in oils (Udensi and Iroegbu, 2007). Iodine value is a useful index for detecting adulteration in oils (Ekwenye and Ijeoma, 2005; Orji and Mbata, 2008; Agbaire, 2012; Henshaw *et al*., 2022).

3.9. Peroxide Value (PV)

Table2 revealed that the peroxide values (PV) obtained in this study ranged from 8.71-9.28mEq/kg. Sample POOMNE had the highest value 9.28mEq/kg while sample POAMOE had the least value 8.71mEq/kg. There were no significant difference (P>0.05) between samples POOMNE and POOMAA; POEMOE and POEMA; samples POAOUA and POAMOE. Peroxide values of the various oil samples are in the following decreasing order: POOMNE (9.28mEq/Kg) > POOMAA (9.23mEq/Kg) > POEMOE (9.11mEq/Kg) > POEMA (9.08mEq/kg) > POAOUA (8.74mEq/Kg) > POAMOE (8.71mEq/Kg). The peroxide values of the various oil samples studied are below 10mEq/kg recommended by SON, (2000) and CODEX, (2015). This suggests that palm oil sold and consumed across Afikpo North and South of Ebonyi State are fresh, rancid free and safe for consumption. The peroxide values in table 2 is in the same range with 7.81-9.30mEq/kg reported by Henshaw *et al.*, (2022), above 7.80-8.40mEq/kg (Agbaire,2012) and 7.90 – 8.80mEq/kg (Udensi and Iroegbu, 2007) and far less than 14.10 – 24.80mEq/kg reported by Enyoh *et al.*, (2017b). Peroxide value is a measure of freshness of lipid matrix. It's a useful tool that indicates early stage of rancidity in oils (Onyeka *et al.*, 2005). Peroxide value is used as an index of quality, safety and stability of fats and oils (Ekwu and Nwagu, 2004; Nwanekezi and Onyeagba, 2007).

3.10. Saponification Value (SV)

The saponification values (SV) as revealed in table2 ranged from 197.06 – 200.30mgKOH/g. Sample POAOUA had the highest value (200.30mgKOH/g) with no significant difference (P>0.05) when compared with sample POAMOE (200.29mgKOH/g) while sample POOMAA had the least saponification value of 197.06mgKOH/g with no significant difference (P>0.05) when compared with sample POOMNE (197.08mgKOH/g). The order of increase of the SV in this table is as follows: POOMAA (197.06mgKOH/g) > POOMNE (197.08mgKOH/g) > POEMOE (197.51mgKOH/g)>POEMA (198.14mgKOH/g)>POAMOE (200.29mgKOH/g) > POAOUA (200.30mgKOH/g). The saponification values (197.06 – 200.30mgKOH/g) obtained in this study were within the standard recommendations of SON, (2000) 195 -205mgKOH/g and CODEX, (2015) 195-209mgKOH/g. These values indicate that the various palm oil samples analysed in this work are very suitable for soap making. Values obtained in this study is high when compared with the values (129.04 – 198.03mgKOH/g) reported by Udensi and Iroegbu, (2007) but less when compared with the values (219.08 – 229.10mgKOH/g) reported by Henshaw *et al.*, (2022). SV indicates the molecular weights of triglycerides of oils. High SV indicates high proportion of low fatty acids since SV is inversely proportional to the average molecular weight or length of fatty acids (Muhammed *et al*., 2011; Agbaire, 2012; Enyoh *et al*., 2017b).

3.11. Moisture Content (MC)

The moisture content of samples in table2 ranged from 0.24 – 0.25%. Samples POOMAA and POAOUA had the highest moisture content of 0.25% with no significant difference (P>0.05) while samples POOMNE, POEMOE, POEMA and POAMOE had the least moisture content of 0.24% with no significant difference among them. These values are within 0.25 – 0.29% recommended standard by SON, (2000) and CODEX, (2015) for palm oils. The low moisture content in all the samples studied is an indication that the final extraction and clarification process of the various palm oils were efficient. The low moisture content will encourage storage stability of the palm oils. The values obtained in this study is higher than 0.14-0.16% (Udensi and Iroegbu, 2007) and 0.14 – 0.17% (Agbaire,2012) but lower than 0.26 – 0.355 reported by Henshaw *et al*., (2022). Moisture content of palm oil is an important index parameter for evaluating the quality of palm oil samples (Agbaire, 2012; Enyoh *et al*., 2017b). The moisture content of any food is an index of it's water activity (aw) (Fraziar and Westoff, 1978; Agbaire, 2012). High moisture content is an indication of ease of spoilage and rancidity as well as short shelf life (Agbaire, 2012; Enyoh *et al*., 2017b).

3.12. Impurity Content (IC)

Table2 showed impurity content ranging from 0.03 – 0.05% which are within the 0.02 – 0.05% recommended as standard for edible palm oils (FAO/WHO,2013).The impurity levels 0.1 -0.31% and 0.11 – 0.14% reported by Ngando *et al*., (2011) and Agbaire, (2012) are higher than the impurity contents 0.03 – 0.05% obtained in this study. The low impurity content of this study is a testament of quality, efficient extraction and clarification procedures employed in the production of these palm oils. Impurity level depend directly on the efficiency of the final extraction and clarification procedures (Wolves-Perges, 1969; Johnson and Pehlergard, 1977; Poku,2002; Agbaire,2012).

4. Conclusion

In conclusion, the research on the physicochemical and safety evaluation of palm oil processed, sold, and consumed in Afikpo North (Ehugbo) and South (Edda) , Ebonyi State, Nigeria, revealed significant insights into the quality and safety of this essential commodity. The study's findings indicate that all the values obtained met the recommended standards for edible palm oil by SON and CODEX Alimenterium. This suggests that the locally produced red palm oils, sold and consumed in Afikpo North (Ehugbo) and South (Edda) are healthy and fit for consumption, showcasing the effectiveness of the current processing methods in maintaining the oil's quality. The results also indicate the suitability of the various palm oils for domestic and industrial use, implying that the samples are of good qualities and safe. The positive outcome from this study suggests a benchmark for other regions to emulate, aiming for high-quality palm oil production that prioritizes consumer health and safety. It also calls for continuous monitoring and evaluation to maintain these standards and for improvements where necessary. The commitment to such quality assurance measures will not only protect consumers but also enhance the reputation of local palm oil on a global scale.

Compliance with ethical standards

Acknowledgement

The researchers of this work attribute the successful and timely completion of this work to YAHWEH most merciful for His guide and gift of life. We acknowledged TETfund for the sponsorship of this research through her institution-based research (IBR) programme. The tireless and meticulous efforts of Pius Uluocha Isaac in carrying out the laboratory and statistical analysis of this study is equally acknowledged.

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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