Quality assessment of palm oils from selected Nigerian markets.

Aniekan S Henshaw[1]*, Ima-Obong Williams[1], Henry E Peters[2], Christine A Ikpeme[2]

[1]Department of Biochemistry, University of Calabar, Calabar PMB, Nigeria
[2]Deparment of Food Science and Technology, University of Calabar, Calabar PMB, Nigeria

Abstract

Aim: This study assessed the quality of the palm oils vended in selected regions of Nigeria. A total of sixty (60) 750 ml bottles of red palm oil were purchased from four (4) randomly selected markets in different cities (Aba, Calabar, Lagos and Kano) across Nigeria. The samples were analyzed for physicochemical parameters, heavy metals and Sudan II dye contamination.
Methods: The Sudan II dye contents and physicochemical properties were determined using standard methods. Heavy metal contents were determined with an Atomic Absorption Spectrophotometer (AAS) Data analysis was carried out with SPSS using one-way analysis of variance (ANOVA).
Key findings: Results of the physicochemical analysis showed that the moisture content ranged from 0.26-0.35%, peroxide value ranged from 7.81-9.30 meq/kg, saponification value ranged from 219.08-229.10 KOH/g, iodine value ranged from 53.87-58.15 wijs, free fatty acid value ranged from 8.60-8.91 KOH/g and carotene value ranged from 1036.54-1868.02 mg/kg. Sudan II dye level ranged from 250-350 ppm. Significant differences ($P<0.05$) were observed in all physicochemical parameters analyzed. All parameters except carotene and specific gravity had values not within the CODEX/SON/NIS standard. All samples tested positive for Sudan II dyes. However, heavy metals were not detected in the samples.
Significance: The results indicated that not only was palm oils vended across the Nigerian market was of poor quality, but also it contained hazardous intentional contaminant. This finding has implication on public health; enhanced awareness might need to be raised.

Keywords: Quality, Red palm oils, Sudan II dyes, Physicochemical parameters, Heavy metals.

Introduction

The term "Quality" denotes the degree of excellence of a product. The quality of red palm oil is determined in terms of its quality parameters. The alterations in these parameters would ultimately change the quality of the red palm oil. Some of the parameters used to assess the quality of red palm oil are; moisture content, iodine value, peroxide value, saponification value, unsaponifiable matter, free fatty acid value [1].

The composition of red palm oil, together with its natural consistency, appearance and pleasant aroma make it an ideal ingredient in the development and production of a variety of edible oil, in particular, margarines and fats and also ideal when making the following products; biscuits, cakes, sauces [2]. Red palm oil serves as the main dietary fat of many people in Nigeria and across West Africa. It also serves as a source of livelihood for many workers who are involved in extraction and processing of the oil.

Red palm oil may contain trace levels of various heavy metals depending on many factors such as species, soil used for cultivation, irrigational water, pollution, mode of processing, storage and contamination [3]. A heavy metal is a member of an ill-defined subset of elements that exhibit metallic properties which would mainly include the transition metals, some metalloids, lanthanides and actinides [4]. It could also be defined as any metallic chemical element that has a relatively high density and is poisonous at low concentrations [4]. Heavy metals such as Lead, Cadmium, Chromium and Mercury could have access into red palm oil during processing, packaging, storage or sale of product [3]. The presence of these toxic metals may appear harmless in low quantities. But their accumulation over time carries potential health risk to humans who regularly consume the product [5]. Once these toxicants are absorbed into the body, they compete with and displace essential minerals (required for metallo-enzymes' activities) and interfere with organ and system functions [6].

The physicochemical indices are useful in examining and characterizing palm oil. A variation in the different indices indicates different properties of red palm oil. The indices are; moisture content, saponification value (the number of milligrams of potassium hydroxide, KOH required to neutralize the fatty acids from complex hydrolysis of oils), Iodine value, unsaponifiable matter (the whole quantity of substances present in the oil, after saponification by potassium hydroxide, KOH and extraction with a specified solvent, are not soluble in aqueous alkali), peroxide value, refractive index (ration of speed of light at a defined wavelength to its speed in the oil itself) and free fatty acids. The objective of this study

***Correspondence to:** Aniekan S Henshaw, Department of Biochemistry, University of Calabar, Calabar PMB, Nigeria, Tel: +2348132303579, E-mail: aniekanhenshaw@gmail.com

***Received:** 15-Nov-2021, Manuscript No. AAJFSN-22-47511; **Editor assigned:** 18-Nov-2021, PreQC No. AAJFSN-22-47511(PQ); **Reviewed:** 02-Dec-2021, QC No. AAJFSN-22-47511; **Revised:** 21-Mar-2022, Manuscript No. AAJFSN-22-47511(R); **Published:** 28-Mar-2022, DOI:10.35841/aajfsn-5.3.113*

***Citation:** Henshaw AS, Williams IO, Peters HE, et al. Quality assessment of palm oils from selected Nigerian markets. J Food Sci Nutr. 2022;5(3):113*

was to evaluate the quality of red palm oil vended across major markets in Nigeria [6].

Methods and Materials

Sample collection

A total of sixty, 750 millilitres bottle of red palm oil samples were purchased from four randomly selected markets in different Nigerian cities namely; Aba, Calabar, Kano and Lagos. In these cities, five samples of red palm oil were each purchased from three different markets. The markets were Ariaria, Cemetery, Ahia Ohuru (Aba), Watt, Marian, Goldie (Calabar), Sabongari, Galadima, Kofar Wabe (Kano) and Balogun, Alade, Ketu (Lagos). The samples were then stored in a transparent plastic container on ice and transported to the laboratory for analysis. The red palm oil samples for qualitative analysis were coded A_1 (red oil samples from Aba), C_1 (red oil samples from Calabar), K_1 (red oil samples from Kano) and L_1 (red oil samples from Lagos). The red palm oil used as control was purchased from Ibiaye Oil Palm in Biase local government area of Cross River state.

Reagents and chemicals

All reagents and chemicals used were of analytical grades and they include; nitric acid (Riedel-deltaen, Germany), perchloric acid (sigma-Aldrich, Germany), Sudan II dye (Sigma-Aldrich, Germany), distilled deionized water (obtained from Department of Biochemistry, University of Calabar), chloroform (Sigma, USA), sulphuric acid (Sigma, USA), phenolphthalein indicator (Sigma, USA), iodine solution (15%) (Sigma, USA). All the chemicals were purchased from a reputable supplier.

Analyses of Sudan II dye and heavy metal contents

Sudan II dye was determined according to the standard methods [7]. Heavy metal content of the red palm oil was determined with an Atomic Absorption Spectrophotometer (AAS) (model: B-250) [8].

Estimation of physicochemical parameters

Moisture content, unsaponifiable matter, saponification value, iodine value, peroxide value, free fatty acid, specific gravity and colour were determined using standard methods as described by Sylvester et al. [9]. Carotene content of the oil sample was determined according to the method described by [10].

Statistical analysis

All data obtained were collated using standard statistical methods. They were expressed as mean ± SEM. Data were analysed using one-way analysis of variance (ANOVA) at 5% level of significance. Statistical analysis was performed using SPSS statistical package.

Results

Table 1 shows the levels of Sudan II dye in red palm oil samples across the major markets in Nigeria. All the red palm oil samples tested positive for Sudan II dyes. The mean value of K_1 (350.00 ± 28.86 ppm) were significantly ($P<0.05$) higher than L_1 (260.00 ± 15.27 ppm), A_1 (250.01 ± 9.27 ppm) and C_1 (250.00 ± 10.13 ppm). In addition, mean values of A_1 and C_1 were significantly ($P<0.05$) lower than L_1.

Table 2 shows the results of the heavy metals in red palm oil samples across the major markets. The results showed that heavy metals such as lead (Pb), Chromium (Cr), Mercury (Hg) and Cadmium (Cd) were not detected in the red palm oil samples.

The results for the physicochemical parameters are presented in Table 3.

Table 1. *Levels of Sudan II dye in red palm oil samples.*

Tested parameters	Samples					
	K_1	L_1	A_1	C_1	Control sample	CODEX/ SON/NIS standards
Sudan II dye,(ppm)	$350.00 \pm 28.86^{c,d,e}$	$260.00 \pm 15.27^{b,d,e}$	250.00 ± 9.27^{c}	250.00 ± 10.13^{c}	ND	-
K_1=red palm oil samples from Kano; L_1=red palm oil samples from Lagos; A_1=red palm oil samples from Aba; C_1=red palm oil samples from Calabar ND=not detected						
*=p<0.05 vs SON	a=p<0.05 vs Control	b=p<0.05 vs K_1		c=p<0.05 vs L_1		
d=p<0.05 vs A_1		e=p<0.05 vs C_1				

Table 2. *Levels of heavy metals in red palm oil samples.*

Tested parameters	Samples					
	K_1	L_1	A_1	C_1	Control sample	Oral component limit (OCL)
Lead (ppm)	ND	ND	ND	ND	ND	1 ppm
Cadmium (ppm)	ND	ND	ND	ND	ND	0.5 ppm
Mercury (ppm)	ND	ND	ND	ND	ND	1.5 ppm
Chromium (ppm)	ND	ND	ND	ND	ND	25 ppm
K_1=red palm oil samples from Kano; L_1=red palm oil samples from Lagos; A_1=red palm oil samples from Aba; C_1=red palm oil samples from Calabar ND=Not detected						

Citation: *Henshaw AS, Williams IO, Peters HE, et al. Quality assessment of palm oils from selected Nigerian markets. J Food Sci Nutr. 2022;5(3):113*

Table 3. *Physicochemical properties of red palm oil samples.*

Tested parameters	Samples					
	K_1	L_1	A_1	C_1	Control sample	CODEX/ SON/NIS standards
Moisture (%)	$0.353 \pm 0.03^{*,a,c,d}$	$0.303 \pm 0.03^{*,a,b,d,e}$	$0.273 \pm 0.03^{*,a,b,c}$	$0.263 \pm 0.03^{*,a,b,c}$	$0.067 \pm 0.03^{*}$	0.25
Peroxide value (Meq/Kg)	$9.303 \pm 0.03^{*,a,c,d,e}$	$8.30 \pm 0.03^{*,a,b,d,e}$	$8.377 \pm 0.03^{*,a,b,c,e}$	$7.817 \pm 0.03^{*,a,b,c,d}$	$2.503 \pm 0.03^{*}$	10
Iodine value (Mg/g)	$58.153 \pm 0.03^{*,a,c,d,e}$	$53.87 \pm 0.67^{*,a,b}$	$54.31 \pm 0.00^{*,a,b}$	$54.85 \pm 0.00^{*,a,b}$	42.20 ± 0.00	45-53
Free fatty acid (% oleic acid)	$8.913 \pm 0.01^{*,a,c,d,e}$	$8.653 \pm 0.00^{*,a,b}$	$8.703 \pm 0.00^{*,a,b}$	$8.606 \pm 0.01^{*,a,b}$	$2.806 \pm 0.00^{*}$	3.5
Saponification value (Mg KOH/g)	$229.103 \pm 0.00^{*,a,c,d,e}$	$215.307 \pm 0.01^{*,a,b,d}$	$220.813 \pm 0.01^{*,a,b,c}$	$219.087 \pm 0.01^{*,a,b}$	$190.01 \pm 0.01^{*}$	195-205
Unsaponifiable matter (g/Kg)	$11.91 \pm 0.01^{*,a,c,d,e}$	$10.537 \pm 0.01^{*,a,b,d,e}$	$10.277 \pm 0.00^{*,a,b,c,e}$	$8.737 \pm 0.01^{*,a,b,c,d}$	$0.41 \pm 0.01^{*}$	10
Specific gravity at 15°C	$0.898 \pm 0.00^{*,c}$	$0.9003 \pm 0.00^{*,a,b,e}$	$0.899 \pm 0.00^{*,a,d}$	$0.898 \pm 0.00^{*,a,c}$	$0.897 \pm 0.00^{*}$	0.897-0.907
Carotene value (Mg/Kg)	1036.541 ± 0.00^{a}	1040.1523 ± 0.00^{a}	1270.8337 ± 0.66^{a}	1450.2977 ± 0.00	$1868.026 \pm 0.00^{*}$	500-2000
Colour	$2.90R^{*,a,c,e}$	$3.00R^{*a,c,e}$	$2.90R^{*,a,c,e}$	$3.00R^{*,a,b}$	2.70R	2.5-3.0 Red
	$27.0Y^{*,a,c}$	$27.4Y^{*,a,b,d,e}$	$27.0Y^{*,a,c}$	$27.0Y^{*,a,c}$	26.8Y	26-28 Yellow
K_1=red palm oil samples from Kano; L_1=red palm oil samples from Lagos; A_1=red palm oil samples from Aba; C_1=red palm oil samples from Calabar.						
*=p<0.05 vs SON; a=p<0.05 vs Control; b=p<0.05 vs K_1; c=p<0.05 vs L_1; d=p<0.05 vs A_1; e=p<0.05 vs C_1						

Discussion

Levels of Sudan II dye in red oil samples

From Table 1, it was evident that Sudan II dye was predominantly used in the adulteration of red palm oil due to its red colour; the values ranged from 250.01 ± 9.27 to 350.00 ± 28.86 ppm in the various samples. The Standard Organization of Nigeria (SON) and the CODEX Alimentarius Commission specifications for edible red palm oil do not permit the use of this dye on any food products. Adulteration of red palm oil samples with Sudan II dye was observed in all samples with varying levels. This possibly suggests the endemic nature of this unwholesome practice. It could therefore be inferred that Sudan II dye was added deliberately to improve the colour of red palm oil samples. The palm fruit has carotenoids which are responsible for the bright orange red colour of the red palm oil. According to Abdallah, any factor which affects the carotene content of the fruit invariably influences the colour of the palm oil [11]. During lipid oxidation, hydroperoxides generated accelerate carotene oxidation resulting in bleaching and discolouration of the red palm which then breaks down the carotenoids and consequently deteriorates the brightly coloured red palm oil has exacerbated the increasing use of this dye.

Heavy metal levels

The concentration of lead (Pb) in this study was non-detectable in the palm oil samples. The non -detectable level of lead in the red palm oil samples indicated that the samples were free from toxicity associated with it. The result in this study is in line with the findings which reported the absence of lead (Pb) in red oil samples marketed in Yenegoa, Bayelsa State [12]. However, the result is in contrast to a lead level of 0.0225-0.038 ppm in red oil samples [13]. Lead is one of the elements that can be described as purely toxic. There is no exposure level below which lead appears to be safe [14].

High level of lead is particularly of great concern as it causes damage to all organs and systems and also reduces cognitive developments and intellectual performance in children. At low levels, haem synthesis and other biochemical processes have been reported to be affected by lead contamination [15].

According to Desideri et al. cadmium (Cd) is generally regarded as the most likely toxic metal to accumulate in the human food chain [16]. In this study, the concentrations of Cadmium in the palm oil samples were not detected. This result is an agreement with the findings reported a non-detectable level of Cadmium in palm oil samples sold in Yenogoa, Bayelsa state [12]. However, the result is in contrast with the findings of Dakiky et al. and Ngando et al. [17,18]. The oral component limit as stipulated by United States Pharmocopea (USP) is 0.5 ppm for Cadmium. Cadmium is known to exert adverse effect in brain metabolism and other severe effects such as prostate cancer, and could cause liver and kidney dysfunction [19]. The non-detectable level of cadmium in this study indicates that the palm oil samples were free from cadmium-associated toxicity.

Chromium (Cr) was also not detected in the red oil samples in this study. The oral component limit as stipulated by United State Pharmocopea (USP) is 25 ppm for chromium. The result is in contrast with the findings of [17], who reported chromium level of 0.021-0.033 ppm in the various samples. Chromium has been reported to damage the kidney, liver, and blood cells through oxidation reactions leading to haemolysis, renal and liver [20]. The non- detectable level of chromium in the red oil samples is indicative of the fact that the samples were free of chromium-associated toxicity.

Physicochemical parameters

The physicochemical parameters assessed in this study were the moisture content, peroxide value, iodine value, free fatty acid value, saponification value, unsaponifiable matter, specific gravity, carotene value and the colour (Table 3). The moisture content of red palm oil is a pertinent index used in assessing the quality of red palm oil. In this study, the moisture content level of red palm oil obtained from the different markets was significantly different (P<0.05) with the values ranging

from 0.26-0.35%. The values obtained from K_1 (red palm oil samples from Kano) and L_1 (red palm oil samples from Lagos) were slightly higher than the recommended standard of 0.25% for edible palm oil (CODEX). Water is an unusual component of oils and fats, as the two are non-miscible and the presence of water have proven to be harmful to oils and fat products [21]. Since water is a catalyst of almost all chemical degradation reactions, assessing the moisture content generally provide a good indication of the other quality parameters and could also help to forecast subsequent variation upon storage. The result is in agreement with the findings of [21] who reported a moisture content of 0.23-0.32% in red palm oil. However, Olurunfemi et al. reported moisture content of 0.7-0.2% in red palm oil samples marketed in Ibadan, also Okechalu et al. reported a moisture content of 1.09-1.275 in red palm oil samples [22,23]. The relatively high moisture content obtained in this study may be due to the heating duration of the palm oil fruit and the amount of water added during boiling processes. It may also be attributed partly to not sufficiently boiling of the extracted oil and poor clarification process before packaging. According to Orji et al. the moisture content of palm oil is dependent directly on the efficiency of the final extraction and clarification processes [24]. The results obtained in this study indicates that the moisture content falls below the CODEX, SON and NIS standards (0.25%) for edible red palm oil respectively. Thus, making the red palm oil offered for sale of poor quality.

The peroxide value obtained from this study was significantly ($P<0.05$) different and the values ranged from 7.82-9.30 meq/Kg. The values obtained in this study were less than the 10 meq/Kg of standard specified by CODEX. The result is in agreement with the findings of Agbaire, who reported a peroxide value of 7.80-8.40 meq/Kg in some red palm oil samples [25]. Aletor et al. reported a peroxide value of 1.48-5.71 meq/Kg while Matthaus reported a peroxide value of 5.6 meq/Kg [26,27]. However, the results are contrary to the findings of Madubuike et al. who reported a peroxide value of 23.2-35.5 meq/Kg in red palm oil samples [28]. The peroxide value obtained in this study is quite below the CODEX standard. However, the relatively high peroxide value recorded could indicate the onset of primary oxidation due to lipid degrading enzymes like peroxidase and lipoxygenase. Peroxide value is used to assess the quality of red palm oil through the measurement of the amount of lipid peroxides and hydroperoxides formed during the initial stages of the oxidative degradation and hence, it estimates the extent to which spoilage of the oil has advanced. Peroxide value may indicate an early onset of rancidity. According to Udensi et al. peroxidation is a very dynamic process and the amount of peroxides might change considerably within a short period of time in favourable conditions such as presence of oxygen, sunlight, high moisture content and metallic ions [29].

Iodine value is a measure of the level of unsaturation in oils. The iodine value obtained in this study ranged from 53.87-58.15 wijs and the iodine values were significantly ($P<0.05$) different comparing the mean values from the different market samples. The iodine values obtained in this study was comparable with the findings of Atinafu et al. who reported an iodine value of 52.55-53.66 wijs in red palm oil samples sold in Delta state and Tagoe et al. who reported an iodine value of 52.46-53.42 wijs in palm oil samples sold in Enugu [28,30]. The values were higher in those obtained by Orji & Mbata [24]. The iodine values obtained in this study was higher than the CODEX recommended standard. The high iodine values in this study may be suggestive of some level of deterioration. It may also suggest high level of unsaturated sigma bonds in the palm oil samples and the potential susceptibility of the palm oil samples to oxidative rancidity.

The Free Fatty Acid (FFA) in this study ranged from 8.606-8.913% and there was significant ($P<0.05$) difference among the mean values from the different markets. The result was higher than the 2.73-2.89% in red palm oil samples in Abia State and 2.67-4.20% in red palm oil samples sold in Jos metropolis [23,29]. Free fatty acids value is a useful index for examining the quality of red palm oil and it must not exceed 5% expressed as oleic or palmitic acid [30].

The free fatty acid values obtained in this study was far higher than the CODEX, SON and NIS standard (3.5%) respectively for edible red palm oil. The high free fatty acid value in this study may be due to the hydrolytic action of lipase which may have been accelerated by the exposure of the red palm oil to oxidizing environment (heat and sunlight). According to Muhammed et al. free fatty acids can be generated by lipases from contaminating microorganisms [31]. Ayoade et al. opined that high free fatty acid can be caused by over-ripped fruits, microbial infestation and the length of storage. Thus, the result obtained in this study indicated that the red palm oil offered for sale in Nigeria is of poor quality.

Saponification value is an indication of the molecular weights of the triglycerides of oils. It is also a useful index used in benchmarking and thus poor quality oil. The saponification value obtained in this study ranged from 215.307-229.103 mg KOH/Kg and there was a significant ($P<0.05$) difference among the mean values from the different market samples. The saponification value obtained in this study exceeded the recommended permissible limit of 195-205 mg KOH/Kg by regulatory body [30]. The result obtained in this study is in agreement with the findings of Agbaire, who reported a value of 218.3-242.7 mgKOH/Kg in red palm oil samples [32]. However, the result is in contrast with the findings of Udensi et al. who reported a value of 1.97.75-204.30 mgKOH/Kg in red palm oil samples marketed in some parts of Anambra state of Nigeria [33]. Akubor et al. also reported similar findings of high saponification values [34]. The high saponification values obtained in this study may indicate high proportion of low fatty acid, since saponification value is inversely proportional to the average molecular weight [35]. Hence, it is suggestive that red palm oil samples may be suitable for edible purposes.

The Unsaponifiable Matter (USM) is defined as the oily (petroleum-ether soluble) which cannot be converted into soap after saponification. In this study, the unsaponifiable matter ranged from 8.737-11.91 g/Kg, with significant ($P<0.05$) differences among samples. The values of unsaponifiable matter obtained in this study was higher than the value of 7.40-7.80 g/Kg and value of 7.66-7.82 g/Kg respectively

[25,28]. In this study, samples of K_1 (red palm oil samples from Kano), L_1 (red palm oil samples from Lagos) and A_1 (red palm oil samples from Aba) showed values higher than the recommended CODEX, SON and NIS standard of 10 g/Kg. The high value of the unsaponifiable matter may indicate adulteration concerns.

The specific gravity value obtained in this study ranged from 0.898-0.9003, with significant ($P<0.05$) difference in the mean values among the samples. The value obtained is in agreement with the value of 0.820-0.896 and value of 0.859-0.885, respectively [25,28]. However, the values are in contrast with the findings of Idoko et al. who reported a value of 0.9516 in crude oil of African canarium [36]. The values obtained in this study are within the permissible limit of 0.897-0.907, set by regulatory body [30].

The carotene value in this study ranged from 1036.541-1450.297 mg/Kg with significant ($P<0.05$) difference in the mean values among samples. Carotene values obtained in this study were within the recommended range of 500-2000 mg/Kg set by CODEX [30]. The level of carotene in this study is comparable to the carotene value of 1273-1568.77 mg/Kg in red palm oil samples in Delta State of Nigeria, and value of 1380.20-1620.64 mg/Kg a carotene value of 1274.4-1882 mg/Kg [25,28-29]. The result of the carotene value in this study is within the permissible limit established by regulatory body [30].

Conclusion

The high levels of the Sudan II dye in the red palm oil samples vended in selected markets across Nigeria as seen in this study, is indicative of the bad quality of the oils. The results of the assessment of the quality indicates that the moisture content, peroxide value, saponification value, free fatty acid value, unsaponifiable matter value of red palm oil samples on sale in selected Nigerian markets were not within the recommended CODEX and SON standards. This in turn indicates inadequate surveillance and testing protocols by the Nigerian Regulatory Institutions.

Therefore, there is a need for efficient and effective monitoring of palm oil quality across the country, as poor quality palm oils could have adverse health effects.

Author's contribution

Peter Henry contributed to the methodology, laboratory analyses and data collection. Aniekan Henshaw contributed to the writing of the paper. Christene Ikpeme and Ima-obong Williams contributed to the conceptualization of the research, validation and supervision of the research. All authors read and approved the final manuscript.

Funding Information

This research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors.

Conflict of Interest

The authors declare no conflict of interest.

Data Availability

All data generated or analyzed during this study are included in this published article.

Acknowledgements

The authors wish to express their profound gratitude to the Department of Biochemistry, University of Calabar for granting permission to use the laboratory.

References

1. Senthilkumar KL. Evaluation of Dabur Refined Coconut Oil in Comparison with Untraded Oil. J Curre Res in Ayurvedic Pharmaceut Scie. 2011;24:2(2).
2. Sambanthamurthi R, Sundram K, Tan Y. Chemistry and biochemistry of palm oil. Progress in lipid research. 2000;39(6):507-58.
3. Ohimain EI, Daokoru-Olukole C, Izah SC, et al. Assessment of the quality of crude palm oil produced by smallholder processors in Rivers State, Nigeria. Nigerian Journal of Agriculture, Food & Environ. 2012;8(2):28-34.
4. Moore JC, Lipp M, Griffiths J. Preventing the adulteration of food protein. Food Technol (Chicago). 2011;65(2).
5. Ferner DJ. Heavy metal toxicity in palm oil samples. Academic J. 2001;6:255-60.
6. Ogabiela EE, Okonkwo EM, Agbaji AS, et al. Trace metal level of human blood from Dareta Village, Anka, Nigeria. Glob J Pure Appl. 2011;17(2):183-88.
7. Genualdi S, MacMahon S, Robbins K, et al. (2016). Method development and survey of Sudan I–IV in palm oil and chilli spices in the Washington, DC, area. Food Addit Contam. 33(4):583-91.
8. Corley RHV, Tinker PB. Ripening, harvesting and oil extraction. The Planter, 2003;77:507-24.
9. Izah SC. Evaluation of selected heavy metals in palm oil sold in some markets in Yenagoa Metropolis, Bayelsa State, Nigeria. EC Nutrition. 2017;11:244-52.
10. Oguntibeju OO, Esterhuyse AJ, Truter EJ. Possible role of red palm oil supplementation in reducing oxidative stress in HIV/AIDS and TB patients: A Review. J Med Plants Res. 2010 Feb 4;4(3):188-96.
11. Abdallah MI. Evaluation of some heavy metal residues in whole milk powder used at confectionery plants regarding their public health significance. J Egypt Vet Med Assoc. 2011;5:1-5.
12. Tong S, Schirnding YE, Prapamontol T. Environmental lead exposure: a public health problem of global dimensions. Bulletin of the world health organization. 2000;78(9):1068-77.
13. Johannesson M. A review of risk associated to Cadmuim, Lead, Mercury and Zinc. Int J Phy Sci. 2000;2:1198-203.
14. Adepoju-Bello AA, Osagiede SA, Oguntibeju OO. Evaluation of the concentration of some toxic metals in dietary red palm oil. J Bioanal Biomed. 2012;4:92-5.
15. Nnorom IC, Alagbaoso JE, Amaechi UH, et al. Determination of beneficial and toxic metals in fresh palm oil (Elaeis guineensis Jacq.) from south-eastern Nigeria: Estimation of dietary intake benefits and risks. J Sci Res Rep. 2014;3(16):2216-26.
16. Desideri D, Meli MA, Cantaluppi C, et al. Essential and toxic elements in meat of wild and bred animals. Toxicol Environ Chem. 2012;94(10):1995-2005.
17. Dakiky M, Khamis M, Manassra A, et al. Selective adsorption of chromium (VI) in industrial wastewater using low-cost abundantly available adsorbents. Adv Environ Res. 2002 Oct 1;6(4):533-40.
18. Albert MM, Laverdure DE, Paul K. Assessment of the quality of crude palm oil from smallholders in Cameroon. J Stored Products Postharvest Res. 2011;2(3):52-8.
19. Olorunfemi MF, Oyebanji AO, Awoite TM, et al. Quality assessment of palm oil on sale in major markets of Ibadan, Nigeria. Int J Food Res. 2014;1:8-15.
20. Okechalu JN, Dashen MM, Lar PM, et al. Microbiological quality and chemical characteristics of palm oil sold within Jos Metropolis, Plateau State, Nigeria. J Micro Tech Res. 2011;1:107-12.
21. Orji MA, Mbata TI. Effects of extraction methods on the quality and spoilage of Nigerian palm oil. Afr J Biochem Res. 2008;2(9):192-96.

22. Agbaire PO. Quality assessment of palm oil sold in some major markets in Delta State, Southern Nigeria. Afr J Food Sci Tech. 2012;3: 223-26.

23. Aletor VA, Ikhena GA, Egharevba V, et al. The quality of some locally processed Nigerian palm oil: An estimation of some critical variables. J Food Chem. 1990;36(4):311-17.

24. Matthaus B. Use of palm oil for frying in comparison with other high stability oils. Eur J Lipid Sci Technol. 2007;109(4):400-09.

25. Madubuike PC, Ezigbo IJ, Ekpe IO, et al. Evaluation of the quality and level of adulteration of palm oil obtained from different locations in Enugu Metropolis, Nigeria. Int J Multidiscip Sci Engineer. 2015;6(6):216-17.

26. Udensi EA, Iroegbu FC. Quality assessment of palm oil sold in major markets in Abia State, Nigeria. J Agrosci. 2007;6(2):25-7.

27. Houria A, Comeau L, Deyris V, et al. Isolation and characterization of an extra-cellular lipase from Mucor specie strain isolated from palm fruit. Enzyme Microb Technol. 2002;31(7):968-75.

28. Tagoe SMA, Dickinson MJ, Apetorgbor MM. Factors influencing quality of palm oil produced at the cottage industry level in Ghana. Int Food Res J. 2017;19(1):271-78.

29. Okonkwo SI, Ogbuneke RU. Assesment of level of adulteration in palm oil within Ihiala Local Government Area of Anambra State of Nigeria. J Baic Phys Res. 2010;1(1):13-6.

30. Atinafu DG, Bedemo B. Estimation of total free fatty acid and cholesterol content in some commercial edible oils in Ethiopia. J Cereals Oil Seeds. 2011;2(5):71-6.

31. Muhammed N, Bamishaiye E, Bamishaiye O, et al. Physicochemical properties and fatty acid composition of Cyperus esculentus (Tiger Nut). Tuber Oil Bioresearch Bulletin. 2011;5:1-54.

32. Ayoade GW, Amoo IA, Gbolahan-Ayoade EE, et al. Phytochemical composition and Antioxidative potential of purple canary (Canarium schweinfurthii) fruit. Pharm Innov J. 2015;4(1):49-52.

33. Udensi EA, Iroegbu FC. Quality assessment of palm oil sold in major markets in Abia State, Nigeria. Agro-Science. 2007;6(2):25-7.

34. Akubor P, Ogu GI. Quality attributes of fresh palm oils produced from selected communities around Anyigba, Kogi State, Nigeria. Niger J Nutr Sci. 2012;33(1):12-7.

35. Chinedu EE, Ebere EC, Emeka AC. Quality assessment of palm oil from different palm oil local factories in Imo State, Nigeria. World Scientific News. 2017;88:152-67.

36. Idoko O, Emmanuel SA, Salau AA, et al. Quality assessment on some soaps sold in Nigeria. Nigerian J Technol. 2018;37:1137-40.

Citation: *Henshaw AS, Williams IO, Peters HE, et al. Quality assessment of palm oils from selected Nigerian markets. J Food Sci Nutr. 2022;5(3):113*