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Determination of Beneficial and Toxic Metals in Fresh Palm Oil (*Elaeis guineensis* Jacq.) from South-Eastern Nigeria: Estimation of Dietary Intake Benefits and Risks

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Authors' contributions

This work was carried out in collaboration between all authors. Author ICN designed the study, wrote the protocol and the first draft of the manuscript. Authors ICN and UE managed the literature searches, while authors JEA, UHA and CK managed the experimental process and performed the spectroscopic analysis. Author UE performed the statistical analysis and revised the first draft of the manuscript. Author ICN identified the species of plant. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

The aim of this study was to determine the levels of twelve elements (Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Na, Ni Pb and Zn) in samples of palm oil (*Elaeis guineensis* Jacq.) from eight (8) towns in Abia State, South-eastern Nigeria. Samples were collected from markets in 8 towns in January, 2013. A total of 32 samples (four samples from each town) were purchased and analyzed using flame atomic absorption spectrophotometer after acid digestion. Analysis of standard reference material as well as metal recovery study was used to validate the analytical method. Data obtained were used to estimate the daily intake of metals from the consumption of about 10 g of palm oil. The range of the results obtained for the beneficial elements (mg/kg) were: Mg (69–192), Ca (145–686), Mn (6.55-12.05), K (77–165), Na (115–533), Zn (3.6–14.6), Fe (65–232), Cu (0.56-2.09) and Cr (0.101-0.298), while values for toxic metals determined were Pb (0.024-0.067), Cd (0.024-0.089), and Ni (0.15-0.81). The results of this study have shown that palm oil will

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contribute to dietary intake of Zn, Mn, Fe, Cu, Ca, Cr, K, and Na; and that the levels of toxic metals Pb and Cd were low. Comparison of results with literature, and levels set by regulatory authorities indicate that the consumption of palm oil does not pose toxicological risk (from Pb and Cd) to consumers.

Keywords: Palm oil; heavy metals; trace elements; Nigeria; dietary intake.

1. INTRODUCTION

The oil palm *(Elaeis guineensis* Jacq.) is indigenous to West Africa (though now planted in all tropical areas of the world) and the fruits grow in bunches weighing up to 10-40 kg and containing hundreds of fruitlets, like small plums with the fleshy mesocarp enclosing a kernel that is covered by a hard shell [1,2]. Nigeria is among the leading producers of palm oil and the palm oil industry is a major agro based enterprise in Nigeria, especially in the southern part where palm trees are found both in the wild and in plantations [3]. Palm oil, an edible vegetable oil that is naturally reddish in colour because of high beta-carotene content (a precursor of vitamin A) is derived from the mesocarp of the palm fruit [1]. Each fruit consists of a single seed (the palm kernel) which is surrounded by a soft oily pulp [2]. The oil from the flesh of the fruitlets can be recovered by very simple means such that some authors are of the opinion that: ‘it is probable that palm oil has been recovered and used for human food for tens of thousands of years’ [1].

The oil palm tree provides employments for millions in Nigeria in the formal and informal sectors [3]. In the informal sector, most youths earn their living through cutting of palm fruits for clients, as well as making local baskets and trays; older men and women engage in palm wine tapping and making brooms for sale respectively. Several industrial uses of palm oil have led to the creation of more jobs for the populace. In the food industry, palm oil is used as cooking oil. Due to its high resistance to oxidation and consequent long shelf life, it is suitable for use in hot climates as frying fat in the snack and fast food industry.

Palm kernel cake (PKC) and palm kernel oil (PKO) are produced from palm kernel and are used in many industrial manufacturing activities including the manufacture of margarine, compound cooking fats, soap, candles, cosmetics, confectionery and as a lubricant in tin plating. Palm kernel cake, a by-product from the extraction of palm kernel oil, contains about 20% protein and is widely used as livestock feed [3,4].

Human exposures to toxic elements occur through a variety of routes, including the consumption of contaminated foods and water as well as through the inhalation of air pollutants. For individuals that are not exposed at workplace, the most likely source of trace elements intake is the diet. Food composition data is very important in estimating the intakes of essential nutrients as well as exposure risks from intake of toxic non-essential heavy metals. Consequently, studies of food composition especially the trace metal contents is important [5].

Several studies have investigated the levels of metals in different types of edible vegetable oil [5-13]. However, only few of these studies have focused on palm oil [14-17]. Matos Reyes and coworker observed that for vegetable oils, the trace metal composition is an important criterion for the assessment of the quality since it has been shown that trace metals affect their rate of oxidation, influencing freshness, keeping properties as well as storage [5]. Several methodologies and instrumentations have been used in the study of metal contents of edible oils. For instance, Cypriano and co-workers employed ultrasound-assisted treatment on palm oil and determined Cu and Pb by stripping chronopotentiometry and graphite furnace atomic absorption spectrophotometry [15]. However, the present study made use of flame atomic absorption spectrophotometry after acid digestion.

Elements such as sodium, potassium, copper, zinc, iron, magnesium and manganese play important roles in human biological systems and are therefore considered essential elements. However excessive intake of these elements above threshold limits can also result in harmful effects including morphological abnormalities, reduce growth and increase mortality and mutagenic effects in humans [18]. Metals such as cadmium and lead are well known for their toxic effects especially above certain thresholds. There is a dearth of data on the levels of minerals as well as toxic elements in edible palm oil consumed in Nigeria [14,15]. This study therefore, assesses the levels of twelve (12) elements (Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, and Zn) in Palm oil (*Elaeis guineensis* Jacq.) consumed in South-eastern Nigeria.

2. MATERIALS AND METHODS

2.1 Sampling

Fresh palm oil (*Elaeis guineensis* Jacq.) samples displayed for sale were purchased from eight (8) towns (Isuikwuato, Omoba, Uzuakoli, Umuahia, Umugo, Ubakala, Umudike, Ntigha) in Abia State, Southeastern Nigeria in January 2013. Four samples were collected for each town (a total of 32 samples) and used in this study.

2.2 Sample Analysis

All samples were analyzed as purchased without any further pre-treatment. 1 g 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 20 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 digests were subsequently analyzed for Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb and Zn using Phoenix 986 (Biotech Engineering Management Co. Ltd. UK) flame atomic absorption spectrophotometer.

2.3 Quality Assurance

Adequate quality assurance procedures and precautions were carried out to guarantee the reliability of the results of the present study. All chemicals used were of analytical grade: $HClO_4$ (70%, Sigma-Aldrich, St. Louis, USA), H_2SO_4 (98%, BDH Laboratory Supplies, Poole, England); HNO_3 (69%, BDH Laboratory Supplies, Poole, England). All plastics and glassware were carefully cleaned by washing, rinsing severally with tap water, and then soaking in 5% HNO_3 solution for a minimum of 24 h to eliminate the risk of contamination during the experiments. Before use, they were rinsed severally with deionized water before use. Blanks were inserted at 10%. The accuracy of the analytical method was verified by analyzing a certified reference material (Accu Standards, New Haven Connecticut, USA). Spike recovery studies were also conducted on some of the samples. Detection limit was defined as the concentration corresponding to three times the standard deviation of seven blanks. Recoveries for the CRM varied from 97.0 – 101.6% and for the spiking study, from 93.6 – 99.7% (Tables 1 and 2 respectively).

Table 1. Metals concentration of certified reference material (Accu standards, USA)

Elements	Certified value (mg/L)	Measured value (mg/L)[a]	Recovery (%)
Ca	4.67±0.58	4.61±0.55	99.1
Cd	0.188±0.089	0.191±0.091	101.6
Cu	0.188±0.088	0.187±0.089	99.5
K	3.10±0.10	3.02±0.15	97.4
Na	1.67±0.58	1.62±0.55	97.0
Ni	0.189±0.091	0.187±0.089	98.9
Zn	0.188±0.081	0.186±0.075	98.9

[a] *Mean ± standard deviation (n= 3)*

Table 2. Recovery study of selected metals

Elements	Spiked concentration (mg/kg)	Recovered concentration (mg/kg)[a]	Recovery (%)
Ca	380.8±69.4	379.7±68.9	99.7
Cd	0.060±0.010	0.058±0.020	96.7
Cr	0.171±0.020	0.160±0.030	93.6
Fe	147.9±9.9	146.8±1.0	99.3
K	128.9±5.7	128.3±6.1	99.5
Mn	9.29±0.90	9.24±0.91	99.5
Na	243.9±19.8	243.2±20.1	99.7
Ni	0.189±0.091	0.187±0.089	98.9

[a] *Mean ± standard deviation (n= 3)*

2.4 Statistical Analysis and Estimation of Metal Intakes from Palm Oil

Statistical analysis of data was treated using SPSS 16.0 and Excel 2007 statistical package programs. One-way ANOVA was employed with significance set at .05. Also, two–tailed correlation analyses of elements determined and the sampling sites were also conducted. Literature indicates that the current palm oil consumption in France is estimated at 5.5 g per person per day, and that a person with a daily energy need of 2000 kilocalories is recommended to not exceed about 20 g of saturated fats per day. [http://www.eufic.org/page/en/page/FAQ/faqid/question-answer-palm-oil/]. Consequently, in estimating metal intakes from the consumption of palm oil in south-eastern Nigeria, a consumption rate of palm oil in meals per day was assumed to be between 5 and 10 g. The recommended average daily intakes of some elements (mg per day) are Ca, 1000; Cu, 2; Fe, 18; K, 1000; Mg, 400; Mn, 2; Na 2400 and Zn, 15 mg per day [19].

3. RESULTS AND DISCUSSION

3.1 Elemental Concentrations of Palm Oil and Metal Intake

The concentration of metals in palm oils should be one of the important criteria in the assessment of oil qualities with regard to their influence on palm oil freshness and storage as well as on human nutrition and health on consumption. The elemental content of palm oil samples according to areas studied is presented in Table 3. The Na concentration ranged from 115 to 533 mg/kg. The highest mean sodium concentration of 254±188 mg/kg was found in samples from Isuikwuato, while the lowest concentration of 178±45 mg/kg was found in samples from Omoba. Na is necessary 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 of the kidneys and increase in the possibilities of hypertension [20]. There are no dangers of excess intake of Na as the consumption of 5-10g/day of palm oil will expose a consumer to less than 6 mgNa/day.

Potassium content of palm oil samples from all the areas ranged from 77 to 165 mg/kg (overall mean: 115±21 mg/kg). Mean K content of most sites were found to be within 113-119 mg/kg, except for samples from Omoba (108 mg/kg) and Ntigha (121 mg/kg) (Table 3). The mean values varied from 108±28 mg/kg (Omoba) to 121±18 mg/kg (Ntigha). K has been described as being vital for disease prevention and control; it is an essential electrolyte for maintaining normal fluid balance in cells and a delicate balance of this element is reported to prevent an increase in blood pressure and maintain normal cardiac rhythm [21]. Daily intake of K from palm oil is estimated at between 0.39 and 1.65 mg/day which is very low compared to the recommended K intake of 1000 mg/day.

The mean Mg concentration ranged from 97±18 mg/kg for samples from Omoba to 146±35 mg/kg for samples from Umudike. The overall mean concentration is 123±28 mg/kg (Range: 69-192 mg/kg). The importance of Mg has been revealed in its function in the skeleton as well as in muscles and soft tissues, such as a co-factor of many enzymes involved in energy metabolism, protein synthesis, RNA and DNA synthesis, and maintenance of the electrical potential of nerve tissues and cell membranes [20]. However, it should be noted that magnesium dietary deficiency, which is sufficient to induce pathologic changes, is rare [22]. The recommended daily intake of Mg is 400 mg/day. Considering the range of this study, the intake of Mg is estimated at between 0.35-0.96 and 0.69- 1.9 mg per day for the consumption of 5g and 10 g of palm oil in a meal per day.

The results showed that the highest mean Ca concentration of 414±333 mg/kg (range: 131-867 mg/kg) was for samples from Uzuakoli while the lowest mean concentration of 237±62 mg/kg was for samples from Omoba. Ca, amongst the macro elements determined showed the highest overall mean concentration (339±166 mg/kg; range 145-686) followed by Na (195±74 mg/kg), Mg (123±28 mg/kg) and then K (115±21 mg/kg) (Table 3). Ca plays essential role in neuromuscular function, many enzyme-mediated processes, blood clotting, and providing rigidity to the skeleton via phosphate salts [20]. Daily intake of Ca from palm oil is estimated at 0.73-3.43 and 1.45-6.86 mg per day for the consumption of 5g and 10g of fresh palm oil in meals and this is far below the recommended intake of 1000 mgCa/day.

The results of this research have shown that palm oil contains lead and copper at very low concentrations (Table 3). The Pb concentrations (overall mean, 0.039±0.011; range, 0.024-0.067 mg/kg) of this study were below the values reported by Cypriano et al. [15] (ND-1.82±0.01 µg/g (mg/kg) and ND-1.90±0.03 mg/kg). Adepoju-Bello et al. [14] reported a Pb concentration of 0.0225-0.038mg/kg in palm oil bought from several markets in Lagos, Nigeria and this result compares well with the results of this study. Lead accumulates and substitute's calcium in bone tissues and the resultant effect is disruption of mineralization, alteration of compositional properties and bone formation mechanisms, as well as the gradual depletion of bone minerals [23-25]. The Codex Standard for Named Vegetable Oils (210-1999) refers to lead and arsenic and the Codex Standard for Contaminants and Toxins in Food and Feed (193/1995, amended 2010) gives maximum levels of lead and arsenic of

0.1 mg/kg in crude and edible oils of palm and palm kernel including palm olein, stearin and superolein [26] Similarly, the EU limit for Pb contamination of fats and oils including milk fat is 0.10mg/kg [27].

The overall mean Cd concentration in the palm oil samples studied was 0.064±0.020 mg/kg (data ranging from 0.024 to 0.089 mg/kg) with mean values for the various sites varying from 0.061±0.022 mg/kg (Umudike) to 0.068±0.024 mg/kg (Omoba). Adepoju-Bello et al. [14] reported a Cd concentration of 0.025-0.065 mg/kg which compares well with the results of this study. Cd is known to exert adverse effects on brain metabolism and other severe effects such as prostate cancer, and could also cause kidney, liver, lungs, and bone damage [21]. There is no European Standard for Cd in fats and oil, however, the limit for soybean is 0.2mg/kg [27].

The mean Fe concentration ranged from 105±27 mg/kg to 151±61 mg/kg for Isuikwuato and Omoba respectively with the individual concentrations ranging from 65-232 mg/kg. It has been recognized that adequate Fe in a diet is very imperative for diminishing the incidence of anemia [28]. The recommended Fe intake is 18 mg/day. Daily intake from palm oil is estimated at 0.33-1.16 and 0.65-2.32 mg/day on consumption of 5-10 g of palm oil in meals per day.

Cu in the samples investigated ranged from 0.56 to 2.09 mg/kg with mean values varying from 1.00±0.26 mg/kg for Omoba to 1.34±0.52 mg/kg Ubakala. Considering the highest Cu content of this study, the daily intake of Cu from consumption of 10 g of palm oil is about 1% (0.0209 mg/day) of the recommended daily intake of 2 mg/day. The Cu concentration of this research (overall mean 1.22±0.42 mg/kg; range: 0.56-2.09 mg/kg) compares well with the Cu content obtained by Cypriano and co-workers (ND - 2.67±0.04 and ND-2.55±0.06) [15].

Trivalent chromium is an essential nutrient for man as it is involved in the glucose tolerance [20]. Adequate chromium nutrition may reduce risk factors associated with cardiovascular disease as well as diabetes mellitus, though hexavalent chromium is, in contrast, very toxic [29]. The overall mean concentration of Cr in samples from all towns investigated is 0.176±0.048 mg/kg (range 0.101-0.298 mg/kg) and this is higher than the values reported by Adepoju-Bello et al. (0.021-0.033 mg/kg) [14].

Mean Mn concentrations ranged from 8.09±1.53 mg/kg for samples from Isuikwuato to 10.5±1.26 mg/kg for samples from Umugo (overall mean concentration of 9.18±1.60 mg/kg; range: 6.55-12.05 mg/kg). Zhu and co-workers have identified that the deficiency of manganese can result in severe skeletal and reproductive abnormalities in mammals while high doses of manganese produce adverse effects primarily on the lungs and on the brain [13]. Considering the highest Mn content of this study (12.1 mg/kg) the daily intake from 5-10 g of palm oil will be between 3-6% (0.06-0.12 mg) of the recommended 2 mg/day.

The overall mean Zn and Ni concentrations off this study are 8.4±2.5 mg/kg (range: 3.6-14.6 mg/kg) and 0.25±0.12 mg/kg (range: 0.15-0.81 mg/kg) respectively. Adepoju-Bello et al. reported a Ni concentration of 0.0435-0.068 mg/kg which is lower than the results of this study [14]. The Draft East African Standard for Edible palm oil set the maximum limit of Pb, As and Ni in edible palm oil at 0.1mg/kg [30]. Zn plays essential roles as metalloenzymes and as a cofactor of large number of enzymes [31]. More so, Zhu et al. [13] and Spears et al. [32] have confirmed that nickel toxicity at elevated level is more prominent, but trace amounts may be beneficial as an activator of some enzyme systems. The recommended daily intake of Zn is 15 mg per day and the consumption of 5-10mg of palm oil per day will amount to an intake of 0.018-0.073 and 0.036-0.146 mg/day considering the range of Zn in palm oil of this study (3.6-14.6 mg/kg).

Umar (2004) studied four Nigerian vegetable based oils (palm oil, palm kernel oil, sheabutter and groundnut oil) and reported concentration ranges of 19.4–44.0µg/g for Al; 30.0–81.0 µg/g for Ca; 11.9–60.4 µg/g for Cl; 1.43–5.96 µg/g for Cu; 7.3–28.1 µg/g for Mg; 0.47–1.69 µg/g for Mn; 17.5–72.8 µg/g for Na and 0.04–0.07µg/g for V [11]. Though our results for elements studied were mostly above the results of Umar, their daily intakes were adequate and pose no toxicological health concern.

3.2 Influence of Sampling Areas on Metals Content of Samples

Results of the one-way ANOVA indicated that sampling areas did not significantly influence the elements content of palm oil. The P-value indicates how likely it is that the F-ratio of at least that size will occur if there are no differences among the means. The significance was set at α = .05. Thus, for P-value less than α, the null hypothesis was rejected and concluded that at least a sampling site must have influenced the level of metals; whereas for P-value greater than α, conclusion was reached that there was no significant difference in the mean metals concentration with respect to sampling sites.

Based on the above assumptions, it was observed that the entire elements studied were not influenced by sampling sites. For instance, the mean of Cd did not differ significantly with sampling sites having $F(7, 24)$ = .059 and P= 1.000. For the macro elements, the $F(7,24)$ and P-values of K, Na and Ca are .116, .997; .406, .889 and .520, .811 respectively. Among the micro essential elements, Cu with $F(7,24)$ = .237 and P = .972; Zn with $F(7,24)$ = .502 and P-value = .823; Fe with $F(7,24)$ = .409 and P-value = .887, all proved that their means were not significantly influenced by sampling sites.

3.3 Relationship between Metals

The results of the correlation analyses indicated that strong positive correlation, which is significant at P = .05 level exists among some metals in samples from all areas studied, than at P = .01 level. The only metal pair that showed significant correlation for samples from Isuikwuato were Mg and Ca with r = .95 at P = .05. Significant positive correlation exist for Ni-Cr (r = .96) and Zn-Ca (r = .98) respectively at P = .05 in samples from Omoba. The only positively correlated metals in samples from Uzuakoli were Ni and Cr with r = .93; the others were negatively correlated and include: Ni-Pb (r = -.98) and Zn-Mg (-.96). In samples from Umugo, Zn-Na (r = .98) and Na-Cd (r = -.99) correlation were significant at P = .05; while Zn-Cd (r = -.99) correlation was significant at P = .01. Mg-Pb (r = -.98) correlation was significant at P = .05 for samples from Umuahia. For palm oil samples from Ubakala, the significant correlation at P = .05 for the following metal pairs: Pb-Ca (r = .98), Mg-Cd (r = -.98) and Na-Cd (-.95).

Some metals are also significantly correlated for Ntigha samples. For P =.05, the correlated metals are: Fe-Cu (r = .96), Na-K (r = .98), Zn-Na (r = .97), Na-K (r = .98) and Na-Mg (r = .97); while only K-Mg (r = .999) are correlated at P = .01. For the Umudike site, the data showed that some of the metals were significantly correlated both positively and negatively at P = .05 or .01. For instance, Pb-Cr (r = .99), Ni-Mn (r = -.95), Mn-Fe (r = .995) and Na-K (r = .97) correlated significantly at P = .05, while at P = .01, only K-Mn (r = -.996) correlated significantly.

Table 3. Metal concentration (mg/kg) of palm oil from areas in Southeastern Nigeria

	Uturu	Omoba	Uzuakoli	Umuahia	Umugo	Ubakala	Ntigha	Umudike	Combined (n=32)
Cd	0.065±0.023	0.068±0.024	0.062±0.025	0.066±0.013	0.062±0.026	0.063±0.024	0.067±0.022	0.061±0.022	0.064±0.020
	0.038-0.094*	0.047-0.092	0.029-0.087	0.055-0.084	0.024-0.081	0.031-0.085	0.037-0.089	0.028-0.078	0.024-0.089
Ca	311±106	237±62	414±333	392±197	358±95	408±241	297±30	298±118	339±166
	183-439	164-316	131-867	277-686	230-430	221-762	259-325	149-420	145-686
Cr	0.168±0.045	0.198±0.010	0.210±0.051	0.178±0.022	0.155±0.046	0.174±0.018	0.172±0.044	0.155±0.034	0.176±0.048
	0.136-0.234	0.101-0.298	0.157-0.277	0.149-0.202	0.119-0.221	0.156-0.198	0.115-0.214	0.111-0.189	0.101-0.298
Cu	1.15±0.43	1.00±0.26	1.17±0.44	1.22±0.59	1.29±0.51	1.34±0.52	1.33±0.53	1.23±0.31	1.22±0.42
	0.56-1.56	0.61-1.18	0.60-1.66	0.64-2.04	1.13-2.04	0.79-1.95	0.96-2.09	0.99-1.66	0.56-2.09
Fe	105±27	151±61	136±42	122±40	136±26	133±47	124±41	131±40	130±39
	74-131	88-232	91-189	65-156	100-159	74-189	100-185	78-166	65-232
Pb	0.043±0.016	0.037±0.013	0.043±0.013	0.033±0.008	0.037±0.013	0.041±0.018	0.039±0.004	0.042±0.001	0.039±0.011
	0.028-0.065	0.024-0.054	0.031-0.059	0.026-0.044	0.024-0.054	0.028-0.067	0.034-0.042	0.030-0.050	0.024-0.067
Mg	104±25	97±18	139±34	121±14	132±34	123±30	119±8	146±35	123±28
	69-129	77-120	93-168	102-134	89-172	94-159	109-129	106-192	69-192
Mn	8.09±1.53	8.55±1.42	8.66±0.92	9.92±2.17	10.50±1.26	9.98±1.34	8.74±1.87	9.04±1.75	9.18±1.60
	6.7-9.6	7.02-10.45	7.99-10.01	7.18-11.66	9.00-12.05	8.66-11.14	7.60-11.50	6.55-10.55	6.55-12.05
Ni	0.23±0.06	0.26±0.08	0.25±0.06	0.25±0.08	0.19±0.04	0.21±0.01	0.22±0.06	0.39±0.29	0.25±0.12
	0.17-0.30	0.18-0.35	0.18-0.31	0.19-0.36	0.16-0.24	0.19-0.22	0.15-0.30	0.26-0.81	0.15-0.81
K	113±9	108±28	119±38	115±30	114±21	115±22	121±18	117±11	115±21
	99-120	77-144	79-165	77-148	100-145	89-140	100-144	108-133	77-165
Na	254±188	178±45	179±36	190±74	183±52	181±29	200±20	191±42	195±74
	136-533	115-222	139-219	115-292	153-261	157-222	182-228	147-248	115-533
Zn	7.1±2.5	8.4±3.3	8.5±3.4	7.3±1.9	9.4±3.6	7.7±0.8	10.0±2.8	8.5±1.5	8.4±2.5
	4.7-10.6	3.6-10.6	4.5-12.6	5.0-9.3	6.2-14.6	7.0-8.6	8.2-14.2	7.4-10.6	3.6-14.6

Mean ± SD = Mean values ± Standard deviation of four experiments;
Range

4. CONCLUSION

The micronutrient and toxic metal (Cd and Pb) contents of thirty-two (32) fresh palm oil samples from eight (8) towns in South-eastern Nigeria were investigated. The levels of toxic, non-essential metals (Pb and Cd) were considerably low in all samples investigated. The samples are rich in micronutrients such as Ca, Fe, Mg, K, Na and Zn. The results of this study confirmed the results documented by Adepoju-Bello et al, which reported the levels of Pb, Cd, Hg, Cr Ni and As to be very low and below regulatory limits. Overall, our study has shown that the palm oils do not pose any health risk from toxic heavy metals including Pb and Cd, as they were generally low, but would rather act as a source of micronutrients in diets.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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