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Health Risk Assessment of Some Metals in Commonly Consumed Edible Vegetable Oils Sold in Sango-Ota, Southwestern Nigeria

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Abstract

The presence of metals in edible oils poses significant health risks to consumers due to their potential toxicity and bioaccumulation. In this study, the concentration of Aluminium (Al), Calcium (Ca), chromium (Cr), iron (Fe), potassium (K), magnesium (Mg), cobalt (Co), sodium (Na), and copper (Cu), were investigated in six (6) commonly available edible oil samples namely: palm kernel oil. olive oil, melon seed oil, coconut oil. corn oil and sunflower oil sold in Sango-Ota, Southwestern Nigeria. The determination of these metals was carried out using inductively coupled plasma-optical emission spectrometry (ICP-OES). The metal concentrations range from 2.23-5.90 mg/kg (Ca), 0.53-1.26 mg/kg (Fe), 0.05-0.56 mg/kg (Mg), 0.71-1.35 mg/kg (K), 6.46-10.54 mg/kg (Na), 0.06-1.19 mg/kg (Al), 0.05-0.69 mg/kg (Cu). Cobalt and Chromium were only present in the olive oil sample and were below detection limits in the remaining oil samples. The estimated daily intake (EDI) of potentially toxic metals were below the permissible limits set by the FAO/WHO. The Hazard Quotient (HQ) values in the present report ranged from $8.0 \times 10^{-6} – 1.26 \times 10^{-5}$ in adults and $11.25 \times 10^{-6} – 1.26 \times 10^{-5}$ in children and the hazard indices ranged from $9.67 \times 10^{-6} – 4.59 \times 10^{-4}$ for children and $3.57 \times 10^{-7} – 1.59 \times 10^{-5}$ for adults. These values were < 1 hence, would not result in adverse health effects if consumed. Regular monitoring and stricter quality control regulations are recommended to ensure the safety of edible oils consumed in this region

Keywords: contamination; metals; inductively coupled plasma-optical emission spectrometry; health risk

Citation
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Introduction

More than inhalation and dermal contact, the main path through which humans are exposed to harmful metals and contamination is food consumption (Yohannes et al., 2024). There exist many potentially toxic substances in the environment which may contaminate foods, these include inorganic (metals) and organic (pesticides, polyaromatic hydrocarbons (PAHs) substances which may arise from wide range of sources (Thompson, & Darwish, 2016). Edible vegetable oils are among the most consumed foods worldwide and are commonly obtained from plant materials such as fruits (palm, olive), seeds (corn, sesame), nuts (walnuts, cashew) and plants (soya bean, canola) (Adeyeye et al.,2022).

Edible oils are essential components in most worldwide diets, serving not only as a primary energy source for the body, and also as essential fatty acids. In Nigeria, cheap oils from palm fruits, groundnut, and soybean are used in everyday cooking. However, edible oils are also a means of transporting toxins - especially when they contaminate during processing and/or storage, or are absorbed from environmental elements (Abdolmaleki et al., 2021; Gharby, 2022; Sánchez-Arévalo 2020; Xia et al., 2021; Zio et al., 2020). An important major influential factor for food quality is the presence of potentially toxic metals (PTMs) (Lehel et al., 2025). Trace metals when present in small amount in oils and fats are known to cause harmful effects on quality. Consumption of vegetables and edible oils contaminated with PTMs can lead to health risks and intoxication (Abate et al., 2024; Adewuyi et al., 2023)

Common heavy metals (Pb, Fe, Cd, and Zn) occurs naturally in the environment, but they could be a significant public health threat, particularly at high concentrations (Zaynab et al., 2022). Heavy metals accumulation in edible oils has been documented increasingly in recent years, where it was reported these metals could come from a variety of sources including contaminated soils, agricultural activities (using rain/sewage water for irrigation, phosphate fertilizers) and/or metals originating during processing (Olafisoye et al., 2020; Yohannes et al., 2024). Chronic exposure to heavy metals is also associated with multiple health risks. One example, lead is a strong neurotoxin which has been linked to degenerative brain issues in children and hypertension in adults. Contamination of edible oils with metals such as nickel, zinc, copper, cadmium, and lead has been linked to coronary heart diseases via cholesterol levels (Gong et al., 2024).

In addition, their presence in edible oils can have both positive and negative effects. Some trace metals like Fe, Cu, Ca, Mg, Co, Ni, and Mn can increase the rate of oil oxidation, which can affect the freshness and stability of the oil (Owaba, Bunu, & Oparaodu, 2021). On the other hand, metals such as Cr, Cd, and Pb are known for their toxicity and can have adverse effects on human health (Jomová et al., 2024). Potentially toxic metals such as As, Cr (VI), Cd, Pb, Cu, Zn, Ni, Hg, and Mn can contaminate oil-bearing plants during their growth stage, which can severely affect the safety of edible (Zhou, et al., 2019; Mehri et al., 2024). Additionally, industrial waste waters can contribute to high concentrations of PTMs in edible oils (Ugulu, et al., 2023).

The superiority of edible oils is greatly influenced by the concentration of the trace metals they contain. High levels of toxic metals can pose health risks to consumers, while metals that promote oxidative degradation can affect the flavour, odour, and taste of the oil (Karima et al., 2012). In Nigeria, there are few reports on the metals present in some edible oils and their health risk assessment most of which are done from the Northern part of the country. Therefore, it is important to determine the trace metal concentrations in edible oils to assess their quality in terms of freshness, stability, and storage (Karima et al., 2012) in the Southwestern, Nigeria.

Sango-Ota located in Ogun state in southwestern Nigeria is a rapidly growing industrial area with many small- to medium-scale manufacturing industries. Reports show that these industries discharge waste improperly, leading to soil, air, and water contamination in the natural environment (Zhou, et al., 2019). While Sango-Ota continues to become more urbanized and industrialized, there is little documented literature of any environmental impacts that may affect food safety and edible oils used by the local people. This is important and warrants urgency because edible oils can be significant exposure pathways for metals, given their lipophilic properties. While other studies in other Nigerian regions have considered heavy metals in oils (Ojezele, et al., 2021; Ajibade et al., 2021; Amua et al., 2023; Opara, 2023), there is no known cumulative risk assessment for Sango-Ota (to-date). This assessment will therefore, address the gap in knowledge by reporting the concentration of metals in regularly consumed vegetable oils in the Sango-Ota market and conducting the relevant health risk assessment. The results will provide important baseline data for public health advocacy, regulatory issues, and public health interventions.

Materials and Methods

Sampling Sites

The choice of sampling was centered on three (3) major markets in Sango-Ota axis, Ado-Odo Ota

Local Government of Ogun State. These locations are Joju, Oju-Ore and Sango as shown in Figure 1. The coordinates of these locations are 6° 42´33"N 3° 14´16"E, 6° 41´18"N 3° 13´35"E, 6° 42´20"N 3° 14´43"E, for Joju, Oju-Ore and Sango respectively.

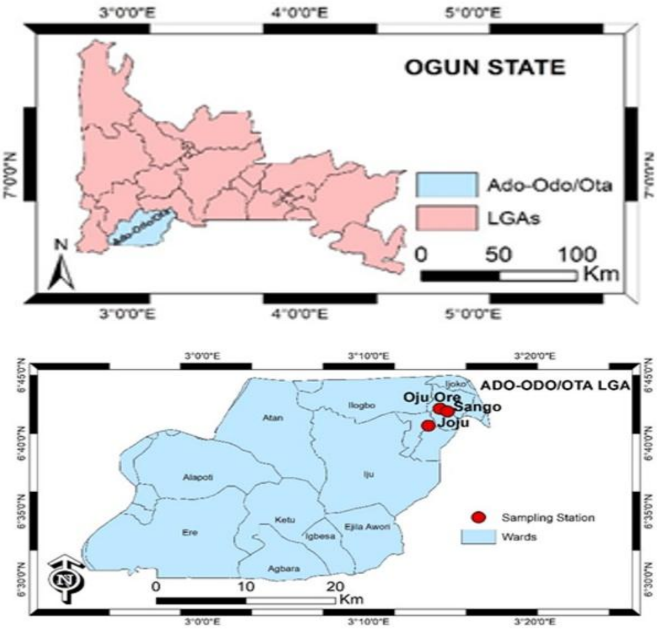

Fig. 1 Map showing the sampling areas

Sample collection

A total of 1 Litre of six (6) samples of edible vegetable oils (olive oil, coconut oil, palm kernel oil, melon seed oil, corn oil and sunflower oil samples) were purchased in Sango Ota market, Ogun State, Nigeria. These samples were designated as, OLO, CCO, PKO, MSO, COO, and SFO, respectively. The collected oil samples were packed in polyethylene bags and stored at room temperature until analysis.

Reagents

All reagents used were of analytical grade. Ultrapure Merck Lichrosolv water was used for preparation and dilutions of standard solutions. Concentrated nitric acid (HNO_3), sulphuric acid (H_2SO_4) and hydrogen peroxide (H_2O_2) were used.

Determination of Selected Metals

The samples were subjected to wet digestion using the method according to Bereket and Alemayehu, (2016). To a 1 g of each oil sample (olive oil, coconut oil, palm kernel oil, melon seed, corn oil and sunflower oil) into 100 mL conical flasks, a freshly prepared 20 mL mixture of concentrated HNO_3–H_2O_2 (2: 1, v/v) and 3 mL of H_2SO_4 was added to each flask and the solution was kept at room temperature for 10mins. The resulting solutions were digested on Kjeldahl furnace at 250 °C to obtain a clear solution. The evaporation of the sample to a semi-dried mass was done, followed by dissolution in 5 mL 0.2 M HNO_3, filtered through Whatman number 42 filter paper, and made up to final volume of 50 mL using deionized water. The filtered solution was carefully transferred to an appropriately labeled sample vial.

Instrumental analysis

The analysis of calcium (Ca), iron (Fe), magnesium (Mg), potassium (K), sodium (Na), aluminium (Al), chromium (Cr), cobalt (Co), and copper (Cu) was done using Agilent 720-ES Inductively Couple Plasma-Optical Emission Spectrophotometer ICP-OES with megapixel CCD detector which provided simultaneous measurement under optimized operating conditions. Sample introduction was achieved with the Agilent SPS3 autosampler. Agilent Expert II Software was used to control the instrument and acquire data. Calibration and Quality Control solutions were prepared from the following reference materials; Accustandard QCSTD-27 multi-element solution AG-QCS27-ASC-1, Agilent Calibration Mix Majors 6610030700, Agilent Calibration Mix2 6610030600, Agilent ICMS Internal Standard Solution 6610030400 and Ultrapure Merck Lichrosolv water was used for dilution of standard and QC solutions. The concentration of working standards prepared ranged from 0.050 – 5.00 ppm. Then, sample measurements were carried out at 396.847 (Ca), 238.892 (Co), 267.716 (Cr), 327.395 (Cu), 598.592 (Na), 238.204 (Fe), 396.152 (Al), 279.553 (Mg) and 766.491 (K).

ICP-OES Working Conditions

Parameters	Setting
Power	1KW
Plasma gas flow (Ar)	15 L/min
Auxiliarygas flow (Ar)	1.5 L/min
Nebulizer gas pressure	220 kPa
Sample uptake	30s
Replicate read time	30s
Stabilization time	15s

Quality Assurance

The glasswares were thoroughly cleaned with distilled water after soaking with about 2 M nitric acid for 24 hours. The calibration and quality control solutions were prepared from certified reference materials. The calibration curves were based on five standards. Reagent blanks were prepared and measurements carried out in the same manner as the samples.

Statistical analysis

The statistical analysis of the results was achieved by carrying out the coefficient of variation between the data sets. For each of the oils sampled, the mean and standard deviations were calculated based on duplicate measurements.

Health Risk Assessment

This is required for the evaluation of the metal's health risks and quality of life. The health risk assessments of metals (Fe, Zn, Cu, Mg, Co) consumption through cooking oils were calculated based on Average Daily Dose (ADD) and non-cancer hazard quotient (HQ). (United States environmental protection agency, integrated risk information system [USEPA IRIS], 2021.

$$ADD = \frac{C\ x\ (IR\ xEF\ x\ ED)}{BW\ x\ AT}\ x\ CF \qquad \text{Eqn 1}$$

Target Hazard Quotient

In all the samples, the metals were calculated as the total hazard quotient (HQ) according to equation (2)

$$HQ = \frac{ADD}{RfD} \qquad \text{Eqn 2}$$

where ADD = Average daily dose in mg/kg/day
C= Concentration of metals in mg/kg
IR = Ingestion rate
ED = Exposure duration in years (6 years for children and 24 years for adults), (USEPA IRIS, 2021).
EF = Exposure frequency = 350 days year^{-1}, (USEPA IRIS, 2021).
BW = Body weight (Kg) = 15 kg for children and 70 kg for adults. (Hu, et al., 2010).
AT = Averaging time or life expectancy = ED×365 days (6 x 365 days for children and 70 x 365 days for adults), (Xheng, & Lan, 2007).
CF = Conversion factor = x10^{-6},
RfD =Reference Dose (mg/kg/day) for Fe, Mg, Co, Cr and Cu were 0.7 (Fe), 0.14 (Mg), 2.0x10^{2}(Co),

0.0003(Cr) and $4.0x10^{-2}$(Cu) respectively (Yang, Ma, Zhou, Song, & Li, 2018).

The acceptable non-carcinogenic value for the health risk associated with the consumption of a given element is defined as one (HQ = 1) (Giri & Singh, 2015). This means that when the non-carcinogenic risk (HQ) of ingesting a particular element exceeds an acceptable threshold (HQ > 1), the risk of adverse health effects may affect health and is therefore a cause of concern. On the other hand, if HQ < 1, the non-carcinogenic risk remains within acceptable levels (Onwordi et al., 2024).

Total hazard index

The metal contents in the different edible vegetable oil were calculated as the total hazard index (HI), represented in equation (3) (Masri, et al., 2021).

$$\sum_{N=1}^{i} THQ_n \qquad \textbf{Eqn} \ 3$$

$$HI = THQ_{Fe} + THQ_{Mg} + THQ_{Cu} + THQ_{Co} + THQ_{Cr}$$

The HI represents the total hazard index for all the metals analyzed (Eq. 3; n = 5). A non-carcinogenic health risk is considered significant when HI > 1, indicating potential adverse effects, while HI < 1 suggests that the risk remains within the acceptable range. An HI value equal to 1 represents the threshold of acceptability (Onwordi et al., 2024; Zeiner, et al., 2010; Bereket & Alemayehu, 2016). Non-carcinogenic risk is classified on the basis of HI values into negligible (< 0.1), low (≥ 0.1 < 1) medium (≥ 1 < 4) and high risks (≥ 4), based on their HI values (Mgbenu, & Egbueri, 2019).

Results and Discussion

Figure 1 shows the level of metals found in all the edible vegetable oils sampled. The concentration of metal differed between oil types. Metal concentrations (Table 1) in edible oils were found between 2.23-5.90 (Ca), 0.53-1.26 (Fe), 0.05-0.56 (Mg), 0.71-1.35 (K), 6.46-10.54 (Na), 0.06-1.19 (Al), 0.05-0.69 (Cu), 0.14 (Co), 0.09(Cr) mg/kg respectively.

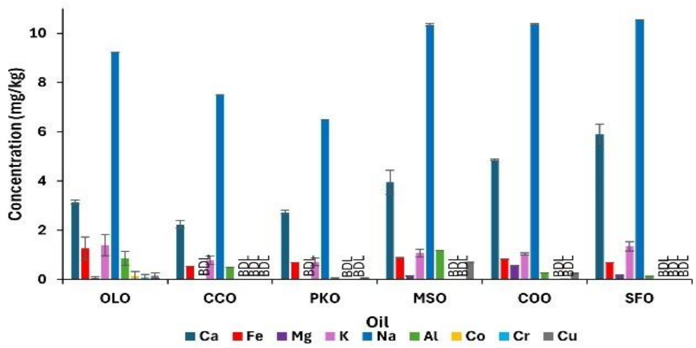

Figure 2: Concentration of metals (mg/kg) in the edible oils

BDL= below detectable limits; olive oil = OLO, coconut oil = CCO, palm kernel oil = PKO, melon seed oil = MSO, corn oil = COO, sunflower oil = SFO;

Table 1: **Means of metal (mg/kg) in the samples**

Concentration found in samples									
	Ca	Fe	Mg	K	Na	Al	Co	Cr	Cu
Mean	3.79	0.81	0.15	1.06	9.07	0.5	0.02	0.015	0.19
S.D	1.26	0.22	0.19	0.25	1.55	0.40	0.05	0.03	0.24
CV%	33.29	28.16	123.25	24.40	17.18	81.10	223.60	223.60	126.57

SD= standard deviation, CV%= coefficient of variation

Depending on several variables, including the species, soil used for cultivation, irrigation water, and stage of maturation, vegetable oils and fats may contain trace amounts of different metals. Ca, Mg, P, and Fe are the core elements, followed by ultra-trace amounts of Zn, Cr, Mn, Ni, and Cu.

Calcium had the highest concentration (5.90 mg/kg) in the sunflower oil while it is lowest in the coconut oil sample (2.23 mg/kg). Calcium had maximum concentration (5.90 mg/kg) in the sunflower oil while it is lowest in the coconut oil sample (2.23 mg/kg). WHO's recommended daily allowance (RDA) for calcium in children with age range of 9-18 years is 1300 mg/day, which is significantly lower in all the oil samples. Ca levels are lower in sunflower in this present study compare to the study done in Iran by Farzin and Moassesi (2014), (Figure 2) but higher than the edible oil performed in Ghana studied by Ashong, Ababio, and Kwaansa-Ansah (2024). In the human body, calcium is deposited primarily in bones and teeth, where it plays a significant role in maintaining bone structure, facilitating muscle contractions, transmitting nerve impulses, and promoting glandular secretion (Zhukouskaya, & Bardet, 2022; European Food Safety Authority [EFSA] NDA Panel, 2015). Calcium deficiency can lead to rickets in children and osteoporosis in adults, which increases the risk of bone fractures (Cong & Zhang, 2025; Cotruvo & Bartram, 2009). In addition, inadequate calcium intake has been linked to a higher risk of kidney stones, colon cancer, hypertension, stroke, coronary artery disease, insulin resistance, and obesity (Cong & Zhang, 2025; Cotruvo & Bartram, 2009).

Iron had the highest concentration (1.26 mg/kg) in the olive oil while it is lowest in the coconut oil sample (0.53 mg/kg). The levels of iron in the oil samples were comparatively lower than the maximum allowable limit (i.e. Recommended Daily Allowance (RDA) of 11 and 18 mg/day for children and adults respectively (Russell et al., 2001).

Iron is an essential element for humans and animals, and serves as a component of haemoglobin. It plays a key role in the oxidation of carbohydrates, proteins, and fats, processes that help regulate body weight—an important factor in diabetes treatment and management. In addition, iron deficiency can lead to anaemia (Alrajhi & Idriss, 2020). In the edible oil samples, the Fe values range from 0.53 - 1.26 mg/kg with an average of 0.81 and a coefficient of variation (CV%) value of 28.16. These values were comparably lower than those reported by Adeyeye et al. (2022) which was 32.1%.

Magnesium had the highest concentration (0.56 mg/kg) in the CCO while it is lowest in the PKO sample (0.05 mg/kg), but was below detection limit in CCO and PKO. The level found were below the RDA of 310 mg/day (EFSA NDA Panel, 2015).

Magnesium functions as a cofactor in approximately 350 enzymatic reactions in the body (Institute of Medicine [IOM], 1997) and is essential for intermediate metabolism, including the synthesis of proteins, carbohydrates, lipids, and nucleic acids. It also facilitates the active transport of calcium and potassium ions across cell membranes (Cotruvo & Bartram, 2009). It is worth noting that magnesium deficiency can lead to hypocalcemia and hypokalemia, which can trigger neurological or cardiac complications, especially in cases of severe hypomagnesemia (Cotruvo & Bartram, 2009; EFSA NDA Panel, 2015). Approximately 60% of the body's magnesium is stored in the bones, and approximately 25% is found in the muscles (EFSA NDA Panel, 2015).

K and Na were also detected (Figure 2) having highest concentration in OLO (1.40 mg/kg) and lowest in PKO (0.71 mg/kg) for K while Na had highest in SFO (10.54 mg/kg) and lowest in PKO (0.49 mg/kg). There is no known RDA value for K by WHO while Na RDA is 2000 mg/day, however, this value is higher than the value obtained in the edible oil analysed. Potassium and Na are essential minerals and major intracellular electrolyte involved in the regulation of blood pressure, muscle contraction and nerve transmission in humans. Excessive sodium intake is linked to several non-communicable diseases, including high blood pressure, stroke, and heart disease, and reducing sodium intake can help lower blood pressure and mitigate related health risks (World Health Organization [WHO], 2012).

Aluminium had the highest concentration (1.19 mg/kg) in the MSO while it is lowest in the PKO sample (0.06 mg/kg) (Figure 2). The FAO-WHO tolerable weekly intake value for Al is 1 mg/ kg body weight/week (Zhu, Fan, Wang, Qu, & Yao, 2011), the result obtained in this study for MSO is higher than the tolerable weekly intake. The effect of continuous consumption of this brand of edible oil could lead to Al toxicity in the body. Aluminum toxicity has a variety of complex effects, including damage or inhibition of enzyme activity, alterations in protein synthesis, disruption of nucleic acid function, and changes in cell membrane permeability. Aluminum toxicity can also interfere with DNA repair processes, damage DNA structure, increase the production of reactive oxygen species (ROS), trigger oxidative stress, reduce the activity of antioxidant enzymes, and disrupt cellular iron homeostasis. Furthermore, aluminium toxicity can affect the blood, nervous system, kidneys, liver, and respiratory and cardiovascular systems (Rahimzadeh, Kazemi, Amiri, Pirzadeh, & Moghadamnia, 2022).

Cobalt and chromium were found only in OLO (0.14 mg/kg and 0.09 mg/kg) respectively while others were below the detection limit. The Recommended Dietary Allowance (RDA) mg/day for adults' men and women > 19 y old for Co and Cr are 0.005 and 0.045 and 0.035 and 0.025 respectively. The Co and Cr levels in the OLO are above the RDA respectively. Notably, Co is a part of vitamin B12, which stimulates the production of red blood cells and is related to the activities of the brain and nervous system (Damastuti et al., 2012; Lim & Lim, 2009). Chromium is needed for maintaining normal blood glucose levels; plays a major role in lipid metabolism and insulin function (Lim & Lim, 2009).

The lowest copper levels were found in palm kernel oil (0.05 mg/kg), the highest copper level was found in melon seed oil (0.69 mg/kg), and the copper levels in coconut and sunflower oils were below the < 0.00030 mg/kg. The endorsed daily intake of copper in adults is 1.5-3.0 mg (Onianwa et al., 2001). Copper is known to be one of the essential metals needed by the body at lower concentration, however at higher concentrations is becomes toxic. Cu is necessary for many biological processes such as haemoglobin synthesis and bone development and can prevent cell structure damage (Chakraborty et al., 2022). Copper deficiency can cause anemia, heart disease, and colon cancer, while high copper intake can cause diarrhea, vomiting, and liver or kidney damage in humans (Georgopoulos et al., 2001). It has been observed that copper can contaminate food through various pathways, including uptake from the soil through crop mineralization, food processing activities, and environmental pollution, particularly through the use of copper pesticides, which are commonly used in agriculture in some countries (Onianwa et al., 2001; Koc, Eren, & Ertekin, 2008). Buldini, Ferri, and Sharma, (1997) reported the average Cu content of edible oil samples ranges from 12.71 to 50.5 g/kg which is lower than was reported in this study.

Based on body weight, the FAO/WHO established a limit for the consumption of PTMs. The provisional tolerated daily intake (PTDI) for lead, iron, copper, and zinc is 214 g, 48 mg, 3 mg, and 60 mg, respectively, for an average adult (60 kg body weight) (FAO & WHO, 1999).

In all the samples, sodium and magnesium had the highest and lowest metal concentrations, respectively in all the oil samples with values ranging from 6.49-10.54 (Na) and 0.05-0.56 (Mg) mg/kg. These values are in accordance with Ogabiela et al. (2010). Maximum sodium and aluminium levels were recorded in sunflower oil (10.54 mg/kg) Na and melon seed oil (1.19 mg/kg) Mg while minimum levels were recorded in palm kernel oil (6.46 mg/kg) Na and (0.06 mg/kg) Mg.

The most often found elements in edible oils are Fe, Ni, Pb, Cd, and As (Mendil et al., 2009). The recommended concentrations of these metals in oils are $1-1.5\ mgkg^{-1}(Fe), 0.2\ mgkg^{-1}(Ni), 0.1\ mgkg^{-1}(Cu, Pb, As) and\ 0.$ according to Mendil et al. (2009).

Corn oil had the highest concentration of magnesium (0.56 mg/kg) and it was lowest in olive oil (0.05 mg/kg) while potassium was highest in olive oil (1.40 mg/kg) and lowest in the palm kernel oil samples (0.71 mg/kg).

Harmful and beneficial effects of metals on human life are well documented (Ghaedi et al., 2008; Mendil et al., 2009). In this research, it was observed that the metals are within the tolerable limits for human consumption, however metals can bioaccumulate in the human body (Adeyeye et al., 2022) and as a result, the level of these metals can be decreased or controlled by careful handling techniques and the processing of raw materials (Mendil et al., 2009).

Additionally, the variations in the concentrations of metals found in edible oil worldwide are highlighted in Table 2. Ca levels in olive oil are less than levels found in Iran (Farzin & Moassesi, 2014) while sunflower Ca levels are higher than the study done in Ghana (1.328 mg/kg) but lower than the study done in Iran (32.54±1.88) mg/kg (Farzin & Moassesi, 2014).

The Fe level in olive oil in the present study is lower than the study done in Iran and China. However, the sunflower had higher levels of Fe in the present study when compared with study done in Ethiopia but lower than study done in China, Ghana and Iran. (Table 2). Notably, the Fe level in corn oil is lower than the study done in China (15.1-16.8) mg/kg (Zhu et al., 2011). Generally, Fe level is lower in the present study in olive, sunflower and corn oil when compared to other unnamed varieties of edible oil studied in Saudi Arabia (Alrajhi & Idriss, 2020) and Ethiopia (Tesfaye & Abebaw, 2016).

Mg and K levels in the various olive and sunflower oils are lower compared with other studies as shown in Table 2. More so, the Na level in the olive oil and sunflower oil are lower compared to varieties of edible oil studied in South-south Nigeria (Owaba et al., 2021).

Al is higher in the present study in olive oil compared with variety of oil studied in Saudi Arabia (0.001-0.425) mg/kg. The sunflower oil had lower levels of Al in the present study compared with study done on variety of edible oil in Saudi Arabia (<0.001 – 0.425) mg/kg (Farzin & Moassesi, 2014) and Northwest, Nigeria. (0.02-0.25) mg/kg (Ogabiela et al. 2010).

Cr level in sunflower oil in the present study is similar to the values obtained in the study done in Ghana while olive oil Cr level in the present study is lower compared with the study done in Saudi Arabia (0.002 – 1.898) mg/kg (Alrajhi & Idriss, 2020).

Cu level in Olive oil in the present study is higher than study done in Iran (0.091-0.098) mg/Kg (Taghizadeh et al., 2020) and Greece (0.033-0.139) mg/kg (Drosaki & Anthemidis, 2022), however, lower than the study done in Ukraine (0.355 mg/kg) (Zhuravlev et al., 2015) and China (0.248-0.276) mg/kg (Zhu et al., 2011). Cu was < 0.0003 mg/kg in the sunflower oil and coconut oil in the present study, however, various concentrations were obtained from studies performed in other countries like Brazil, India, Greece etc as shown in Table 2. Cu level in corn oil in the present study is higher than the study done in China (0.146-0.173) mg/kg (Zhu et al., 2011).

Generally, from the results across all the oil samples for the potentially toxic metals, the values were comparably higher than those reported in literature by Adeyeye et al. (2022). The mean vales for individual metals are as follow: Ca (3.79, CV% of 33.29), Fe (0.81, CV% of 28.16), Mg (0.15, CV% of 123.25), K (1.06, CV% of 24.40), Na (9.07, CV% of 17.18), Al (0.5, CV% of 81.10) Co (0.02, CV% of 223.60) Cr (0.015, CV% of 223.60) and Cu (0.19, CV% of 126.57). These observed mean values were substantially greater than those recorded for selected edible oils commonly consumed in south western Nigeria (Adesina et al., 2020).

Health risk

The average daily dose (ADD), and the hazard quotient (HQ)/hazard index (HI) values of Fe, Zn, Cu, Mg and Co found in the various edible vegetable oil samples are presented in Tables 2 and 3 respectively. The ADD is reported separately for children (Ch) and adults (Ad) since risk assessments typically differentiate between age groups due to differences in body weight, metabolism, and dietary exposure.

Table 2. Average Daily Dose of some metals in the edible vegetable oil samples (mg/ kg/day)

Metals	EIBLE OIL SAMPLES											
	OLO		CCO		PKO		MSO		COO		SFO	
	Ch	Ad	Ch	Ad	Ch	Ad	Ch	Ad	Ch	Ad	Ch	Ad
Fe	$1.61x10^{-5}$	$0.59x-10^{-6}$	$6.77x10^{-6}$	$0.25x10^{-6}$	$8.82x10^{-6}$	$0.32x10^{-6}$	$11.25x10^{-6}$	$0.41x10^{-6}$	$10.61x 10^{-6}$	$0.39x10^{-6}$	$8.82x10^{-6}$	$0.32x10^{-6}$
Mg	$0.64x10^{-6}$	$0.02 x10^{-6}$	< 0.00003	< 0.00003	< 0.0003	< 0.00003	$1.92 x10^{-6}$	$0.07 x10^{-6}$	$7.16 x10^{-6}$	$0.26 x10^{-6}$	$2.30 x10^{-6}$	$0.08 x10^{-6}$
Cu	$1.92 x10^{-6}$	$0.07 x10^{-6}$	< 0.0030	< 0.0030	$0.64 x10^{-6}$	$0.02 x10^{-6}$	$8.82 x10^{-6}$	$0.32 x10^{-6}$	$3.19 x10^{-6}$	$0.12 x10^{-6}$	< 0.0030	< 0.0030
Co	$1.79 x10^{-6}$	$0.07 x10^{-6}$	< 0.00074	< 0.00074	< 0.00074	< 0.00074	< 0.00074	< 0.00074	< 0.00074	< 0.00074	< 0.00074	< 0.00074
Cr	$1.15 x10^{-6}$	$0.04 x10^{-6}$	< 0.00125	< 0.00125	< 0.00125	< 0.00125	< 0.00125	< 0.00125	< 0.00125	< 0.00125	< 0.00125	< 0.00125

Ch= children; Ad= Adult

The ADD of Fe is highest in Palm Kernel Oil (PKO) and Melon Seed Oil (MSO) for children. The Fe values for adults are significantly lower than for children, as expected due to lower per kg body weight exposure. Fe levels across all oils fall within reported dietary intake limits but should be further assessed against tolerable intake levels. Mg is detected in trace amounts in some oils but is below detectable levels (<0.00003 mg/kg/day) in certain samples. Melon Seed Oil (MSO) and Coconut Oil (COO) show relatively higher Mg concentrations. Copper is undetectable (<0.0030 mg/kg/day) in some oil samples. MSO and CCO (Coconut Oil) show slightly higher Cu levels in children than in adults. Cobalt and Chromium are below detectable levels (<0.00074 mg/kg/day for Co and <0.00125 mg/kg/day for Cr) in most oil samples. This suggests that contamination from these metals is minimal or negligible. The values for children are consistently higher than those for adults, which is expected due to their higher food intake relative to body weight. Although the detected metal levels seem low, metals such as Cr and Co can be toxic even in small amounts over prolonged exposure. For several metals, values are below the limit of detection, suggesting minimal contamination from these elements.

The ADD values of metals in food samples were generally lower than the permissible limits of the FAO/WHO.

If the HQ value obtained for individual PTM is greater than the tolerable limit, it might pose non-carcinogenic health risk to the consumer (Ambedkar & Muniyan, 2011). The HQ values in the present report ranged as follow: 8.0×10^{-6}– 1.26×10^{-5} for adults and 11.25×10^{-6} – 1.26×10^{-5} for children. These values were lower than 1 and as such would not result in adverse health effects for consumers. Moreso, the hazard index (HI) gave a value range of 9.67×10^{-6} – 4.59×10^{-4} for children and 3.57×10^{-7} – 1.59×10^{-5} for adults. Children have a higher THI than adults in all cases, meaning they face greater exposure risks. The highest THI values appear in Melon Seed Oil (MSO) and Sunflower Oil (SFO), suggesting they contribute the most to cumulative metal exposure. This suggest that the hazard indices for children and adults in this study were below the acceptable limit (HI =1) indicating no immediate non-carcinogenic risk, but long-term exposure should be monitored.

Table 3: Hazard Quotient and target hazard index of some metals in the edible vegetable oil samples (mg/ kg/day)

Metals	EDIBLE VEGETABLE OIL SAMPLES											
	OLO		CCO		PKO		MSO		COO		SFO	
	Ch	Ad	Ch	Ad	Ch	Ad	Ch	Ad	Ch	Ad	Ch	Ad
Fe	2.30×10^{-5}	$8.43x\ 10^{-7}$	$9.67x\ 10^{-6}$	$3.57x\ 10^{-7}$	$1.26x\ 10^{-5}$	$4.57x\ 10^{-7}$	$1.61x\ 10^{-5}$	$5.85x10^{-7}$	$1.52x\ 10^{-5}$	$5.57x10^{-7}$	$1.26x10^{-5}$	$4.57x10^{-7}$
Mg	$4.57x10^{-6}$	1.42×10^{-7}	BDL	BDL	BDL	BDL	$1.37\ x10^{-5}$	$5.00\ x10^{-7}$	$5.11\ x10^{-5}$	$1.86\ x10^{-6}$	$1.66\ x10^{-5}$	$5.71\ x10^{-7}$
Cu	4.80×10^{-5}	1.75×10^{-6}	BDL	BDL	$1.60\ x10^{-5}$	$5.00\ x10^{-7}$	$2.20\ x10^{-4}$	$8.00\ x10^{-6}$	$7.98\ x10^{-5}$	$3.00\ x10^{-6}$	BDL	BDL
Co	8.95×10^{-9}	3.00×10^{-10}	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cr	3.83×10^{-4}	$1.33x10^{-5}$	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
THI	4.59×10^{-4}	1.59×10^{-3}	$9.67\ x10^{-6}$	3.57×10^{-7}	$2.86\ x10^{-5}$	$9.57\ x10^{-7}$	2.50×10^{-4}	9.09×10^{-6}	1.46×10^{-4}	5.47×10^{-6}	2.92×10^{-5}	1.03×10^{-6}

BDL= below detectable limits; Ch= children; Ad= Adult; THI= Target hazard index

Conclusion

The investigation of nine metals (Ca, Fe, Mg, K, Na, Al, Cu, Co and Cr) in six (6) commonly available edible oil samples namely: olive oil, coconut oil, palm kernel oil, melon seed oil, corn oil and sunflower oil sold in Sango-Ota, Southwestern, Nigeria were determined instrumentally using inductively coupled plasma-optical emission spectrometry (ICP-OES). The research enabled us to establish a database of the potentially toxic metal contamination levels in available edible vegetable oil. Although the concentration of Potentially toxic metals in the analyzed edible oils were within the allowed limits of Food Agricultural organisation/ World health organisation and United State Environmental Protection Agency, however, their very existence indicates contamination, irrespective of how minimal that concentration might be. Metals in edible oils can be introduced via a myriad of ways, which may include but not limited to soil infiltration or introduction during the manufacturing process. The hazard quotient and hazard indices level in the edible vegetable oil studied were with the acceptable limit of one (1) as stated by Food Agricultural Organisation/ World Health Organisation and United State Environmental Protection Agency for children and adults. It is however, important that regulatory body should continuously monitor manufacturer processes and ensure they comply with standard acceptable levels of metals in the edible vegetable oils consumed by the populace.

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