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Concentration Of Trace Metals In The Fresh And Fried Edible Vegetable Oils Used In The Production Of Plantain Chips In Ekiti State: Health Implications

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Summary
Seven selected heavy metals namely Fe, Cu, Mn, Pb, Zn, Cd and Ni in five vegetable oils used in frying plantains (fresh and fried) collected from Ado-Ekiti, Ekiti State, were determined by graphite furnace atomic absorption spectrometry (GF-AAS) after microwave digestion. The accuracy of procedure was confirmed by certified reference materials (NIST). The relative standard deviations were found below 10%. In all the various oils (fresh and processed), the concentrations for Fe, Cu, Mn, Pb, Zn, Cd and Ni were observed in the range of 0.0005 -0.0018, 0.0002 – 0.0009, 0.0004 – 0.0021, 0.0001-0.0007, 0.0003 – 0.0016, 0.0001 – 0.006 and 0.0002-0.0010 mg/kg, respectively. In general, among all the oils, fresh palm oil (FPO had the highest concentration) for all the selected heavy metals. Comparing with safety intake levels for these heavy metals recommended by Institute of Medicine of the National Academies (IOM), US Environmental Protection Agency (USEPA) and Joint FAO/WHO Expert Committee on Food Additives (JECFA), the dietary intakes of the seven heavy metals from daily consumption of edible vegetable oils for a 70 kg (adult) and 24 kg (children) body weight should pose no significant health risk to consumers. However, for adults and children, the THQ and HI were low. The TCR values also indicate low to moderate carcinogenic risks for adults and children.

Keywords: Edible Oils, Frying, Heavy Metals, Carcinogenic Risks

Introduction

One of the important food for all people around the world is edible oils [1]. These oils are usually obtained from plant materials: fruits (palm, watermelon, olive, and coconut), plants (soya bean, canola, etc.), seeds (corn, sesame, sun flower) and nuts (walnuts, cashew). Apart from the application of oils in the production of non-food products such as cosmetics, pharmaceuticals and as biofuels, oils are applied in cooking (frying of foods, bread preparation) and for non-cooking products such as salads and pastries as well as other culinary uses.

Fats and oils are utilized in human body for important purposes such as energy and vitamin suppliers as well as essential elements in metabolic reactions in human body [1]. According to human beings, plants and animals rely on oils for major minerals such as Ca, Mg, K, Fe, Mn, Cu, and Zn for maintenance, though some metals are beneficial and others can be toxic, even at low concentration and as a result pose health risks to humans. Deleterious effects on quality resulting from the presence of small amounts of trace metals in oils and fats have been reported [2, 3].

The strongest and most notable peroxidants are copper and iron, which produce a notable oxidative effect at concentrations as low as 0.005 and 0.03 ppm respectively [4, 5]. While the effect of chronic exposure to small amounts of some metals seems to be well understood, several incidents show the seriousness of high levels of exposure to some noxious metals, particularly Cd, Cr3+ and Pb [6]. The determination of metals in vegetable oils and fats has been under investigation for several years and is still a formidable problem [3, 7, 1]. Manjusha et al. (2019) observed that the quality of edible oils is directly linked to the concentration of some trace metals. Concentrations of Fe, Cu, Co, Ni and Mn are known to increase the rate of oil oxidation, while elements like As, Cr, Cd and Pb are significant on account of their toxicity and metabolic roles.

According to Cindiric et al. (2007) and Jamali et al. (2008), the presence of metals in edible vegetable oils relies on many factors, which include: the soil, environment and genetic structure of the plant, as well as fertilizers and pesticides introduced during the production process or by contamination from the metal processing equipment or shipping containers. Also these metals could get into the edible oils through many food processing methods such as frying and baking [7, 8].

Edible oils are consumed every day for cooking and frying. However, in most Nigerian localities, edible oils have been subjected to repeated use most especially in frying foods such as bean cake, plantains, flour rolls, cocoyam etc. These repeated cookings according to Adeyeye et al. (2018; 2019) have brought about reduced nutritional and antioxidants value of the fried foods. During frying of oils, the possibility of introducing or building up of certain toxic metals concentration is high [1]. If toxic metals are consumed, the risk of a particular population may increase, so it is essential to determine the concentration of these metals. Many studies have been recently carried out on the determination of heavy metals in edible oils around the world [9, 10]. In south western part of Nigeria where the research was carried out , use and re-use of edible vegetable oils (refined palm olein, palm, olive, soybean and coconut oils) have become regular practice most especially for the production of plantain and cocoyam chips. The purpose of this work is to determine the concentrations of potentially toxic metals in selected five oils used (fresh and fried) in the production of plantain chips in south western states of Nigeria.

Materials And Methods

Sample Collection And Treatment

Samples of fresh vegetable oils were procured from vendors located in the popular markets in Ado-Ekiti, Ekiti State and Akure, Ondo State. The oils used (refined palm olein, olive, coconut, palm and soya bean) were of good food grades, devoid of any particles or dirt. Fresh samples of each oil (5 mL each) were taken and kept in plastic bottles and refrigerated pending analysis (these were the fresh samples designated as FOO, FCO, FVO, FPO and FSO). About 400 mL each of the oils samples were used in frying plantain chips for 20 minutes, after which aliquot (5 mL) of the oils were collected in sample bottles and kept for further analysis in refrigerator (designated as VO1, CO1, PO1, SO1 and OO1). The same oil was used for frying the second and third day (samples of oils taken were designated as VO2, CO2, PO2, SO2, OO2 and VO3, CO3, PO3, SO3, OO3 respectively). All the samples were kept in plastic sample bottles and refrigerated for further analysis.

Heavy Metal Determination

The metals were analyzed from the solution obtained by initially dry ashing the samples at 550 ^oC. Filtered solutions were used to determine Zn, Fe, Mn, Cu, Ni, Pb and Cd by means of atomic absorption spectrophotometer (Buck Scientific Model- 200A/210, Norwalk, Connecticut 06855). All chemicals used were of British Drug House (BDH, London, UK) analytical grade. Earlier, the detection limits for the metals in aqueous solution had been determined using the methods of Varian Techtron (1975). The optimal analytical range was 0.1-0.5 absorbance units with coefficients of variation from 0.9% to 2.21%. From the mineral elements determined, further calculations were made.

Other calculations

Other calculations made included: the estimated daily intake (EDI), target hazard quotient (THQ), chronic hazard index (HI), EDI/Df ratio and target cancer risk (TCR).

Estimated Daily Intake (Edi)

Daily intake of contaminated vegetables is a general pathway of heavy metal exposure to human. EDI of heavy metals from these foods was calculated using the equation [11, 12].

$$EDI=(Cm \times Df)/Bw \quad (1)$$

where C_m is the concentration of heavy metals (mg kg^{-1} dry weight), Df denotes the daily intake of food in kg per person per day and Bw is the average body weight in kg (70 for adults, 24 for children).

Non-Carcinogenic RiskTarget Hazard Quotient (THQ)

THQ was calculated by the following formula [11]:

$$THQ = EDI \times Ef \times De / Df \times Tavncar \quad (2)$$

where, THQ represents non-cancer risks, Ef denotes the exposure frequency (365 days year-1), and De denotes exposure duration (56 years) [12]. Reference doses (Df) of Fe, Mn, Cu, Zn, Pb, and Cd are 0.7, 0.14, 0.04, 0.03, 0.0035 and 0.003 (mg, kg-1 day -1) respectively (Uddin et al., 2997; USEPA, 2015) and Tavncar represents average time for non-carcinogens (365days year-1 x De) (USEPA, 2011) [11].

Chronic Hazard Index (HI)

Chronic hazard index (HI) is the sum of more than one hazard quotient for multiple toxicants or multiple exposure pathway [12]. This was calculated using the equation:

$$HI = \sum THQ \quad (3)$$

Carcinogenic Risk

Target Cancer Risk (Tcr)

TCR was estimated by using the formula:

$$TCR = THQ \times S_{epo} \quad (4)$$

S_{epo} (carcinogenic potency slope), the reference values for Pb and Cd are 0.0085 and 6.1 mg kg^{-1} body weight day^{-1} respectively (USEPA, 2015).

Results And Discussion

Table I depicted the levels (mg/kg) of heavy metals in the fresh and repeatedly fried vegetable oils used in the production of plantain chips. The determination of the elemental composition in edible oils is highly important, this is because several elements play major roles in various metabolic processes in human body systems. In addition, some of these elements are toxic if consumed in excess. In the present study, 7 elements (Fe, Cu, Mn, Pb, Zn, Cd, and Ni) in both the fresh and repeatedly fried oil samples were assessed and the results clearly shown in Table I.

Table I: Heavy Metals Concentration In The Fresh And Repeatedly Fried Vegetable Oils Used In The Production Of Plantain Chips

Oils	Heavy metals						
	Fe	Cu	Mn	Pb	Zn	Cd	Ni
FOO	0.0014	0.0007	0.0011	0.0003	0.0011	0.0003	0.0005
OO1	0.0012	0.0008	0.0008	0.0004	0.0013	0.0004	0.0007
OO2	0.0013	0.0006	0.0007	0.0003	0.0011	0.0002	0.0004
OO3	0.0013	0.0008	0.0010	0.0004	0.0012	0.0002	0.0006
FSO	0.0016	0.0005	0.0013	0.0005	0.0009	0.0004	0.0004
SO1	0.0015	0.0003	0.0011	0.0004	0.0011	0.0003	0.0003
SO2	0.0011	0.0004	0.0012	0.0003	0.0008	0.0002	0.0004
SO3	0.0012	0.0002	0.0010	0.0003	0.0009	0.0002	0.0002
FVO	0.0009	0.0004	0.0009	0.0003	0.0005	0.0002	0.0004
VO1	0.0007	0.0005	0.0007	0.0002	0.0007	0.0003	0.0005
VO2	0.0010	0.0004	0.0008	0.0003	0.0006	0.0002	0.0003
VO3	0.0008	0.0003	0.0006	0.0002	0.0004	0.0002	0.0004
FPO	0.0018	0.0009	0.0021	0.0007	0.0016	0.006	0.0010
PO1	0.0016	0.0007	0.0018	0.0005	0.0014	0.0004	0.0008
PO2	0.0014	0.0006	0.0016	0.0006	0.0015	0.0003	0.0009
PO3	0.0015	0.0007	0.0014	0.0004	0.0012	0.0004	0.0007
FCO	0.0008	0.0004	0.0006	0.0002	0.0003	0.0002	0.0003
CO1	0.0006	0.0003	0.0005	0.0002	0.0004	0.0002	0.0002
CO2	0.0007	0.0002	0.0007	0.0001	0.0004	0.0001	0.0002
CO3	0.0005	0.0002	0.0004	0.0001	0.0003	0.0001	0.0002
Mean	1.15e-3	4.95e-4	1.02e-3	3.35e-4	8.85e-4	5.40e-4	4.70e-4
SD	3.68e-4	2.13e-4	4.36e-4	1.53e-4	4.08e-4	1.26e-3	2.35e-4
CV%	32.1	43.1	43.0	45.5	46.1	232.6	49.9

FOO= fresh olive oil, OO1= first fried olive oil, OO2= first refried olive oil, OO3= second refried olive oil, FSO= fresh soya bean oil, SO1= first fried soyabean oil, SO2= first refried soyabean oil, SO3= second refried soyabean oil, FVO= fresh refined palm olein, VO1=first fried refined palm olein, VO2= first refried refined palm olein, VO3= second refried refined palm olein, FPO= fresh palm oil, PO1= first fried palm oil, PO2= first refried palm oil, PO3= second refried palm oil, FCO= fresh coconut oil, CO1= first fried coconut oil, CO2= first refried coconut oil, CO3= second refried coconut oil.

For concentrations varied from 0.0005 to 0.0018 mg/kg with an average value of 0.00115. In the fresh oil samples the values (mg/kg) were: olive oil (FOO) (0.0014); soy bean oil (FSO) (0.0016); refined palm olein (FVO) (0.0009); palm oil (FPO) (0.0018) and coconut oil (FCO) (0.0008). It is well known that iron is indispensable for human beings and animals and is an essential component of hemoglobin. It facilitates the oxidation of carbohydrates, proteins and fats to control body weight, which is an extremely important factor in diabetes; furthermore an Fe deficiency can induce anemia [1]. The levels of iron in the oil samples (fresh and fried) 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 [22]. Also comparing the results with global data from literatures, it was found that the obtained values were far below the average values from Pakistan, Turkey and Spain [13, 14]. Copper concentrations across all the samples of oils ranged from 0.0002 to 0.0009 mg/kg in all the samples of oils analyzed, the Cu concentrations were comparatively lower than those reported in similar samples from literatures (0.2 – 0.33 mg/kg) (12.7 – 50.5 mg/kg) and 0.002 – 0.032 mg/kg reported for edible vegetable oils of Riyadh [1, 19]. According to Pfalzer and Bowman (2017), Mn is an essential element indicated in many biological processes such as immunity function, blood sugar regulation and bone growth and also as an antioxidant. In the five oils (fresh and fried) samples, the levels range between 0.0004 and 0.0021 mg/kg with an average value of 0.00102 mg/kg and a CV % value of 43.0. These values were comparably lower than those reported for similar edible vegetable oils in countries like Pakistan, Spain, Riyadh and Egypt [1, 15].

Lead was detected in all the samples with concentration ranging from 0.0001 to 0.0007 mg/kg with an average of 0.000335 mg/kg and a CV % value of 45.5. From all the results obtained, the Pb levels were lower than values (0.001 – 0.321 mg/kg) recorded for similar oils by Alrajhi and [1, 23]. However, the Pb concentrations observed in the present report were comparatively lower than the maximum tolerable limit set by FAO/WHO (0.1 mg/kg) [16]. Lead is a naturally occurring element and it is a widespread industrial metal [1]. Lukomska et al. (2017) reported that lead has severe health effects even at relatively low levels. It is able to cross the placenta and damage the developing fetal nervous system [1, 17]. Other effects of lead include acute and chronic poisoning: its adverse effects have been noticed on kidneys, liver, heart and on both vascular and immune Systems [17, 18]. Zn has been reported to have an essential functions in carbohydrates and cholesterol metabolism [17]. In the present report, levels of zinc in all the oils were within the range of 0.0003 and 0.0016 mg/kg with an average value of 0.000885 mg/kg and a CV % value of 46.1. These levels were comparably low when compared with similar data from literatures: edible vegetable oils of Riyadh (0.001 – 0.511 mg/kg) and also reports by other authors for many similar samples [1, 15, 19].

Cadmium is an extremely toxic metal found naturally in soil, but also spread in environment due to human activities. Over exposure to Cd can lead to lung, liver, skeletal and renal problems as well as cancer [20]. All the vegetable oil samples investigated showed lower Cd levels (0.0001- 0.006 mg/kg) than the legal limits recommended by FAO/WHO (0.5 mg/kg) [16]. Nickel levels in the samples ranged from 0.0002 to 0.0010 mg/kg with a mean value of 0.00047 mg/kg and a CV % value of 49.9. Trace amount of Ni may be beneficial as activators of some enzymes, but its toxicity at higher levels is more prominent [21]. The levels of Ni obtained in the present report fell within the range of values recorded by several authors on similar samples from Spain, Pakistan and Turkey [14, 1].

Percentage differences in the concentrations of heavy metals between repeated fryings and fresh samples of the selected oils were depicted in Table II. The general observations were as follow: For Fe, Cu, Mn and Pb, the major differences were recorded between the fresh, first and second frying of the oils. However, for Zn, Cd and Ni, the trend was opposite. These observations cut across all the oil samples (olive, refined palm olein, soya bean, palm oil and coconut).

Table II. Variations In The Concentrations Of The Heavy Metals From The Repeated Frying

Parameters	Heavy metals						
	Fe	Cu	Mn	Pb	Zn	Cd	Ni
FOO-OO1	0.0002	-0.0001	0.0003	-0.0001	-0.0002	-0.0001	-0.0002
%Diff	(14.3%)	(14.3%)	(27.3%)	(33.3%)	(18.2%)	(33.3%)	(40.0%)
FOO-OO2	0.0001	0.0001	0.0004	0.00	0.00	0.0001	0.0001
%Diff	(7.14%)	(14.3%)	(36.4%)	(0.00%)	(0.00%)	(33.3%)	(20.0%)
FOO-OO3	0.0001	0.0001	0.0001	-0.0001	-0.0001	0.0001	-0.0001
%Diff	(7.14 %)	(14.3%)	(9.09%)	(33.3%)	(9.09%)	(33.3%)	(20.0%)
FSO-SO1	0.0001	0.0002	0.0002	0.0001	-0.0002	0.0001	0.0001
%Diff	(6.25%)	(40.0%)	(15.4%)	(20.0%)	(22.2%)	(2.50%)	(25.0%)
FSO-SO2	0.0005	0.0001	0.0001	0.0002	0.0001	0.0002	0.00
%Diff	(31.3%)	(20.0%)	(7.69%)	(40.0%)	(11.1%)	(5.00%)	(0.00%)
FSO-SO3	0.0004	0.0003	0.0003	0.0002	0.00	0.0002	0.0002
%Diff	(25.0%)	(60.0%)	(23.1%)	(4.00%)	(0.00%)	(5.00%)	(50.0%)
FVO-VO1	0.0002	-0.0001	0.0002	0.0001	-0.0002	-0.0001	-0.0001
%Diff	(22.2%)	(25.0%)	(22.0%)	(33.3%)	(40.0%)	(50.0%)	(25.0%)
FVO-VO2	-0.0001	0.00	0.0001	0.00	-0.0001	0.00	0.0001
%Diff	(11.1%)	(0.00%)	(11.1%)	(0.00%)	(20.0%)	(0.00%)	(25.0%)
FVO-VO3	0.0004	0.0001	0.0003	0.0001	0.0001	0.00	0.00
%Diff	(44.4%)	(25.0%))	(33.3%)	(33.3%)	(20.0%)	(0.00%)	(0.00%)

FPO-PO1	0.0002	0.0002	0.0003	0.0002	0.0002	0.0056	0.0002
%Diff	(11.1%)	(22.2%)	(14.3%)	(28.6%)	(12.5%)	(93.3%)	(20.0%)
FPO-PO2	0.0004	0.0003	0.0005	0.0001	0.0001	0.0057	0.0001
%Diff	(22.2%)	(33.3%)	(23.8%)	(14.3%)	(6.25%)	(95.0%)	(10.0%)
FPO-PO3	0.0003	0.0002	0.0007	0.0003	0.0004	0.0056	0.0003
%Diff	(16.7%)	(22.2%)	(33.3%)	(42.9%)	(25.0%)	(93.3%)	(30.0%)
FCO-CO1	0.0002	0.0001	0.0001	0.00	-0.0001	0.00	0.0001
%Diff	(25.0%)	(25.0%)	(16.7%)	(0.00%)	(33.3%)	(0.00%)	(33.3%)
FCO-CO2	0.0001	0.0002	-0.0001	0.0001	-0.0001	0.0001	0.0001
%Diff	(12.5%)	(50.0%)	(16.7%)	(50.0%)	(33.3%)	(50.0%)	(33.3%)
FCO-CO3	0.0003	0.0002	0.0002	0.0001	0.00	0.0001	0.0001
%Diff	(37.5%)	(50.0%)	(33.3%)	(50.0%)	(0.00%)	(50.0%)	(33.3%)

Estimated daily intakes (for adults and children) were presented in Tables III and IV respectively for the selected edible vegetable oils (both fresh and fried). Generally, from the results across all the oil samples for the heavy metals considered for the two age groups, the values were comparably very low. The mean vales for individual metals are as follow: Fe (8.95e-7, CV% of 32.1), Cu (3.87 e-7, CV% of 43.1), Mn (7.94e-7, CV% of 43.0), Pb (2.62 e-7, CV% of 45.5), Zn (6.92 e-7, CV% of 46.1), Cd (4.22 e-7, CV% of 233) and Ni (3.68 e-7, CV% of 49.9) and Fe (2.61 e-6, CV% of 3.21), Cu (1.13 e-6, CV% of 43.1), Mn (2.32 e-6, CV% of 43.0), Pb (7.65 e-7, CV% of 45.5), Zn (2.02 e-6, CV% of 46.1), Cd (1.23 e-6, CV% of 233) and Ni (1.07 e-6, CV% of 49.9) respectively for adults and children. These observed mean values were comparably lower than those recorded for selected vegetable commonly consumed in south western Nigeria [17]. It is interesting to note that the CV % for the mineral of both adults and children had equivalent values; e.g. Fe [CV%: 32.1 (adult) and 32.1 (children)].

Table III. Calculated Estimated Daily Intake Of The Heavy Metals In The Fresh And Repeatedly Fried Vegetable Oils For Adults (70 Kg Body Weight)

Oils	Heavy metals						
	Fe	Cu	Mn	Pb	Zn	Cd	Ni
FOO	1.09e-6	5.47e-7	8.6e-7	2.35e-7	8.6e-7	2.35e-7	3.91e-7
OO1	9.38e-7	6.26e-7	6.26e-7	3.13e-7	1.02e-6	3.13e-7	5.47e-7
OO2	1.02e-6	4.69e-7	5.47e-7	2.35e-7	8.6e-7	1.56e-7	3.13e-7
OO3	1.02e-6	6.26e-7	7.82e-7	3.13e-7	9.38e-7	1.56e-7	4.69e-7
FSO	1.25e-6	3.91e-7	1.02e-6	3.91e-7	7.04e-7	3.13e-7	3.13e-7
SO1	1.17e-6	2.35e-7	8.6e-7	3.13e-7	8.6e-7	2.35e-7	2.35e-7
SO2	8.6e-7	3.13e-7	9.38e-7	2.35e-7	6.26e-7	1.56e-7	3.13e-7
SO3	9.38e-7	1.56e-7	7.82e-7	2.35e-7	7.04e-7	1.56e-7	1.56e-7
FVO	7.04e-7	3.13e-7	7.04e-7	2.35e-7	3.91e-7	1.56e-7	3.13e-7
VO1	5.47e-7	3.91e-7	5.47e-7	1.56e-7	5.47e-7	2.35e-7	3.91e-7
VO2	7.82e-7	3.13e-7	6.26e-7	2.35e-7	4.69e-7	1.56e-7	2.35e-7
VO3	6.26e-7	2.35e-7	4.69e-7	1.56e-7	3.13e-7	1.56e-7	3.13e-7
FPO	1.41e-6	7.04e-7	1.64e-6	5.47e-7	1.25e-6	4.69e-6	7.82e-7
PO1	1.25e-6	5.47e-7	1.41e-6	3.91e-7	1.09e-6	3.13e-7	6.26e-7
PO2	1.09e-6	4.69e-7	1.25e-6	4.69e-7	1.17e-6	2.35e-7	7.04e-7
PO3	1.17e-6	5.47e-7	1.09e-6	3.13e-7	9.38e-7	3.13e-7	5.47e-7
FCO	6.26e-7	3.13e-7	4.69e-7	1.56e-7	2.35e-7	1.56e-7	2.35e-7
CO1	4.69e-7	2.35e-7	3.91e-7	1.56e-7	3.13e-7	1.56e-7	1.56e-7
CO2	5.47e-7	1.56e-7	5.47e-7	7.82e-8	3.13e-7	7.82e-8	1.56e-7

CO3	3.91e-7	1.56e-7	3.13e-7	7.82e-8	2.35e-7	7.82e-8	1.56e-7
Mean	8.95e-7	3.87e-7	7.94e-7	2.62e-7	6.92e-7	4.22e-7	3.68e-7
SD	2.88e-7	1.67e-7	3.41e-7	1.19e-7	3.19e-7	9.82e-7	1.84e-7
CV%	32.1	43.1	43.0	45.5	46.1	233	49.9

Table IV. Calculated estimated daily intake of the heavy metals in the fresh and repeatedly fried vegetable oils for children (24 kg body weight)

Oils	Heavy metals						
	Fe	Cu	Mn	Pb	Zn	Cd	Ni
FOO	3.20e-6	1.6e-6	2.51e-6	6.85e-7	2.51e-6	6.85e-7	1.14e-6
OO1	2.74e-6	1.83e-6	1.83e-6	9.13e-7	2.97e-6	9.13e-7	1.6e-6
OO2	2.97e-6	1.37e-6	1.6e-6	6.85e-7	2.51e-6	4.57e-7	9.13e-7
OO3	2.97e-6	1.83e-6	2.28e-6	9.13e-7	2.74e-6	4.57e-7	1.37e-6
FSO	3.65e-6	1.14e-6	2.97e-6	1.14e-6	2.05e-6	9.13e-7	9.13e-7
SO1	3.42e-6	6.85e-7	2.51e-6	9.13e-7	2.51e-6	6.85e-7	6.85e-7
SO2	2.51e-6	9.13e-7	2.74e-6	6.85e-7	1.83e-6	4.57e-7	9.13e-7
SO3	2.74e-6	4.57e-7	2.28e-6	6.85e-7	2.05e-6	4.57e-7	4.57e-7
FVO	2.05e-6	9.13e-7	2.05e-6	6.85e-7	1.14e-6	4.57e-7	9.13e-7
VO1	1.6e-6	1.14e-6	1.6e-6	4.57e-7	1.6e-6	6.85e-7	1.14e-6
VO2	2.28e-6	9.13e-7	1.83e-6	6.85e-7	1.37e-6	4.57e-7	6.85e-7
VO3	1.83e-6	6.85e-7	1.37e-6	4.57e-7	9.13e-7	4.57e-7	9.13e-7
FPO	4.11e-6	2.05e-6	4.79e-6	1.6e-6	3.65e-6	1.37e-5	2.28e-6
PO1	3.65e-6	1.6e-6	4.11e-6	1.14e-6	3.2e-6	9.13e-7	1.83e-6
PO2	3.2e-6	1.37e-6	3.65e-6	1.37e-6	3.42e-6	6.85e-7	2.05e-6
PO3	3.42e-6	1.6e-6	3.2e-6	9.13e-7	2.74e-6	9.13e-7	1.6e-6
FCO	1.83e-6	9.13e-7	1.37e-6	4.57e-7	6.85e-7	4.57e-7	6.85e-7
CO1	1.37e-6	6.85e-7	1.14e-6	4.57e-7	9.13e-7	4.57e-7	4.57e-7
CO2	1.6e-6	4.57e-7	1.6e-6	2.28e-7	9.13e-7	2.28e-7	4.57e-7
CO3	1.14e-6	4.57e-7	9.13e-7	2.28e-7	6.85e-7	2.28e-7	4.57e-7
Mean	2.61e-6	1.13e-6	2.32e-6	7.65e-7	2.02e-6	1.23e-6	1.07e-6
SD	8.4e-7	4.87e-7	9.96e-7	3.48e-7	9.31e-7	2.87e-6	5.36e-7
CV%	32.1	43.1	43.0	45.5	46.1	233	49.9

Tables V and VI depicted the results of target hazard quotient (THQ), hazard index (HI) and target cancer risk (TCR) for all the various oil samples (fresh and fried) for adults and children respectively. The THQ across all the samples were all less than 0.1. THQ is a measure of the possibility of developing non-carcinogenic health problems and the acceptable limit is ≤ 0.1 (USEPA, 2011). If the THQ value obtained for individual heavy metal is greater than the tolerable limit, it might pose non-carcinogenic health risk to the consumer [24]. Hazard index (HI), which is determined to assess the combined risk of heavy metals' toxicity is the sum total of all the THQ values in a food sample and a value greater than 1.0 is an indication that the probability of an adverse health effect is associated with such exposure is high [17]. The HI values in the present report ranged as follow: 7.53 e-5 – 1.24 e-4 (adults) and 2.07 e-4 – 5.35e-3 (children). These values were lower than 1.0 and as such would not result in adverse health effects for consumers.

Table V. Calculate Target Hazard Quotient (Thq), Hazard Index (Hi) And Target Cancer Risk (Tcr) Of The Heavy Metals In The Fresh And Repeatedly Fried Vegetable Oils For Adults (70 Kg Body Weight)

Oils	Heavy metals								
	THQ							HI	TCR
	Fe	Cu	Mn	Pb	Zn	Cd	Ni		
FOO	1.56e-6	1.37e-5	6.14e-6	6.70e-5	2.87e-5	7.82e-5	1.96e-5	2.15e-4	4.78e-4
OO1	1.34e-6	1.56e-5	4.47e-6	8.94e-5	3.39e-5	1.04e-4	2.74e-5	2.76e-4	6.37e-4
OO2	1.45e-6	1.17e-5	3.91e-6	6.70e-5	2.87e-5	5.21e-5	1.56e-5	1.81e-4	3.19e-4
OO3	1.45e-6	1.56e-5	5.59e-6	8.94e-5	3.13e-5	5.21e-5	2.35e-5	2.19e-4	3.19e-4
FSO	1.79e-6	9.78e-6	7.26e-6	1.12e-4	2.35e-5	1.04e-4	1.56e-5	2.74e-4	6.37e-4
SO1	1.68e-6	5.87e-6	6.14e-6	8.94e-5	2.87e-5	7.82e-5	1.17e-5	2.22e-4	4.78e-4
SO2	1.23e-6	7.82e-6	6.7e-6	6.7e-5	2.09e-5	5.21e-5	1.56e-5	1.71e-4	3.19e-4
SO3	1.34e-6	3.91e-6	5.59e-6	6.7e-5	2.35e-5	5.21e-5	7.82e-6	1.61e-4	3.19e-4
FVO	1.01e-6	7.82e-6	5.03e-6	6.7e-5	1.3e-5	5.21e-5	1.56e-5	1.62e-4	3.19e-4
VO1	7.82e-7	9.78e-6	3.91e-6	4.47e-5	1.82e-5	7.82e-5	1.96e-5	1.75e-4	4.77e-4
VO2	1.12e-6	7.82e-6	4.47e-6	6.7e-5	1.56e-5	5.21e-5	1.17e-5	1.60e-4	3.19e-4
VO3	8.94e-7	5.87e-6	3.35e-6	4.47e-5	1.04e-5	5.21e-5	1.56e-5	1.33e-4	3.18e-4
FPO	2.01e-6	1.76e-5	1.17e-5	1.56e-4	4.17e-5	1.56e-3	3.91e-5	1.83e-3	9.54e-3
PO1	1.79e-6	1.37e-5	1.01e-5	1.12e-4	3.65e-5	1.04e-4	3.13e-5	3.09e-4	6.37e-4
PO2	1.56e-6	1.17e-5	8.94e-6	1.30e-4	3.91e-5	7.82e-5	3.52e-5	3.09e-4	4.78e-4
PO3	1.68e-6	1.37e-5	7.82e-6	8.94e-5	3.13e-5	1.04e-4	2.74e-5	2.75e-4	6.37e-4
FCO	8.94e-7	7.82e-6	3.35e-6	4.47e-5	7.82e-6	5.21e-5	1.17e-5	1.28e-4	3.18e-4
CO1	6.7e-7	5.87e-6	2.79e-6	4.47e-5	1.04e-5	5.21e-5	7.82e-6	1.24e-4	3.18e-4
CO2	7.82e-7	3.91e-6	3.91e-6	2.23e-5	1.04e-5	2.61e-5	7.82e-6	7.53e-5	1.59e-4
CO3	5.59e-7	3.91e-6	2.23e-6	2.23e-5	7.82e-6	2.61e-5	7.82e-6	7.08e-5	1.59e-4
Mean	1.28e-6	9.68e-6	5.67e-6	7.48e-5	2.31e-5	1.41e-4	1.84e-5	2.74e-4	8.59e-4
SD	4.11e-7	4.17e-6	2.44e-6	3.41e-5	1.06e-5	3.27e-4	9.18e-6	3.64e-4	2.00e-3
CV%	32.1	43.1	43.0	45.5	46.1	233	49.9	133	232
HI=hazard index, THQ=target hazard quotient, TCR=target cancer risk									

Table VI. Calculated Target Hazard Quotient (Thq), Hazard Index (Hi) And Target Cancer Risk (Tcr) Of The Heavy Metals In The Fresh And Repeatedly Fried Vegetable Oils For Children (24 Kg Body Weight)

Oils	Heavy metals								
	THQ							HI	TCR
	Fe	Cu	Mn	Pb	Zn	Cd	Ni		
FOO	4.57e-6	4.00e-5	1.79e-5	0.000196	8.37e-5	0.000228	5.71e-5	6.27e-4	1.39e-3
OO1	3.91e-6	4.57e-5	1.3e-5	0.000261	9.89e-5	0.000304	7.99e-5	8.07e-4	1.86e-3
OO2	4.24e-6	3.42e-5	1.14e-5	0.000196	8.37e-5	0.000152	4.57e-5	5.27e-4	9.30e-4
OO3	4.24e-6	4.57e-5	1.63e-5	0.000261	9.13e-5	0.000152	6.85e-5	6.39e-4	9.31e-4
FSO	5.22e-6	2.85e-5	2.12e-5	0.000326	6.85e-5	0.000304	4.57e-5	8.00e-4	1.86e-3
SO1	4.89e-6	1.71e-5	1.79e-5	0.000261	8.37e-5	0.000228	3.42e-5	6.47e-4	1.39e-3
SO2	3.59e-6	2.28e-5	1.96e-5	0.000196	6.09e-5	0.000152	4.57e-5	5.00e-4	9.30e-4
SO3	3.91e-6	1.14e-5	1.63e-5	0.000196	6.85e-5	0.000152	2.28e-5	4.71e-4	9.30e-4
FVO	2.94e-6	2.28e-5	1.47e-5	0.000196	3.81e-5	0.000152	4.57e-5	4.72e-4	9.30e-4

VO1	2.28e-6	2.85e-5	1.14e-5	0.000130	5.33e-5	0.000228	5.71e-5	5.11e-4	1.39e-3
VO2	3.26e-6	2.28e-5	1.3e-5	0.000196	4.57e-5	0.000152	3.42e-5	4.67e-4	9.30e-4
VO3	2.61e-6	1.71e-5	9.78e-6	0.000130	3.04e-5	0.000152	4.57e-5	3.88e-4	9.30e-4
FPO	5.87e-6	5.14e-5	3.42e-5	0.000457	0.000122	0.004566	0.000114	5.35e-3	2.79e-2
PO1	5.22e-6	4.00e-5	2.94e-5	0.000326	0.000107	0.000304	9.13e-5	9.03e-4	1.86e-3
PO2	4.57e-6	3.42e-5	2.61e-5	0.000391	0.000114	0.000228	0.000103	9.01e-4	1.40e-3
PO3	4.89e-6	4.00e-5	2.28e-5	0.000261	9.13e-5	0.000304	7.99e-5	8.04e-4	1.86e-3
FCO	2.61e-6	2.28e-5	9.78e-6	0.00013	2.28e-5	0.000152	3.42e-5	3.75e-4	9.30e-4
CO1	1.96e-6	1.71e-5	8.15e-6	0.00013	3.04e-5	0.000152	2.28e-5	3.63e-4	9.30e-4
CO2	2.28e-6	1.14e-5	1.14e-5	6.52e-5	3.04e-5	7.61e-5	2.28e-5	2.20e-4	4.65e-4
CO3	1.63e-6	1.14e-5	6.52e-6	6.52e-5	2.28e-5	7.61e-5	2.28e-5	2.07e-4	4.65e-4
Mean	3.73e-6	2.83e-5	1.66e-5	0.000219	6.73e-5	0.000411	5.37e-5	7.99e-4	2.51e-3
SD	1.2e-6	1.22e-5	7.11e-6	9.95e-5	3.10e-5	0.000956	2.68e-5	1.06e-3	5.83e-3
CV%	32.1	43.1	43.0	45.5	46.1	233	49.9	133	232
HI=hazard index, THQ=target hazard quotient, TCR=target cancer risk									

Carcinogenic risk is estimated and expressed as a probability of contracting cancer over a lifetime of 70 years. In the present study, the possibility of developing cancer condition is calculated based on the USEPA approach. It has been adequately shown that prolonged exposure to a specific carcinogen may develop cancer and the probability increases with the contact time [25, 26]. As suggested by the New York State Department of Health, the TCR categories are as follows: low risk, if the TCR value ≤ 10e-6, moderate risk, if the TCR value is between 10e-5 and 10e-3, high risk, if the TCR value is 10e-3 and 10e-1 and very high risk, if TCR value is ≥ 10e-1 [17]. As evident in the results from the present study (Tables V and VI), for adults and children respectively, the TCR (Pb +Cd) with values range of 1.59 e-4 – 9.54e-4 with a mean value of 88.59e-4 (adults) and 4.65e-4 – 1.86e-3 with a mean value of 2.51e-3 (children) revealed low to moderate carcinogenic risks for individuals consuming these oils directly or indirectly.

Conclusion

From this study, it was possible to establish a database about the contamination status of heavy metals in popular edible vegetable oils sold and consumed (fresh and fried) among the populace in the south western region of Nigeria. Although the concentration of heavy metals in the analyzed oils (fresh and fried) were within the permissible limits of FAO/WHO and USEPA, their presence is an indication of contamination, no matter how low they might be. The presence of heavy metals in the vegetables might be due to anthropogenic activities (industrial, processing and handling during food preparation) as well as from vehicular emissions. For adults and children, the THQ and HI were low. The TCR values also indicate low to moderate carcinogenic risks for adults and children particularly for Pb and Cd, although Hg which could have behaved in a similar way was not determined due to technical reasons [27-30].

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