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Study of Heavy Metals Bio Toxicity Present in Locally Produced Palm Kernel Oil in Osun State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author PT designed the study, author OAA performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author TVO managed the analyses of the study. Authors FJO and Michael OA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This study investigates the heavy metals content presents in locally produced Palm Kernel Oil in Osun State, Nigeria. 16 samples were collected from four major factories in four towns in the study area. Atomic Absorption Spectrometry (AAS) was used for the concentration of the heavy metals analysis in the samples. The results show the contents of the heavy metal present were 0.022, 0.018, 0.090, 0.071, 0.166 and 0.010 ppm for Cd, As, Fe, Zn, Cu and Pb, respectively. The range of measured concentration of heavy metal contents in the palm kernel oil varies within the same factory which may be due to the fact that the production processes and most especially the source of the palm kernel used by the factories and nature of the soil where the palm tree is planted varied. The mean concentration of Cd, Zn, As, Fe and Pb were below the bio-recommended limit published by joint FAO/WHO. Only Cu is well above the permissible limit.

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1. INTRODUCTION

Apart from radionuclides, heavy metals also contribute serious health effect in humans especially when consumed above the bio-recommended limit [1].

Heavy metals are metals or metalloids (elements that have both metal and non-metal characteristics) are persistent in all parts of the environment and have densities above 5 g /cm^3**.** Heavy metals occur as natural constituents of the earth crust and are persistent environmental contaminants since they cannot be degraded or destroyed. To a small extent, they enter the body system through food, air, water and bio-accumulate over a period of time [2]. Some heavy metals such as copper (Cu), selenium (Se) and zinc (Zn) are essential to maintain the metabolism of the human body and so are beneficial as trace elements but at high concentration they become poisonous to the human body. These heavy metals can cause serious health effects with varied symptoms depending on the nature and quantity of the metal ingested. Humans are in turn exposed to heavy metals by consuming contaminated plants and animals. This has been known to result in various biochemical disorders. The bio toxic effects of heavy metals refer to the harmful effects of heavy metals to the body when consumed above the bio-recommended limits. Although individual metals exhibit specific signs of their toxicity, the following have been reported as general signs associated with cadmium, lead, arsenic, mercury, zinc, copper and aluminium poisoning: gastrointestinal (GI) disorders such as diarrhoea, stomatitis, tremor and hemoglobinuria [3]. The most common heavy metals that humans are exposed to are: arsenic, cadmium and lead.

Also, heavy metals are among the most common pollutants whose occurrence in soil is due to man-made pollution (from anthropogenic sources) rather than natural enrichment by geological weathering [4]. The anthropogenic heavy metals accumulate readily in the topsoil and would cause toxicity to plants and animals with detrimental effects on human health [1,5].

Radionuclides and Heavy metals generally move through the environment and into the body through many different pathways such as: air, water, consumer products and the food chain. Heavy metals are dangerous because they tend to bio accumulate. Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time compared to the chemical concentration in the environment. The presence of heavy metals in the environment above the required limit is detrimental to human health. Hence, this study aim to determine the heavy metals biotoxicity present in the palm kernel oil consumed by the inhabitants and its possible risk in the study area.

2. METHODOLOGY

2.1 Description of Palm Kernel Oil (PKO)

The oil palm fruit is 5 cm in diameter; it is elongated, nutlike, glossy bright red to black when ripe and takes about 6 months for fruits to ripen. The palm fruit is drupe, oval in shape, and contains a nut. The nut is surrounded by fibrous fruit pulp or oil-bearing tissue (mesocarp) and the skin. This is shown in Fig. 1. The nut consists of a hard shell and a kernel that is used for the production of palm kernel oil. Palm kernel oil is semi-solid at room temperature and is more saturated than palm oil because of its high level of stability. It is commonly used in commercial cooking and has the following advantages over other vegetable oils [6].

(a) It is relatively low cost
(b) It remains stable at high cooking temperatures and
(c) It can be stored longer than other vegetable oils.

The palm kernel oil production process is a relative complex process, requiring a number of distinct process steps as shown in Chart 1.

Palm kernel oil provides raw materials in the manufacture of soaps and detergents, margarine, candle, confectionery, bakery trade, lubricants, pomades and cosmetics. Other uses include palm kernel cake obtained from the crushing of palm kernel to extract oil. It serves as additives in livestock feed manufacture.

2.2 Sample Collection

A collection protocol was established which includes locating the major factories of palm kernel oil production in the specified areas; major market was visited to ask the traders where the major factories in the specified area were situated. A total of 16 samples were collected from four major factories in four towns namely; Modakeke, Ife, Sekona and Ede. The samples were carefully labelled to avoid cross contamination and were stored in appropriate containers. All the samples collected were identified and grouped according to their location.

Chart 1. The palm kernel oil production process

1. Receipt and Storage of Nuts
2. Drying of Nuts if Wet or Damp
3. Cracking of Nuts
4. Sieving of Cracked Nuts
5. Separation of Kernels by Flotation
6. Sun Drying of Kernels
7. Winnow Kernels
8. Remove Undesired Objects
9. Roast Kernels to Aid Oil Extraction
10. Mill Roasted Kernels into Paste
11. Cook Emulsion and Collect Oil
12. Package into Containers

2.3 Sample Preparation

In preparation for the heavy metals analysis, 1 g of each sample was weighed and digested using nitric acid and hydrofluoric acid. The digested samples was transferred into plastic reagent bottle for Atomic Absorption Spectrometry (AAS) analysis in order to determine the concentration of the heavy metals present and their level of toxicity to mankind.

2.4 Determination of Heavy Metals (Atomic Absorption Spectroscopy Analysis)

Atomic Absorption Spectrometry (AAS) is an analytical technique that measures the concentrations of metals in solution. Atomic absorption is so sensitive that it can measure down to parts per billion of a gram (μg dm^{-3}) in a sample. The technique makes use of the wavelengths of light specifically absorbed by an element. They correspond to the energies needed to promote electrons from one energy level to another higher energy level. The quantitative analysis by AAS depends on the: accurate measurement of the light intensity and radiation absorbed must be proportional to the atomic concentration.

3. RESULTS AND DISCUSSION

3.1 Heavy Metal Concentration in Palm kernel Oil

3.1.1 Heavy metal contents

The results of the heavy metals concentration in palm kernel oil is shown in Table 1. Cadmium (Cd) concentration varied from 0.020 to 0.023 ppm with a mean of 0.021 ppm, 0.021 to 0.028 ppm with a mean of 0.024 ppm, 0.013 to 0.023 ppm with a mean of 0.018 ppm and 0.018 to 0.031 ppm with a mean of 0.025 ppm for Ife, Modakeke, Sekona and Ede, respectively while Arsenic (As) ranged from 0.021 to 0.029 ppm with a mean of 0.026 ppm, 0.010 to 0.015 ppm with a mean of 0.012 ppm, 0.012 to 0.015 ppm with a mean of 0.014 ppm and 0.018 to 0.022 ppm with a mean of 0.020 ppm for Ife, Modakeke, Sekona and Ede, respectively. Similarly, Iron (Fe) ranged from 0.088 to 0.092 ppm with a mean of 0.090 ppm, 0.090 to 0.101 ppm with a mean of 0.095 ppm, 0.073 to 0.081 ppm with a mean of 0.077 ppm and 0.093 to 0.104 ppm with a mean of 0.010 ppm for Ife, Modakeke, Sekona and Ede, respectively while Zinc (Zn) ranged from 0.070 to 0.091 ppm with a mean of 0.080 ppm, 0.059 to 0.071 ppm with a mean of 0.066 ppm, 0.060 to 0.077 ppm with a mean 0.068 ppm and 0.055 to 0.082 ppm with a mean of 0.069 ppm for Ife, Modakeke, Sekona and Ede respectively. Furthermore, Copper (Cu) ranged from 0.166 to 0.174 ppm with a mean of 0.170 ppm, 0.180 to 0.194 ppm with a mean of 0.188 ppm, 0.150 to 0.182 ppm with a mean of 0.166 ppm and 0.133 to 0.144 ppm with a mean of 0.140 ppm for Ife, Modakeke, Sekona and Ede respectively. Conclusively, Lead (Pb) ranged from 0.009 to 0.015 ppm with a mean of 0.012 ppm, 0.010 to 0.015 ppm with a mean of 0.012 ppm, 0.004 to 0.010 ppm with a mean of 0.007 and 0.007 to 0.010 ppm with a mean of 0.009 ppm.

The overall mean concentration of Cd, As, Fe, Zn, Cu and Pb in the palm kernel oil were 0.022, 0.018, 0.090, 0.071, 0.166, 0.010 ppm, respectively. Fig. 2 showed that there is more concentration of Cu followed by Fe, Zn, Cd, As with Pb having the least concentration.

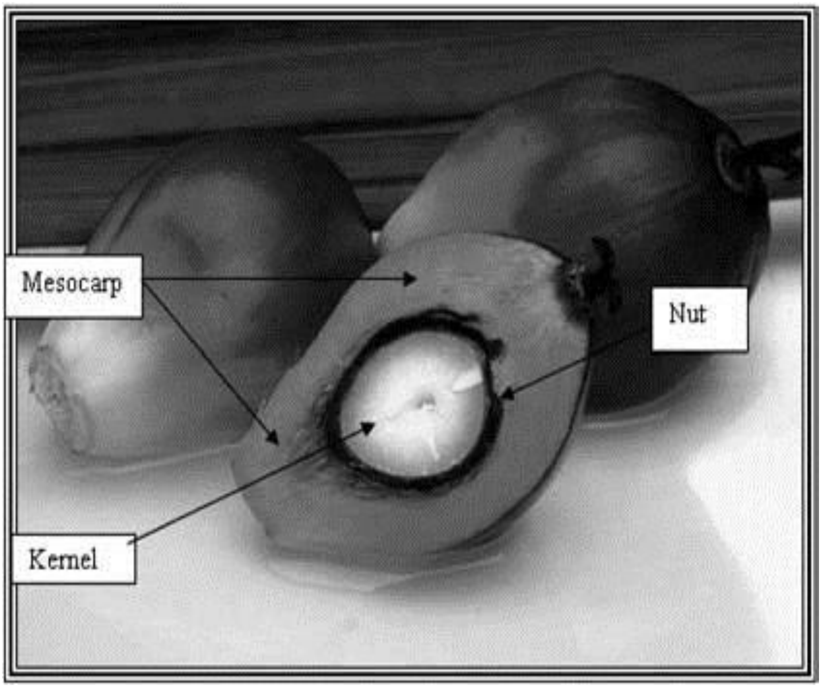

Fig.1. Photograph of palm fruit showing the kernel

3.2 Health Impact of Heavy Metal Contents

The toxic effect of these metals will only manifest when the bio-recommended limit is exceeded. Table 2 shows the maximum limit for the selected heavy metals published by Joint FAO/WHO Food Standards Programme Codex Committee on Contaminants in Food throughout the world. Pb, Cd, Zn, Fe and As have a mean value lesser than their maximum limit published by joint FAO/WHO as shown in Figs below. Only Cu is well above the permissible limit as shown in Fig. 6.

Copper has a mean concentration of 0.166 ppm which is well above the permissible limit as shown in Fig. 6. Copper is essential for human body but very high intake can cause adverse health problems. Long-term exposure to copper can cause irritation of the nose, mouth and eyes and it causes headaches, stomachaches, dizziness, vomiting and diarrhoea (Fosmire, 1990). Chronic copper poisoning results in Wilson's disease, characterized by a hepatic cirrhosis, brain damage, demyelination, renal disease, and copper deposition in the cornea. Copper deficiency may also lead to hypochromic anemia, leucopenia and osteoporosis in children.

Deficiencies of these heavy metals can also lead to serious health risk. Iron deficiency is frequently associated with anaemia and, thus, reduces working capacity and impaired intellectual development [7]. It is known that adequate iron in diet is very important for decreasing the incidence of anaemia. Iron (Fe) is an important trace element and iron-protein mixtures play a vital role in metabolism in all living organisms. However, Fe overdose has been one of the leading reasons of death caused by toxicological agents in children younger than 6 years of age.

Cadmium is a very unique mineral and appears to play a very pivotal role in thyroid disease. It is extremely toxic and has toxic biological effects at concentrations smaller than almost any commonly found mineral. Cadmium can be found in soil, but it is also spread in the environment due to human activities. After ingestion, Cadmium is first transported to the liver through the blood. There, it bonds to proteins to form complexes that are transported to the kidneys. Excessive cadmium exposure may give rise to renal, pulmonary, hepatic, skeletal, reproductive effects and cancer [8].

Arsenic has a mean concentration of 0.018 ppm as shown in Fig. 3. Over consumption of Arsenic for a long period of time could lead to Arsenic poisoning [8]. Symptoms of arsenic poisoning begin with headaches, confusion, severe diarrhoea, and drowsiness. When the poisoning becomes acute, symptoms may include diarrhoea, vomiting, blood in the urine, cramping muscles, hair loss, stomach pain, and more convulsions [9,10]. The organs of the body that are usually affected by arsenic poisoning are the lungs, skin, kidneys, and liver. The final result of arsenic poisoning is coma and death.

Table 1. Concentration of heavy metals (ppm) in palm kernel oil

Samples	Cd	As	Fe	Zn	Cu	Pb
IFE						
PKI1a	0.022	0.029	0.089	0.091	0.166	0.015
PKI1b	0.020	0.028	0.088	0.088	0.170	0.013
PKI2a	0.020	0.024	0.092	0.070	0.171	0.009
PKI2b	0.023	0.021	0.090	0.071	0.174	0.010
MEAN	0.021	0.026	0.090	0.080	0.170	0.012
MODAKEKE						
PKM1a	0.023	0.010	0.101	0.065	0.187	0.011
PKM1b	0.021	0.011	0.096	0.059	0.180	0.010
PKM2a	0.025	0.015	0.090	0.071	0.190	0.013
PKM2b	0.028	0.013	0.092	0.069	0.194	0.015
MEAN	0.024	0.012	0.095	0.066	0.188	0.012
SEKONA						
PKS1a	0.013	0.015	0.081	0.060	0.182	0.004
PKS1b	0.015	0.013	0.073	0.063	0.181	0.006
PKS2a	0.021	0.014	0.077	0.071	0.150	0.009
PKS2b	0.023	0.012	0.076	0.077	0.152	0.010
MEAN	0.018	0.014	0.077	0.068	0.166	0.007
EDE						
PKE1a	0.019	0.020	0.104	0.055	0.144	0.009
PKE1b	0.018	0.018	0.100	0.060	0.143	0.010
PKE2a	0.030	0.021	0.101	0.082	0.139	0.008
PKE2b	0.031	0.022	0.093	0.080	0.133	0.007
MEAN	0.025	0.020	0.100	0.069	0.140	0.009
Min	0.013	0.01	0.073	0.055	0.133	0.004
Max	0.031	0.029	0.104	0.091	0.194	0.015
Overall Mean Mean	0.022	0.018	0.090	0.071	0.166	0.010

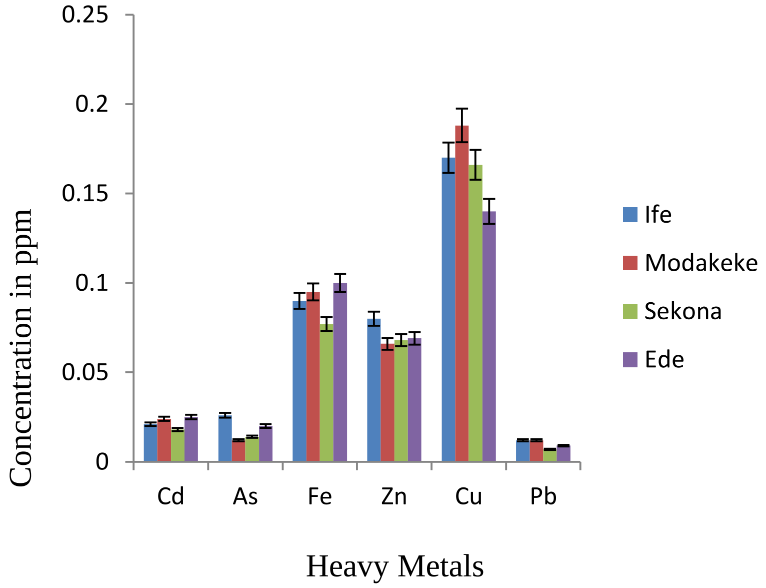

Fig. 2. Mean Concentration of the element compared with the sample location

Table 2. Joint FAO/WHO food standards programme codex committee on contaminants in foods

Elements	Maximum Limit (mg/kg)
Copper(Cu)	0.1
Iron(Fe)	2.5
Cadmium (Cd)	0.1
Zinc (Zn)	1.0
Arsenic (As)	0.1
Lead (Pb)	0.1

SOURCE: Food and Agriculture Organization of the United Nation (FAO) and World Health Organization (WHO) [15].

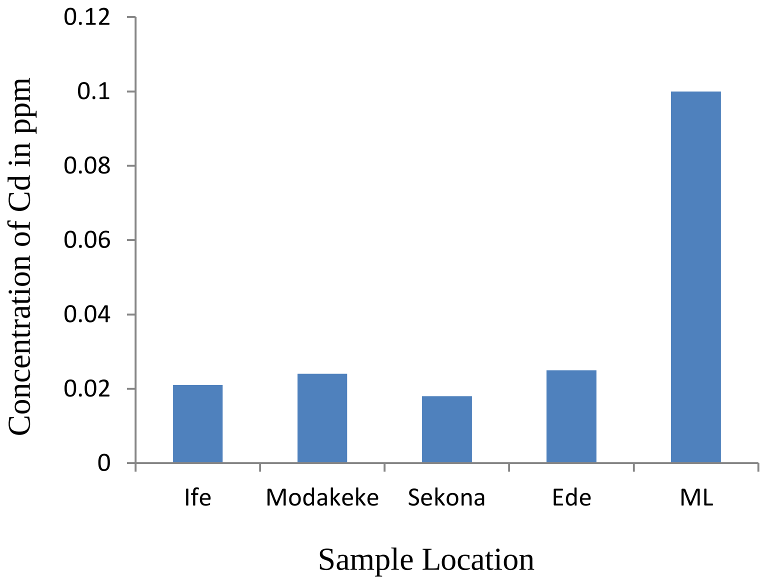

Fig. 3. Mean concentration of cadmium in palm kernel oil compared with the samples area
ML is the Maximum Limit [15]

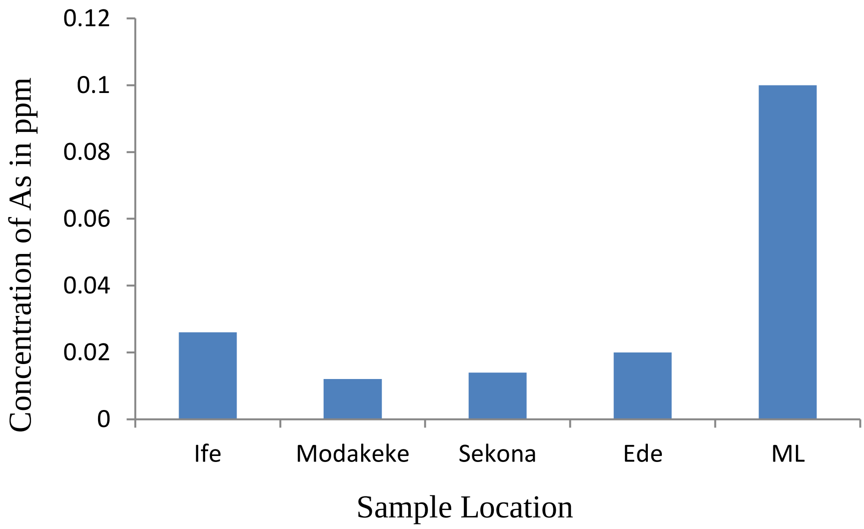

Fig. 4. Mean concentration of arsenic in palm kernel oil compared with the samples location
ML is the Maximum Limit [15]

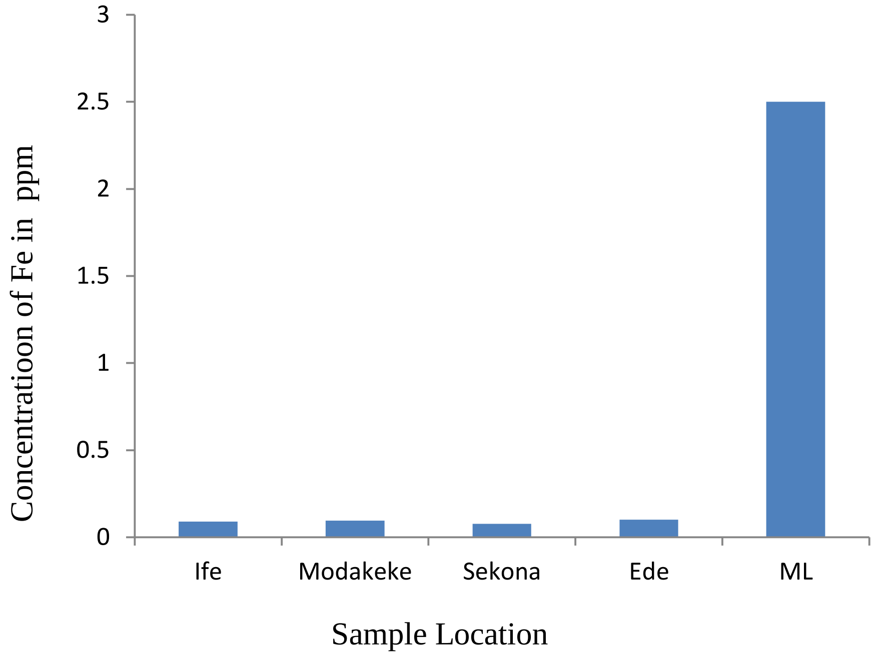

Fig. 5. Mean concentration of iron in palm kernel oil compared with the samples location
ML is the Maximum Limit [15]

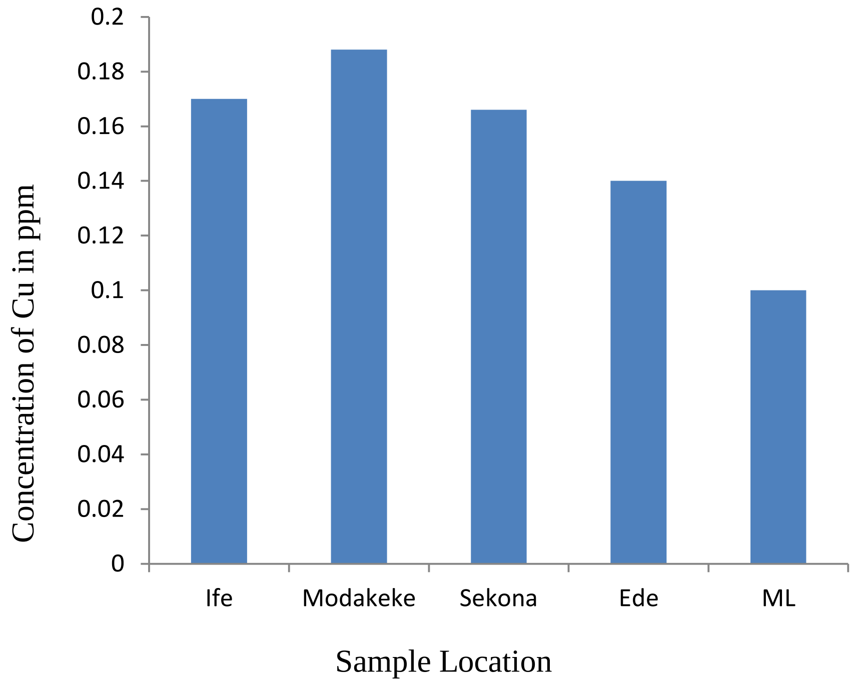

Fig. 6. Mean concentration of copper in palm kernel oil compared with the samples location
ML is the Maximum Limit [15]

The mean concentration of Cd, Zn, As, Fe and Pb were below the bio-recommended limit. Nevertheless, excessive ingestion of these metals can still be risky as heavy metals are non-biodegradable and can accumulate in the body over time unlike radionuclides in the body that have biological half-lives.

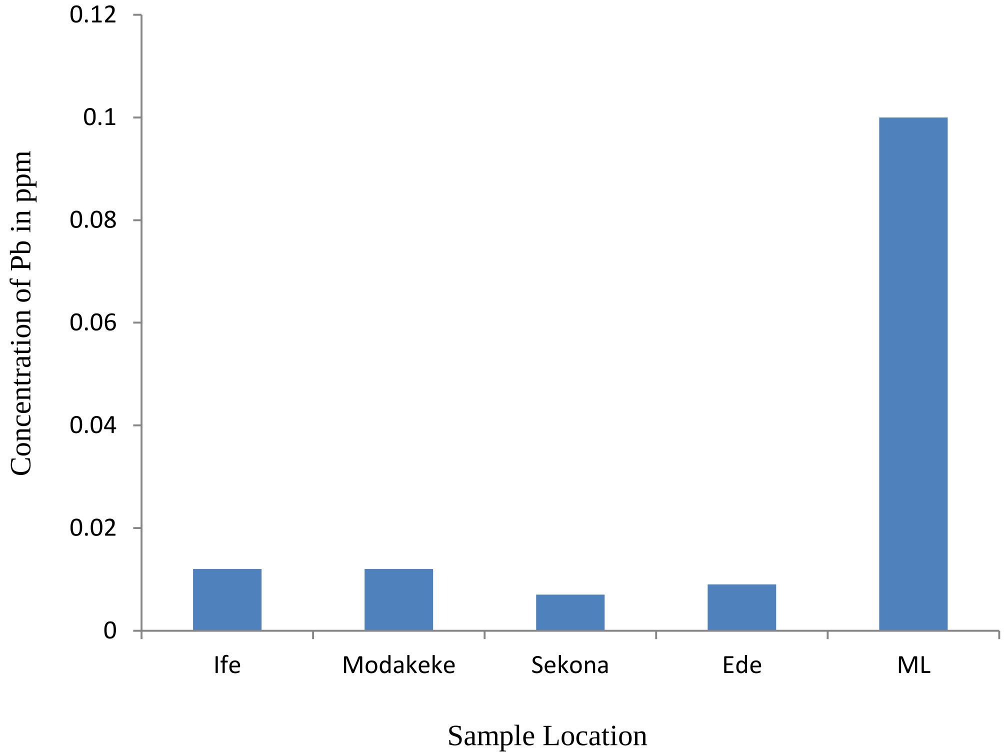

Fig. 7. mean concentration of lead in palm kernel oil compared with the samples location
ML is the Maximum Limit [15]

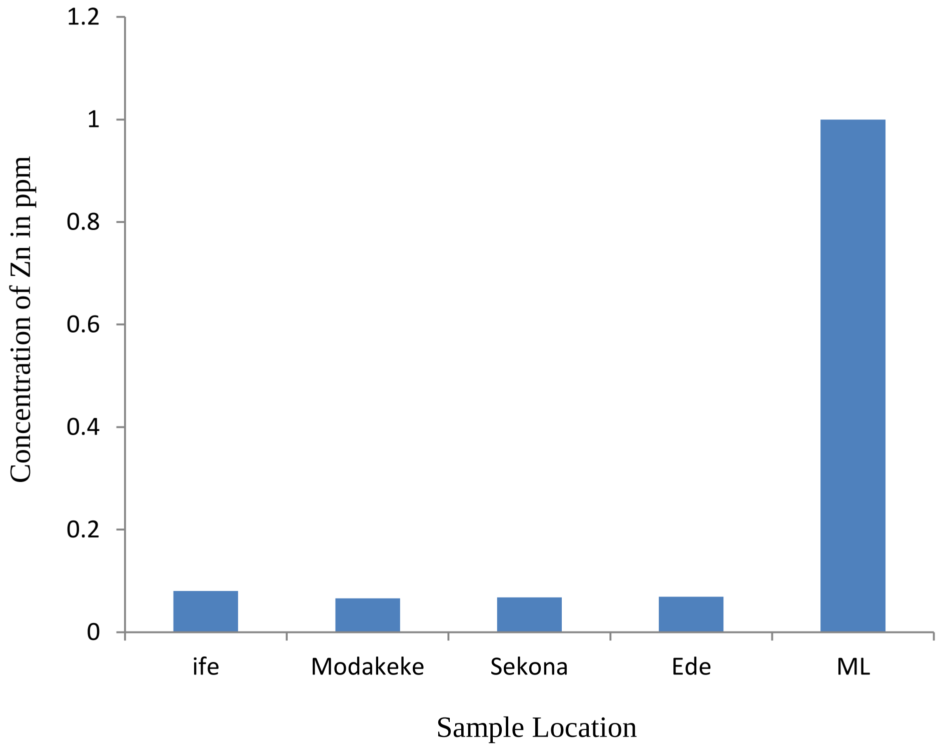

Figure 8. Mean concentration of zinc in palm kernel oil compared with the samples location
ML is the Maximum Limit [15]

Zinc is considered to be relatively non-toxic, especially if taken orally. However, excess amount can cause system dysfunctions that result in impairment of growth and reproduction [11,12]. The clinical signs of zinc toxicity have been reported as vomiting, diarrhea, bloody urine, icterus (yellow mucus membrane), liver failure, kidney failure and anaemia [13].

Lead serves no useful purpose in the human body, but its presence in the body can lead to toxic effects, regardless of exposure pathway. Lead poisoning causes inhibition of the synthesis of haemoglobin and dysfunctions in the kidneys [14].

4. CONCLUSION

The main aim of this research work was to determine the content of heavy metals present in locally produced Palm Kernel Oil as well as their derived health implication in Osun State, Nigeria. The contents of heavy metals present in the locally produced Palm Kernel Oil in the study areas were 0.022, 0.018, 0.090, 0.071, 0.166 and 0.010 ppm for Cd, As, Fe, Zn, Cu and Pb, respectively. The heavy metal contents in the palm kernel oil varies within the same factory which may be due to the fact that the production processes and most especially the source of the palm kernel used by the factories and nature of the soil where the palm tree is planted varied. However, heavy metals bio accumulates over a long period of time and hence may cause long term health problems.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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