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COMPARATIVE ANALYSIS OF TRACE ELEMENTS' CONTENTS OF FRESH AND SUN-DRIED TIGER NUTS IN IGBESA, OGUN STATE, NIGERIA

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Keywords - *Sun-Dried Tiger Nut, Fresh Tiger Nut (Cyperus esculentus), Trace Elements, Iron (Fe), Zinc (Zn), Copper (Cu), Manganese (Mn), Lead (Pb), Cadmium (Cd).*

Abstract: *This study investigated the comparative analysis of trace elements which included iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), lead (Pb), and cadmium (Cd) in fresh andeun-dried tiger nut (Cyperus esculentus), with the aim of assessing its nutritional value and potential toxicological risks. The research adopted a laboratory-based analytical approach using Atomic Absorption Spectrophotometry (AAS) to determine the concentrations of selected trace elements in both fresh and traditionally sun-dried tiger nut samples obtained from local markets. The findings revealed that essential elements such as Fe, Cu, and Mn were present in appreciable quantities and were generally higher in sun-dried samples, likely due to moisture reduction concentrating the elements. Conversely, Pb levels were significantly elevated in sun-dried samples, indicating a high likelihood of environmental contamination during the traditional sun-drying process. Zinc showed relatively stable concentrations between fresh and dried samples, while cadmium (Cd) was detected in low concentrations with no significant variation. The study concluded that although sun-dried tiger nut remains a rich source of essential nutrients, traditional sun-drying methods practiced in open environments expose the nuts to potential contamination by toxic metals, especially lead. This raises significant food safety concerns for regular consumers. The research recommends the adoption of hygienic drying methods, public awareness on safe*

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	food handling, and routine regulatory monitoring to minimize contamination risks

INTRODUCTION

Tiger nut (*Cyperus esculentus*) is an underutilized tuberous crop cultivated in many parts of the world, including Africa, where it is appreciated for its nutritional and medicinal properties. Despite being called a "nut," tiger nut is actually a small tuber of sedge origin, consumed raw, roasted, or processed into beverages such as "kunnu aya" in Nigeria (Adebayo & Olagunju, 2021). The global interest in tiger nut has surged in recent years due to its rich composition in dietary fibre, starch, essential fatty acids, vitamins, and minerals (Salawu *et al.*, 2022).

Trace elements, including iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), lead (Pb), and cadmium (Cd), are essential or toxic micro-minerals present in food in varying concentrations. While essential trace elements such as Fe, Zn, Cu, and Mn play critical roles in metabolic functions, excess intake or contamination from environmental sources can pose serious health risks. Conversely, non-essential and toxic elements such as Pb and Cd have no known biological functions and are harmful even at low concentrations (; Ezekiel *et al.*, 2020, WHO, 2021).

Drying is one of the most common post-harvest techniques applied to increase the shelf-life of agricultural produce. Sun-drying, a traditional method still widely used in many developing countries, is cost-effective but often associated with environmental exposure and contamination risks, including heavy metal deposition from dust and polluted air (Umeoguaju *et al.*, 2021). Consequently, assessing the effect of sun-drying on the trace element content of edible crops such as tiger nut becomes critical to food safety and public health.

Comparative analysis of trace elements in food products is an important aspect of food quality control and environmental monitoring. In the context of tiger nut, understanding the concentrations of both essential and toxic trace metals is fundamental to establishing its safety for consumption, especially given its increasing use as a functional food. Several studies have highlighted varying levels of heavy metal contamination in food crops due to soil content, water source, processing, and handling methods (Olalekan *et* al., 2020; Iwegbue *et al.*, 2021).

The growing consumption of tiger nut for its nutritional, medicinal, and economic benefits has made it a common food ingredient in many parts of Nigeria and globally. However, there is

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increasing concern about the safety of sun-dried agricultural products due to potential contamination by toxic trace elements, especially when drying is done in open environments where dust, smoke, and industrial pollutants can easily settle on the produce (Umeoguaju *et al.*, 2021). This raises serious questions regarding the safety of such products for human consumption, particularly in urban and semi-urban areas with high levels of environmental pollution.

Trace elements such as iron (Fe), zinc (Zn), copper (Cu), and manganese (Mn) are essential for various physiological functions in humans, but excessive intake can lead to adverse health effects. Conversely, non-essential metals like lead (Pb) and cadmium (Cd) are toxic even at very low concentrations and are associated with chronic diseases including kidney damage, neuro-toxicity, and cancer (WHO, 2021). Unfortunately, there is a scarcity of localized data on the concentration levels of these metals in commonly consumed sun-dried tiger nut, especially in regions where processing conditions are poorly regulated. The primary purpose of this study is to evaluate the concentration levels of selected trace elements iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), lead (Pb), and cadmium (Cd) in sun-dried fresh tiger nut to determine both its nutritional value and potential toxicological risks. By conducting a comparative analysis of these trace elements, the study aims to establish whether the levels of essential metals are within the recommended dietary intake and whether the levels of toxic metals exceed internationally accepted safety limits such as those set by the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) (2021).

The increasing consumption of tiger nut as a healthy snack, beverage ingredient, and functional food across Nigeria and other parts of the world underscores the need for a thorough evaluation of its safety and nutritional profile. . Furthermore, heavy metals like Pb and Cd are recognized environmental pollutants with no known biological benefits and pose serious health risks even at low concentrations (WHO, 2021).

In many local settings where sun-drying is the common post-harvest practice, agricultural produce like tiger nut is exposed to airborne contaminants including vehicle emissions, industrial activities, and soil dust all of which can contribute to elevated heavy metal content (Umeoguaju *et al.*, 2021). By analysing trace element concentrations in sun-dried tiger nut, this study will contribute important scientific data regarding its safety and compliance with international food safety standards, such as those set by FAO (2021). While essential metals such as Fe, Zn, Cu, and Mn play critical roles in blood formation, immune response, and

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enzymatic activities, their excessive accumulation can have harmful effects (Iwegbue *et al.*, 2021). This study investigated the presence, nutritional importance and potential toxicological risks associated with the trace element composition of both sfresh and sun-dried tiger nuts.

MATERIALS AND METHODS

Sample Collection

To ensure representativeness, tiger nut samples were purchased in triplicates from three different vendors. Fresh tiger nut samples were obtained from a local market Lusada, Igbesa, Ogun State. The samples were transported in clean polyethylene bags to the laboratory, where they were divided into fresh and sun-dried categories. Handling procedures were carried out with powder-free gloves to avoid external contamination. Two categories were prepared: Fresh samples were used immediately after purchase without any processing and fresh tiger nuts were thoroughly washed with de-ionised water and oven-dried at 60^{O}C until constant weight was achieved. The sun-dried samples were first sun-dried under natural sunlight for 5–7 days under hygienic conditions and further oven-dried until residual moisture content completely removed.



Figure 1 – Sun-dried Tiger Nut

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Sample Preparation

Both fresh and sun-dried tiger nuts were washed with de-ionised water to remove dirt and contaminants. The samples were then separately oven-dried at 60 °C to constant weight (to ensure uniform dryness and ease of grinding).

The sun-dried nuts were first dried under natural sunlight (5-7 days) and further oven-dried to remove residual moisture. After drying, all samples were pulverised using a clean stainless steel electric grinder to fine powder.

The powders were sieved using a 2 mm mesh and stored in labelled airtight containers under refrigeration (4^{o}C) until when used for analysis.

Quality assurance of tiger nuts

During the study, appropriate quality assurance precautions and procedures were followed in both field and laboratory methods to ensure data quality. As a result, sample bottles were thoroughly cleaned with mild hydrochloric acid and rinsed in the laboratory with a de-ionised water. All the reagents were analytical grade and glasswares were properly cleaned. The tiger nuts samples were purchased within Igbesa town and examined independently. All laboratory tests for the quality of fresh and sun-dried tiger nuts were performed according to standard methods for the investigation of heavy metals using AAS. De-ionised water was used throughout the study.

Digestion of Samples (Wet Digestion Method)

To extract trace elements, about 0.5 g of each sample was weighed into a digestion flask and10 mL of a mixture of concentrated nitric acid (HNO_3) and perchloric acid ($HClO_4$) (in a ratio of 3:1) was added. The mixture was heated on a hot plate under a fume hood until a clear solution was obtained. After cooling, the digest was filtered and made up to 50 mL with de-ionised water in a volumetric flask. A reagent blank was prepared in the same manner to account for background contamination. Certified reference materials (NIST, SRM 1570a, spinach leaves) was digested alongside the samples to validate accuracy. Blanks and standard reference materials were prepared alongside for quality control.

Determination of Trace Elements

The trace elements analysed included: Iron (Fe), Zinc (Zn), Copper (Cu), Manganese (Mn), Lead (Pb) and Cadmium (Cd).

The analysis was carried out using FS240AA Atomic Absorption Spectrophotometer (AAS) (Model: e.g., Buck Scientific 210 VGP or equivalent), using the APHA technique (American Public Health Association (.APHA, 1995).

Half a gramme (0.5 g.) of the sample was placed in 250 ml conical flasks, followed by 6 ml nitric acid (HNO_3) and 3 ml perchloric acid ($HCLO_3$),

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stirred, and heated at 1200C for 10 minutes. To decrease the bubbling effects of boiling solution, boiling chips were utilized as an anti-buble agent. Brown nitric acid (HNO3) vapour show first when heated, followed by whit frost, indicating that digestion is complete. After allowing the solution to cool to room temperature, Whatman filter paper was used to filter it. The filter was placed into a calibrated plastic container that was suitably labelled and distilled water was added to get it up to the mark (50 ml). The container was corked and placed in a storage area for further investigation. Using an Atomic Absorption Spectrophotometer, the digested samples were further examined (GBC Avanta Ver 2.20 equipped with lamp).

Calibration curves were prepared using standard solutions of known concentrations and triplicate readings were taken for each sample to ensure accuracy and reproducibility. Instrument performance was validated by running quality control standard after every 10 samples readings. Limits of detection (LOD) and limits of quantification (LOQ) were established based on three and ten times the standard deviation of blank signals respectively.

Data Analysis

Data were expressed as mean ± standard deviation, Comparative analysis was conducted using t-test to determine significant differences between the trace element concentrations in fresh and sun-dried tiger nuts. Statistical significance was set at $p < 0.05$.

RESULTS AND DISCUSSION

The trace element concentrations in both fresh and sun-dried tiger nut samples were determined using Atomic Absorption Spectrophotometry (AAS). The mean concentrations (± standard deviation) of selected elements are presented in the table 1 below and the concentrations of Fe, Cu, Mn and Pb were statistically significant, while the concentrations of others trace metals were insignificant (Table 1).

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Table 1 - Trace Element Concentrations in Both Fresh and Sun-Dried tiger nuts

Element	**Fresh Tiger Nut (mg/kg)**	**Sun-Dried Tiger Nut (mg/kg)**	**p-value**	**Remark**
Iron (Fe)	12.34 ± 0.56	15.67 ± 0.48	0.003	↑ Significant
Zinc (Zn)	4.56 ± 0.21	4.49 ± 0.18	0.521	NS
Copper (Cu)	2.11 ± 0.10	2.96 ± 0.12	0.010	↑ Significant
Manganese (Mn)	1.89 ± 0.09	2.45 ± 0.11	0.007	↑ Significant
Lead (Pb)	0.12 ± 0.01	0.18 ± 0.02	0.031	↑ Significant
Cadmium (Cd)	0.04 ± 0.01	0.05 ± 0.01	0.164	NS

NS: Not Significant ($p>0.05$);

↑ Sun-dried tiger nuts showed higher concentrations of most of the trace elements analysed.

Iron was higher in sun-dried samples, possibly due to moisture loss concentrating the mineral content, Copper and Manganese were significantly higher in sun-dried samples.

Lead also increased, thereby suggesting possible contamination during drying, while Zinc and Cadmium **s**howed no statistically significant differences.

Table 2 shows the standard deviation of all the various trace elements decreasing in the sun dried tiger nuts. The fresh tiger nuts had a relatively higher standard deviation in all the trace elements i.e. Fe>ZCu>Mn>Pb>Cd.

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Table 2: Comparative summary of standard deviation of race elements in tiger nuts.

Element	Fresh (mg/kg)	Sun-Dried (mg/kg)	Std Dev (Fresh)	Std Dev (Sun-Dried)
Fe	12.34	15.67	0.56	0.48
Zn	4.56	4.49	0.21	0.18
Cu	2.11	2.96	0.1	0.12
Mn	1.89	2.45	0.09	0.11
Pb	0.12	0.18	0.01	0.02
Cd	0.04	0.05	0.01	0.01

The results from the trace elements analysis of sun-dried fresh tiger nut samples offer important insight into both the nutritional benefits and potential toxicological risks associated with the consumption of tiger nuts processed using traditional sun-drying methods.

The elevated concentration of iron observed in sun-dried samples may suggest that the drying process reduces the moisture content, so causes a relative increase in the concentration of this essential metal. This finding agrees with report by Ezekiel *et al.* (2020) that a high concentration of iron and other trace metals can be hazardous to human health.

The iron build-up in both fresh and sun-dried tiger nuts is less than FAO allowed limit of 422.5 mg/kg according to Mohammed *et al.* (2018), who reported 11,.260.04mg/ kg in their tiger nuts. Iron is vital for red blood cell formation and oxygen transport, hence, its high presence reinforces the value of tiger nut as a functional food. However, iron levels that exceed recommended dietary intake can result in iron overload, especially in individuals with predispositions to haemo-chromatosis (WHO, 2021). However, it was observed from this study that the iron concentrations from all the tiger nuts tested fell within the limit of WHOFAO, so may unlikely to cause diseases associated with consumption of excess of iron. The difference in iron concentration may have a direct link with the iron concentration of the soil on which they are cultivated (Mohammed *et al.*, 2018).

The concentrations of zinc were relatively stable between fresh and sun-dried samples, implying that zinc may not be significantly affected by drying processes or environmental contamination. Since zinc is essential for immune function, cell repair, and enzyme activity, its consistent presence underscores the

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nutritional value of tiger nut in contributing to micro-nutrients intake of organisms.

Copper and manganese levels showed a notable increase in sun-dried samples. While both are essential trace elements, their elevation in dried samples may be due to environmental exposure or surface contamination during the drying process. Prolonged exposure to excessive manganese has been linked to neurological effects, and elevated copper intake may affect liver function over time (Ezekie*l et al.*, 2020). This suggests that while these metals are beneficial, their concentration must be carefully monitored to prevent chronic health risks.

Of uttermost concern is the increase in lead levels in sun-dried tiger nut samples. Lead is a known environmental pollutant and neurotoxin with no beneficial physiological role. Its presence is likely a consequence of environmental contamination during open-air drying, particularly in areas close to roadways, industrial activities, or where airborne particles are prevalent (Umeoguaju *et al.*, 2021). Chronic exposure to lead, even at low levels, is associated with cognitive impairment, developmental disorders in children, and kidney dysfunction.

Cadmium was detected in low concentrations, and although it did not show significant variation between fresh and dried samples, its presence is still a concern. Cadmium has a long biological half-life and bio-accumulates in the body, potentially leading to kidney damage and bone demineralisation with prolonged exposure. There is the likelihood that cadmium can be bio-magnified in human and animal tissues, thus result in non-communicable diseases. This findings is similar to reports by Ezekiel *et al.* (2020) and Umeoguaju *et al.* (2021).

This study has further contributed to knowledge that concentrations of macro-nutrients and micro-nutrients are of high medical and public health significance in food independent of the purpose for which it is consumed, as such nutrients can be magnified with time in tissues. A similar finding has been reported by EL-Naggar (2016).

This study reports the comparative levels of trace elements iron, zinc, copper, manganese, lead, and cadmium in sun-dried fresh tiger nut samples, with the aim of assessing both the nutritional significance and toxicological implications of consuming sun-dried tiger nuts commonly sold and consumed in Nigeria.

The findings revealed that essential trace elements such as Fe, Cu, and Mn were present in appreciable quantities and tended to be higher in sun-dried samples, likely due to moisture loss during the drying process. This suggests that sun-drying may improve the bio-availability of certain micro-nutrients, reinforcing the nutritional value of tiger nut as a rich source of minerals important for haematopoiesis, enzyme

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function, and antioxidant defence, which agrees with the findings of Pelegrin *et al.* (2022).

However, the study also uncovered a significant increase in the concentration of toxic elements, particularly lead, in sun-dried samples. This contamination is likely due to environmental exposure during open-air drying, such as contact with polluted surfaces, dust, vehicular emissions, or industrial fallout. Although, cadmium levels remained relatively low and consistent, its detection in all samples signals a potential bio-accumulative risk if tiger nut is consumed frequently over time especially by consumers who are likely to be unconscious of the associated risks in the consumption of such nuts.

The nutritional profile from this study underscores the value of tiger nut as a functional food, capable of contributing appreciable amounts of essential trace elements necessary for metabolic and physiological functions, which agrees with Zhang *et al.* (2023). However, the elevated levels of toxic metals, particularly Pb in sun-dried samples pose a considerable food safety concern. This calls for safer post-harvest handling and processing methods to minimise contamination risks without compromising nutritional quality.

Consequently, while tiger nuts remain a promising dietary resource with nutritional and medicinal benefits, its safety highly depends on the processing method.

CONCLUSION

There were high concentrations of trace elements such as Fe, Zn and Cu, but relatively lower concentrations of Cd, Mn and Pb in the sun-dried tiger nuts as against the fresh tiger nuts. Zinc and Cd showed no statistically significant difference in both fresh and sun-dried tiger nuts and their relative concentrations, which indicated that sun-drying has little or no effect on their concentrations.

The results of the study provide information on trace metals in tiger nuts in the study area and the probable human health risks associated with the consumption of tiger nuts and tiger nuts drinks. The Zn, Mg and Cu concentrations varied considerably among the tiger nuts examined, but Fe and Cu exhibited no significance differences. The trace metals concentration diminished in all cases when sun-dried.

Consumption of tiger nuts is unlikely to be harmful to human health, perhaps because Pb values were below detection limit in the tiger nuts. However, the high level of Fe detected in the tiger nuts suggests that if not consumed moderately, it may lead to haema-chromatiasis in humans, hence the amount of daily consumption of tiger nuts by humans should be controlled. Open sun-drying and poor handling of nuts generally expose their consumers to numerous health hazards which are avoidable with necessary precautions. Sun-drying, while

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beneficial for prolonging shelf life and concentrating nutrients such as Fe, Cu, and Mn, also significantly increased the levels of Pb, suggesting a high likelihood of environmental contamination during open-air-drying practices. Zinc concentrations remained relatively stable across both fresh and sun-dried samples, while Cd was detected at low levels with no significant variation. Adoption of improved drying techniques, like the use of solar dryers or hygienically controlled environments, routine monitoring of heavy metals contamination and public education on safe food handling practices are therefore strongly recommended.

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