

Assessment Of Heavy Metals And Micro Nutrients In Milo And Some Selected Sachet Milk Brands Consumed In Gombe Using Xrf Machine

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Abstract

This study assessed the concentrations of heavy metals and micronutrients in Milo and selected sachet milk brands consumed in Gombe Metropolis, Nigeria, using X-ray Fluorescence (XRF) spectrometry. The objective was to evaluate both the nutritional quality and potential health risks associated with these widely consumed beverages. Four samples comprising three milk brands and one Milo sample were collected from Gombe Main Market and analyzed for elemental composition. The results revealed the presence of essential micronutrients such as calcium, potassium, phosphorus, iron, zinc, and copper at significantly elevated concentrations. Notably, calcium (281,500–320,140 ppm) and potassium (193,440–220,000 ppm) were found in extremely high amounts, suggesting possible fortification or concentration beyond standard dietary levels. Iron concentration was exceptionally high in the Milo sample (13,079 ppm), indicating heavy fortification. Conversely, toxic heavy metals such as arsenic (As), lead (Pb), nickel (Ni), and chromium (Cr) were not detected in any of the samples, indicating minimal contamination from these hazardous elements. However, the concentrations of some trace elements, particularly copper and zinc, exceeded permissible limits recommended by international standards (WHO/FAO), raising concerns about potential health risks associated with excessive intake. The findings suggest that while the products are rich in essential nutrients, their unusually high elemental concentrations may pose risks of mineral toxicity if consumed regularly. In conclusion, Milo and sachet milk sold in Gombe are significant sources of micronutrients but require continuous monitoring and regulatory control to ensure consumer safety.

Keywords: Heavy metals, micronutrients, milk, Milo, Gombe.

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I. Introduction

Milk and cocoa-based beverages such as Milo are widely consumed across Nigeria and globally due to their rich nutritional composition and energy-boosting properties. Milk is often regarded as a near-complete food because it contains essential macronutrients and micronutrients required for human growth and development. It is particularly rich in high-quality proteins (casein and whey), fats, vitamins (A, D, E, and B-complex), and minerals such as calcium and phosphorus, which are crucial for bone formation, tissue repair, and metabolic functions (Nagpal *et al.*, 2012; Rotondo *et al.*, 2021). Similarly, malt-based beverages like Milo are fortified with essential nutrients, including iron, zinc, and vitamins, making them popular among children and adults as dietary supplements for energy and vitality.

Despite their nutritional benefits, there is growing concern about the potential contamination of these products with heavy metals. Heavy metals are elements with relatively high atomic weight and density that can be toxic even at low concentrations. They are broadly classified into essential elements (such as iron, zinc, and copper), which are required in trace amounts for physiological functions, and non-essential or toxic elements (such as lead, cadmium, and arsenic), which pose serious health risks (Filon *et al.*, 2020). While essential metals play critical biological roles, their excessive accumulation can result in toxicity, leading to adverse health effects.

The presence of heavy metals in milk and related products can be attributed to several environmental and anthropogenic sources. These include contamination of animal feed and water, industrial emissions, agricultural practices involving fertilizers and pesticides, and contamination during processing, storage, or packaging (Bilandžić *et al.*, 2011; Meshref *et al.*, 2014). Additionally, cocoa-based products may accumulate metals from soil and environmental exposure during cultivation and processing stages. The level of contamination varies depending on geographical location, environmental conditions, and production practices (Bousbia *et al.*, 2019).

Chronic exposure to heavy metals through dietary intake has been associated with numerous health complications, including neurological disorders, kidney damage, cardiovascular diseases, and developmental abnormalities, particularly in children (Filon *et al.*, 2020). To evaluate these risks, several health risk assessment models such as Estimated Daily Intake (EDI), Target Hazard Quotient (THQ), and Hazard Index (HI) are commonly employed to estimate the potential non-carcinogenic effects of contaminated food consumption (Storelli *et al.*, 2020).

Although milk and Milo are extensively consumed in Gombe Metropolis due to their affordability, availability, and nutritional value, there is limited localized data on their heavy metal content and associated health risks. Rapid urbanization, increased industrial activities, and environmental pollution in developing regions have heightened the possibility of contaminants entering the food chain. However, insufficient monitoring and lack of comprehensive studies make it difficult to assess the safety of these widely consumed products.

Therefore, this study aims to assess the levels of heavy metals and micronutrients present in selected sachet milk brands and Milo consumed in Gombe using X-ray Fluorescence (XRF) analysis. The study also seeks to evaluate the potential health risks associated with their consumption and provide baseline data that can support regulatory agencies and public health policies in ensuring food safety.

II. Materials And Methods

Study Area

This research was carried out within Gombe Metropolis, the capital city of Gombe State, located in the northeastern part of Nigeria. Gombe State lies between latitude 10°17'N and longitude 11°10'E, with an average elevation of about 450–500 meters above sea level. The state shares boundaries with Bauchi State to the west, Borno State to the northeast, Taraba State to the south, Adamawa State to the southeast, and Yobe State to the north.

The metropolis serves as the commercial and administrative center of the state and is a hub for the distribution and sale of various food products, including milk and cocoa-based drinks such as Milo.

The climate of Gombe is tropical, characterized by two distinct seasons a rainy season that lasts from May to October and a dry season that extends from November to April. The average annual rainfall ranges between 850 mm and 1000 mm, and the average temperature varies between 21°C during the cool season to 38°C in the dry season. The selection of Gombe Metropolis for this research was based on its high consumption rate of both local and imported milk and Milo products, easy accessibility, and its representation of a typical urban Nigerian setting where different milk brands are available for public consumption.

Sample Collection

The samples used for this research were collected exclusively from Gombe Main Market, located in the heart of Gombe Metropolis, Gombe State, Nigeria. The market is the largest and busiest commercial center in the metropolis, serving as a major distribution point for various food products, including dairy and cocoa-based beverages. It was selected as the sampling location because it provides access to a wide variety of milk brands and Milo commonly consumed by residents of the city.

A total of four (4) samples were collected three (3) different brands of milk and one brand of Milo. The milk brands were selected based on their availability, popularity, and frequency of consumption among the people of Gombe Metropolis.

Each sample was purchased in its original, sealed, and unopened packaging to prevent contamination and ensure that the product retained its original composition as sold to consumers. Care was taken to select products that were within their expiration dates and stored under proper hygienic conditions by the vendors.

Immediately after purchase, the samples were placed in clean, labeled polythene bags. Each label indicated the product name, brand, batch number, and date of collection. The samples were then transported to the Laboratory of the Department of Pure and Applied Physics, Gombe State University, for proper storage and analysis.

All samples were kept in a cool, dry environment at room temperature until they were ready for digestion and subsequent analysis. This approach ensured that the samples accurately represented the quality of milk and Milo products available to consumers within Gombe Main Market, reflecting what is commonly

Sample Description

- I Sample A: Peak Milk
- II Sample B: Dano Milk
- III Sample C: Cowbell Milk
- IV Sample D: Milo

Sample Preparation

The milk and Milo samples were first checked for any foreign materials before processing. Each sample was thoroughly mixed to ensure uniformity. The milk and Milo samples were measured About 10 grams each and was accurately weighed using a digital weighing balance. The samples were then pressed into pellets using a hydraulic press under a pressure of 10 tons to form uniform circular discs suitable for XRF analysis. All sample preparation steps were carried out using plastic and stainless-steel tools to prevent metallic contamination.

Equipments And Apparatus

The following materials and laboratory apparatus were used in the course of this research:

Materials

- I. Different brands of powdered milk (e.g., Peak, Cowbell, Dano)
- II. One brands of Milo beverage powder (e.g., Nestlé Milo)
- III. Distilled water (for cleaning and rinsing apparatus)
- IV. Polythene sampling bags (for storing collected samples)
- V. Labeling stickers and markers
- VI. Sample pellets and sample cups

Apparatus and Equipment

- I. Digital weighing balance (for accurate measurement of sample mass)
- II. Hydraulic press (for pelletizing samples before XRF analysis)
- III. X-Ray Fluorescence (XRF) spectrometer (for elemental analysis)
- IV. Desiccator (for cooling and storing the samples to prevent moisture absorption)
- V. Beakers, spatulas, and gloves (for handling samples safely)

All instruments and containers were cleaned thoroughly with distilled water and air-dried before use to prevent contamination.

Determination Of Heavy Metals And Micronutrients

The XRF spectrometer was used for the determination of heavy metals and micronutrients in the samples. XRF is a non-destructive analytical technique that provides both qualitative and quantitative information about the elemental composition of a sample.

Principle of Operation

When a sample is exposed to a primary X-ray beam, the atoms within the sample become excited and emit secondary (fluorescent) X-rays. The energy of these emitted X-rays is characteristic of specific elements in the sample, while their intensity is proportional to the concentration of the elements present.

Instrument Configuration

- I. Model: PANalytical Minipal-4 XRF Spectrometer (or equivalent)
- II. X-ray Source: Rhodium (Rh) anode X-ray tube
- III. Voltage: 30–50 kV
- IV. Detector: Si-PIN or SDD detector
- V. Analysis Time: 600 seconds (10 minutes per sample)
- VI. Atmosphere: Vacuum condition for light element sensitivity
- VII. Software: SuperQ or Omnian software for data processing

Before analysis, the XRF spectrometer was calibrated using certified reference materials (CRM) to ensure accuracy. Blank runs were also conducted to check for background contamination. Standard formula most commonly used to determine the concentration of heavy metals using X-Ray Fluorescence (XRF) is given as:

$$Cx = \frac{Ix - Ib}{Sx} \quad (2.1)$$

Where:

- **Cx** = concentration of the element (heavy metal) in the sample (ppm or mg/kg)
- **Ix** = measured XRF intensity (net peak count rate) of the element in the sample
- **Ib** = background intensity (blank or baseline counts)
- **Sx** = sensitivity or calibration slope (counts per unit concentration), obtained from standard reference materials

III. Results And Discussion

The results obtained from the X-ray Fluorescence (XRF) analysis provide important insights into the elemental composition, nutritional value, and potential health risks associated with the consumption of Milo and selected sachet milk brands in Gombe Metropolis.

Micro-Mineral Composition

The study revealed exceptionally high concentrations of major minerals such as calcium (Ca), potassium (K), and phosphorus (P) across all samples as presented in Table 3.1. Calcium levels ranged from 281,500 to 320,140 ppm, while potassium concentrations ranged between 193,440 and 220,000 ppm. These values are significantly higher than standard nutritional ranges reported for powdered milk products. The elevated calcium content confirms that both milk and Milo are highly fortified products, as calcium is essential for bone development, muscle function, and enzymatic activities.

Similarly, potassium, an essential electrolyte responsible for nerve transmission and fluid balance, was present in large quantities. The consistently high levels of phosphorus across samples further support their nutritional richness, as phosphorus works synergistically with calcium in bone formation. However, the extremely high concentrations suggest that these products may not be typical ready-to-consume formulations but could contain concentrated mineral premixes or additives.

Iron (Fe) showed significant variation among the samples, with values ranging from 790 to 1,476 ppm in milk and an exceptionally high value of 13,079 ppm in the Milo sample. This indicates deliberate fortification, as iron is essential for hemoglobin formation and prevention of anemia. However, the iron concentration in Milo far exceeds typical fortification levels reported in food products. Excessive iron intake may lead to oxidative stress, gastrointestinal distress, and long-term organ damage if consumed in large quantities over time.

Table 3.1: Elemental Concentrations of Major Micronutrients (ppm)

Element	Sample A	Sample B	Sample C	Sample D
Ca	315,980	281,500	285,290	320,140
K	220,000	205,000	196,760	193,440
P	69,820	78,550	78,550	74,188
Fe	804	1,476	790	13,079

Trace Elements and Nutritional Significance

Trace elements such as zinc (Zn) and copper (Cu) were detected in all samples, confirming their role as essential micronutrients. Zinc concentrations ranged from 749 to 1,421 ppm, while copper ranged from 245 to 428 ppm as shown in Table 3.2. These elements are crucial for immune function, enzyme activity, and metabolic processes. However, their concentrations greatly exceeded recommended permissible limits, suggesting potential toxicity risks. Prolonged exposure to high levels of zinc may interfere with copper metabolism, while excessive copper intake can result in liver damage and gastrointestinal disorders.

Other trace elements such as sulfur (S), chlorine (Cl), bromine (Br), rubidium (Rb), and strontium (Sr) were also detected. The high chlorine levels, particularly in the Milo sample, may be attributed to industrial processing or the presence of chloride-containing additives. Sulfur content reflects the presence of sulfur-containing amino acids, especially in milk proteins. The presence of bromine and rubidium, though not typically regulated, may be linked to environmental factors such as soil composition and water sources used during production.

Heavy Metal Contamination

A significant finding of this study is the absence of toxic heavy metals such as arsenic (As), lead (Pb), chromium (Cr), and nickel (Ni) in all samples as shown in Table 3.2. This suggests that the products are free from major industrial contamination and are relatively safe in terms of heavy metal exposure. This result aligns with safety expectations and indicates good manufacturing practices and quality control during production and packaging.

Table 3.2 Concentrations of Trace Elements and Heavy Metals (ppm)

Element	Sample A	Sample B	Sample C	Sample D
S	22300	19076	23010	14500
Cl	76900	65200	75600	86300
Cr	ND	ND	ND	ND

Element	Sample A	Sample B	Sample C	Sample D
Ni	ND	ND	ND	ND
Cu	258	258	245	428
Zn	1310	1421	1210	749
As	ND	ND	ND	ND
Br	2120	2021	2120	976
V	ND	ND	ND	ND
Rb	1590	1430	1432	1130
Sr	285	269	212	505
Y	(35.7)	(45.8)	(33.2)	(52.8)
Ag	53.6	64.6	53.6	ND
Sn	ND	ND	ND	ND
Sc	ND	ND	ND	ND
Sb	ND	ND	ND	ND
Ba	ND	ND	ND	ND
Pd	ND	ND	ND	ND
Rh	ND	ND	ND	ND
Mo	ND	ND	ND	ND
Zr	ND	ND	ND	ND
Pr	ND	ND	ND	ND
Nd	ND	ND	ND	ND
Ta	ND	ND	ND	ND
Rn	ND	ND	ND	ND
Fr	ND	ND	ND	ND
Pm	ND	ND	ND	ND

Tables 3.3 provide the quantitative data for the elemental composition of the samples. Major components were converted from oxide mass percent to elemental parts per million (ppm) to facilitate direct comparison.

Table 3.3 Comprehensive Elemental Profile and Statistical Analysis (ppm)

Element	Sample A	Sample B	Sample C	Sample D	Mean	Std. Deviation (σ)
Ca	315,980	281,500	285,290	320,140	300,727.50	19,926.87
K	220,000	205,000	196,760	193,440	203,800.00	11,827.47
Cl	76,900	65,200	75,600	86,300	76,000.00	8,617.81
P	69,820	78,550	78,550	74,188	75,277.00	4,206.56
S	22,300	19,076	23,010	14,500	19,721.50	3,894.62
Fe	804	1,476	790	13,079	4,037.25	6,036.72
Br	2,120	2,021	2,120	976	1,809.25	557.86
Rb	1,590	1,430	1,432	1,130	1,395.50	191.79
Zn	1,310	1,421	1,210	749	1,172.50	296.22
Sr	285	269	212	505	317.75	128.53
Cu	258	258	245	428	297.25	87.31
Ag	53.6	64.6	53.6	ND	57.27*	6.35
Y	35.7	45.8	33.2	52.8	41.88	9.07
Cr	ND	ND	ND	ND	N/A	N/A
Ni	ND	ND	ND	ND	N/A	N/A
As	ND	ND	ND	ND	N/A	N/A
V	ND	ND	ND	ND	N/A	N/A
Sn	ND	ND	ND	ND	N/A	N/A
Sc	ND	ND	ND	ND	N/A	N/A
Sb	ND	ND	ND	ND	N/A	N/A

Element	Sample A	Sample B	Sample C	Sample D	Mean	Std. Deviation (σ)
Ba	ND	ND	ND	ND	N/A	N/A
Pd	ND	ND	ND	ND	N/A	N/A
Rh	ND	ND	ND	ND	N/A	N/A
Mo	ND	ND	ND	ND	N/A	N/A
Zr	ND	ND	ND	ND	N/A	N/A
Pr	ND	ND	ND	ND	N/A	N/A
Nd	ND	ND	ND	ND	N/A	N/A
Ta	ND	ND	ND	ND	N/A	N/A
Rn	ND	ND	ND	ND	N/A	N/A
Fr	ND	ND	ND	ND	N/A	N/A
Pm	ND	ND	ND	ND	N/A	N/A
Dy	ND	ND	ND	ND	N/A	N/A
Yb	ND	ND	ND	ND	N/A	N/A

Health Risk Implications

Despite the absence of toxic heavy metals, the extremely high concentrations of essential elements raise concerns regarding potential health risks. While micronutrients are required in small quantities for optimal physiological functioning, excessive intake can lead to toxicity. The observed levels of calcium, potassium, iron, zinc, and copper far exceed recommended dietary limits, which may predispose consumers to conditions such as hypercalcemia, mineral imbalance, oxidative stress, and organ dysfunction.

These findings suggest that frequent or excessive consumption of these products, particularly by vulnerable groups such as children, may pose significant health risks. Therefore, it is critical to evaluate not only the presence of toxic metals but also the concentration of essential nutrients.

Comparison with Standards and Previous Studies

When compared with WHO/FAO permissible limits as shown in Table 3.4, most of the detected elements particularly calcium, potassium, zinc, copper, and iron greatly exceed recommended values. This contrasts with previous studies conducted in other parts of Nigeria, where micronutrient concentrations in milk products were reported within acceptable ranges. The discrepancy may be due to differences in product formulation, environmental factors, or analytical techniques.

Overall Interpretation

Overall, the findings indicate that while Milo and sachet milk consumed in Gombe are rich in essential nutrients and free from harmful heavy metal contamination, their mineral composition is unusually high and may not be suitable for regular consumption without moderation. The results highlight the need for stricter regulatory monitoring and quality control to ensure that nutrient fortification remains within safe and acceptable limits.

Table 3.4: Comparative Elemental Analysis: Lab Results vs. WHO/Codex Standards

Element	Lab Result Mean (ppm)	Lab Result Range (ppm)	WHO/Codex Standard (ppm)	Remark
Ca	300,727.50	281,500 – 320,140	9,000 – 15,000	Significantly High. Levels far exceed standard fortification ranges.
K	203,800.00	193,440 – 220,000	9,000 – 10,000	Significantly High. Concentrations are ~20x higher than typical fortified milk.
P	75,277.00	69,820 – 78,550	6,000 – 11,000	High. Above standard levels for milk powder products.
Fe	4,037.25	790 – 13,079	50 – 150	Extremely High. Sample D (Milo) is a massive outlier; all samples exceed safety limits.
Cl	76,000.00	65,200 – 86,300	5,000 – 10,000	High. Exceeds typical dairy chloride levels.
Cu	297.25	245 – 428	1.50 (MPL)	Toxic Levels. Levels are ~200x above the safety limit for consumption.
Zn	1,172.50	749 – 1,421	5.00 (MPL)	Toxic Levels. Levels are ~230x above the safety limit.
Cr	ND	ND	0.05 (MPL)	Safe. Not detected in samples.
As	ND	ND	0.01 (MPL)	Safe. Not detected in samples.
Ni	ND	ND	0.02 (MPL)	Safe. Not detected in samples.

Element	Lab Result Mean (ppm)	Lab Result Range (ppm)	WHO/Codex Standard (ppm)	Remark
Sn	ND	ND	50.0 (MPL)	Safe. Not detected in samples.
S, Br, Rb, Sr, Y	(Detected)	(Various)	No Fixed MPL	Informational. Typically not regulated unless toxicity is suspected.
Rare Earths*	ND	ND	< 0.01	Safe. All rare earth elements (Pr, Nd, etc.) were Not Detected.

IV. Conclusion

This study evaluated the concentrations of heavy metals and micronutrients in selected sachet milk brands and Milo consumed in Gombe Metropolis using X-ray Fluorescence (XRF) analysis. The findings provide valuable insight into both the nutritional composition and potential health implications associated with these widely consumed products.

The results showed that all samples contained high levels of essential macro- and micro-nutrients such as calcium, potassium, phosphorus, iron, zinc, and copper. These elements are vital for normal physiological functions, including bone development, immune response, and metabolic activities. However, their concentrations were found to be significantly higher than the recommended permissible limits established by international standards such as WHO and FAO. In particular, the extremely high levels of calcium and potassium suggest possible over-fortification or the presence of concentrated mineral formulations, while the exceptionally high iron content in the Milo sample indicates excessive fortification beyond typical nutritional requirements.

Importantly, toxic heavy metals such as arsenic, lead, nickel, and chromium were not detected in any of the samples, indicating that the products are relatively safe from environmental or industrial contamination. This reflects good manufacturing practices and suggests minimal exposure to hazardous heavy metals.

Despite this positive finding, the elevated concentrations of essential elements especially zinc and copper raise concerns about potential health risks associated with prolonged or excessive consumption. High intake of these elements may lead to mineral toxicity, metabolic imbalance, and adverse health effects, particularly among vulnerable populations such as children.

In conclusion, while the analyzed milk and Milo products serve as rich sources of essential nutrients, their unusually high mineral content may pose potential health risks if consumed without moderation. Therefore, there is a need for continuous monitoring, strict regulatory enforcement, and proper quality control to ensure that nutrient fortification levels remain within safe and acceptable limits. Further research is recommended to investigate the bioavailability of these elements and to conduct comprehensive health risk assessments on long-term consumption.

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