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Assessment of Heavy Metal Concentrations and Proximate Composition in Milk from Cow, Goat, and Sheep at Yobe State University Farm, Nigeria

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ABSTRACT

This study investigated the concentrations of Pb, As, Cd, Cu, Ni, and Cr, as well as the proximate composition of cow, goat, and sheep milk collected from the Yobe State University Farm in Damaturu, Nigeria. Samples were collected during the early rainy season, and digested using a microwave digester. Heavy metals were determined using Atomic Absorption Spectrometry (AAS), whereas proximate analysis was conducted using standard methods. The AAS results showed that copper concentrations (0.09 ± 0.00, 0.22 ± 0.00, and 0.50 ± 0.00 mg/L in cow, goat, and sheep milk, respectively) were within the WHO permissible limits. Lead (0.07 ± 0.01 and 0.04 ± 0.01 mg/L) and arsenic (0.02 ± 0.00 and 0.09 ± 0.01 mg/L) concentrations in cow and goat milk respectively also fell within acceptable limits. However, in sheep milk, lead (0.04 ± 0.00 mg/L), arsenic (0.12 ± 0.00 mg/L), and chromium (0.63 ± 0.00 mg/L) concentrations exceeded the WHO standards. Fat content was highest in sheep milk, whereas protein content was more prominent in goat milk. This study underscores the importance of routine monitoring of dairy products to ensure consumer safety and nutritional quality. The findings may provide a scientific basis for local food safety regulations and help to shape public health policies on dairy production and consumption.

Keywords: Heavy metals, proximate composition, milk, Yobe State, cow, goat, sheep

INTRODUCTION

Most heavy metals are naturally occurring elements characterized by high atomic weights and densities exceeding 5 g/cm³ and specific gravities greater than 4.0 [1]. Whereas heavy metals such as zinc, copper, and iron are essential micronutrients for various physiological functions in living organisms, their excessive accumulation can lead to toxic and sometimes fatal effects [2]. Historical records suggest that lead poisoning, partly from lead-coated utensils, may have contributed to the decline of the Roman Empire [3].

Heavy metal contamination arises from both anthropogenic and natural sources. Industrial activities such as smelting, coal burning, and manufacturing are significant contributors to environmental pollution [4-5]. Additionally, natural sources, including arsenic-rich geological deposits, leach into groundwater, further aggravating the problem [6]. These contaminants find their way into the food chain primarily through crops grown on polluted soils or irrigated with contaminated water, posing serious health risks to both animals and humans [7]. Furthermore, individuals working in occupations like welding, painting, and dentistry are at increased risk due to direct exposure. The use of sewage sludge and untreated wastewater in agriculture also contributes to heavy metal accumulation in crops, as observed in urban areas such as Faisalabad. Animals that consume contaminated feed or water may bioaccumulate these toxic elements in their tissues, including the mammary glands, which can lead to the presence of heavy metals in milk [8].

As a widely consumed dietary staple, milk contaminated with heavy metals, pesticides, and other xenobiotics presents serious public health concerns [1]. Previous studies have reported the presence of cadmium, lead, and zinc residues in milk, though levels vary due to geographic and methodological differences [8]. Given the distinct environmental and agricultural conditions, there is an urgent need for localized assessments of heavy metal contamination in animal-derived foods. Much of the existing data on heavy metal contamination and nutritional composition of milk are based on Western settings, which may not accurately reflect the dynamics of milk quality and environmental exposure in tropical and developing regions.

This study, therefore, aims to evaluate the concentrations of selected heavy metals and the proximate composition in milk obtained from cow, goat, and sheep at Yobe State University farm, Damaturu, in Nigeria.

MATERIALS AND METHODS

Sample collection

Different milk samples (cow, goat, and sheep) were collected from Yobe State University farm during early morning milking. The samples were collected directly into sterile bottles labeled as A, B, and C, respectively. To prevent fermentation, the samples were immediately stored in a refrigerator.

Sample digestion and heavy metal determination

Approximately 0.5 g of each milk sample was weighed into clean Teflon microwave digestion tubes. To each tube, 6 mL of 65% nitric acid (HNO_3) and 3 mL of hydrogen peroxide (H_2O_2) were added, and the mixture was allowed to stand for 5 minutes. The tubes were then sealed and placed in a microwave digestion system. Digestion was performed at 180 °C for 30 minutes. Hydrogen peroxide was used to reduce nitrous vapors and to accelerate the digestion process by increasing the reaction temperature.

After digestion, each sample was cooled and diluted to a final volume of 50 mL with deionized water. The resulting digests were analyzed for nickel (Ni), chromium (Cr), lead (Pb), copper (Cu), arsenic (As), and cadmium (Cd) using a graphite furnace atomic absorption spectrometer (Shimadzu AA-6800 series) [9].

Proximate composition

Determination of dry matter and moisture content

A clean crucible was dried in an oven, cooled in a desiccator, and weighed (W_1). Ten grams (10 g) of the sample were added and the new weight recorded (W_2). The crucible was placed in an oven at 105 °C for 3 hours, removed using tongs, and cooled in a desiccator. The final weight was recorded (W_3).

$$\text{Moisture content} = \frac{W2 - W1}{W2} \text{ x } 100 \qquad (1)$$

Dry Matter = 100 - Moisture content (2)

Determination of ash content

A clean silica dish was ignited, cooled, and weighed (W_1). Five grams (5 g) of the test sample (W_2) were placed in the dish. The dish was transferred into a muffle furnace set at 500 °C until fully ashed (indicated by grey color). After ashing, the dish was cooled in a desiccator and weighed again (W_3) [10].

Determination of crude fiber

Ten grams (10 g) of each sample (W) were placed in a round-bottom flask with 150 mL of 1.25% sulfuric acid (H_2SO_4), then boiled under reflux for 30 minutes. The mixture was filtered using muslin cloth, and the residue was washed with hot water until acid-free. The residue was then treated with 150 mL of 1.25% potassium hydroxide (KOH) and again boiled under reflux for 30 minutes. After filtering and washing with boiling water to remove any remaining base, the residue was dried at 100 °C, cooled, and weighed (C_1). The sample was then incinerated in a muffle furnace at 600 °C for 1 hour, cooled, and reweighed (C_2).

Determination of crude fat

Ten grams (10 g) of the sample were mixed with 40 mL of petroleum ether and shaken vigorously for 30 minutes. The mixture was allowed to stand for one hour to separate the organic and aqueous phases. The ether layer was filtered into a crucible and allowed to evaporate completely. The remaining fat extract was weighed.

Determination of protein content (Kjeldahl method)

Digestion

Five grams (5 g) of sample were weighed into a Kjeldahl digestion tube. Twenty milliliters (20 mL) of concentrated sulfuric acid were added, and the mixture was digested for 3 hours. After cooling, 50 mL of 40% NaOH was added, and the volume was adjusted to 100 mL with distilled water.

Distillation

Five milliliters (5 mL) of 2% borate solution were pipetted into a conical flask, and 3 drops of a mixed indicator (bromocresol green and methyl red) we added. Then, 5 mL of the digested sample were introduced into a distillation flask, followed by 20 mL of 40% NaOH. The flask was connected and heated, and 75 mL of distillate were collected into the conical flask. The collected distillate was titrated with 1.0 M HCl to determine the nitrogen content.
[11]

RESULTS AND DISCUSSION

The concentrations of heavy metals in cow, goat, and sheep milk are presented in Table 1

Table 1: Heavy metal concentrations in cow, goat, and sheep milk

Sample	Pb (mg/l)	As (mg/l)	Cd (mg/l)	Cu(mg/l)	Ni (mg/l)	Cr (mg/l)
Cow	0.07 ± 0.01	0.02 ± 0.00	0.02 ± 0.00	0.09 ± 0.00	0.00 ± 0.00	0.04 ± 0.00
Goat	0.04 ± 0.01	0.09 ± 0.01	0.01 ± 0.00	0.22 ± 0.00	0.00 ± 0.00	0.10 ± 0.00
Sheep	0.04 ± 0.00	0.12 ± 0.00	0.09 ± 0.01	0.50 ± 0.00	0.00 ± 0.00	0.63 ± 0.00
WHO Standard	0.02	0.1	0.003	24.2	10	0.05

The highest concentration of lead was found in sheep milk (0.04 ± 0.00 mg/L), whereas the lowest was observed in goat milk (0.03 ± 0.01 mg/L). Among the three, sheep milk had the highest concentration, followed by cow and then goat milk. The lead concentrations in all the samples exceeded the WHO permissible limit of 0.02 mg/L [12].

The highest concentration of arsenic was also found in sheep milk (0.12 ± 0.00 mg/L), followed by goat (0.09 ± 0.01 mg/L) and hen cow milk (0.02 ± 0.00 mg/L). The concentration of arsenic in sheep milk was above the WHO permissible limit of 0.1 mg/L [13]

Cadmium concentration was highest in sheep milk (0.09 ± 0.01 mg/L), followed by cow milk (0.02 ± 0.00 mg/L), and then goat milk (0.01 ± 0.00 mg/L). The elevated cadmium levels in sheep milk may be attributed to the consumption of contaminated feed and water [10]. Cd is an environmental pollutant that is toxic to both humans and animals. It is non-biodegradable, and its accumulation in the environment poses serious agricultural and public health concerns [10-11].

The concentration of copper in all samples was within the WHO permissible limit of 24.2 mg/L [14]. Copper is an essential micronutrient required for hormone secretion, nerve conduction, and the development of bones and connective tissues [15]. Cu plays a critical role in various biochemical processes [16]. In this study, copper concentration was highest in sheep milk (0.50 ± 0.00 mg/L), followed by goat (0.22 ± 0.00 mg/L) and cow milk (0.09 ± 0.00 mg/L).

Nickel was not detected in any of the samples (cow, goat, or sheep), indicating its presence was below the detection limit of the instrument.

Chromium concentrations in cow (0.04 ± 0.00 mg/L) and goat (0.10 ± 0.00 mg/L) milk were within the WHO permissible limit of 0.3 mg/L [17]. However, sheep milk showed a Cr concentration of 0.62 ±0.00 mg/L, which exceeds the permissible level, potentially posing a health risk.

The proximate composition of cow, goat, and sheep milk is presented in Table 2.

Table 2: Proximate composition in Cow, Goat, and Sheep milk

Sample	Protein content	Fat content	Fiber content	Dry matter content	Moisture content
Cow	2.97% ± 0.06%	4.59% ± 0.01%	0.2% ± 0.00%	87.65% ± 0.01%	8.75% ± 0.01%
Goat	5.74% ± 0.03%	2.6%±0.01%	0.29%±0.00%	87.33%±0.01%	8.73%±0.02%
Sheep	4.18% ±0.00%	6% ±0.01%	0.12% ±0.02%	86% ±0.04%	8.6% ±0.02%

Fat content was highest in sheep milk (6% ±0.01%), followed by cow (4.59% ± 0.01%) and goat milk (2.6%±0.01%). Fats are vital for the body and aid in the transport of fat-soluble vitamins [11]. Protein content was highest in goat milk (5.74% ± 0.03%), followed by sheep

(4.18% ±0.00%) and cow milk (2.97% ± 0.06%), suggesting goat milk may offer superior nutritional value in terms of protein content. Significant differences were observed in ash and fiber content among the milk samples [18]. The highest dry matter content was found in cow milk (87.65% ± 0.01%), whereas the lowest in sheep milk the lowest was in sheep milk (86% ± 0.04%).

CONCLUSION

In this study, the determination of heavy metal and proximate composition in cow, goat, and sheep milk samples collected from Yobe State University Farm during the rainy season was carried out. The samples were analyzed for Pb, As, Cd, Cu, Cr, and Ni using the AAS technique. The proximate composition including dry matter content, moisture content, crude fiber, crude protein, and fat content was assessed using standard analytical methods. The results showed that the levels of Cd, Cu, As (in cow and goat milk), and Cr (in cow and goat milk) were within the permissible limits set by the World Health Organization [20]. However, the concentrations of Pb in all the milk samples, as well as As and Cr in the sheep milk, exceeded the recommended limits, indicating potential health risks. On the nutritional composition, sheep milk had the highest fat content, whereas goat milk had the highest protein content compared to cow and sheep milk. Ni was not detected in any of the samples. Further studies are recommended to assess Ni presence using more sophisticated techniques. Continuous monitoring and control measures are recommended to ensure the safety and quality of milk consumed by the public.

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