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Comparative Analysis of Minerals and Lactose Composition of Milk from Various Mammalian Sources

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Abstract

Milk is a vital dietary staple for many animals, providing essential nutrients in precise proportions crucial for the neonatal stages of numerous mammals. Both adult humans and their infants rely on milk as a primary source of nutrients. This study aimed to compare the mineral and lactose composition of milk from sheep, goats, cows, and pigs. Raw milk samples from these animals were collected from various local farmers into sterilized bottles and preserved in a refrigerator before laboratory analysis. Standard methods were employed to

determine the mineral and lactose composition of the milk samples. The results showed that potassium levels in domestic sheep, red Sokoto goats, and pigs were significantly higher (P<0.05) than in white Fulani cows, with calcium being highest in domestic sheep. Magnesium content was lowest in pig milk and highest in red Sokoto goat milk, while domestic sheep and white Fulani cows showed no significant differences (P>0.05). Additionally, red Sokoto goat milk had the highest zinc levels and significantly higher (P<0.05) iron content than other sources, while domestic sheep milk had the highest cobalt concentration and the lowest iron levels among the groups. Furthermore, lactose content was significantly higher (p<0.05) in Fulani cow milk than in sheep, goat, and pig milk, with pig milk containing the least amount. Overall, the diverse nutritional profiles observed in the milk of different animals suggest that these alternative milk sources could be explored further to reduce reliance on cows and better meet the dairy needs of the populace.

Keywords: Milk, minerals, lactose, nutrients, mammals, and compositions

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Introduction

Milk, a pale liquid containing essential nutrients such as proteins, fats, lactose, vitamins, and minerals, has been a vital part of human diets since ancient times (Guetouache *et al*., 2014). Dating back to as early as the seventh millennium BC, dairying provided a convenient means of sustenance without the need for slaughter (Evershed *et al*., 2008). Historical evidence, including the discovery of processed dairy products in pottery vessels in the Libyan Sahara, attests to the ancient origins of dairy processing (Dunne *et al*., 2013).

Milk composition varies significantly among mammals and is believed to have evolved in response to various selection pressures (Skibiel *et al*., 2013). It is a vital source of nutrition for newborns, reflecting its high regard as a nutritious food (Roy, 2020). Milk primarily comprises water, fat, lactose, whey proteins, and minerals, with its composition subject to variation influenced by genetic, physiological, nutritional factors, and environmental conditions (Pietrzak-Fiećko and Kamelska-Sadowska, 2020).

Minerals are crucial for the human body, serving numerous vital functions such as acting as enzyme co-factors, contributing to metalloproteins, aiding in vitamin and bone formation, regulating osmolarity, facilitating nutrient absorption, and supporting oxygen transport (Stergiadis *et al*., 2019). Various minerals in milk, including Sodium, Magnesium, Phosphorus, Chlorine, Potassium, Calcium, Copper, and Zinc, contribute significantly to human growth and development (Nebedum and Obiakor, 2007). Properly preserved milk, such as Nunu, offers nourishment and refreshment at an affordable cost (Nebedum and Obiakor, 2007). These minerals also play crucial roles in bodybuilding and regulating metabolic processes, including nerve impulse transmission (Okpara *et al*., 2021).

Pasteurization, introduced by Louis Pasteur in 1863, revolutionized milk preservation by eliminating harmful bacteria, ensuring its safety for consumption (Vallery-Radot, 2003). The industrialization of milk production has led to increased consumption, underscoring its nutritional importance and cultural significance worldwide (Chouinard and Girard, 2014). After childhood, humans continue to drink milk. Moreover, raw milk and its derivatives (such as cheese, cream, butter, yogurt, and kefir) are always accessible due to the various technical processes or modifications applied to it (Landi *et al*., 2021). However, to meet the growing demand for dairy products, exploring alternative milk sources from different mammalian species is imperative to avoid overburdening specific animal populations (Arrichiello *et al*., 2022).

While cow's milk remains predominant in global milk production, other animal species, such as buffalo, goats, and sheep, contribute significantly (Arrichiello *et al*., 2022). These species offer alternative milk sources, each with its unique composition and nutritional profile. Therefore, understanding and comparing milk mineral and lactose content from pigs, goats, sheep, and cows is essential for evaluating their suitability as alternative milk sources for human consumption.

Materials and Methods

Sample Collection

Raw milk samples from domestic sheep, red Sokoto goat, white Fulani cow, and pigs were collected from local farmers in Abakaliki, Ebonyi State, Nigeria, in sterilized bottles and preserved in a refrigerator before laboratory analysis.

Determination of Mineral Compositions of Milk

The method for measuring the concentrations of Copper (Cu), Iron (Fe), Zinc (Zn), Cobalt (Co), Sodium (Na), Potassium (K), Calcium (Ca), Manganese (Mn), and Magnesium (Mg) involved atomic absorption spectrometry (AAS), as outlined by Malbe *et al*. (2010). The Samples were digested to break down organic matter and release elements into solution. Calibration standards covering the expected range of concentrations were prepared, creating a calibration curve. Samples and standards were then analyzed using an atomic absorption spectrometer (AA-6800/7000, Shimadzu). A hollow cathode lamp emits light at a specific wavelength in AAS, and the sample solution was atomized in a flame furnace. The absorbance readings were compared to the calibration curve to determine element concentrations. Additionally, Phosphorous (P) concentration was determined colorimetrically in the ash, following the method described by Medhammar *et al*. (2011), which involved forming a colored complex between phosphorus and a reagent, providing a sensitive and reliable way to quantify phosphorus concentrations in the sample ash.

Lactose determination

Lactose determination was conducted using the method developed by Marier and Boulet, 1959.

Statistical analysis

The mean ± standard deviation was used to express the data. Using the Statistical Package for the Social Sciences (SPSS) version 20, comparisons between groups were made using one-way analysis of variance (ANOVA). The least significant differences were identified at $p < 0.05$.

Results

Mineral components of milk for different sources

Figure 1 illustrates the mineral compositions of milk from various sources. Among domestic sheep, red Sokoto goats, white Fulani cows, and pigs, potassium contents were 171.35, 186.85, 149.9, and 182.25 mg/100g, respectively. Although the potassium levels in domestic sheep, red Sokoto goat, and pig milk were similar ($p>0.05$), they were all significantly higher than that of white Fulani cow milk. Notably, calcium content was markedly higher ($p<0.05$) in domestic sheep, while there were no significant changes ($p>0.05$) in calcium levels in red Sokoto goat, white Fulani cow, and pig milk. Pig milk exhibited the lowest magnesium content at 9.69 mg/100g, whereas red Sokoto goat milk had the highest concentration, significantly surpassing white Fulani cows and domestic sheep. The latter two sources showed no statistical differences in magnesium levels. Regarding phosphorus, domestic sheep and red Sokoto goat milk were comparable, significantly higher than white Fulani cow and pig milk. Sodium levels were notably higher in white Fulani cow milk compared to the others ($p<0.05$). In contrast, domestic sheep, red Sokoto goat, and pig milk did not exhibit significant differences in sodium levels ($p>0.05$). The sodium content of white Fulani cow was significantly higher ($p<0.05$) that other milk sources studied as shown in Figure 1.

Red Sokoto goat milk displayed significantly higher zinc levels compared to other sources. However, domestic sheep and pig milk had comparable zinc concentrations ($p>0.05$). Red Sokoto goat milk also showed higher manganese levels, followed by pig milk, white Fulani cow, and domestic sheep milk, although the differences were not statistically significant. Domestic sheep milk recorded the highest cobalt concentration, significantly differing from other sources. White Fulani cow and pig milk showed similar cobalt concentrations but were lower than red Sokoto goat. Pig milk had significantly higher iron levels than other sources ($p<0.05$), followed by white Fulani cow milk, which was also significantly higher than red Sokoto goat. Conversely, domestic sheep milk had significantly lower iron levels than other groups. Copper levels in domestic sheep, red Sokoto goat, white Fulani cow, and pig milk were 0.56, 0.93, 0.55, and 0.045 mg/100g, respectively.

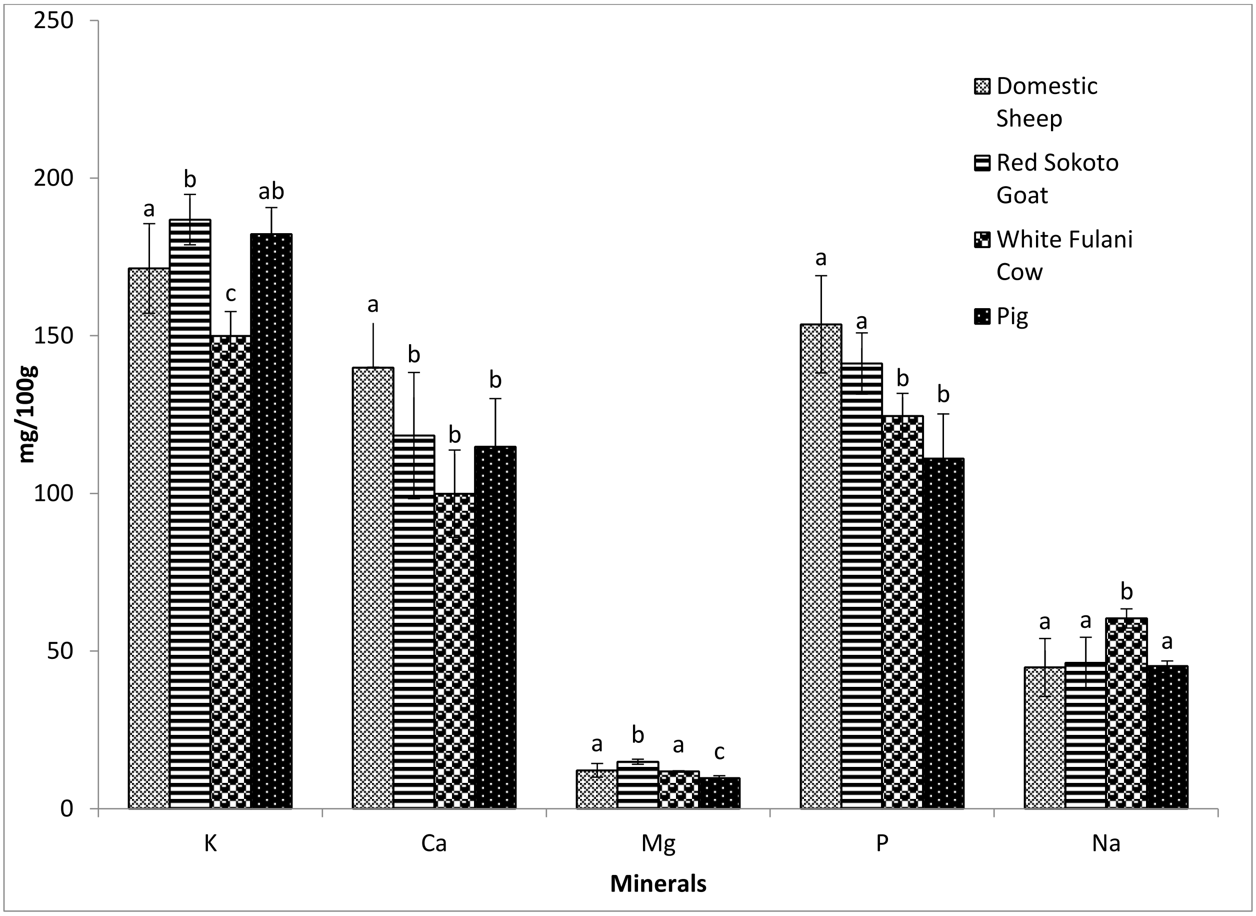

Fig 1a: Potassium, calcium, magnesium, phosphorous, and sodium composition of milk for different sources

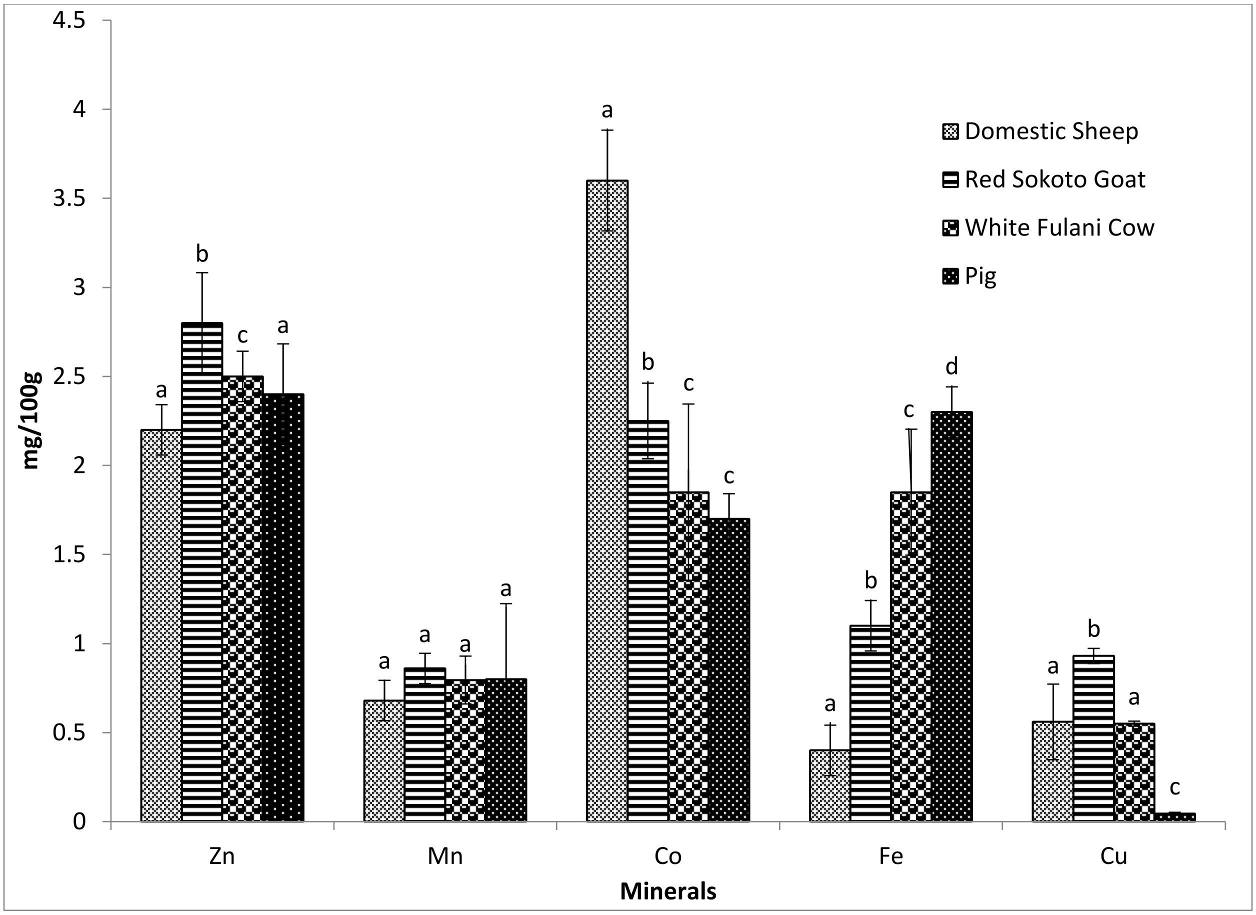

Fig 1b: Zinc, manganese, cobalt, iron, and copper composition of milk for different sources

Lactose constituent of milk from various sources

Figure 2 illustrates that pig milk exhibited a significantly lower (P<0.05) lactose content compared to the milk of domestic sheep, red Sokoto goat, and white Fulani cow milk. However, no significant difference (P>0.05) in lactose composition was observed among the milk samples from domestic sheep, red Sokoto goats, and white Fulani cow.

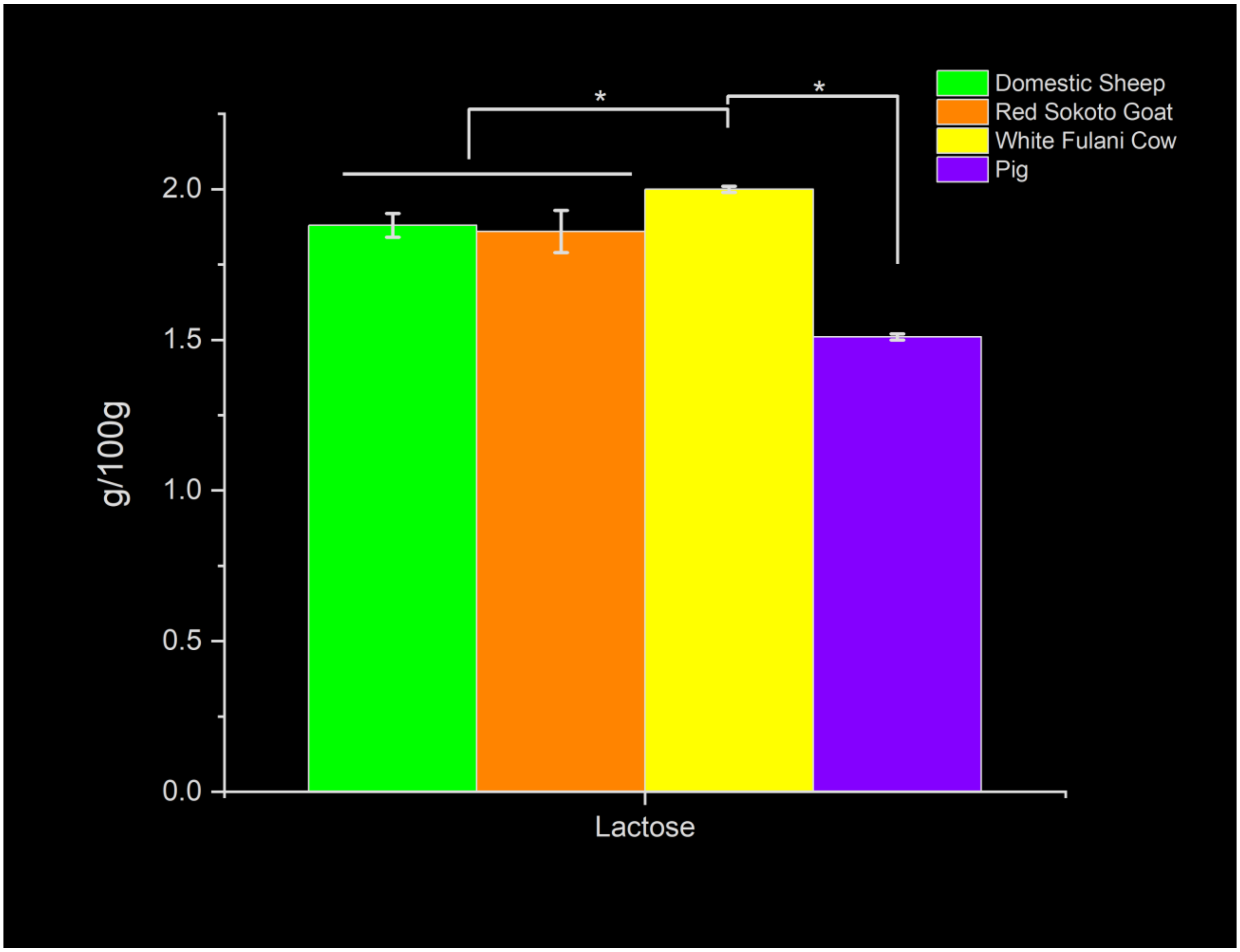

Fig 2: Lactose composition of milk from Fulani cow, domestic sheep, red Sokoto goat, and pig milk

Discussion

Minerals are essential components of our diet, serving multiple purposes such as forming the building blocks for bones, affecting muscle and nerve function, controlling water balance, and being present in hormones, enzymes, and other physiologically active substances (Weyh *et al*., 2022; Eluu *et al*., 2018; Oko *et al*., 2017). Our observations revealed significantly higher levels of potassium in domestic sheep, Red Sokoto goat, and pig milk than in Fulani cow milk, suggesting that pig milk could serve as a worthy potassium source, ranking second after Red Sokoto goat in potassium concentration. Conversely, domestic sheep exhibited a higher calcium content than other sources, crucial for maintaining healthy bones, teeth, and cellular functions. Prospective cohort studies and outcome trials indicate that higher potassium intake is linked to a reduction in cardiovascular disease mortality, primarily due to its blood pressure-lowering effects and potentially due to its direct benefits on the cardiovascular system (Aburto *et al*., 2013). Additionally, a high-potassium diet may prevent or slow the progression of renal disease, reduce urinary calcium excretion, aid in managing hypercalciuria and kidney stones, and potentially lower the risk of osteoporosis. Magnesium levels were elevated in Red Sokoto goat milk and lowest in pig milk (He and MacGregor, 2008). Magnesium is a cofactor for various enzyme systems, regulating biochemical reactions essential for energy production and membrane transport (Haug *et al*., 2007; Eluu *et al*., 2019). Phosphorus content was higher in domestic sheep and Red Sokoto goat milk, with pig milk containing the least, albeit not significantly different from White Fulani cow milk. Phosphorus is a critical human body component, necessary for many functions including ATP generation, signal transmission, and bone mineralization (Serna, 2020; Oko *et al.*, 2012). White Fulani cow milk displayed the highest sodium concentration, while the other sources showed no significant differences in sodium levels (Fig. 1a).

Red Sokoto goat milk exhibited the highest zinc content, while domestic sheep had the lowest. Zinc is the second most abundant transition metal ion in living organisms, following iron, and is crucial across all three domains of life. Approximately 5–6% of proteins in prokaryotes and 9–10% in eukaryotes rely on zinc for their biological functions (Cuajungco *et al.*, 2021). Cow milk is recognized as a good zinc source, with higher bioavailability than non-milk sources (Haug *et al.*, 2007). Our findings support this: cow milk ranked second in zinc concentration among the evaluated mammals. Manganese was highest in Red Sokoto goat milk, while domestic sheep had the least. Domestic sheep also had the highest cobalt content, with pigs containing the least. Manganese is crucial for human health, playing an essential role in development, metabolism, and the antioxidant system (Avila *et al.*, 2013; Oko *et al.*, 2015). However, excessive exposure or intake can result in manganism, a neurodegenerative disorder characterized by the death of dopaminergic neurons and symptoms resembling Parkinson's disease. Iron levels were higher in pig milk and lower in domestic sheep milk. Copper content was lowest in pigs but highest in Red Sokoto goat milk (Fig.1b).

The result showed that white Fulani cow milk exhibited a significantly higher ($P<0.05$) lactose content compared to the milk of domestic sheep, red Sokoto goat, and pig milk. However, no significant difference ($P>0.05$) in lactose composition was observed among the milk samples from domestic sheep, red Sokoto goats, and pigs (Fig.2). Lactose, a distinctive carbohydrate presents in most mammalian milk, has been a component of the human diet since the beginning of our species. Due to its chemical properties, lactose is included in numerous milk-derived products and is a crucial ingredient in pharmaceutical manufacturing (Romero-Velarde *et al.*, 2019).

The irregular pattern observed in the mineral composition of different animal milk sources underscores the importance of exploring alternative sources to alleviate the pressure on cows, which currently dominate the milk supply for human nutrition.

Conclusion

Our comparative analysis of minerals and lactose composition in milk from various mammalian sources revealed diverse nutritional profiles across different species. These findings highlight the importance of exploring alternative milk sources to meet diverse dietary needs and reduce reliance on specific animal populations. Further research is crucial for optimizing dairy production and enhancing human nutrition.

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