Research Article

Effect of Parity on the Proximate and Mineral Composition of Milk from White Fulani Cows Raised Extensively in the Derived Savanna Zone of Nigeria

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Abstract | Milk production from local Nigeria cattle is a vital part of small-scale farming, with significant economic, nutritional and social impacts. This study examined the effect of parity on milk quality characteristics of White Fulani cows. Specifically, physicochemical properties of milk, mineral composition of milk, and microbial load of milk were evaluated across different parity levels. Milk samples were collected and analyzed using standard laboratory procedures. Data were analyzed using one-way analysis of variance (ANOVA), while mean differences were separated using Tukey's Honestly Significant Difference (HSD) test at $p < 0.05$. Moisture content decreased significantly ($p < 0.05$) with increasing parity, with milk from first-parity cows recording the highest moisture content (89.10%), while third-parity cows recorded the lowest (87.90%). Milk pH increased significantly ($p < 0.05$) with parity, with third-parity cows producing milk with the highest pH value. Milk from third-parity cows exhibited significantly higher pH, specific gravity, and lactose content, while titratable acidity was significantly lower compared with milk from first- and second-parity cows. All minerals analyzed showed significant variation across parity ($p < 0.05$). Mineral composition of milk differed significantly across parity levels, with higher concentrations of calcium, phosphorus, potassium, magnesium, and iron observed in milk from third-parity cows. Second-parity cows consistently recorded the lowest mineral values. Coliform and Staphylococcus aureus counts differed significantly across parity ($p < 0.05$), with higher microbial loads observed in milk from first-parity cows. Salmonella was absent in all milk samples irrespective of parity. In conclusion, parity significantly influences milk quality characteristics of White Fulani cows. Higher parity was associated with improved nutritional composition, physicochemical quality, and lower microbial load. These findings emphasize the importance of parity consideration in improving milk quality and in developing effective management strategies for indigenous cattle production systems.

Keywords: Parity, White Fulani cows, Milk quality, Mineral composition, Microbial loads

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INTRODUCTION

Milk production remains a vital component of global food security and a major source of livelihood for millions of smallholder farmers in developing countries, particularly in sub-Saharan Africa (FAO, 2023). In Nigeria, the dairy sector is largely sustained by indigenous cattle breeds, which constitute over 90% of the national herd.

Despite this dominance, local milk production remains inadequate, leading to a heavy reliance on imported dairy products to meet domestic demand (Olagunju *et al.*, 2022). Indigenous cattle breeds play an essential role in providing milk and beef for both rural and urban populations while supporting the livelihoods of pastoral communities (Adeyeye, 2012).

Among Nigeria's indigenous breeds, the White Fulani (Bunaji) cattle are considered the most important dual-purpose breed due to their adaptability, resilience, and comparatively higher milk production potential than other native breeds such as Sokoto Gudali and Red Bororo (Yakubu *et al.*, 2019; Yahaya *et al.*, 2020). These cattle are predominantly managed under extensive systems and contribute significantly to national milk output. Understanding factors that influence milk composition and quality in this breed is therefore essential for improving productivity and utilization.

Parity is a key biological factor affecting milk yield, composition, and quality in dairy cattle. Differences between primiparous and multiparous cows are often attributed to mammary gland development, physiological maturity, and metabolic adaptations that occur over successive lactations (Bonded *et al.*, 2018). In White Fulani cattle, variations in milk constituents have been observed across parities. First-parity cows tend to exhibit higher milk protein content, whereas cows in later parities produce milk with increased ash, moisture, calcium, iron, and salt content (Alphonsus *et al.*, 2012). These changes are associated with cumulative physiological adjustments and improved mammary efficiency as cows advance in age (Alade *et al.*, 2013).

Parity also influences post-calving metabolism, hormonal balance, and nutrient partitioning, all of which can affect milk composition and quality (Bonded *et al.*, 2018). However, despite its importance, there is limited information on the effect of parity on the proximate composition, physicochemical properties, and microbial quality of milk from indigenous cattle breeds in Nigeria.

This study therefore seeks to address this gap by evaluating the influence of parity on milk proximate composition, physicochemical characteristics, mineral profile, and microbial load in White Fulani cows reared under an extensive management system. Such information is critical for optimizing production practices, improving milk quality, and enhancing the economic sustainability of indigenous dairy production systems.

MATERIALS AND METHODS

Ethical considerations

All procedures involving animals were conducted in accordance with accepted animal welfare guidelines. Milk collection was performed without causing harm or distress to the animals.

Study area

This study was conducted in Department of Animal Health and Production Technology at Oyo State College of Agriculture and Technology, Igboora, Nigeria, an area characterized by a tropical climate with distinct wet and dry seasons. The region supports extensive and semi-intensive cattle production systems, making it suitable for studies involving indigenous cattle breeds such as the White Fulani. Ambient temperature, relative humidity, and management practices in the study area reflect typical conditions under which White Fulani cattle are raised for milk production.

Experimental animals

Thirty lactating White Fulani cows were used for this study. The cows were managed under an extensive production system. The cows were clinically healthy and free from visible signs of disease throughout the period of sample collection. Animals were selected based on their parity status and further sub-divided into three parities.

Parity was classified as follows: First parity (cows that had calved once), second parity (cows that had calved twice) and the third parity (cows that had calved three times). Only cows within similar stages of lactation were included to minimize variations unrelated to parity.

Experimental design

The study adopted a completely randomized design (CRD) with parity as the main factor. The experimental design evaluated the effect of parity on physicochemical properties, mineral composition and microbial load of milk. Each parity group constituted a treatment, and samples were analyzed independently.

Sample collection

250ml of fresh milk samples were collected through hand milking from White Fulani cows during the morning milking hours. Prior to milking, the udder and teats were thoroughly cleaned with clean water and wiped with sterile towels to reduce external contamination. The first few streams of milk were discarded, after which approximately 250 mL of milk was collected into sterile sample bottles.

Milk samples intended for Proximate composition, physicochemical and mineral analyses were transported to

the laboratory in an ice-packed cooler and analyzed within 24 hours. Samples for microbial analysis were kept at 4 °C and analyzed immediately upon arrival at the laboratory.

Proximate composition of milk

Proximate composition was determined using standard methods of the Association of Official Analytical Chemists (AOAC). Moisture content was determined by oven drying at 105 °C to constant weight, crude protein by the Kjeldahl method (N × 6.38), crude fat by Soxhlet extraction, and ash content by incineration in a muffle furnace at 550 °C. Total solids and solid-not-fat were calculated by difference. All determinations were carried out in triplicate and results expressed as percentages (%).

Physicochemical properties of milk

Milk physicochemical properties were determined using standard dairy analysis methods. The pH was measured using a calibrated digital pH meter. Specific gravity was determined using a lactometer at room temperature. Lactose content was determined using standard titrimetric methods. Titratable acidity was determined by titration with 0.1 N NaOH using phenolphthalein as an indicator and expressed as percentage lactic acid.

Mineral composition of milk

Milk samples were digested using wet digestion techniques before mineral analysis. The concentrations of minerals were determined as follows: Calcium, magnesium, iron, sodium, and potassium were analyzed using Atomic Absorption Spectrophotometry (AAS). Phosphorus was determined using a spectrophotometric method. Mineral concentrations were expressed in mg/100 mL of milk.

Microbial analysis of milk

Microbial analysis was carried out using standard microbiological techniques. Total coliform count was determined using the pour plate method on MacConkey agar and expressed as colony-forming units per milliliter (CFU/mL). Staphylococcus aureus count was determined using Mannitol Salt Agar. Salmonella detection was carried out using selective enrichment and plating on Salmonella-Shigella agar. Plates were incubated at 37 °C for 24–48 hours, and colonies were counted using a colony counter.

Statistical analysis

A one-way analysis of variance (ANOVA) was employed to determine the effect of parity on proximate composition, physicochemical properties, mineral composition, and microbial load of milk samples. Where significant differences were observed, Tukey's Honestly Significant Difference (HSD) post-hoc test was used to separate means. Statistical significance was declared at $p < 0.05$.

RESULTS

Proximate composition

The proximate composition of White Fulani cow milk as influenced by parity is presented in Table 1. Parameters evaluated included moisture, crude protein, crude fat, crude fibre, ash, carbohydrate, metabolizable energy, and total solids. Moisture content decreased significantly ($p < 0.05$) with increasing parity, with milk from first-parity cows recording the highest moisture content (89.10%), while third-parity cows recorded the lowest (87.90%). This trend suggests increased solid matter deposition in milk as parity advances. Crude protein content differed significantly across parity levels ($p < 0.05$). Milk from third-parity cows exhibited the highest crude protein content (3.94%), indicating improved protein accretion associated with physiological maturity. Crude fat content was significantly influenced by parity ($p < 0.05$), with second-parity cows recording the highest fat content (4.30%). The relatively lower fat content observed in first-parity cows suggests limited fat deposition at earlier reproductive stages. Crude fibre was absent in all samples, and no significant difference ($p > 0.05$) was observed across parity, confirming that milk contains negligible fibre regardless of reproductive stage. Ash content showed a slight but significant difference ($p < 0.05$), with lower ash content observed in milk from third-parity cows, suggesting minor variations in total mineral residue.

Table 1: Effect of parity on the proximate composition of white fulani cow milk

Parameter	First Parity	Second Parity	Third Parity
Moisture (%)	89.10^{a}	88.50^{b}	87.90^{c}
Crude Protein (%)	3.85^{b}	3.73^{c}	3.94^{a}
Crude Fat (%)	1.94^{c}	4.30^{a}	3.16^{b}
Crude Fibre (%)	0.00^{a}	0.00^{a}	0.00^{a}
Ash (%)	0.45^{a}	0.45^{a}	0.41^{b}
Carbohydrate (%)	4.66^{a}	3.02^{c}	4.59^{b}
ME (kcal/100 ml)	51.50^{c}	65.70^{a}	62.56^{b}
Total Solids (%)	10.90^{c}	11.50^{b}	12.10^{a}

^{abc} mean within the same row with different superscripts are statistically different ($p<0.05$), %: percent, me: metabolizable energy

Physicochemical properties

Milk pH increased significantly ($p < 0.05$) with parity, with third-parity cows producing milk with the highest pH value as presented in Table 2. This suggests improved milk stability at later parities. Specific gravity and lactose content were also significantly affected by parity ($p < 0.05$), with third-parity cows producing milk with higher values, indicating enhanced milk quality and nutrient concentration. Titratable acidity showed no significant difference between first and second parity ($p > 0.05$) but

was significantly lower in third parity milk ($p < 0.05$), suggesting reduced acidity as parity advances.

Table 2: Physicochemical properties of white fulani cow milk by parity

Parameter	First Parity	Second Parity	Third Parity
pH	6.60[b]	6.54[c]	6.80[a]
Specific Gravity	1.031[b]	1.026[c]	1.034[a]
Lactose (%)	4.72[b]	4.65[c]	4.73[a]
Titratable Acidity (%)	0.18[a]	0.18[a]	0.13[b]

[abc] mean within the same row with different superscripts are statistically different ($p<0.05$)

Mineral composition

The mineral composition of milk as influenced by parity is shown in Table 3. All minerals analyzed showed significant variation across parity ($p < 0.05$). Milk from third-parity cows consistently recorded higher mineral concentrations, particularly calcium, potassium, and phosphorus, indicating enhanced mineral secretion capacity with advancing parity. Second-parity cows generally recorded the lowest mineral values, suggesting a transitional physiological stage between early and advanced lactation performance.

Table 3: Mineral composition of white fulani cow milk by parity

Parameter (mg/100 ml)	First Parity	Second Parity	Third Parity
Phosphorus	76.96[b]	72.84[c]	83.40[a]
Potassium	12.41[b]	8.31[c]	21.61[a]
Calcium	150.61	116.32[c]	164.51[a]
Magnesium	18.73[b]	16.30[c]	20.87[a]
Sodium	0.36[b]	0.29[c]	0.33[a]
Iron	132.14[b]	120.45[c]	130.34[a]

[abc] mean within the same row with different superscripts are statistically different ($p<0.05$)

Table 4: Microbial load of white fulani cow milk by parity.

Microorganism	First Parity	Second Parity	Third Parity
Coliform (CFU/ml)	130.34[a]	80.00[b]	60.00[c]
Salmonella	Absent	Absent	Absent
Staphylococcus aureus (CFU/ml)	3500[a]	2800[b]	2100[c]

[abc] mean within the same row with different superscripts are statistically different ($p<0.05$)

Microbial load

The microbial quality of milk samples across parity is summarized in Table 4. Coliform and Staphylococcus aureus counts differed significantly across parity ($p < 0.05$), with higher microbial loads observed in milk from first-parity cows. This may be attributed to lower udder immunity and milking experience at early parity stages. Salmonella was absent in all samples irrespective of parity, indicating acceptable microbiological safety of the milk.

DISCUSSION

This study assessed the influence of parity on the quality of milk (mineral, physicochemical, and microbiological parameters) and the proximate composition of milk in White Fulani cows. The results unequivocally indicate that parity substantially impacts the majority of quality characteristics of milk, affirming parity as a vital biological determinant of animal product quality.

The findings indicated that the mineral composition of milk varied markedly across parity levels, with third-parity cows consistently exhibiting the highest quantities of calcium, phosphorus, potassium, magnesium, sodium, and iron, whilst second-parity cows displayed the lowest values. This signifies enhanced mineral secretion efficiency with increasing parity. The increased moisture content of the milk could increase the phosphorus and sodium concentrations (Tesfiye, 2019).

These findings corroborate previous data indicating that milk mineral concentration rises with advancing parity in cows, attributed to better mammary gland development and improved metabolic capacity (Walstra *et al.*, 2006). (Dauda *et al.*, 2023). similarly noted that multiparous indigenous cows yielded milk with markedly elevated mineral concentrations compared to primiparous cows in extensive management systems in Nigeria. The reduced mineral concentrations noted in second-parity cows may indicate a transitional physiological phase in which nutrition allocation prioritises bodily maintenance and reproduction over milk mineral secretion.

Calcium and phosphorus, vital for bone development and milk processing quality, considerably increased at third parity, indicating that milk from older cows may be nutritionally superior for human consumption. This phenomenon has also been observed in tropical cow breeds, where parity-associated alterations in mineral metabolism influence milk quality (Silanikove *et al.*, 2011). The present study's finding was in line with the report of Nantapo. that breeds significantly affected selected milk minerals, such as magnesium, phosphorus, and calcium (Nantapo and Muchenje, 2013). Calcium is important in bone formation, metabolism, muscle contraction, nerve transmission, and blood clotting. Calcium and phosphorus are required in large quantities for the rapid growth of neonates, bone growth, and the development of soft tissues.

Parity had a substantial impact on milk pH, specific gravity, lactose concentration, and titratable acidity. Milk

from third-parity cows exhibited elevated pH, lactose concentration, and specific gravity, although titratable acidity was minimized at this parity. Elevated pH and lactose levels signify enhanced milk stability and energy content, which are advantageous quality characteristics.

The range value of milk moisture (87.90-89.10%) was within the recommended range of 84-88% for milk moisture in cows (Auldist *et al*., 1998). The results were also lower than 87.42 and 86.58 for Muturu and Red Bororo, as reported by Adesina (2012). The variations in the milk moisture could be ascribed to parity, season, and feed. The high milk moisture content is directly proportional to high water activity, which supports microbial growth, consequently decreasing the milk's shelf life. The value of milk protein is 3.85% as obtained in this present current study agreed with the range value of 3.72 - 4.01 for local cows in Sudan and Holstein Friesian in their first parity (Shuiep *et al*., 2016; Aminat *et al*., 2022). The milk protein obtained from the present study was higher than 3.51% for Murrah buffaloes in their first parity (Yadav *et al*., 2013), and higher than 3.24 for Holstein Friesian in their first parity as reported in a study by Bonded *et al*. (2018). The variations in crude fat could be attributed to breed and feed ingested by the cows, which could change the fatty acids produced in rumen fermentation. The higher the ratio of acetate to propionate in the rumen, the higher the crude fat content of the milk will be produced (Dauda 2021). This finding on crude milk fat also were in line with a study by Adesina (2012), who opined that crude milk fat was significantly ($p < 0.05$) higher in Red Bororo 4.49, compared to White Fulani 3.60 (Arrichiello *et al*., 2022). The variations in milk fat might be due to inherited characteristics (Bonded *et al*., 2018). Cows in their first parity tend to produce lower milk yields, which in turn can result in higher milk protein concentrations compared to cows in their second and third parities. Parameters (fat, ash, calcium, and sodium) in the current study grew with an increase in parity except the milk protein. This boost might be due to increased age and physiological organ maturity. Body weight and development of the udder during recurring pregnancies, which result in a larger mass of mammary glands for milk synthesis, could also be effective. Calcium growth due to increased parity might increase lactation, leading to high calcium demand for milk production (Londhe *et al*., 2012).

The findings align with those of Fox and McSweeney (2015), who indicated that the physicochemical qualities of milk enhance with increasing parity due to augmented secretory activity of mammary epithelial cells. The decrease in titratable acidity at increased parity indicates less microbial fermentation and enhanced udder health, a phenomenon also documented by Walstra *et al*. (2006).

Microbial investigation indicated markedly elevated coliform and Staphylococcus aureus levels in milk from first-parity cows, with microbial load diminishing progressively with increasing parity. The lack of Salmonella in all parity groups signifies satisfactory microbiological safety of the milk.

Elevated microbial counts in first-parity cows may result from immature udder immunity, lack of milking expertise, and increased vulnerability to contamination (Ruegg, 2017). Olaloku and Oyenuga (2018) found analogous findings, noting elevated bacterial counts in milk from primiparous indigenous cows in comparison to multiparous cows. Enhanced udder defense systems and milking adaptability in older cows likely contributed to the reduced microbial loads reported at third parity.

CONCLUSION AND RECOMMENDATION

This research examined the influence of parity on the quality attributes of milk in White Fulani cows. Parity greatly influenced the physicochemical qualities of milk. Milk from third-parity cows demonstrated elevated pH, specific gravity, and lactose concentration, coupled with reduced titratable acidity, indicating enhanced milk stability and quality at increased parity levels. The lack of Salmonella in all parity groups signifies satisfactory microbiological safety of the milk samples. Implementing parity-based management practices may improve product quality, customer safety, and the overall productivity of indigenous cow breeds. Dairy processors and quality control agencies should incorporate parity information into milk quality assessment protocols. Future studies should investigate the combined effects of parity, age, nutrition, lactation and milk quality characteristics of White Fulani cows.

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NOVELTY STATEMENT

The study offers contribution to dairy science by systematically investigating how parity influences the proximate and mineral composition of milk from white Fulani raised under extensive production systems in the Derived Savannah zone of Nigeria

AUTHOR'S CONTRIBUTION

A.O.M, O.A.O, A.I.A & O.O.T.: Data collection &

Analysis.
O.O.O, L.T.E & A.M.O.: Conceptualization of research idea.
L.T.E, O.O.O, O.O.A & A.J.A: Data analysis, Interpretation and writing up.

GENERATIVE AI AND AI-ASSISTED TECHNOLOGY STATEMENT

The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

CONFLICT OF INTEREST

The authors have declare that there is no conflict of interests regarding the publication of this article.

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