Acta Scientific AGRICULTURE (ISSN: 2581-365X)

Volume 10 Issue 1 January 2026

Research Article

Morphometric Analysis of Udders and Teats Relationships to Milk Production of Crossbred Cows During Lactation Stage

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Received: October 29, 2025

Published: December 31, 2025

Abstract

This study was undertaken to study morphometric analysis of udders and teats' relationships to milk production of Crossbred cows during the lactation stage. The research was carried out on 28 crossbred dairy cows under Sudanese conditions at the farm of the University of Khartoum, Sudan. The udders were studied by udder-shaped and teat-shaped. In addition to udder measurements of udder length, width, and depth, and teat measurements of teat length, width, and distance between teats, milk yield is also measured. The results indicated that the globular udder was the most common type (44%), followed by the bowl (39.33%), pendulous (10.66%), and goaty (6%). Similarly, cylindrical teats were more common (35.66%), followed by teats shaped as bottles (28.33%) and pears (20%), and funnel-shaped (12%) teats were the least common.

Additionally, the pear-shaped teats represented the highest length (6.92 cm), and the funnel-shaped teats represented the lowest length (6.18 cm). In cows with primiparous parity, the frequency of bowl-shaped and goaty-shaped udders was high (38.47%) and (30.76%). while, in multiparous cows, the frequency was lower (26.66% and 6.66%), respectively. Moreover, the pendulous-shaped and globular udders demonstrated a rise in udder frequency in the primiparous (15.38%) and (15.38%) cows and increased advancement in multiparous (40.02%) and (26.66%) cows, respectively. The average milk yield/day recorded was 9.13 ± 0.22 L) per cow, higher milk yields were observed in the bowl-shaped udder (10.57 ± 0.46) and cylindrical-shaped teat (9.59 ± 0.17). Therefore, the udder- and teat-shaped measurements and the selection of the udder and teat shape could be used as important criteria in selecting high-quality cows for milk production.

Keywords: Milk Yield; Udder; Teat; Typology and Measurement

Introduction

Sudan's agricultural economy heavily relies on dairy production, as the demand for liquid milk and its byproducts has risen sharply in recent years. The dairy sector makes a major contribution to both national food security and the overall economy [1]. Among the key aspects of dairy production that have been extensively studied is the relationship between the morphometric traits of cows' udders and teats and their milk yield [2,3].

This relationship is particularly significant in crossbred cows, which are increasingly used in developing countries such as Sudan to enhance milk productivity [4]. However, several constraints hinder dairy production in Sudan, which can be broadly categorized as environmental and genetic. These include endemic diseases, poor nutritional management, and a shortage of veterinary professionals [5]. The primary approaches to improving milk yield in cattle involve crossbreeding and selective breeding, both of which have been shown to significantly increase dairy productivity. The performance of crossbred cows under local Sudanese conditions has proven promising in meeting the growing demand for dairy products in urban areas [6,7].

According to [8], udder and teat morphometric traits, which can be used as selection criteria in buffalo breeding programs, have a direct influence on milk production capacity. Several studies have demonstrated a positive correlation between milk yield and udder and teat dimensions and conformation [9-11]. Based on visual assessment, teats are commonly classified into bottle-shaped, funnel-shaped, cylindrical, and pear-shaped types, whereas udders are categorized as round, bowl, pendulous, or goaty in shape [12-14]. When evaluating dairy cows for milk production potential, the morphometric characteristics and conformation of the udder and teats are critical parameters. The size and shape of the udder significantly affect milk productivity and should therefore be considered in selection and breeding programs [3,9,13]. Accordingly, this study aims to measure and analyze the morphometric characteristics of the udders and teats of crossbred cows, and to determine the relationship between these morphometric traits and milk production across different 65 stages of lactation. The findings are expected to provide insights that will aid in the 66 selection and management of crossbred cows to enhance dairy productivity at the 67 University of Khartoum dairy farm, Sudan.

Materials and Methods

Study area

This cross-sectional study was conducted on crossbred cows at the educational farm field, University of Khartoum, Sudan between January and November of 2022. Khartoum is located between longitudes 31.5 to 34°E and latitudes 15 to 16°N. It is surrounded by River Nile State in the north-east, in the north-west by the Northern State, in the east and southeast by the states of Kassala, Qadarif, Gezira and White Nile.

State, and in the west by North Kurdufan [16]. Khartoum experiences a hot desert climate characterized by extremely high temperatures and very low precipitation. The city has two distinct seasons - a hot, dry season from October to April and a scorching hot season from May to September. During the summer months, temperatures can exceed 40°C (104°F) regularly. It receives minimal rainfall, with most of it occurring in the form of sporadic heavy showers between June and September [16].

Experimental animals and management

Twenty-eight apparently healthy lactating crossbred cows with different parties were selected and examined in this study. Of these, 15 cows were multiparous and 13 were primiparous, with ages ranging from 3 to 12 years. The animals were maintained at the Educational Farm, University of Khartoum, Sudan. Each cow was tagged for ease of identification. All animals were kept under similar management and nutritional conditions. Measurements were recorded for cows of both parties (multiparous and primiparous) across three stages of lactation: early (N = 28; 1–3 months), mid (N = 28; 4–6 months), and late (N = 28; 7 months to drying). The milking schedule for each group was randomly assigned to minimize potential crossover effects between milking periods.

During milking, cows were offered a concentrate mixture composed of 94 cottonseed cake, wheat bran, corn syrup, and salt.

Clean drinking water was made 95 continuously available to all animals throughout the study.

Data collection

The study was conducted over a period of 11 months, from January to November 2022. Measurements were taken monthly throughout all lactation stages, beginning 15 days after calving and continuing until the late lactation stages. Data collection was performed repeatedly at specific intervals during different stages of lactation and milking on days 15, 45, 75, 105, 135, 165, 195, 225, and 255 postpartum. Milking arrangements for the cow groups were randomly assigned to minimize potential crossover effects between experimental milking periods. Milk yield was recorded during hand milking, which was performed twice daily at 12-hour intervals. Prior to milking, the udder was cleaned with water and massaged manually to stimulate milk let-down. Udder and teat morphology were assessed before the second milking (PM) to determine the lactation stages (early, mid, and late). Udder typology was evaluated visually following the method described by [12] and classified into four types: bowl, goaty, pendulous, and round. Similarly, teat morphology was assessed by gross observation and categorized into four shapes bottle, cylindrical, funnel, and pear according to the visual appraisal technique described by [13].

Statistical analysis

A completely randomized design (CRD) was employed to assess the impact of lactation stage and parity on udder morphology traits and milk yield. The data were analyzed using the following statistical model:

$Yij = u + ai + bj + eij$

Where:

Yij = examined dependent variables (UL, UW, UD, CU, TL, TW, and TDB), u = overall mean, ai = the impact of parity (i = primiparous and multiparous), bj = lactation stage (j = early, mid, and late), and eij = random experimental error. In addition, a Duncan test was used to determine the associations between measurements, which was declared at $P < 0.05$ using the LSD test [17]. Data on udder typology were analyzed using the chi-square test.

Result and Discussion

Regarding the distribution of udder typology (Table 1), the presence of suspensory ligaments was observed in 89%, 96%, and 92% of cases at the early, mid, and late stages of lactation, respectively. This percentage indicates a satisfactory level of suspensory ligament development among the experimental cows. According to [18], studies on Holstein-Friesian cattle have shown that selection based on well-developed suspensory ligaments is positively correlated with milk production. In contrast, the proportion of cows exhibiting differences in udder depth above the level of the hooks was 67%, 64%, 42%, and 48%, respectively, across the different stages of lactation (Table 1).

Table 1: Evaluating udder characteristics: suspensory ligaments, udder depth, and udder shaping of crossbred cows in phase lactation stage.

Parameters (Traits)	Lactation stage			
	15 day	105 day	195 day	380 day
Suspensory ligaments (SL, %)[1]				
0	11.00	4.00	4.00	8.00
1	89.00	96.00	96.00	92.00
Udder depth (UD, %)[2]				
1	67.00	64.00	42.00	48.00
2	18.00	29.00	54.00	48.00
3	15.00	7.00	4.00	4.00
Shaper udder (Sh U, %)[3]				
1	15.00	11.00	11.00	15.00
2	85.00	89.00	89.00	85.00

1 Suspensory ligament 1 (presence) or 0 (not present): 2 Udder depth as 1 (over the level of hook); 2 (at the hook level); 3 (below the level of hook): 3 Shaper udder 1 (mis-shaped udder); 2 (balanced udder).

This udder type is considered preferable for dairy cows because it is less susceptible to mastitis. Similar findings were reported by [19], in Jersey crossbred cows, where pendulous udders extending below the hook level were found to be more prone to intramammary infections. The relatively small proportion of udders located below the hook level (15%) observed during the early lactation stage (compared to the late stage) (Table 1) may help explain the higher incidence of mastitis observed in this breed during early lactation. Most crossbred cows in this study had well-balanced udders (Type 2) compared with misshapen udders (Type 1), representing 89% and 11% 149 of the total, respectively. The simple effect of the lactation stage indicated that the 150 proportion of misshapen udders increased slightly during late lactation (15%) compared 151 with mid-lactation (11%).

Visual inspection was used to assess the external morphology of udders and teats. Udder shapes were categorized into four types: bowl, globular, goaty, and pendulous; while teat shapes were classified as cylindrical, funnel, bottle, and pear (Table 2) Observations of udder morphology revealed that globular udders were the most common type, followed by bowl-shaped and pendulous udders, whereas goaty udders were the least frequent among all parities of crossbred cows. The overall frequencies of the udder types were as follows: bowl (39.53%), globular (44%), goaty (6%), and pendulous (10.66%). Cows with high milk yields are often selected based on udder conformation, as udder size and shape are traits that may have genetic heritability [20]. Similar observations were reported by [21] who found that 72% of crossbred cows had rounded udders. Regarding the effect of the lactation stage, globular udder types were more frequent during the early stage of lactation, accounting for 50% of the total observations (Table 2). In contrast to the findings of the present study, several cattle breeds have been reported to exhibit a higher frequency of bowl-shaped udders [22-24], and [25], (56.50%) of bowl-shaped udders in crossbred cows. [26] also found that 59.6% of udders were bowl-shaped in Gir cows. However, [27] reported a high incidence of goaty-shaped udders (59.18%) in Ongole cattle. When the udder is shaped like a bowl, there are no appreciable variations in the stages of milking; in this experiment, it was more frequent in the (mid) milking stage 47% (Table 2). In this study, 39.33% of the experimental cows had bowl-shaped udders. A related discovery was made public. 49.56 % of the udders in Kankrej cows had a bowl shape [28]. In the current investigation, the smallest number of goaty udders (6%) were discovered. Numerous researchers have documented comparable results for Gir cows (6.19%), Murrah buffaloes (9%), and crossbred cows (7.2%), [25,28,29]. It was found in this study that 10.66% of the udders were pendulous. Pendulous udders were observed in 9.4% of Friesian × Hariana cows, according to [21]. In addition, [29] made similar findings in Murrah buffaloes (a case of 13%) and [25] in a case of 16% crossbred cows. Only 3% of crossbred cows had pendulous udders, according to [21].

Table 2: Frequency and percentage of Tyap udder and Tyap teat during lactation in crossbred cows.

Traits	Frequency			Percentage %		
	Early 1-3 month	Mid 4-6 month	Lite 7- end of drying	Early	Mid	Lite
Udder shape:						
Bowl	9.00	13.00	11.00	32	47	39
Globular	14.00	11.00	12.00	50	39	43
Goaty	1.00	2.00	2.00	4	7	7
Pendulous	4.00	2.00	3.00	14	7	11
N	28	28	28	100	100	100
Teats shape:						
Botal	9.00	7.00	8.00	32	25	28
Cylindrical	11.00	9.00	9.00	41	33	33
Pear	3.00	7.00	7.00	10	25	25
Funnel	5.00	5.00	4.00	17	17	14
N	28	28	28	100	100	100

N; number cows use experimental.

Regarding teat shape, the current study's observations revealed that cylindrical teats were more common, followed by teats shaped like bottles and pears. On the other hand, of the strains and parity of crossbred cows on the Khartoum University farm, the funnel-shaped teat was the least common. The overall frequencies of the following were noted: bottle (28.33%), pear-shaped teat (20%), cylindrical teat (35.66%), and funnel (12%) (Table 2).

The form of the teat is crucial for milk flow or the release of milk from the udder, and it aids in the selection of cows with high milk yields. Similar results were reported by [38] in Deoni cattle, who found that (42.96%) of the teats were cylindrical. The frequencies of the other three teat shapes were different: bottle (15.62%), funnel (32.81%), and pear (8.60%). Similar findings from a related study revealed that Spanish Gir cows were found to have a similar frequency of cylindrical teats (39%) according to [26].

In addition, [30] found that cylindrical teats were the most common type 199 (51.61%). On the other hand, [29] in Murrah buffaloes (52.50%), and [24] validated the 200 findings in Red Kandhari cows (43.50%). The frequency of funnel-shaped teats was the 201 least (12%) in this study. In contrast to the present study, [31] found that crossbred cows 202 had a high incidence of funnel-shaped teats (78.19%). On the other hand, (48.27%) of 203 Karan-Fries cows had funnel-shaped teats, according to [22]. These findings confirm 204 similar findings by [25] in crossbred (48.63%). The frequency of pear-shaped teat was 205 (20%) in this study. However, pear-shaped teats are as high as those reported by [30], 206 have reported (35.48%) in crossbred cows. The wide variation observed in the udder 207 and teat shapes of crossbred cows in the present investigation might be attributable to 208 no specific selection for them in any of Sudan's cow breeding programs.

Table 3: Effect of udder shape on the measurement of udder at crossbred cows.

Udder Shape	U L (cm)	U W (cm)	U D (cm)
	Mean ± S. E.	Mean ± S. E.	Mean ± S. E.
Bowl	53.20 ± 0.76^{b}	40.92 ± 0.51^{b}	24.10 ± 0.76^{b}
Globular	65.65 ± 0.69^{a}	40.22 ± 0.73^{b}	23.74 ± 0.64^{b}
Goaty	52.30 ± 0.86^{b}	36.47 ± 0.55^{c}	20.80 ± 0.59^{b}
Pendulous	66.67 ± 0.73^{a}	44.11 ± 0.48^{a}	26.56 ± 0.69^{a}

a, b. The means in the columns with distinct superscripts show a significant difference ($P < 0.05$); UL:udder length; UW: udder width; UD: udder depth.

In the current study, crossbred cows at Khartoum University's udder length, width, and depth mean values and standard error are the udder shape of a goat represents the lowest form, and the shape of a pendulous udder represents the highest. Moreover, were 66.67 ± 0.73 cm for pendulous udders, to 52.30 ± 0.86 cm for goaty udders, 44.11 ± 0.48 cm for pendulous udders to 36.47 ± 0.55 cm for goaty udders, 26.56 ± 0.69 cm for pendulous udders to 20.80 ± 0.59 cm for goaty udders, respectively. The loosening of udder ligaments with age. We found that the udder lengths were highest in pendulous udders, followed by globular, bowl, and goaty udders. We found that the width and depth of the udders were highest in pendulous udders, followed by bowl, globular, and goaty udders (Table 3).

Due to udder form variations, differences in mean udder length, width, and depth were found; these differences were statistically significant ($P < 0.05$). The current conclusion supports the findings of crossbred studies [25,32], which showed that In crossbred cows, the measures of the udders were highest in pendulous udders and lowest in goaty-shaped udders. [29] observed comparable udder length and depth in 228 Murrah buffaloes. The average udder length, width, and depth were 58.24 ± 0.68 cm 229 for length, 65.45 ± 0.70 cm, and 23.06 ± 0.34 cm, respectively. The lower frequency 230 of goat-shaped udders may be because crossbred cows were less preferred owing to 231 their non-suitability for fast milking.

Table 4: Effect of shape teat on the measurement of teats in the crossbred cows.

Teats Shape	TL (cm)	TW (cm)	DBT (cm)
	Mean ± S. E.	Mean ± S. E.	Mean ± S. E.
Botal	6.26 ± 0.71[c]	2.76 ± 0.22[a]	5.76 ± 0.58[b]
Cylindrical	6.56 ± 0.57[b]	2.81 ± 0.15[a]	5.50 ± 0.53[b]
Pear	6.92 ± 0.61[a]	2.86 ± 0.15[a]	6.95 ± 0.86[a]
Funnel	6.18 ± 0.60[c]	2.26 ± 0.17[b]	4.16 ± 0.30[c]

a, b. The means in the columns with distinct superscripts show a significant difference (P < 0.05); TL: Teat length; TW: Teat width; DBT: The distance between teats.

The mean values and standard error in the current study teat length, width, and distance between the teats ranged from 6.18 ± 0.60 cm in funnel-shaped teats. This represents the lowest form to 6.92 ± 0.61 cm in pear-shaped teats, and the highest 2.26 ± 0.17 cm in funnel-shaped teats. Which represents the lowest form to 2.86 ± 0.15 cm in pear-shaped teats, which represents the highest form and 4.16 ± 0.30 cm in funnel-shaped teats. which represents the lowest form to 6.95 ± 0.86 cm in pear-shaped teats, which represents the highest form, respectively (Table 4). Because the teats have diverse shapes, there were statistically significant differences in mean teat length, diameter, and distance between the teats (P < 0.05). Pear-shaped teats were the largest in Khartoum crossbred cows, followed by cylindrical, total, and funnel-shaped teats. In contrast to the current experiment, [25] found that crossbred cows had lower teat measurements in pear-shaped teats and higher teat measurements in bottle-shaped teats. Thus, the present study indicated that crossbred cows with cylindrical teat shapes should be recommended for upgrading programs because milk yield is higher in crossbred cows with cylindrical teat shapes than in other teat types.

Table 5: Effect Parity on frequency, and percentage% of distribution udder-shapes in Crossbred cows.

Tarts	Parity			
	Multiparous		Primiparous	
	Frequency	Percentage %	Frequency	Percentage %
Bowl	4	26.66	5	38.47
Globular	4	26.66	2	15.38
Goaty	1	6.66	4	30.76
Pendulous	6	40.02	2	15.38
N	15	100	13	100

N; number cows use experimental.

In primiparous cows, the frequency of bowl-shaped udders was high (38.47%). However, there were fewer multiparous cows (26.66%) with bowl udders. In addition, goaty-shaped udders were most common (30.76%) in primiparous cows, whereas their frequency in multiparous cows was lower (6.66%). In addition, the pendulous-shaped and globular udders demonstrated a rise in udder frequency in the primiparous (15.38%) and (15.38%) cows, with advancement parity to in multiparous (40.02%) and (26.66%) respectively (Table 5). Similar findings from related studies were revealed in Kankrej cows by [28] and in crossbred cows by [25].

We evaluated milk yield at the lactation stage in Crossbred cows. This resulted in the bowl-shaped udder having the highest milk yield (10.57 L), followed by the pendulous-shaped (10.20 L) and globular-shaped (9.92 L) udders. The goat-shaped udder had the lowest milk yield (9.72 L) in the present study. Furthermore, the results show that the teat with the cylindrical shape yielded the most milk (9.59 L), followed by teats with bottle-shaped and funnel-shaped shapes (9.20 L and 9.02 L), and the teat with the pear-shaped shape yielded the least (8.93 L) (Table 6).

Table 6: Effect of udder shape and teat shape on milk yield (AM and PM) during the lactation stage in crossbred cows.

Traits	MY (AM)	MY (PM)	Total (MY)
Milk production (L/d), Udder shape:			
Bowl	5.77 ± 0.35	4.80 ± 0.11	10.57 ± 0.46[a]
Globular	5.52 ± 0.13	4.40 ± 0.13	9.92 ± 0.25[ab]
Goaty	5.24 ± 0.31	4.49 ± 0.02	9.73 ± 0.32[b]
Pendulous	6.48 ± 0.44	3.72 ± 0.02	10.20 ± 0.45[ab]
Milk production (L/d), Teats shape:			
Botal	4.99 ± 0.28	4.21 ± 0.11	9.20 ± 0.39a
Cylindrical	5.38 ± 0.16	4.21 ± 0.01	9.59 ± 0.17a
Pear	5.00 ± 0.28	3.94 ± 0.22	8.93 ± 0.50a
Funnel	5.10 ± 0.43	3.92 ± 0.17	9.02 ± 0.60a

a, b. Means in the same column and within a factor carrying different superscripts differ ($p < 0.05$); MY: Milk yield production over a 24-h period by hand-milking twice a 12:00 AM and 12:00 PM/day.

The crossbred cows showed that the form of the udder and teat had no significant impact on the amount of milk produced during the lactation stage. Similarly, was reported by [29] found that there was a positive relationship between the shapes of the udder and teat, with the highest average milk yielding (6.41 kg) for the udder with a bowl shape yields the greatest milk (6.41 kg), while the teat with a cylindrical-shaped yields the most milk (7.06 kg) in Murrah buffalo. In addition, [33] reported that udder and teat shape affect average milk yield in cattle. By comparison, in the current investigation, as reported by [2] in Murrah buffaloes, the udder and teat forms had no significant effect on daily milk yield, however, higher yields were observed in round- shaped udders and conical teats. In addition, a report by [34], in Dehong Crossbred Dairy Buffaloes and [35] in Nili-Ravi buffaloes found no correlation between milk yield and the morphologies of the udder and teat. In addition, Udder shape and milk yield have a positive relationship, but teat size and shape have no relationship with milk production by [3]. Udder shape affects milk yield in dairy cattle, with bowl-shaped udder cows having 25.4% to 29.3% higher daily milk yield than their different udder shapes [36]. Udder shape affects milk productivity, with bath-shaped udders being superior to bowl-shaped udders in the first lactation by 1.5% and in the third lactation by 14%, with greater total milk yield over the lifetime [37].

Conclusion

The globular udder was the most common type (44%), followed by bowl (39.33%), pendulous (10.66%), and goaty (6%). Similarly, cylindrical teats were more common (35.66%), followed by teats shaped like bottles (28.33%) and pears (20%), and funnel-shaped (12%) teats were the least common. We found that in the udder, length, width, and depth were highest in pendulous udders, followed by bowl, globular, and goaty udders. Additionally, we found that in teat length, width, and distance between the teats, the pear-shaped teats represented the highest length (6.92 cm), and the funnel-shaped teats represented the lowest length (6.18 cm). Therefore, the udder- 307 and teat-shaped measurements could be used as important criteria in selecting high- 308 quality cows for milk production.

Acknowledgment

The authors would like to thank Department of Dairy Production, Faculty of Animal Production, University of Khartoum, for support and facilities offered during conducting this study. Assistance and help extended to us from university`s farm staff also acknowledged.

Author Contributions

Hayani A.A, Tayib T.A.A. and Nikhaila. A.M. authors equally contributed on protocol proposal, collection, processing, analyzed, interpretation of data and wrote first & final version of Manuscript. All Authors have approved this version of the manuscript.

Funding Statement

This research received no specific grant from any funding agency, commercial or not-for-profit sectors.

Conflict of Interest

The authors have declared no conflict of interest.

Ethical Standards

The Faculty of Animal Production, University of Khartoum, Sudan, approved the study.

Data Availability

All data generated and analysed during this study are included in this published article.

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