

## Udder morphology and linear udder scoring as indicators for functionality and selection in Yemeni indigenous sheep breeds

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### ABSTRACT

Yemeni indigenous sheep are well adapted to diverse agro-ecological environments, however, limited information is available regarding their udder morphology and linear udder characteristics. The present study evaluated the measurements of udder and teats, linear udder scores, and their relationships in Yemeni indigenous sheep breeds. A total of 150 lactating ewes representing six indigenous breeds were assessed in semi-extensive management conditions. Eight udders and teat measurements and four linear udder traits (scored on a 1- 9 scale) were recorded. The mean udder length, depth, and circumference were 13.49, 12.70, and 24.61 cm, respectively, indicating considerable phenotypic variation among animals. Most of udder measurements ( $P < 0.01$ ) and linear udder scores were significantly affected by breed, whereas dam age significantly influenced only udder circumference and udder width. Udder circumference and udder width had a high positive correlation ( $r = 0.82$ ,  $P < 0.01$ ), while distance between teats had negative correlation with distance to the ground ( $r = -0.49$ ,  $P < 0.01$ ). Significant correlations were also observed between objective udder measurements and linear udder scores, indicating consistency between the two evaluation approaches. The results demonstrated substantial variation in udder morphology among Yemeni indigenous sheep breeds and suggested that both udder measurements and linear scoring traits may serve as a useful criteria for phenotypic characterization and within-breed selection programs.

**Keywords:** Indigenous breeds, Linear scoring, Phenotypic characterization, Udder morphology, Yemeni sheep

Yemeni indigenous sheep breeds are a significant livestock genetic resource and have key role in rural livelihood and food security in various production systems. These breeds are common in various agro-ecological areas of Yemen, such as coastal, arid and highlands and have acquired adaptation characteristics through long-term natural and human selection. Although they are socioeconomically and ecologically significant, little is known scientifically about their function and phenotype. Within the framework of climate change and growing environmental pressure, the functional and adaptive characteristics have become crucial for sustainable genetic enhancement. Of special significance among these characteristics are the udder morphology which is closely related to the milk production, nursing capabilities, udder well being and survivability of the lambs (Labussiere *et al.* 1981, Mavrogenis *et al.* 1988, Fernandez *et al.* 1997). It has been established through the studies that there are pronounced connections between the milk yield and external udder measurements like udder circumference, depth, width and teat space (Labussiere *et al.* 1981; Dogan

*et al.* 2013). Moreover, linear udder scoring systems founded on standardized ordinal scales (1-9) have been extensively used as viable tools of assessing the udder conformation and functionality, particularly in low-input systems where direct milk recording is challenging (Labussiere *et al.* 1981, Marie-Etancelin *et al.* 2006, Makovicky *et al.* 2013). The indigenous sheep are mostly kept in extensive systems in Yemen and little data is available on udder measurements and linear udder scores and their relationships with each other. Therefore, it is important to have some baseline data on these characteristics to explain phenotypic variation across local breeds and to determine functional indicators that can be used for intra breed selection programs that can be used to enhance adaptation and resilience to changing climatic conditions. In this regard, the present research was aimed to assess the influence of breed and age of dam on the characteristics of the morphology of the udder and the relationship between the udder measurements and the linear udder measurements, to support of functional selection and sustainable genetic improvement of local sheep populations in Yemen.

### MATERIALS AND METHODS

**Study area and animals:** The experiment was conducted in the Central Highlands Research Station, Yemen, where indigenous breeds of sheep are kept in semi-extensive

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management conditions. The study involved 150 lactating ewes of six Yemeni local sheep breeds (Jawfi, Black Boni, Ganadi, White Boni, Marbi and Barri). The animals were aged 2-6 years old and represented various parities. The breeds are traditionally spread all over in various agro-ecological zones of Yemen and are characterized by their adaptation to various and usually harsh environmental conditions. During the study, all the animals were healthy condition and reared under similar husbandry conditions.

**Udder and teat measurements:** At the 60<sup>th</sup> day of lactation of sheep, measurements of the udder traits were taken as it was described by Labussiere *et al.* (1981) and Altincekic and Koyuncu (2011). Eight traits were measured using ruler, measuring tape, and protractor and they covered udder length (UL), udder depth (UD), udder circumference (UC), udder width (UW), teat length (TL), teat diameter (TD), distance between teats (TT) and distance between teats and ground (TG) (Fig.1). Besides this, the morphology of the udder was rated on a linear scoring system (1-9 scale), where increasing scores represented increasing expression of the trait. Linear udder characteristics included of udder height, udder angle, teat length score and udder shape score in line with the methodology suggested by Labussiere *et al.* (1981) and Casu *et al.* (2006).

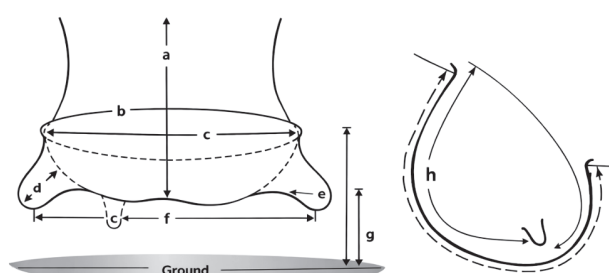
**Statistical analysis:** Data analysis was done through the General Linear Model (GLM) procedure of SAS (SAS

2002). Least square means (LSMeans) were estimated to evaluate the effects of breed and dam age on udder measurements and linear udder scores. Duncan's multiple range test was used to compare differences among means. Coefficients of Pearson correlation were used to measure relationship between measurements of udder traits and Spearman rank reference correlation coefficients measured between linear udder scores and between the measurements of udder traits.

## RESULTS AND DISCUSSION

The variability in the udder size and teat conformation characteristics of the studied animals was characterized in 150 ewes (Table 1). The length of the udder averaged 13.49 cm and had a relatively wide range (9-18 cm) which mean that the size of the udder varied significantly among the population of Yemeni sheep. The same was found in the case of udder depth (11-20 cm), udder circumference (15-31 cm), which indicated that there was heterogeneity in the capacity of the udder, and structure among the ewes. The coefficients of variation were moderate in most of the udder traits, which is in line with others that were in indigenous and dairy sheep breeds (Mavogenis *et al.* 1988, Fernandez *et al.* 1997, Makovicky *et al.* 2013, Shettima *et al.* 2022). There was significant dispersion in udder circumference and udder width, which are typically linked to milk storage capacity, an indication of the existence of exploitable phenotypic diversity to be used in selection (Labussiere *et al.* 1981). The traits of the teats had a relatively low variation in comparison to the udder size traits. The length of the teats was 2.0 to 3.0 cm and the teat diameter was 1.0 to 2.9 cm. These values fell within the ranges reported for local and unimproved sheep breeds but are generally lower than those observed in recognized dairy sheep, reflecting the non-dairy-oriented selection background of Yemeni indigenous sheep (Dogan *et al.* 2013, Marie-Etancelin *et al.* 2006). The distance between teats and the distance from teats to the ground had large variation, especially the latter (19- 35 cm) that has significant implications on the functionality of the udder, ease of milking, and vulnerability to environmental contamination.

The variance in udder measures in Yemeni indigenous sheep breeds (Table 2) indicated that the breed had a highly significant effect ( $P < 0.01$ ) on most of the udder measures to



- a: Udder depth
- b: Udder circumference
- c: Udder width
- d: Udder teat length
- e: Udder teat diameter
- f: Udder length
- g: Distance between udder teats
- h: Distance between teats and ground
- i: Udder teat length

Fig. 1. Morphological parameters measured on udder and teats

Table 1. Descriptive statistics of udder and teat measurements (cm) in Yemeni indigenous sheep breeds

| Trait                                  | N   | Mean  | Std. Deviation | Minimum | Maximum |
|----------------------------------------|-----|-------|----------------|---------|---------|
| Udder length (cm)                      | 150 | 13.49 | 3.37           | 9.00    | 18.00   |
| Udder depth (cm)                       | 150 | 12.70 | 2.50           | 11.00   | 20.00   |
| Udder circumference (cm)               | 150 | 24.61 | 4.27           | 15.00   | 31.00   |
| Udder width (cm)                       | 150 | 12.64 | 2.18           | 8.00    | 17.00   |
| Teat length (cm)                       | 150 | 2.67  | 0.40           | 2.00    | 3.00    |
| Teat diameter (cm)                     | 150 | 1.68  | 0.34           | 1.00    | 2.90    |
| Distance between teats (cm)            | 150 | 11.83 | 1.92           | 8.00    | 18.00   |
| Distance between teats and ground (cm) | 150 | 26.89 | 4.12           | 19.00   | 35.00   |

Table 2. Variance analysis of udder traits (cm) in Yemeni indigenous sheep breed

|       | N  | Udder length (UL)         | Udder depth (UD)           | Udder circumference (UC)   | Udder width (UW)           | Teat length (TL)          | Teat diameter (TD)        | Distance between teats (TT) | Distance teats-ground (TG) |
|-------|----|---------------------------|----------------------------|----------------------------|----------------------------|---------------------------|---------------------------|-----------------------------|----------------------------|
| Breed |    | **                        | **                         | **                         | **                         | ns                        | ns                        | **                          | **                         |
| GF    | 12 | 8.83 ± 0.58 <sup>c</sup>  | 11.67 ± 0.74 <sup>bc</sup> | 19.17 ± 1.15 <sup>d</sup>  | 11.50 ± 0.66 <sup>bc</sup> | 2.42 ± 0.15 <sup>b</sup>  | 1.50 ± 0.13 <sup>b</sup>  | 10.83 ± 0.62 <sup>b</sup>   | 32.83 ± 1.03 <sup>a</sup>  |
| BB    | 33 | 13.20 ± 0.64 <sup>b</sup> | 17.20 ± 0.81 <sup>a</sup>  | 28.80 ± 1.25 <sup>a</sup>  | 15.60 ± 0.72 <sup>a</sup>  | 2.76 ± 0.16 <sup>ab</sup> | 1.98 ± 0.14 <sup>a</sup>  | 11.80 ± 0.68 <sup>ab</sup>  | 25.60 ± 1.13 <sup>bc</sup> |
| GN    | 20 | 16.57 ± 0.37 <sup>a</sup> | 11.17 ± 0.46 <sup>c</sup>  | 26.67 ± 0.73 <sup>a</sup>  | 13.13 ± 0.41 <sup>b</sup>  | 2.67 ± 0.09 <sup>ab</sup> | 1.72 ± 0.08 <sup>ab</sup> | 13.40 ± 0.39 <sup>a</sup>   | 23.13 ± 0.65 <sup>c</sup>  |
| WB    | 25 | 9.17 ± 0.58 <sup>c</sup>  | 12.17 ± 0.74 <sup>bc</sup> | 23.17 ± 1.15 <sup>bc</sup> | 12.33 ± 0.66 <sup>b</sup>  | 2.80 ± 0.15 <sup>ab</sup> | 1.67 ± 0.13 <sup>ab</sup> | 10.00 ± 0.62 <sup>b</sup>   | 28.50 ± 1.03 <sup>b</sup>  |
| MR    | 23 | 12.83 ± 0.58 <sup>b</sup> | 13.83 ± 0.74 <sup>b</sup>  | 21.17 ± 1.15 <sup>cd</sup> | 10.33 ± 0.66 <sup>c</sup>  | 2.50 ± 0.15 <sup>b</sup>  | 1.55 ± 0.13 <sup>b</sup>  | 11.08 ± 0.62 <sup>b</sup>   | 28.00 ± 1.03 <sup>b</sup>  |
| BR    | 37 | 15.67 ± 0.58 <sup>a</sup> | 13.25 ± 0.74 <sup>b</sup>  | 26.33 ± 1.15 <sup>ab</sup> | 12.67 ± 0.66 <sup>b</sup>  | 2.92 ± 0.15 <sup>a</sup>  | 1.65 ± 0.13 <sup>b</sup>  | 11.50 ± 0.62 <sup>b</sup>   | 28.67 ± 1.03 <sup>b</sup>  |
| Age   |    | ns                        | ns                         | ns                         | ns                         | ns                        | ns                        | ns                          | ns                         |
| 2     | 23 | 13.83 ± 0.58 <sup>a</sup> | 10.83 ± 0.74 <sup>a</sup>  | 21.83 ± 1.15 <sup>a</sup>  | 11.00 ± 0.66 <sup>a</sup>  | 2.25 ± 0.15 <sup>a</sup>  | 1.47 ± 0.13 <sup>a</sup>  | 13.33 ± 0.62 <sup>a</sup>   | 27.50 ± 1.03 <sup>a</sup>  |
| 3     | 59 | 13.41 ± 0.34 <sup>a</sup> | 12.85 ± 0.44 <sup>a</sup>  | 25.00 ± 0.68 <sup>a</sup>  | 12.82 ± 0.39 <sup>a</sup>  | 2.71 ± 0.09 <sup>a</sup>  | 1.68 ± 0.08 <sup>a</sup>  | 11.88 ± 0.37 <sup>a</sup>   | 27.00 ± 0.62 <sup>a</sup>  |
| 4     | 51 | 13.50 ± 0.37 <sup>a</sup> | 13.23 ± 0.46 <sup>a</sup>  | 25.27 ± 0.73 <sup>a</sup>  | 13.27 ± 0.41 <sup>a</sup>  | 2.80 ± 0.09 <sup>a</sup>  | 1.76 ± 0.08 <sup>a</sup>  | 11.37 ± 0.39 <sup>a</sup>   | 26.47 ± 0.65 <sup>a</sup>  |
| 5     | 17 | 13.20 ± 0.64 <sup>a</sup> | 12.80 ± 0.81 <sup>a</sup>  | 24.80 ± 1.25 <sup>a</sup>  | 12.20 ± 0.72 <sup>a</sup>  | 2.70 ± 0.16 <sup>a</sup>  | 1.78 ± 0.14 <sup>a</sup>  | 11.20 ± 0.68 <sup>a</sup>   | 27.40 ± 1.13 <sup>a</sup>  |

Values are least square means ± standard error (SE). ns = non-significant; \*  $P < 0.05$ ; \*\*  $P < 0.01$ . Means within the same column with different superscripts differ significantly ( $P \leq 0.05$ ). GF= Gawfi sheep, BB= Black Boni sheep, GN= Ganadi sheep, WB=White Boni sheep, MR= Marbi sheep, BR= Barri sheep

including udder length, udder depth, udder circumference, udder width, but teat length and teat diameter was not significantly ( $P > 0.05$ ) influenced. These results showed that Yemeni sheep breeds are characterized by a significant phenotypic variation, considering the difference in genetic background and evolutionary changes over the years to different environmental and management conditions.

Ganadi sheep and Barri sheep showed the highest ( $P < 0.01$ ) mean value for udder length whereas Black Boni sheep was highest in terms of mean value for udder depth and udder circumference. A bigger udder size is usually related to a larger mammary secretory capacity and a higher potential of milk storage. Ozyurek *et al.* (2018) reported similar breed-related differences in the traits of the udder in Morkaraman, Tuj, and Awassi sheep, and Shettima *et al.* (2022) also reported similar observation in the Nigerian native sheep breeds, where it was shown that there were strong phenotypic relationships between the udder measurements, milk production, and body weight. Moreover, Murphy and Taylor (2021) stated that the score of udder conformation has a close relationship with the productivity of ewes and the performance of lambs. These findings support the use of udder morphology as an indirect indicator of productive performance in indigenous sheep Yemeni populations. Such information is particularly valuable for developing low-cost, phenotypic

selection criteria, which aimed at improving productivity and resilience under harsh environmental conditions. The present study did not find significant differences in the teat length and teat diameter ( $P > 0.05$ ) between breeds and in this case, the results were consistent with those of Awassi ewes reported by Karakus (2024). However, large differences were also noted in the distance between teats and ground with the highest figures noted in Jawfi sheep. This characteristic has a practical significance because exaggerated teat height can deteriorate the efficiency of lambs in sucking and the health of the udder. Similarly, Vnucet *et al.* (2020) stated that the shape of the udder and the location of the teats are significant in the milk output and working life of ewes. The age at which the dams were used had a great influence on the udder circumference and udder width ( $P < 0.01$ ) but it had no significant influence on other traits. There was a tendency among older ewes to exhibit greater size of the udder, probably because of the cumulative growth of the mammary glands in the course of consecutive lactations. Similar effect of age on the morphology of the udder are observed in a number of sheep breeds (Ozyurek *et al.* 2018, Karakus 2024).

Table 3 represents the variance analysis of linear udder scores in Yemeni indigenous breed of sheep. Breed had a significant effect on udder height, udder angle, and teat length ( $P < 0.01$ ), and teat length ( $P < 0.01$ ), and a

Table 3. Variance analysis of udder linear score (1–9 scale) in Yemeni indigenous sheep breed

| Breed | N  | Udder height              | Udder angle              | Teat length               | Udder shape               |
|-------|----|---------------------------|--------------------------|---------------------------|---------------------------|
|       |    | **                        | **                       | **                        | *                         |
| GF    | 12 | 7.71 ± 0.39 <sup>a</sup>  | 3.14 ± 0.44 <sup>b</sup> | 4.14 ± 0.22 <sup>bc</sup> | 4.00 ± 0.21 <sup>c</sup>  |
| BB    | 33 | 5.14 ± 0.39 <sup>d</sup>  | 5.14 ± 0.44 <sup>a</sup> | 4.71 ± 0.22 <sup>ab</sup> | 5.00 ± 0.21 <sup>a</sup>  |
| GN    | 20 | 6.43 ± 0.23 <sup>c</sup>  | 5.48 ± 0.26 <sup>a</sup> | 3.71 ± 0.13 <sup>c</sup>  | 3.90 ± 0.13 <sup>c</sup>  |
| WB    | 25 | 5.57 ± 0.39 <sup>cd</sup> | 5.57 ± 0.44 <sup>a</sup> | 4.86 ± 0.22 <sup>a</sup>  | 4.71 ± 0.21 <sup>ab</sup> |
| MR    | 23 | 7.00 ± 0.42 <sup>ab</sup> | 4.67 ± 0.48 <sup>a</sup> | 4.17 ± 0.24 <sup>bc</sup> | 4.33 ± 0.23 <sup>bc</sup> |
| BR    | 37 | 5.29 ± 0.39 <sup>d</sup>  | 4.71 ± 0.44 <sup>a</sup> | 4.14 ± 0.22 <sup>bc</sup> | 4.14 ± 0.21 <sup>c</sup>  |
| Age   |    | **                        | ns                       | ns                        | ns                        |
| 2.0   | 23 | 5.64 ± 0.31 <sup>b</sup>  | 5.45 ± 0.35 <sup>a</sup> | 4.36 ± 0.18 <sup>a</sup>  | 4.64 ± 0.17 <sup>a</sup>  |
| 3.0   | 59 | 5.93 ± 0.29 <sup>ba</sup> | 5.00 ± 0.33 <sup>a</sup> | 4.27 ± 0.17 <sup>a</sup>  | 4.33 ± 0.16 <sup>a</sup>  |
| 4.0   | 51 | 6.81 ± 0.27 <sup>a</sup>  | 4.94 ± 0.31 <sup>a</sup> | 3.88 ± 0.16 <sup>a</sup>  | 3.88 ± 0.15 <sup>a</sup>  |
| 5.0   | 17 | 6.50 ± 0.54 <sup>ab</sup> | 4.25 ± 0.61 <sup>a</sup> | 4.25 ± 0.31 <sup>a</sup>  | 4.25 ± 0.30 <sup>a</sup>  |
| 6.0   | 23 | 7.00 ± 0.48 <sup>a</sup>  | 4.80 ± 0.54 <sup>a</sup> | 4.20 ± 0.27 <sup>a</sup>  | 4.40 ± 0.26 <sup>a</sup>  |

Udder and teat traits were evaluated using a subjective scoring system (1–9 scale)

ns = non-significant; \*  $P < 0.05$ ; \*\*  $P < 0.01$ .

Means within the same column with different superscripts differ significantly ( $P \leq 0.05$ ).

GF= Gawfi sheep, BB= Black Boni sheep, GN= Ganadi sheep, WB=White Boni sheep, MR= Marbi sheep, BR= Barri sheep

moderate significant effect on udder shape ( $P < 0.05$ ). In contrast age of dam did not show a significant influence on any of the evaluated linear udder characteristics. These results indicate that genetic differences among breeds played a major role in shaping udder conformation, while age-related effects appear to be limited for subjective udder scoring traits. Jawfi and Marbi breeds showed significantly higher scores in the udder height than the Black Boni and Barri breeds. Higher udder height scores generally reflect a more elevated udder position relative to the ground, which is considered advantageous for udder health and longevity by reducing the risk of contamination and reduce mastitis. Ozyurek *et al.* (2018) and Karakus (2024) also found similar breed-related variations in udder height in Morkaraman, Tuj, and Awassi sheep, and in Norduz sheep, respectively, which confirmed that udder height is a highly variable trait and breed-dependent trait. The score on udder angle had a comparatively little difference amongst most of the breeds, yet Jawfi sheep had considerably lower scores than other breeds. Udder and teat angle are significant functional characteristics of ease of milking and efficiency of suckling. Another aspect and importance that the previous studies highlighted with regard to dairy and dual-purpose sheep breeds is the applicability of the teat and udder angle, especially in milk flow and milking aptitudes (Ivanova and Raicheva 2019, Murphy and Taylor 2021). There were also significant breed variations in the case of teat length scores. The highest scores on teat length were registered by White Boni sheep and the lowest scores were registered by Ganadi sheep. Teat length is a vital functional characteristic that impacts suckling capability of a lamb, and where practicable, efficiency of milking machine. A similar breed-related difference in the length of the teats has been observed in Awassi sheep and crosses between

Awassi sheep and crosses (Dzidic *et al.* 2004, Iniguez *et al.* 2009), and in Nigerian indigenous sheep breeds (Shettima *et al.* 2022), indicating that the trait has a high level of phenotypic and genetic variability.

Black Boni sheep had better udder shape ( $P > 0.05$ ) than the majority of other breeds, whereas Ganadi and Jawfi sheep showed lower scores. Udder shape is a complex characteristic that expresses udder attachment and it has been linked to milk production and functionality of the udder. Prpic *et al.* (2020) documented that udder shape is a significant factor of milk production in sheep, whereas Vnucce *et al.* (2020) cited its applicability in selection sheep to enhance the dairy performance. The current study did not find any significant impact of age of dams on the udder height, udder angle, and teat length and shape of the udder. This was consistent with the results of Ozyurek *et al.* (2018) and Karakus (2024) who noted that linear udder scores reach a stable value at a mature age and do not vary significantly with the growing age. Conversely, some studies have found age-related variation in certain udder characteristics, specifically in highly specialised dairy breeds (Gelasakis *et al.* 2012, Prpic *et al.* 2020), which indicates that effects of age might be different based on type of breed, level of production, and production system.

Pearson correlation coefficients (Table 4) showed some important relationships among the features of the udder that point to high interdependence of the features of the udder dimensions. The udder length was positively correlated with udder circumference ( $r = 0.58$ ,  $P < 0.01$ ) and distance between teats ( $r = 0.62$ ,  $P < 0.01$ ) and negatively correlated with distance between the teats and the ground ( $r = -0.66$ ,  $P < 0.01$ ). These relationships suggested that ewes with longer udders tend to have larger udder capacity and wider teat placement, but a lower udder position relative to the

Table 4. Correlations between udder measurements in Yemeni indigenous sheep breed

| Trait                       | UL   | UD   | UC     | UW     | TL    | TD     | TT     | TG      |
|-----------------------------|------|------|--------|--------|-------|--------|--------|---------|
| Udder length (UL)           | 1.00 | 0.09 | 0.58** | 0.29   | 0.13  | 0.19   | 0.62** | -0.66** |
| Udder depth (UD)            |      | 1.00 | 0.28   | 0.35*  | 0.18  | 0.28   | 0.10   | -0.05   |
| Udder circumference (UC)    |      |      | 1.00   | 0.82** | 0.30* | 0.36*  | 0.40** | -0.46** |
| Udder width (UW)            |      |      |        | 1.00   | 0.20  | 0.35*  | 0.29   | -0.27   |
| Teat length (TL)            |      |      |        |        | 1.00  | 0.45** | 0.02   | -0.23   |
| Teat diameter (TD)          |      |      |        |        |       | 1.00   | 0.19   | -0.40** |
| Distance between teats (TT) |      |      |        |        |       |        | 1.00   | -0.49** |
| Distance teats-ground (TG)  |      |      |        |        |       |        |        | 1.00    |

\*  $P < 0.05$ , \*\*  $P < 0.01$ .

ground. Awassi, Morkaraman, and Tuj sheep have been reported to have similar correlations between udder length, circumference, and teat location (Ozyurek *et al.* 2018), along with Nigerian indigenous sheep breeds (Shettima *et al.* 2022). The depth of the udder had a moderate positive relationship with the width of the udder ( $r = 0.35$ ,  $P < 0.05$ ) which suggested that udders with more depth are wider. This relationship reflects the notion that udder size traits are biologically related. Other authors, including Mavrogenis *et al.* (1988) and Fernandez *et al.* (1997), also made similar contributions and found that the depth and width of the udder were effective predictors of the volume of the udder and its capacity to store milk. The relationship between the udder circumference and udder width was observed to be a very strong positive correlation ( $r = 0.82$ ,  $P < 0.01$ ) which indicates that most of the changes in the udder circumference are accompanied by changes in the udder width. Udder circumference also had a positive relationship with teat length ( $r = 0.30$ ,  $P < 0.05$ ), teat diameter ( $r = 0.36$ ,  $P < 0.05$ ), and distance between teats ( $r = 0.40$ ,  $P < 0.01$ ) and negative relationship with distance between teats and ground ( $r = -0.46$ ,  $P < 0.01$ ). The findings aligned with the past literature bigger udders are likely to be characterized by longer and fatter teats whereas smaller udders record a lower position of the udder (Labussiere *et al.* 1981, Dogan *et al.* 2013; Prpic *et al.* 2020). There was a positive relationship between teat length and teat diameter ( $r = 0.45$ ,  $P < 0.01$ ), which implied that longer teats are usually fatter. This association has also been reported in some sheep breeds and is deemed to be of significance to both the lamb suckling capacity and the milking performance (Dzidic *et al.* 2004, Ivanova and Raicheva 2019). No significant correlation was, however, noted between teat length with distance between teats and weak negative correlation with distance between teats and ground. The distance between teats had a significant negative correlation with the distance between teats and ground ( $r = -0.49$ ,  $P < 0.01$ ) which meant that the larger the spacing of the teats, the lower the udder position. The practical implications of this finding is that when udders are too low, they pose a higher risk of injury and contamination, especially where the management is done at large scale. Gelasakis *et al.* (2012) and Vnucce

*et al.* (2020) suggested similar relationships, emphasizing that both conformation of the udder and its functionality were important variables to consider when defining functional efficiency.

The Spearman correlation coefficients between udder measurements (cm) and udder linear scores (1–9 scale) in Yemeni indigenous sheep are presented in Table 5. The findings revealed that there are a number of significant correlations pointing to the fact that objective measurements of the udder and subjective linear scoring characteristics are very much related. Udder height score also had negative relationships with most of the udder measurements with significant negative correlations between the udder height and udder circumference ( $p = 0.360$ ,  $P < 0.05$ ) as well as the udder width ( $p = 0.334$ ,  $P < 0.05$ ). This indicated that the ewes that were placed higher in the udder were also likely to have lesser udder sizes especially in its width and circumference. The same converse associations have been observed between udder height and udder size traits on dairy and dual purpose sheep breeds by Milerski *et al.* (2006) and Margetin *et al.* (2013), which also noted the practical pertinence of the udder suspension to the udder capacity. The udder angle score showed significant positive relationship with udder circumference ( $\rho(r) = 0.310$ ,  $P = 0.05$ ), and a high negative relationship with the distance between teats and ground ( $\rho(r) = -0.421$ ,  $P = 0.01$ ). These

Table 5. Spearman correlation coefficients among udder and teat scores (1–9 scale) in Yemeni indigenous sheep breed

| Trait        | Udder height | Udder angle | Teat length | Udder shape |
|--------------|--------------|-------------|-------------|-------------|
| Udder height | 1.00         | -0.10       | -0.50**     | -0.49**     |
| Udder angle  |              | 1.00        | 0.02        | 0.01        |
| Teat length  |              |             | 1.00        | 0.60**      |
| Udder shape  |              |             |             | 1.00        |

Udder and teat traits were evaluated using a subjective scoring system (1–9 scale)

\*\*  $P < 0.01$

results suggested that large udder insertion and improved teat posturing are typically correlated with low udder placement that is deemed to be favourable for milking. Similar findings were obtained with Awassi and other dairy sheep breeds by Altintsekcic and Koyuncu (2011) and Prpic *et al.* (2020). Teat length score showed a highly significant negative correlation with udder length ( $p = -0.511$ ,  $P < 0.01$ ), but positive correlations with udder depth ( $p = 0.324$ ,  $P < 0.05$ ) and udder width ( $p = 0.343$ ,  $P < 0.05$ ). This indicated that longer teats are more closely associated with deeper and wider udders rather than with overall udder length. The same tendencies were also noted by Kominakis *et al.* (2009) and Shettima *et al.* (2022) who found that teat morphology is better associated with udder depth and width than with linear udder dimensions. The score of udder shape had significant positive relationships with udder depth ( $P = 0.401$ ,  $P < 0.01$ ) and udder width ( $p = 0.422$ ,  $P < 0.01$ ), indicating that good udder conformation is related to large udder volume and capacity. This observation is consistent with the prior researches by Ivanova and Raicheva (2019) and Murphy and Taylor (2021) who showed that the udder shape scores are valid predictors of the udder development and productive capacity.

The present study, a significant breed-linked difference and significant relations between udder measurements and linear udder scores were found among Yemeni indigenous sheep. Subjective linear scoring and objective udder measurements showed a consistent result in the reliability of such traits as a tool of selection. In general, Yemeni indigenous sheep exhibit considerable variation in udder traits, which could be successfully applied in within-breed selection schemes. The inclusion of udder measurements and linear scoring in breeding technology could support the selection and improvement of udder-related traits in Yemeni indigenous sheep in a wide range of different and adverse environmental factors.

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