



Sheep Breeds in Focus: A Comparative Study of Carcass Traits and Morphometric Differences

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ABSTRACT

Background: This study carefully examined the carcass composition, physical measurements and growth development of three economically important indigenous Saudi sheep breeds: Neaimi, Harri and Najdi.

Methods: The research was conducted under uniform management and feeding conditions. A total of 45 healthy male lambs (15 each breed), initially weighing 24 kg on average, were observed over a 13-week period. Out of these, 24 lambs (8 from each breed) were slaughtered when they reached a target market weight of approximately 45-50 kg to evaluate key production parameters.

Result: Significant breed effects ($p < 0.05$) were statistically confirmed across major carcass components, dressing metrics and body dimensions. Neaimi lambs demonstrated a superior lean-to-fat ratio, characterized by the highest meat proportion and greatest carcass compactness. Conversely, Harri lambs exhibited pronounced fat deposition and the highest dressing percentage, typical of fat-tailed breeds. Najdi lambs, possessing the largest skeletal frame, displayed longer carcasses and superior leg development, suggesting high potential for total muscularity. These findings provide essential, differentiated data on the phenotypic and carcass attributes of Saudi sheep, offering direct insights for optimizing breed-specific selection indices, conservation strategies and strategic meat production goals within arid and semi-arid environments.

Key words: Carcass composition, Harri, Meat yield, Morphometric traits, Najdi, Neaimi.

INTRODUCTION

The indigenous sheep population of the Kingdom of Saudi Arabia, comprising breeds such as Neaimi, Harri and Najdi, is fundamental to the national agricultural economy, supporting food security and rural livelihoods. These breeds possess remarkable resilience, demonstrating exceptional adaptation to the harsh, arid climate, characterized by heat tolerance and efficient energy utilization under fluctuating feed availability (Suliman *et al.*, 2021 and Saleh *et al.*, 2025). To effectively improve production efficiency and formulate robust genetic selection programs, a comprehensive understanding of their comparative growth and carcass characteristics is paramount (Osman *et al.*, 2021 and Aldawish *et al.*, 2025).

Carcass composition, which quantifies the proportions of muscle, fat and bone, is the primary determinant of meat market value and consumer preference (Passamonti *et al.*, 2021 and Li *et al.*, 2024). Similarly, linear body measurements, or morphometric traits, such as body length and heart girth, are reliable, non-invasive predictors of growth potential, live weight and ultimate carcass yield, making them invaluable tools in genetic improvement and selection indices (Yang *et al.*, 2016 and Rivero *et al.*, 2021). Furthermore, understanding these traits is vital for implementing Genomic Selection strategies tailored to the unique genetic structure of desert-adapted livestock (Yang *et al.*, 2016, Eusebi, 2019 and Li *et al.*, 2024).

While the economic significance of Saudi sheep breeds is recognized, comparative studies under controlled, identical nutritional and managerial settings remain limited. Previous investigations have indicated

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variability in yield and tissue distribution (Abdel-Baki *et al.*, 2018 and Mahmoud *et al.*, 2018); however, isolating the inherent genetic effects from management- or environment-induced variances requires strictly standardized experimental conditions (Jiang *et al.*, 2014). The ability of these breeds to thrive in high-temperature environments underscores their potential value for global meat production, but requires detailed phenotypic profiling (Mortimer *et al.*, 2010 and Matika *et al.*, 2016).

This research was systematically designed to address a critical knowledge gap through a controlled comparison, quantifying breed-related differences in final carcass yield and tissue composition, primal cut distribution and growth and body conformation *via* linear morphometrics and

producing data-driven recommendations for targeted breeding and selection to support sustainable meat production.

MATERIALS AND METHODS

Animals, housing and experimental design

The experiment involved 45 healthy, uncastrated male lambs, averaging 3 months in age and 24 kg in weight. These lambs were evenly divided into three groups, each representing one of the indigenous breeds: Neaimi, Harri and Najdi (15 lambs per breed). To minimize genetic variability and ensure consistent management history, all animals were sourced from a reputable local breeder. Each lamb was ear-tagged and treated for internal and external parasites. They were kept in identical semi-open concrete pens at the Animal Production Department, College of Food and Agricultural Sciences, King Saud University, Riyadh. Each pen was equipped with feeding and watering troughs. This setup ensured that all groups experienced the same environmental conditions, including temperature, humidity and light cycles, which helped eliminate any environmental factors that could affect breed comparisons. The 13-week study period (September–November 2020) was chosen to evaluate growth and development until the lambs achieved the standard commercial market weight, aligning with local market recommendations that favor a weight range of 45–55 kg. Prior to the start of the experiment, all animals underwent a 14-day adaptation period.

Feeds and feeding regimen

The feeding regimen was designed to allow unlimited intake of a balanced, high-quality finishing diet to maximize growth potential for all breeds. This diet comprised two main components: roughage, which consisted of Alfalfa hay (a high-quality forage source) and a concentrate supplement that was a commercial pelleted feed with a specified composition of 14% crude protein (CP) and 2.5 Mcal/kg metabolizable energy (ME). Both roughage and concentrate were provided twice daily at 08:00 and 16:00, ensuring an equal distribution of the concentrate. The amount of feed offered was adjusted weekly to maintain approximately 10% refusal in the troughs, thereby promoting *ad libitum* consumption. Fresh, clean drinking water was available at all times.

Morphometric measurements

Linear body measurements reflecting skeletal growth and body conformation were recorded at the start (Week 1) and end (Week 13) of the experiment. To maintain consistency, the same trained technician collected all measurements using a calibrated measuring tape for girth and length and a height-measuring stick for height. Animals were securely restrained but allowed to stand naturally on a flat surface during data collection. Morphometric variables included withers height (ground to the highest point of the shoulder),

rump height (ground to the highest point of the pelvic girdle), body length (shoulder to pin bone), heart girth (chest circumference just behind the forelegs), body depth (vertical distance from the back to the sternum at the heart girth level), head length (poll to tip of the nose) and ear length (base to tip).

Slaughtering and carcass trait assessment

Before slaughter, all animals were fasted for 16 hours with free access to water to obtain consistent empty body weights. Slaughter followed standard Islamic (Halal) requirements. Immediately after slaughter, the slaughter weight (SW) was recorded as live weight just before slaughter and hot carcass weight (HCW) was recorded immediately after dressing (removal of hide, head, feet and viscera). Empty body weight (EBW) was calculated by subtracting digestive tract content from SW and dressing percentage was determined relative to EBW using the stated formula:

$$\text{Dressing (\%)} = \frac{\text{HCW}}{\text{EBW}} \times 100$$

After carcasses were chilled at 4°C for 24 h, cold carcass weight (CCW) was recorded and chill shrinkage (%) was calculated as:

$$\text{Chill Shrinkage (\%)} = \frac{\text{HCW} - \text{CCW}}{\text{HCW}} \times 100$$

Cold carcasses were then split longitudinally along the midline and the left side was used for carcass measurements and tissue composition analysis. Linear measurements, including internal and external carcass lengths, width, rump width and leg width, were obtained using a specialized measuring ruler. Rib-eye area (REA) of the Longissimus dorsi muscle was determined by tracing the muscle outline between the 12th and 13th ribs onto transparent paper and measuring the area with an electronic planimeter (Topcon KP-92N, TOPCON, Pleasanton, CA, USA). The average of two readings was recorded (Suliman *et al.*, 2025).

Carcass composition and primal cuts

The left side of each cold carcass was completely dissected following standard procedures to determine tissue composition. Carcasses were separated into meat (muscle with associated fat and connective tissue), fat (subcutaneous, intermuscular and kidney/pelvic fat), bone and trimmings. Each component was weighed and expressed as a percentage of side weight. The carcass was also divided into commercial primal cuts (shoulder, rack, loin, leg, foreshank and breast), with each cut expressed as a percentage of cold carcass weight (CCW).

Statistical analysis

Differences in the means of the different treatment groups were tested using analysis of variance in SPSSR software program version 21 (SPSS, Chicago, IL), while separation

of the means was performed using Duncan's multiple range test. Data were expressed as the mean $\pm$ standard error of the mean (SEM).

RESULTS AND DISCUSSION

The statistical analysis indicated significant effects of breed on most of the measured carcass, compositional and morphometric parameters (Tables 1-6).

Carcass composition and yield

Significant breed difference ($p < 0.05$) was evident in the composition of bone (Table 1). The Neaimi breed showed a statistically higher proportion of Meat (43.35%) compared to both Harri (40.38%) and Najdi (38.72%) lambs, indicating a favorable lean profile. Conversely, Harri lambs exhibited the highest percentage of fat (26.20%), exceeding the Neaimi breed (20.76%). The Najdi breed demonstrated the highest proportion of bone (28.94%), significantly greater than both the Neaimi (25.52%) and Harri (23.42%) breeds.

The results regarding Pearson's correlations between carcass characteristics (Table 2), showed strong positive relationships between slaughter weight and empty body weight ($r=0.977$, $p<0.001$), between slaughter weight and hot carcass weight ($r=0.773$, $p<0.001$) and between empty body weight and hot carcass weight ($r=0.753$, $p<0.001$). Dressing percentage showed moderate and statistically significant negative correlations with slaughter weight ($r= -0.439$, $p=0.032$) and with empty body weight ($r=-0.495$, $p=0.014$), whereas the correlation between hot carcass weight and dressing percentage was positive but not significant ($r=0.198$, $p=0.355$). Finally, rib-eye area (REA, cm^2) exhibited no meaningful correlations with the other traits, with all associations non-significant (largest magnitude $r \approx 0.074$ to -0.089 ; $p \geq 0.680$).

Carcass linear measurements and primal cuts

The Najdi breed consistently exhibited superior skeletal dimensions, recording significantly ($p<0.05$) greater internal carcass length (67.87 cm) and external carcass length (67.25 cm) compared to Neaimi and Harri lambs (Table 3). Najdi lambs also had the largest ($p<0.05$) leg width (39.94 cm), which is indicative of heavier primal leg cuts. Conversely, Neaimi lambs showed the highest ($p<0.05$) rump width (42.81 cm), while Harri lambs were lowest in this measurement (40.31 cm).

The distribution of primal cuts (Table 4) was largely comparable across the three breeds, with no significant differences observed in the percentage of shoulder, loin, leg, or foreshank and Breast. This uniformity suggests that while total carcass composition differs, the proportional anatomical distribution of cuts remains stable. However, the rack portion was significantly ($p<0.05$) higher in Harri lambs (9.62%) compared to Neaimi lambs (8.70%), with Najdi (9.28%) being intermediate. This suggests a slight difference in anterior body conformation and muscle distribution in the thoracic region.

Growth morphometric traits

The comparison of body measurements at week 1 (Table 5) and week 13 (Table 6) clearly established the inherent size differences among the breeds. At both time points, Najdi lambs consistently demonstrated superior linear growth, recording significantly ($p<0.05$) greater body height at withers, body height at rump and body length compared to the other two breeds. This confirms the Najdi breed's classification as a large-framed breed with a higher mature body size potential. For example, at week 12, Najdi's body height at rump was 72.33 cm, significantly higher than Neaimi (66.70 cm) and Harri (68.30 cm). Neaimi lambs, while smaller in linear measurements, demonstrated a

Table 1: Carcass compositions of the three Saudi sheep breeds ($n=8$).

Component (%)	Breed			limits		SEM
	Neaimi	Harri	Najdi	Minimum	Maximum	
Meat	43.35	40.38	38.72	20.89	51.14	1.17
Fat	20.76	26.20	24.50	13.36	38.73	1.27
Bone	25.52 ^b	23.42 ^b	28.94 ^a	21.22	34.39	0.69
Trimming	7.92	7.17	5.54	3.29	11.17	0.43

^{a,b}Means within rows not sharing the same superscripts are differ ($p<0.05$).

Table 2: Pearson's correlations between carcass characteristics of the sheep breeds.

Parameter	Slaughter wt.	Empty body wt.	Hot carcass wt.	Dressing %	REA cm^2
Slaughter wt.	1	.977**	.773**	-.439*	.074
Empty body wt.		1	.753**	-.495*	.028
Hot carcass wt.			1	.198	-.040
Dressing %				1	-.089
REA cm^2					1

**Correlation is significant at the 0.01 level.

*Correlation is significant at the 0.05 level.

compensatory muscular development, as evidenced by their high body depth at week 12 (39.33 cm), which was significantly greater than Harri (38.23 cm) and Najdi (38.33 cm) at this final stage. This suggests a more compact, blocky conformation associated with superior muscle-to-bone ratio. Heart girth showed no significant difference among the breeds at either week, implying similar thoracic capacity or muscle development around the chest, despite differences in overall frame size.

The marked breed differences in this controlled study strongly suggest that inherent genetic background shaped by centuries of selection in distinct Saudi ecosystems drives body conformation and carcass composition. Clear phenotypic variation among the three registered breeds was observed; however, extrapolation should be cautious because the number of slaughtered animals per breed was limited by resources. Thus, results reflect breed-specific biological characteristics under these conditions, not conclusive guidance for national breeding programs. Larger, multi-system studies with genomic evaluation are needed to validate differences and estimate their genetic and economic impact (Abousoliman *et al.*, 2020; Langford *et al.*, 2024).

Carcass composition and fat partitioning

Neaimi lambs produced the leanest carcasses, with the highest meat percentage (43.35%) and lowest fat percentage (20.76%), a highly significant finding. This suggests an energy allocation pattern favoring muscle accretion over adipose deposition (Ferreira *et al.*, 2015; Ayele *et al.*, 2019; Jawasreh *et al.*, 2019). Therefore, Neaimi is a strong candidate for selection in modern meat systems targeting leaner cuts, consistent with findings related to

muscle fiber characteristics (Jawasreh *et al.*, 2019; Fan *et al.*, 2022).

In contrast, Harri had the highest fat content (26.20%) and consequently the highest dressing percentage (54.96%). As a fat-tailed breed, Harri accumulates adipose tissue as an adaptation to arid-region feed scarcity and heat stress, serving as an energy and water reservoir. Fat deposition is genetically distinct and involves molecular regulation of adipose partitioning (Peña *et al.*, 2005; Van der Merwe *et al.*, 2020). While this can increase carcass weight and dressing yield, it may reduce saleable lean meat proportion (Brady *et al.*, 2003). Similar high dressing in other fat-tailed breeds (e.g., Iraqi Awassi) likely reflects shared tail physiology (Khaleel *et al.*, 2019; Argyriadou *et al.*, 2022). Thus, dietary energy must be managed to balance fatness and lean growth.

Najdi lambs showed superior skeletal development (highest bone proportion, 28.94%), larger body dimensions and heavier carcass weights, indicating greater capacity for overall carcass growth. This pattern is typical of larger, later-maturing breeds (Suliman *et al.*, 2021; Aldawish, 2025). Although higher bone proportion may slightly reduce proportional carcass yield relative to Harri's blocky, fat-covered carcass, the larger frame supports greater total muscle mass. Moreover, Neaimi lambs achieved higher meat ratio and primal wholesale cuts (Table 1 and 4), indicating higher potential for total meat production.

Strong positive correlations among slaughter weight, empty body weight and hot carcass weight are biologically expected, as increases in overall body mass are generally accompanied by proportional increases in both carcass and non-carcass components. In contrast, the moderate negative correlation between dressing percentage and

Table 3: Carcass linear measurements of the three Saudi sheep breeds ($n=8$).

Measurement (cm)	Breed			limits		SEM
	Neaimi	Harri	Najdi	Minimum	Maximum	
Internal carcass length	64.13 ^b	63.38 ^b	67.87 ^a	55.00	71.00	0.67
External carcass length	63.13 ^b	61.31 ^b	67.25 ^a	59.00	76.00	0.81
Carcass width	30.63 ^{ab}	29.75 ^b	31.56 ^a	28.00	34.00	0.31
Rump width	42.81 ^a	40.31 ^b	41.31 ^{ab}	37.00	46.00	0.41
Leg width	36.56 ^b	37.31 ^b	39.94 ^a	35.00	44.00	0.43

^{a,b}Means within rows not sharing the same superscripts are differ ($p<0.05$).

Table 4: Primal wholesale cuts of the three Saudi sheep breeds ($n=8$).

*Cut (%)	Breed			Limits		SEM
	Neaimi	Harri	Najdi	Minimum	Maximum	
Shoulder	28.35	27.81	27.48	24.85	30.75	0.33
Rack	8.70 ^b	9.62 ^a	9.28 ^{ab}	7.27	10.22	0.16
Loin	12.49	13.62	12.82	9.32	14.53	0.25
Leg	30.18	29.91	30.31	26.98	32.81	0.29
Foreshank and breast	19.22	18.48	19.08	16.08	23.34	0.42

^{a,b}Means within rows not sharing the same superscripts are differ ($p<0.05$).

*Cut (%) is computed as a percentage of the whole carcass weight.

slaughter or empty body weight suggests that carcass weight does not increase proportionally with total body weight. Heavier animals may accumulate relatively more non-carcass tissues and exhibit greater variation in gut fill, resulting in lower dressing percentages. This pattern is consistent with allometric growth, whereby non-carcass components increase at a rate equal to or greater than carcass tissues. The positive but non-significant association between hot carcass weight and dressing percentage further indicates that dressing percentage is influenced more by variation in non-carcass components than by carcass mass alone. Ribeye area (REA) showed no meaningful correlations with other traits, suggesting that muscularity is largely independent of body weight and carcass yield in this dataset. Therefore, selection for heavier slaughter or carcass weights alone may reduce dressing percentage and is unlikely to improve REA without targeted selection.

Morphometric traits and growth

Morphometric analysis supported the carcass findings. Najdi lambs consistently exhibited greater body height and body length than the other breeds from Week 1 to Week 13, confirming their large frame size and high skeletal growth potential. A larger skeletal frame is a prerequisite for attaining higher slaughter weights and is an important selection criterion for increasing meat production (Van der Merwe *et al.*, 2020). These results agree with previous studies (Kumar *et al.*, 2021; Kumar *et al.*, 2018; Rangamma *et al.*, 2023), which reported strong associations between

body measurements, growth performance, live weight and carcass traits in sheep. Linear measurements, particularly body length, body height and heart girth, are widely recognized as practical indicators of production potential and valuable selection criteria in breeding programs. They also serve as effective, non-invasive predictors of slaughter weight and carcass characteristics in indigenous sheep breeds (Obeidat, 2021; Al-Qargouli and Salim, 2023).

The Neaimi breed's compact morphology, characterized by lower linear dimensions but greater body depth at Week 13, suggests enhanced muscular development relative to skeletal growth, which may contribute to a favorable lean-to-fat ratio and improved feed conversion efficiency (Souza *et al.*, 2019). The absence of significant differences in heart girth at the final stage (Table 4) indicates that, despite Najdi lambs being taller and longer, all breeds achieved comparable thoracic development and muscularity, likely due to the ad libitum feeding regime. Such morphological variation is consistent with patterns reported in resilient indigenous breeds, where multivariate analyses have successfully differentiated populations based on skeletal traits while reducing multicollinearity in selection programs (Hamadani *et al.*, 2022). The ability of indigenous breeds to maintain muscle integrity and protein turnover under physiological stress further enhances their production value (Abudabos *et al.*, 2021).

Overall, significant breed-specific differences were observed in carcass composition and morphometric development. Neaimi lambs produced leaner carcasses with higher meat yield, Harri lambs showed superior fat

Table 5: Body linear measurements (cm) of the three Saudi sheep breeds at the 1st week ($n=15$).

Measurement (cm)	Breed			Limits		SEM
	Neaimi	Harri	Najdi	Minimum	Maximum	
Body height at withers	57.91 ^c	60.78 ^b	63.41 ^a	56.30	67.80	0.46
Body height at rump	59.97 ^c	63.00 ^b	65.08 ^a	57.30	70.80	0.50
Body length	58.65 ^b	58.27 ^b	60.67 ^a	54.00	66.50	0.39
Heart girth	67.87	67.87	67.43	61.00	71.00	0.32
Body depth	31.93	32.73	32.57	28.00	37.00	0.27
Head length	17.23 ^b	18.37 ^a	19.23 ^a	13.50	21.00	0.21
Ear length	15.97 ^a	13.30 ^c	14.73 ^b	12.00	17.50	0.22

^{a,b,c}Means within rows not sharing the same superscripts are differ ($p<0.05$).

Table 6: Body linear measurements (cm) of the three Saudi sheep breeds at the 13th week ($n=15$).

Measurement (cm)	Breed			Limits		SEM
	Neaimi	Harri	Najdi	Minimum	Maximum	
Body height at withers	64.57 ^b	65.80 ^b	69.80 ^a	60.00	75.50	0.55
Body height at rump	66.70 ^b	68.30 ^b	72.33 ^a	63.50	78.00	0.60
Body length	69.90 ^b	67.63 ^b	72.63 ^a	64.00	77.00	0.54
Heart girth	83.40	82.90	83.53	76.00	89.00	0.43
Body depth	39.33 ^a	38.23 ^b	38.33 ^b	35.00	42.00	0.20
Head length	22.57 ^b	21.37 ^c	23.67 ^a	20.00	27.00	0.21
Ear length	18.10 ^a	15.80 ^b	18.13 ^a	14.00	19.50	0.21

^{a,b,c}Means within rows not sharing the same superscripts are differ ($p<0.05$).

deposition, higher dressing percentage and lower chill shrinkage, while Najdi lambs exhibited greater frame size and carcass weight. These differences support the development of breed-specific breeding objectives. Although the limited sample size may reduce the precision of estimated relationships, the consistency of the results across breeds supports the biological relevance of tailored selection strategies.

CONCLUSION

This study evaluated carcass composition, physical measurements and growth development in three indigenous Saudi sheep breeds to support improved, breed-specific breeding strategies. The results demonstrate clear differences among breeds in carcass traits and morphometric development under a unified management system. The Neaimi breed showed a genetic tendency toward lean, muscle-dense carcasses with low fat deposition, making it well suited to lean meat markets. The Harri breed exhibited superior fat deposition and dressing yield, consistent with its specialization as a traditional fat-tailed breed. The Najdi breed presented a large skeletal frame associated with longer carcasses and greater absolute weights, indicating strong potential for increased total meat mass. However, the relatively small sample size per breed in this study warrants caution when generalizing baseline values to national averages. Despite this limitation, the distinct and directionally consistent differences support the role of inherent genetic variation that is likely to remain stable across registered breeds. Therefore, uniform selection metrics are not appropriate. Sustainable improvement in Saudi Arabia will require differentiated breeding goals: emphasizing muscling traits in Neaimi, yield and fat-tail-related carcass characteristics in Harri and skeletal-frame expansion to drive growth and meat mass in Najdi. These targeted strategies can help livestock managers improve production efficiency, support genetic conservation and protect local biodiversity in arid and semi-arid environments.

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Disclaimers

The authors' views and conclusions are their own and may not reflect those of their affiliated institutions. They are responsible for the information's accuracy and completeness and do not accept liability for any losses from its use.

Informed consent

This study was conducted in accordance with the ethical guidelines approved by the Research Ethics Committee (REC) of King Saud University, Ref. No. (KSU-SE-20-17),

considering all accepted ethical standards in research involving animals and human participants.

Conflict of interest

The authors declare no conflicts of interest. No funding or sponsorship influenced the study's design, data collection, analysis, publication, or manuscript preparation.

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