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Research Article

Integrative Assessment of Morphometric and Reproductive Characteristics in Kamori Bucks for Genetic Diversity and Breeding Value

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Abstract | Genetic diversity is crucial for sustainable livestock breeding, enabling adaptation to environmental challenges and maintaining productivity. This study evaluated morphometric and reproductive traits in Kamori bucks to assess genetic diversity and breeding potential. Phenotypic characterization included qualitative and quantitative traits, while semen quality parameters were analyzed in four bucks. Data from 34 bucks revealed uniform dark red coat color and spiral horns but variability in body hair patterns (41.18% plain, 58.82% patchy). Morphometric traits like body weight (89.97 ± 5.73 kg) and scrotal circumference (28.17 ± 3.50 cm) showed moderate variability (CV: 5.38–43.99%). Semen evaluation demonstrated high quality, with creamy white color, optimal pH (6.7–6.8), and motility (88–92%). Buck A outperformed others in volume (1.36 ± 0.05 mL) and post-thaw motility (51.80 ± 0.32%). It is concluded that sufficient genetic diversity in Kamori bucks, indicating no immediate risk to the breed. However, structured breeding programs are recommended to mitigate inbreeding risks and enhance desirable traits. These findings support the conservation and genetic improvement of Kamori goats, ensuring their sustainability for smallholder livelihoods.

Keywords | Breeding strategies, Genetic diversity, Kamori goat, Morphometric traits, Semen quality

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INTRODUCTION

Genetic diversity is a foundational element in sustainable livestock breeding programs, playing a critical role in enabling populations to adapt to environmental fluctuations, combat emerging diseases, and maintain reproductive and productive capabilities (FAO, 2015). In indigenous breeds such as the Kamori goat (*Capra aegagrus hircus*), which is renowned in Pakistan for its dual-purpose utility in milk and meat production, evaluating the genetic diversity of breeding bucks is particularly important. These bucks are the primary transmitters of genetic material in structured or semi-structured herd reproduction systems, and their genetic makeup significantly influences herd performance, resilience, and overall productivity. Despite the breed's economic value, challenges such as uncontrolled mating, repeated use of a few selected sires, and a lack of systematic breeding programs have contributed to reduced genetic variation. This often leads to inbreeding depression, manifesting in diminished fertility, poor semen quality, higher neonatal mortality, and reduced adaptability to climatic and health stressors (Ijaz *et al*., 2024). Therefore, regular genetic evaluation of bucks used for artificial insemination (AI) or natural breeding is essential for avoiding genetic bottlenecks and maintaining long-term herd viability (Ijaz *et al*., 2024).

Genetic diversity can be assessed through both phenotypic and molecular means. Morphometric traits such as body length, chest girth, scrotal circumference, testicular length, and body weight are practical field indicators of genetic variation and reproductive potential. Their variability within a population reflects underlying genetic diversity and offers a reliable basis for selection and culling decisions (Ahmed *et al*., 2021). At the molecular level, tools such as microsatellite markers, single nucleotide polymorphisms (SNPs), and mitochondrial DNA profiling allow for more precise characterization of genetic structure, relationships among individuals, and levels of heterozygosity (FAO, 2015). These data provide the foundation for evidence-based breeding strategies, conservation planning, and the identification of genetically superior animals.

Community-based goat production systems, integrating phenotypic and molecular assessment methods into breeding strategies holds significant promise. It allows for the selection of genetically diverse and high-merit bucks, whose semen can be cryopreserved and distributed regionally to improve genetic gain while conserving valuable indigenous traits (Jimma *et al*., 2024). This strategy is particularly relevant for breeds like Kamori, which are adapted to semi-arid conditions and are critical for smallholder livelihoods.

The breeding potential of bucks is also an essential component of productivity in goat production systems. Male fertility traits including semen motility, viability, concentration, and morphological normalcy are direct indicators of reproductive soundness (Tırpan *et al*., 2020). Additionally, scrotal circumference and testicular volume are positively associated with semen output and reproductive hormone levels, influencing overall fertility and age of puberty in progeny (Barbas *et al*., 2024). Behavioral traits, such as libido and copulatory efficiency, further determine a buck's effectiveness in natural mating systems.

With the advent of genomic selection and advanced reproductive biotechnologies, breeding decisions can now be more precise. The use of Estimated Breeding Values (EBVs), derived from phenotypic and genotypic data, has improved the accuracy of selecting animals that are more likely to transmit desirable traits such as disease resistance, growth performance, and enhanced milk production (Mrode, 2014). Molecular tools, including SNP arrays and next-generation sequencing, facilitate the identification of elite bucks and provide a scientific basis for the conservation of rare genetic lines within the Kamori breed. The comprehensive evaluation of genetic diversity and breeding potential of semen donor bucks in the Kamori goat population is imperative for long-term breed sustainability, genetic improvement, and enhanced productivity. This study aims to assess both the morphometeric and reproductive parameters of Kamori bucks for genetic diversity and breeding value.

MATERIALS AND METHODS

Place of study

The study was conducted in regions where Kamori bucks were predominantly found, including Matiari, Hyderabad, Dadu, Jamshoro, Shaheed Benazirabad, and Mirpurkhas. Sindh Agriculture University (SAU), Tandojam served as the central research site where bucks were readily available to support the study's objectives.

Assessment of genetic diversity

To assess genetic diversity, phenotypic data were collected through both qualitative and quantitative parameters using a structured proforma adapted from FAO guidelines (FAO, 2011). Qualitative traits included characteristics such as coat color, horn shape, and ear orientation (Table 1), while quantitative measurements included body weight, height at withers, and chest girth (Table 2). A total of 34 Kamori bucks were randomly selected to ensure representative sampling. These phenotypic traits served as indirect indicators of genetic variation and were used to identify distinct characteristics within the population.

Breeding potential assessment

Animal selection and management

Four healthy, fertile Kamori bucks aged between 8 and 12 months were selected for semen evaluation. The bucks were sourced from a government Kamori goat farm in Dadu, Sindh, with complete pedigree records. The bucks, identified as A, B, C, and D, were maintained at SAU, Tandojam. They were allowed 4 to 5 hours of daily grazing and supplemented with seasonal grasses, wheat bran, and concentrate feed consisting of barley, wheat, oats, sorghum, and polished rice. Water was provided ad libitum. The animals were vaccinated and dewormed prior to the experiment.

Artificial vagina preparation and semen collection

The artificial vagina (AV) was sterilized the night before and pre-warmed to 42-45°C. Internal pressure was maintained at 35 mmHg. Lubrication was achieved using petroleum jelly (Ali *et al*., 2024; Kaka *et al*., 2025). Semen

Table 1: Qualitative variables considered for Kamori bucks characterization.

S. No	Qualitative variable	Symbol	Categories / Descriptions
1	Body hair coat color pattern	BHCP	Plain, patchy/pied, spotted
2	Body hair coat color	BHC	Black, dark red, light red, fawn, grey
3	Body skin color	BSC	Pigmented, not pigmented
4	Fiber type	FT	Mohair/Angora, Cashmere
5	Hair type	HT	Smooth hair, straight long hair, curly rough hair, dull
6	Hair length	HL	Short (1–2mm), long (>2 mm)
7	Horn shape	HS	Scurs, straight, curved, spiral, corkscrew
8	Horn orientation	HO	Lateral, obliquely, upward, backward
9	Ear orientation	EO	Semi-pendulous, pendulous, horizontally carried
10	Facial (head) profile	FP	Concave, convex, ultra convex
11	Wattles	W	Present, absent
12	Beard	B	Present, absent
14	Ruff	R	Present, absent
15	Tail type	TT	Thin, fat rump, thick at base, fat
16	Tail shape	TS	Cylindrical and straight, cylindrical and turned up at end, bilobed without appendage, broad without lobe
17	Back profile	BP	Straight, slopes up towards the rump, slopes down from withers, dipped (curved)
18	Rump profile	RP	Flat, sloping, roofy

Table 2: Quantitative morphometric variables for Kamori Bucks characterization.

S. No	Quantitative variables	Unit	Symbol	Definition
1	Body Weight	kg	BW	Live body wight
2	Body length	cm	BL	Horizontal length from pin bone to shoulder
3	Height at withers	cm	HW	Height from the bottom of foot to highest point of shoulder between the withers
4	Chest girth	inches	CG	Measurement around the body behind the withers and brisket
5	Chest depth	cm	CD	Vertical depth behind the withers and brisket
6	Shoulder point width	cm	SPW	Distance from the highest point of the shoulder (withers) to the femur joint
7	Rump length	cm	RL	Distance from the withers to the base of the tail
8	Rump width	cm	RW	Distance between the two pin bones
9	Head length	cm	HL	Distance from the base of the horns to the muzzle
10	Head width	cm	HWd	Distance between the bases of the two horns
11	Horn length	cm	HOL	Distance from the base of the horn to the tip
12	Ear length	cm	EL	Distance from the base of the ear to the tip
14	Tail length	cm	TL	Distance from the base of the tail to the tip
15	Hair/wool length (rump area)	cm	HWL	Length of hair taken from the rump region
16	Scrotal circumference	cm	SC	Circumference around both testicles
17	Testicular length	cm	TstL	Distance from the epididymis to upper point of testicles

was collected early in the morning twice a week during March 2025. Each buck provided up to ten ejaculates using artificial vagina which imitation of natural method.

Fresh semen evaluation

Collected semen was evaluated immediately in the Semen Processing Lab at Nuclear Institute of Agriculture and Biology (NIAB) Faisalabad and at 37 °C. Parameters assessed included volume, color, pH, wave motion, sperm motility, concentration, morphology, viability, and membrane integrity. Volume was measured using a graduated collection tube (Goswami *et al*., 2020). Color was visually assessed based on categories like creamy, milky, and watery (Hafez and Hafez, 2000). pH was recorded using a calibrated digital pH meter. Wave Motion was graded on a 0 to ++++ scale by examining a drop of semen under 10X magnification (Table 3). Motility was observed under 40X magnification, with sperm diluted 1:100 and

Table 3: Frequency (%) of each level for qualitative traits recoded in Kamori goat breed.

S. No	No of samples	Qualitative trait	Categories	Frequency	Percentage (%)
1	34	Body hair coat colour pattern	Plain Patchy/pied, spotted	14 20	41.18 58.82
2	34	Body hair coat colour	Black Dark red Light red Fawn, grey	0 34 0 0	0 100 0 0
3	34	Body skin colour	Pigmented Non pigmented	20 14	58.82 41.18
4	34	Fibre type	Mohair/Angora Cashmere	0 34	0 100
5	34	Hair type	Smooth hair Straight long hair Curly rough hair, dull	34 0 0	100 0 0
6	34	Hair length	Small (1–2mm) Long (>2 mm)	0 34	0 100
7	34	Horn shape	Scurs Straight Curved Spiral Corkscrew	0 0 0 34 0	0 0 0 100 0
8	34	Horn orientation	Lateral Obliquely Upward Backward	0 34 0 0	0 100 0 0
9	34	Ear orientation	Semi-pendulous pendulous Carried horizontally	0 34 0	0 100 0
10	34	Facial (head) profile	Concave Convex Ultra convex	0 34 0	0 100 0
11	34	Wattles	Present Absent	34 0	100 0
12	34	Beard	Present Absent	0 34	0 100
14	34	Ruff	Present Absent	0 108	0 100
15	34	Tail type	Thin Fat rump Thick at base Fat	34 0 0 0	100 0 0 0
16	34	Tail shape	Cylindrical and straight Cylindrical and turned Up at end	0 34 0	0 100 0
17	34	Back profile	Straight Rump Slopes down from withers Dipped (curved)	0 0 0 34	0 0 0 100
18	34	Rump profile	Flat Sloping Roofy	0 34 0	0 100 0

100 sperm cells assessed per sample (Iqbal *et al*., 2015). Sperm count was conducted using a Neubauer chamber with a fixing solution (Table 4). The formula used was: Sperm/ml = n × 5 × df × 10 × 1000 (Kaka *et al*., 2025).

Table 4: Mean Morphometric measurements of Quantitative Variables in Kamori bucks (n=34).

Quantitative variable	Label	Unit	Mean±SD	Minimum	Maximum	CV %
Body length	BL	cm	109.20±5.88	96.00	122.00	5.38
Hight at withers	HW	cm	91.70±6.82	80.00	115.00	7.43
Chest girth	CG	Cm	92.41±6.79	63.00	100.00	7.34
Body weight	BW	Kg	89.97±5.73	80.00	99.00	6.36
Chest depth	CD	Cm	38.41±8.23	25.00	53.00	21.42
Shoulder point width	SPW	Cm	42.64±9.02	28.00	56.00	21.15
Rump length	RL	cm	19.38±9.69	19.00	22.00	16.59
Rump width	RW	cm	18.85±2.43	16.00	29.00	12.92
Head length	HL	cm	28.20±3.18	19.00	35.00	11.27
Head width	HeW	cm	17.00±5.19	12.00	44.00	30.52
Horn length	HOL	cm	17.91±7.88	11.00	58.00	43.99
Ear length	EL	cm	52.82±6.24	21.00	60.00	11.81
Tail length	TL	cm	22.17±5.78	7.00	40.00	26.07
Wool length	WOL	cm	3.005±0.90	2.00	6.00	30.00
Scrotal circumference	Sc	cm	28.17±3.502	23.0	35.00	12.42
Testicular length	TeL	cm	16.67±2.19	9.00	19.00	13.13

Morphology, Viability, and Membrane Integrity using a 10 µL semen sample was mixed with eosin-nigrosine stain, smeared, incubated at 37°C for 3 minutes, washed, fixed with ethanol, and air-dried (Kaka *et al*., 2015). Live sperm appeared colorless; dead sperm stained pink and normal sperm had coiled tails and intact membranes.

Extender composition

Semen was centrifuged at 315g for 3 minutes. The supernatant was discarded, and the sperm pellet diluted with a Tris-egg yolk extender (Naijian *et al*., 2013). pH 6.8–7.2, osmolarity 425 mOsm. The semen was cooled to 4°C over 120 minutes in a cold cabinet. It was then filled into 0.5 mL straws with $30{\times}10^6$ motile sperm/straw. Pre-freezing was done 10 cm above liquid nitrogen vapor for 7 minutes, followed by immersion into -196 °C liquid nitrogen.

Post-thaw evaluation

Frozen straws were thawed in a 37 °C water bath for 30 seconds. Post-thaw evaluation included motility, viability, morphology, and membrane integrity assessments similar to fresh semen evaluation (Kaka *et al*., 2017).

Statistical analysis

Data were analyzed using ANOVA to determine statistical significance (p<0.05). LSD was used for post-hoc comparisons. SAS OnDemand for Academics software was used to perform the analysis.

RESULTS

The qualitative trait analysis of 34 Kamori bucks, presented in Table 3, revealed a high degree of uniformity for several traits. All sampled animals exhibited a dark red coat color, suggesting potential fixation of this characteristic within the population. Traits such as horn shape (spiral), horn orientation (obliquely), ear orientation (pendulous), facial profile (convex), and tail type (thin) were consistently observed across all individuals, indicating strong genetic selection or limited variability. All bucks also possessed wattles, while beards were absent. Some variation was noted in body hair coat pattern, with 41.18% showing a plain pattern and 58.82% exhibiting patchy or pied patterns, and in skin pigmentation, where 58.82% were pigmented and 41.18% were not.

The morphometric data in Table 4 provide a detailed overview of Kamori bucks' physical characteristics. The average body length (109.20 cm) and height at withers (91.70 cm) reflect a robust and well-proportioned physique suitable for both meat and milk production. Chest girth (92.41 cm) and body weight (89.97 kg) further emphasize the breed's substantial build. The coefficients of variation (CV) for these traits, ranging from 5.38% to 7.43%, indicate moderate variability, suggesting potential for selective breeding. Higher variability was observed in horn length (CV: 43.99%), head width (CV: 30.52%), and tail length (CV: 26.07%), reflecting considerable phenotypic diversity.

Reproductive traits, including scrotal circumference (28.17 cm) and testicular length (16.67 cm), are important indicators of male fertility, showing moderate variability (CV: 12.42% and 13.13%, respectively) and suggesting stable reproductive potential. The consistency in ear length (52.82 cm, CV: 11.81%) aligns with the breed's distinctive long-eared phenotype, while uniformity in wool length (3.005 cm, CV: 30%) highlights a stable trait valuable for breeding decisions.

Table 5 presents a comparative analysis of fresh semen characteristics of four Kamori bucks (A, B, C, and D), including ejaculate volume, color, pH, and wave motion. Buck A exhibited the highest semen volume (1.36 ± 0.05 mL), significantly (P<0.05) higher than bucks B and C (both 1.00 mL), while Buck D had a slightly lower volume (0.99 ± 0.11 mL). Semen pH ranged from 6.70 ± 0.01 (Buck A) to 6.80 ± 0.01 (Buck B), with all values within the optimal range for goat semen (6.4–7.0), indicating a favorable environment for sperm viability. Wave motion was rated '++++' for all bucks, reflecting vigorous and progressive motility.

Table 5: Assessment of fresh semen of Kamori Bucks (Mean ± SEM) (n=34).

Bucks	Volume (mL)	Color	pH	Wave motion %
A	1.36 ± 0.05^{a}	Creamy white	6.70 ± 0.01^{a}	++++
B	1.00 ± 0.02^{b}	Creamy white	6.80 ± 0.01^{a}	++++
C	1.00 ± 0.10^{b}	Creamy white	6.72 ± 0.01^{a}	++++
D	0.99 ± 0.11^{bc}	Creamy white	6.71 ± 0.02^{a}	++++

$^{a,\,b,c}$ different superscripts within a column shows significant difference at p<0.05. ++++ describes more than 80 percent wave motion

Table 6 summarizes fresh semen quality parameters, including motility, sperm concentration, morphology, viability, and membrane integrity. Buck A showed the highest sperm motility (92.50±0.89%), significantly (P<0.05) higher than bucks B (90.00±1.80%), C (89.30±1.30%), and D (88.50±1.94%). Sperm concentration was consistent across all bucks (2.23–2.25×10^9/mL), within acceptable ranges for artificial insemination. Normal sperm morphology was highest in Buck A (89.10±0.16%), with slight differences among the other bucks (86.50–87.50%). Viability and membrane integrity were also highest in Buck A (88.80±0.30% and 89.50±0.33%, respectively), indicating superior overall semen quality.

Table 7 presents post-thaw semen characteristics. Motility was highest in Buck A (51.80±0.32%) and lowest in Buck D (49.80±0.60%). Morphologically normal sperm post-thaw was greatest in Buck A (68.20±0.80%) andowest in Buck D (62.90±0.69%). Viability followed a similar trend, with Buck A at 68.10±0.90% and Buck D

Table 6: Quality characteristics of fresh semen of Kamori bucks (Mean ±SEM; n=10).

Bucks	Motility (%)	Concentration (1x 10^9)	Morphology (%)	Viability (%)	Membrane integrity (%)
A	92.50 ± 0.89^{a}	2.23 ± 58.77^{a}	89.10 ± 0.16^{a}	88.80 ± 0.30^{a}	89.50 ± 0.33^{a}
B	90.00 ± 1.80^{b}	2.23 ± 19.17^{a}	87.50 ± 1.20^{a}	88.60 ± 0.97^{a}	87.20 ± 1.34^{a}
C	89.30 ± 1.30^{b}	2.24 ± 46.40^{a}	86.60 ± 0.89^{a}	88.40 ± 0.89^{a}	87.70 ± 1.52^{a}
D	88.50 ± 1.94^{b}	2.25 ± 55.00^{a}	86.50 ± 1.05^{a}	87.20 ± 1.59^{a}	86.00 ± 2.55^{a}

^{a,b} different superscript within a column shows significant difference at p<0.05

lat 63.80±1.20%. Membrane integrity was significantly (P<0.05) lower in Buck D (56.00±1.90%) compared to the other bucks (66.00–68.10%), highlighting individual variability in sperm resilience to cryopreservation. Overall, Buck A consistently demonstrated superior semen quality, both fresh and post-thaw, suggesting higher fertility potential and suitability for artificial insemination programs.

Table 7: Frozen-thawed assessment of Kamori buck semen in Tris extender (Mean ±SEM; n=10).

Bucks	Motility (%)	Morphology (%)	Viability (%)	Membrane integrity (%)
A	51.80±0.32[a]	68.20±0.80[a]	68.10±0.90[a]	68.10±1.19[a]
B	50.60±0.72[ab]	66.40±0.81[b]	65.30±0.83[ab]	66.20±2.08[a]
C	49.70±0.65[bc]	65.10±0.76[b]	64.20±0.57[b]	66.00±2.44[a]
D	49.80±0.6[c]	62.90±.69[c]	63.80±1.2[b]	56.00±1.90b[b]

[a, b,c] different superscripts within a column shows significant difference at p<0.05

DISCUSSION

Selecting a high-quality breeding buck is a crucial step in goat farming, as a single male can produce thousands of offspring annually through artificial insemination (A.I.). Bucks with superior genetic traits play a vital role in enhancing reproductive efficiency and herd improvement (Bezjian *et al.*, 2013). A genetically superior buck can significantly accelerate genetic progress within a herd (Farshad et al., 2009).

The current study assessed the genetic diversity of Kamori bucks through phenotypic evaluation (qualitative and quantitative traits), with findings consistent with previous research (Kaka *et al.*, 2025; Ijaz *et al.*, 2024; Kunbhar *et al.*, 2016; Aliyu et al., 2021; Muner et al., 2018). Phenotypic characterization, including body weight and linear measurements, is essential for developing efficient breeding systems, breed conservation, and optimizing genetic resource utilization (Tsegaye *et al.*, 2013). These results further support existing studies on genetic diversity based on morphological traits in bucks.

In the present study, Kamori buck semen exhibited a creamy white color, aligning with observations by Ali *et al.* (2024); Kashif (2022) in Kamori goats at home tract and Batool *et al.* (2024) conducted study at other place than home tract) in Kamori goats, as well as (Sancho et al., 2004) in West African dwarf goats.

Semen volume, a key factor in reproductive performance, ranged from 0.9 to 1.36 mL in Kamori bucks, consistent with earlier studies (Ali *et al.*, 2024; Kashif, 2022) in kamori goats at home tract, Batool *et al.* (2024). The semen pH ranged between 6.7 and 6.8, matching previous reports. Wave motion was scored as ++++, and motility ranged from 88% to 92%, in agreement with prior research on Kamori bucks. Additionally, post-thaw semen quality parameters including motility, morphology, viability, and membrane integrity were high, further corroborating earlier findings (Ali *et al.*, 2024; Batool *et al.*, 2024; Kashif, 2022) in Kamori goats.

CONCLUSION

Based on the findings of this study, it is concluded that Kamori bucks exhibit sufficient genetic diversity, indicating that the breed is not currently at risk. Additionally, a substantial number of Kamori bucks possess high-quality breeding potential. However, scientifically planned breeding strategies should be implemented to minimize the risk of inbreeding.

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NOVELTY STATEMENT

This study provides the first integrative assessment of both phenotypic diversity and semen quality parameters in Kamori bucks, combining qualitative morphometric traits with comprehensive fresh and post-thaw semen evaluation to establish baseline data for breeding value estimation.

AUTHOR'S CONTRIBUTION

Kaka A conceived the study, designed the methodology, supervised semen collection and evaluation, and drafted the manuscript. Qayyum A helped in phenotypic data collection, conducted statistical analysis, and contributed to manuscript writing. Waheed HM developed the methodology for quantitative trait assessment and validated the data. Ulhaq M supported in field data, characterized qualitative traits. Rafiq N supported in literature review. Oad Z guided and supported statistical data analysis. Kaka S coordinated sample collection manuscript checking and finalization . Bilal G supervised the overall research, secured funding, and approved the final manuscript. All authors reviewed and approved the final version

Ethical consideration

The research conducted in this study does not caused any harm or painful condition that is why there was no any requirement for approval of ethics committee.

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 declared no conflict of interest.

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