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Morphometric Characterization for Productivity Enhancement and Conservation of Gir Cattle in Gujarat, India

Tejashree Shirsath[1*], Nikhil Punde[1], Yuvraj Gaundare[1], Akshay Joshi[1], Naresh Joshi[2], Manu Chavda[2], Sachin Joshi[1] and Jayant Khadse[1]

[1]BAIF Development Research Foundation, Central Research Station, Pune, India
[2]BAIF Institute of Sustainable Livelihoods and Development, Gujrat, India

**Corresponding author*

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A B S T R A C T

This study characterises the morphometric and qualitative traits of adult lactating Gir cattle from the Saurashtra region of Gujarat, aiming to identify physical and behavioural features associated with milk yield to improve breed selection. Surveying 1,307 cows from four districts and engaging native breeders, the research recorded 27 qualitative traits (such as body coat colour, ear and horn shape, temperament, and milking behaviour) and 9 quantitative traits (including hump circumference, forehead dimensions, dewlap and tail measurements, body surface area, and peak milk yield). Statistical correlation and principal component analysis revealed that eleven morphometric traits had a significant association with milk production, with the first principal component explaining 43.45% of the overall variability. Top-ranked, favourable subtypes included non-spotted body coat, bright skin, tortuous milk vein, docile temperament, and peaceful milking behaviour, underscoring their economic value for breeding decisions. The findings suggest that targeted selection based on these traits supports both conservation of pure Gir cattle and enhancement of dairy productivity in Gujarat.

Introduction

The Gir cattle breed, indigenous to the Kathiawar region of Gujarat, India, represents one of the country's most distinguished milking breeds and forms the cornerstone of dairy production in this area, especially in the forests and foothills of the southern Junagadh district from which the breed derives its name (Hewlett, 1912). Gir cows are highly valued for their substantial milk yield, while Gir bulls, though somewhat less vigorous than specialised draught breeds, have traditionally served in general utility roles. For generations, breeding practices in India have incorporated crossbreeding between Gir cattle and local draught breeds in efforts to enhance milk production in draught animals and impart work capacity to Gir bulls—a phenomenon documented since the early twentieth century (Hewlett, 1912). The trend toward genetic improvement continued with the introduction of exotic breeds from as early as 1875, which further shaped the genetic landscape of Gir cattle in pursuit of increased milk productivity (Wakchaure, *et al*., 2015). As a consequence, there is now considerable variability within the Gir population, and original breed characteristics are at risk of dilution. Nonetheless, sustained commitment by traditional cow-keeping communities, Gaushalas, and native breeders has ensured the preservation of select

pure Gir herds and the retention of valuable phenotypic traits. Recognising the importance of breed conservation and the potential for productivity gains, it is crucial to systematically characterise the morphometric and qualitative traits that define the Gir cattle and to assess their relationship with milk production. The objective of the present study is to analyse the influence of key physical and behavioural subtypes on milk yield in pure-bred adult Gir cows in the Saurashtra region, with the hypothesis that selection for favourable morphometric traits can promote both genetic improvement and conservation of this iconic dairy breed.

Materials and Methods

Study Area and Population

The study was conducted in four major Gir breeding districts of Gujarat—Amreli, Bhavnagar, Rajkot, and Surendranagar—between January and March 2017. These areas represent the heart of the Gir breeding tract. A total of 1,307 adult lactating cows maintained by native breeders were included in the study.

Data Collection

Data on 27 qualitative and 9 quantitative traits were recorded following standard field protocols. Qualitative traits included coat colour, ear shape, horn orientation, udder size, vulval colour, eye type, temperament, and milking behaviour. Quantitative traits measured were hump circumference, forehead height and breadth, dewlap length and width, tail length, body surface area, fat percentage, and lactation milk yield.Coat colour subtypes (Bagali, Bawali, Galakadi, Gori, Swarn Kapila, Kabari, Makadi, Liladi, Pingal, Telami, and Krishna Kapila) were classified into two analytical categories—spotted and non-spotted—based on predominant pigmentation for statistical clarity.

Statistical Analysis

Lactation yield data were adjusted for deviations using a linear regression model following Pool and Meuwissen (1997). Principal Component Analysis (PCA) was conducted using R statistical software to determine key components explaining morphological variation (Ananda B. W. Manage (2013). Eigenvalues, variance percentages, and loading coefficients were derived to quantify trait contributions. Subtype ranking was based on L_1 (PC1) scores, representing overall morphometric supremacy.

Results and Discussion

A total of eleven coat colour subtypes—Bagali, Bawali, Galakadi, Gori, Swarn Kapila, Kabari, Makadi, Liladi, Pingal, Telami, and Krishna Kapila—were identified in the Gir cattle population surveyed, reflecting the breed's rich phenotypic diversity as previously documented by Hewlett (1912). Given that most colour patterns consisted of various shades of brown, often intermixed with white, the subtypes were grouped into two broader analytical categories: “spotted” (Galakadi, Kabari, Bawali, Liladi, Pingal, Bagali) and “non-spotted” (remaining brown shades). This binary classification, similar to approaches recommended for field-based breed characterization (Wakchaure *et al*., 2015), allowed for clearer statistical comparison of colour patterns with production traits.

Each trait subtype was encoded numerically, and correlations with monthly lactation milk yield were calculated. Notably, udder type (93.25%), ear shape (99.84%), vulvar colour (82.23%), eye type (78.04%), dewlap (67.93%), and forehead height (65.45%) exhibited particularly strong associations with milk yield, supporting the premise that morphometric variation can significantly influence productive potential (Pool & Meuwissen, 1997). Body coat colour (63.87%), skin smoothness (50.53%), tail length (43.72%), and temperament (47.24%) also displayed moderate to high correlations, while horn shape, herd behaviour, and hooves colour contributed little to yield prediction.

To objectively combine trait effects and enable ranking, principal component analysis (PCA) was conducted on nine quantitative traits using R statistical software, in line with established methods (Ananda B. W. Manage (2013). The first principal component (PC1) had the highest eigenvalue (65.2544), explaining 43.453% of the total data variance, while additional components accounted for less—an expected outcome, as most population variability is typically captured in the first few principal components (Ananda B. W. Manage (2013). Cumulatively, PC1 and PC2 explained 66.533% of trait variance, reinforcing the dominant role of select morphometric features, chiefly hump circumference, tail length, and dewlap length, in phenotypic and performance differences.

These findings indicate that targeted selection for subtypes with higher PC1 scores—such as medium-sized udders, Bhungalia ear shape, black vulvar colour, non-spotted coat, bright skin, and docile temperament—can enhance milk yield in Gir cattle. Such results affirm the value of morphometric characterization for breed improvement and conservation, validating traditional selection criteria with quantitative evidence and aligning with previous research on indigenous cattle evaluation (Hewlett, 1912; Wakchaure *et al*., 2015; Pool & Meuwissen, 1997; Ananda B. W. Manage (2013).

Principal Component Analysis of Morphometric and Production Traits in Gir Cattle

Principal Component Analysis (PCA) was carried out to identify the most influential morphometric traits contributing to phenotypic variation in *Gir* cattle. The first principal component (PC1) accounted for 43.45% of the total variability, with an eigenvalue of 62.25, indicating its dominance in explaining trait variation among animals. The loadings (coefficients) of different traits on PC1 are presented in Table 2.

The hump circumference (0.89368) exhibited the highest positive loading, followed by tail length (0.35114), dewlap length (0.19411), and forehead height (0.15268). These traits contributed most substantially to the variability represented by PC1. The positive coefficients suggest that increases in these morphometric measures enhance the overall PC1 score, reflecting a more pronounced *Gir* breed type.

Conversely, lactation milk yield (-0.0000135) had a very small but negative loading, indicating an inverse association with PC1. Although this relationship is weak, it implies that morphometric robustness, represented by PC1, is not necessarily correlated with higher milk yield in this dataset. Similar observations were reported by Bharambe *et al*. (2018) and Chauhan *et al*. (2021), who found that morphometric traits contributing to body conformation were largely independent of milk production performance in indigenous cattle breeds.

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The linear equation for the first principal component (L_1) was derived as follows:

Consequently, the first principle component for lactation milk yield was,

L1=0.89368*Hump Circumference + 0.15268 * Forehead Height + 0.046981 * Forehead Breadth +0.19411 * Dewlap Length + 0.35114* Tail Length + 0.11126*Dewlap width + 0.027315* Body surface area + 0.041456*Fat% - 0.000000135*Lactation milk yield.

The strong positive loading of hump circumference suggests that this trait can serve as a morphological indicator of breed purity and adaptive capacity in tropical conditions. According to Raghuwanshi *et al*. (2020) and Pundir *et al*. (2015), hump and dewlap dimensions are characteristic features of Bos indicus breeds and are closely associated with thermoregulatory adaptation and breed identity. The moderate contributions from dewlap length and tail length also reflect the distinct morphology of the Gir breed, which aids in heat dissipation and insect protection (Choudhary *et al*., 2022).

The predominance of positive loadings in PC1 indicates that higher values of these traits correspond to more desirable morphometric profiles. Hence, PC1 effectively represents a "conformation factor" describing structural development and breed type expression. Similar structural components were identified in Sahiwal and Tharparkar cattle by Singh *et al*. (2020) and Jaiswal *et al*. (2022), emphasizing that the first principal component often captures overall body frame and conformational variation.

Ranking and Subtype Evaluation

Based on the PCA-derived L_1 scores, ranking of morphometric subtypes was performed following the method described by Ananda B. W. Manage (2013),

where a higher L_1 score indicates superior morphometric performance. Subtypes with correlations exceeding 40% were considered for comparison.

Results revealed that among ear types, Bhungalia had the highest mean L_1 score (50.09), followed by Gedia (49.83) and Fafda (49.28). In udder type, medium-sized udders (51.81) outperformed both small and large types, suggesting an optimal balance between udder capacity and structural support. Similarly, black vulval colour (51.55), bright skin (50.20), and tortuous milk veins (51.49) were associated with higher L_1 scores, indicating a strong association between these phenotypes and desirable morphometric conformation.

Behavioural and physical traits also showed consistent trends. Docile temperament (50.56) and peaceful milking behaviour (49.64) corresponded to higher L_1 values, implying that animals with calm disposition and longer tails may exhibit better adaptability and management ease—attributes valuable for dairy farming in tropical environments. Comparable behavioural–morphometric associations have been reported in Gir and Red Sindhi cattle by Sharma *et al*. (2023) and Kumar *et al*. (2019).

Table.1 Principal Component Analysis with Eigenvalue and Percentage of Variance

PC	1	2	3	4	5	6	7	8	9
Eigenvalue	65.2544	34.659	26.9536	15.0852	4.278	1.73705	1.46145	0.455168	0.28737
% variance	43.453	23.08	17.949	10.045	2.8487	1.1567	0.97319	0.3031	0.19136

Table.2 Different Morphometric traits with PC1

Sr.No.	Traits	PC 1
1	Hump Circumference	0.89368
2	Forehead Height	0.15268
3	Forehead breadth	0.046981
4	Dewlap length	0.19411
5	Tail Length	0.35114
6	Dewlap width	0.11126
7	Body Surface Area	0.027315
8	Fat%	0.041456
9	Lactation milk yield	- 0.000000135

Biological and Breeding Implications

The findings from PC1 highlight the major morphometric traits that define the Gir cattle phenotype, supporting their inclusion in phenotypic selection indices. Since hump circumference, dewlap length, and tail length are heritable and easily measurable, they can serve as indirect selection criteria for maintaining breed standards and improving adaptability. The weak negative loading of milk yield suggests that structural conformation and production traits should be balanced in breeding objectives to avoid undesired trade-offs. Understanding the distribution of variance through PCA provides valuable insight into the relationship between morphometric and production traits. Similar multivariate approaches have been successfully applied in other indigenous breeds, such as Kankrej and Rathi, to identify key morphometric indicators for selection (Singh *et al*., 2020; Jaiswal *et al*., 2022).

In conclusion, the morphometric characterization of adult Gir cattle in the Saurashtra region revealed considerable phenotypic diversity, reflecting both the adaptive and genetic richness of the breed. Principal Component Analysis identified hump circumference, tail length, and dewlap dimensions as the most influential traits defining the Gir breed type, accounting for 43.45% of the total variance. These morphometric features, along with qualitative attributes such as non-spotted coat colour, bright skin, tortuous milk vein, and docile temperament, were positively associated with higher milk yield and better management suitability. The findings confirm that phenotypic selection based on measurable morphometric indicators can effectively support both productivity enhancement and genetic conservation of the Gir breed. Incorporating these key traits into structured breeding and conservation programs will strengthen the long-term sustainability of Gir cattle, ensuring the preservation of their distinct genetic identity while improving dairy

performance in the region.

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Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Author contributions

Tejashree Shirsath: Investigation, analysis, writing original draft, Nikhil Punde: Methodology, investigation, Yuvraj Gaundare: writing, Investigation, analysis, Akshay Joshi: Formal analysis, writing—review and editing, Naresh Joshi: Validation, methodology, writing—reviewing. Manu Chavda: Resources, investigation writing—reviewing. Sachin Joshi: Validation, formal analysis, writing, Jayant Khadse: Conceptualization, methodology, data curation.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

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Conflict of Interest The authors declare no competing interests.

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