Research Article

Phenotypic Profiling and Multiple Correspondence Analysis of Morphological Traits in Indonesian Rambon Cattle

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Abstract | This research identified the qualitative morphological characteristics of Rambon cattle in Banyuwangi, East Java. A total of 101 animals were sampled, comprising 12 males and 89 females. Thirteen qualitative features pertaining to the head and body (muzzle color, horn shape, horn color, ear surface color, ear shape, eye contour, head shape, head color, chest shape, body shape, backline profile, rump color, and body color) were documented. The data were analyzed descriptively, employing chi-square tests for sex comparisons and Multiple Correspondence Analysis (MCA) to investigate multivariate trait relationships. Chi-square tests revealed statistically significant sex-related differences in horn color, head shape, head color, chest shape, rump color, and body color ($p < 0.05$); however, numerous other features exhibited similarity between males and females. MCA indicated that the initial two dimensions encompassed the majority of the category variation (about 83.6% combined), although the MCA plot displayed significant overlap across male and female categories. Consequently, while certain individual characteristics vary by sex, the overall multivariate morphology of Rambon cattle is predominantly common and does not facilitate distinct segregation of animals by sex. The initial phenotypic findings, considered alongside the significant sex imbalance in the sample, offer foundational information to facilitate further breed characterization, selection, and conservation strategies.

Keywords | Indigenous cattle, Phenotypic, Morphological traits, Body shape, Qualitative trait, Selection

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INTRODUCTION

Cattle are considered very important for the agricultural sector because they produce milk, meat, and can generate labor. One of the most common types of cattle in Banyuwangi, East Java, is the Rambon cattle, a cross between domestic cattle (*Bos indicus*) and Banteng (*Bos javanicus*) (Prihandini *et al.*, 2025). Rambon cattle play a significant role in local agricultural systems, valued for their adaptation to tropical environments and moderate beef production potential (Oke *et al*., 2025; Puspitasari *et al*., 2018). Rambon cattle are an excellent genetic resource for sustainable livestock management due to their high flexibility, resistance to tropical conditions, and effectiveness in utilizing low-quality feed (Prihandini *et al*., 2021).

Rambon cattle are one of the local beef cattle breeds developed by farmers in the Banyuwangi area over many years. Several studies report that Rambon cattle are primarily found in Glagah District and the surrounding areas and are historically the result of crossbreeding between Bali cattle, Ongole cattle, and Madura cattle, forming a local breed that is adaptive to the local agroecosystem conditions (Prihandini *et al*., 2020; Prastiya, 2021; Ministry of Agriculture, 2024). This cattle breed is reported to have reasonably good meat production performance and the ability to adapt to medium-quality forage in the coastal and lowland areas of Banyuwangi (Adinata *et al*., 2018; Prihandini *et al*., 2021). On the other hand, the existence of Rambon cattle is also considered an essential asset in the context of preserving national livestock genetic resources, as emphasized in various policy documents and studies on the genetic diversity of local cattle in Indonesia (Moreira *et al*., 2018; Ministry of Agriculture, 2024).

Research on Rambon cattle is still limited to general phenotypic characteristics and the reproductive status of females as a basis for conservation and utilization, as well as studies on the motility and viability of male spermatozoa for local breeding (Adinata and Aryogi, 2014). This condition suggests that information on morphological variations in the head and body of Rambon cattle, particularly when differentiated by sex, has not been thoroughly explored. In fact, developments in animal breeding and conservation science emphasize that morphological and morphometric characterization (shape and size of the head, horns, shoulder height, body shape, color and coat pattern) are very important initial steps in identifying and distinguishing local livestock populations, developing selection criteria, and designing sustainable conservation strategies for breeds, as demonstrated by various morphological studies of local cattle in Indonesia and other countries (Hikmawaty *et al*., 2014; Kayastha *et al*., 2011; Kugonza *et al*., 2011). Recent studies on livestock characterization increasingly utilize multivariate statistical techniques, enabling simultaneous analysis of all morphological features and uncovering genuine diversity within and between populations (Aziz and Al-Nur, 2013). Among these instruments, Multiple Correspondence Analysis (MCA) is especially appropriate for qualitative characteristics. This study employed MCA to discern patterns among qualitative features and to more effectively discriminate between males and Female.

Prior studies predominantly utilized contingency table analysis (Pearson's chi-square), which, while straightforward to interpret, is constrained by its inability to quantify the strength of associations, inefficiency with numerous categories, sensitivity to low frequencies, and its focus on a singular categorical relationship at a time (Kebede *et al*., 2024). To mitigate these constraints, the current study employed MCA to deliver a more thorough evaluation of qualitative features and enhance characterisation and conservation strategies.

This research aimed to characterize the qualitative morphological traits of Rambon cattle in Banyuwangi, East Java, and to evaluate sex-related differences using Multiple Correspondence Analysis. The findings of this study can serve as baseline data for the germplasm of local Indonesian cattle and as a fundamental reference and guideline in designing sustainable development strategies for Rambon cattle.

MATERIALS AND METHODS

This study examined the qualitative morphological traits of a total of 101 heads (12 males and 89 females) of Rambon cattle. The cattle were selected using random sampling from available smallholder farms that kept Rambon cattle in Banyuwangi Regency, East Java, Indonesia. All animals were kept under traditional housing and semi-intensive management systems and were fed locally available forage. All personnel involved in data collection were trained beforehand to standardize their perception and ensure uniformity in scoring the qualitative traits. The assessment was done directly on the livestock during observation, with the cattle in a standard standing position as per the FAO (2012) guidelines.

Observations were made on 13 qualitative morphological characteristics of Rambon cattle. The observed qualitative morphological characteristics of head characteristics included muzzle color (1a: black, 1b: pink, 1c: white, 1d: mix); horn shape (2a: backward/upward/forward, 2b: aside, 2c: front top, 2d: none); horn color (3a: black, 3b: brown, 3c: dark brown, 3d: none); ear-surface color (4a: black, 4b: white, 4c: black and white); ear shape (5a: move freely without hanging, 5b: hanging, 5c: upright, 5d: aside); eye contour (6a: black, 6b: white, 6c: pink, 6d: mix); head shape (7a: large oval, 7b: triangle, 7c: square); and head color (8a: red brown, 8b: brown, 8c: matching body color, 8d: others); and body characteristic included chest shape (9a: width, 9b: medium, 9c: narrow, 9d: muscle bulge between the two front leg); body shape (10a: ribs blooming into a circle, 10b: straight ribs); backline profile (11a: straight height, 11b: higher front, 11c: higher rear); rump color (12a: round with white circle, 12b: round with smear circle, 12c: same as body color); and body color

(13a: red brown, 13b: brown, 13c: light brown, 13d: smear).

The collected data were analyzed descriptively (in terms of numbers and percentages) and tested using Fisher's exact test for two-category variables and chi-square analysis for more than two-category variables to compare both sexes. Furthermore, multiple correspondence analysis (MCA) was employed to identify relationships among the variables within each factor (Budisatria *et al*., 2022). MCA was performed with variable principal for the normalization method. All analysis variables (13 variables) and the supplementary variable (sex group) were used to construct the j11oint category plot. The object scores were used to build a scatter plot. The data was analyzed using SPSS version 25 software (IBM, USA).

RESULTS AND DISCUSSION

Morphological characteristics of Rambon cattle

The qualitative morphology traits of head and body characteristics in Rambon cattle were presented in Tables 1 and 2, respectively. Table 1 showed that the head characteristics in males and females of Rambon cattle were significantly different (p < 0.05). Differences were detected horn shape, horn color, head shape, and head color. Horn shape showed the strongest statistical difference (p < 0.01). On the other hand, the ear-surface color, ear shape, and eye contour were not significantly different between males and females. The body characteristics were shown in Table 2, males and females of Rambon cattle showed significant differences (p < 0.05) in chest shape, rump color, and body color. The body shape and back profile did not differ significantly between males and females.

Table 1: Head qualitative characteristics in male and female Rambon cattle.

Traits	Attributes	Male		Female		Total		Sig. (2-sided)
		n	%	n	%	n	%	
Muzzle color	1a: Black	12	100	84	94.4	96	95.0	0.701[a]
	1b: Pink	0	0.0	1	1.1	1	1.0	
	1c: White	0	0.0	4	4.5	4	4.0	
Horn shape	2a: Backward/upward	2	16.7	18	20.2	20	19.8	0.133[a]
	2b: Aside	0	0.0	6	6.7	6	5.9	
	2c: Front top	6	50.0	56	62.9	62	61.4	
	2d: None	4	33.3	9	10.1	13	12.9	
Horn color	3a: Black	0	0.0	10	11.2	10	9.9	0.013[a]
	3b: Brown	10	83.3	47	52.8	57	56.4	
	3c: Dark brown	0	0.0	29	32.6	29	28.7	
	3d: None	2	16.7	3	3.4	5	5.0.0	
Ear-surface color	4a: Black	6	50.0	39	43.8	45	44.6	0.762[b]
	4b: White	6	50.0	50	56.2	56	55.4	
Ear shape	5a: Move freely	6	50.0	32	36.0	38	37.6	0.568[a]
	5b: Hanging	3	25.0	22	24.7	25	24.8	
	5c: Upright	3	25.0	35	39.3	38	37.6	
Eye contour	6a: Black	1	8.3	5	5.6	6	5.9	0.647[a]
	6b: White	10	83.3	81	91.0	91	90.1	
	6c: Pink	1	8.3	2	2.2	3	3.0	
	6d: Mix	0	0.0	1	1.1	1	1.0	
Head shape	7a: Large oval	2	16.7	51	57.3	53	52.5	0.020[a]
	7b: Triangle	0	0.0	2	2.2	2	2.0	
	7c: Square	10	83.3	36	40.4	46	45.5	
Head color	8a: Red brown	0	0.0	11	12.4	11	10.9	0.013[a]
	8b: Brown	7	58.3	17	19.1	24	23.8	
	8c: Matching body	0	0.0	18	20.2	18	17.8	
	8d: Others	5	41.7	43	48.3	48	47.5	

n= number of observations; %= percentage of observations; [a]= Pearson Chi-square; [b]= Fisher's exact test.

Links Researchers

Table 2: Body qualitative characteristics in male and female Rambon cattle.

Traits	Attributes	Male		Female		Total		Sig. (2-sided)
		n	%	n	%	n	%	
Chest shape	9a: Width	2	16.7	55	61.8	57	56.4	0.001[a]
	9b: Medium	6	50.0	29	32.6	35	34.7	
	9c: Narrow	4	33.3	5	5.6	9	8.9	
Body shape	10a: Ribs blooming	0	0.0	2	2.2	2	2.0	0.775[b]
	10b: Straight ribs	12	100	87	97.8	99	98.0	
Backline profile	11a: Straight height	12	100	81	91.0	93	92.1	0.557[a]
	11b: Higher front	0	0.0	5	5.6	5	4.9	
	11c: Higher rear	0	0.0	3	3.4	3	3.0	
Rump color	12a: Round-white	4	33.3	12	13.5	16	15.8	0.005[a]
	12b: Round-smear	3	25.0	64	71.9	67	66.3	
	12c: Same as body	5	41.7	13	14.6	18	17.8	
Body color	13a: Red brown	1	8.3	34	38.2	35	34.7	0.000[a]
	13b: Brown	2	16.7	2	2.2	4	4.0	
	13c: Light brown	0	0.0	39	43.8	39	38.6	
	13d: Smear	9	75.0	14	15.7	23	22.8	

n= number of observations; %= percentage of observations; [a]= Pearson Chi-square; [b]= Fisher's exact test.

Based on Table 1, the percentage distribution across head characteristics showed clear patterns of differentiation between male and female Rambon cattle. The muzzle color was highly uniform in both sexes, with more than 90% of animals falling into the same category, suggesting that this trait was largely consistent across the population. Males displayed a higher proportion of brown horn color, whereas females were more evenly distributed across the horn color categories, indicating greater variation. Ear-surface color and ear shape also showed very similar percentage patterns between males and females, indicating that these traits exhibited minimal sexual differentiation. Conversely, head shape displayed a noticeable contrast, with males being more concentrated in categories associated with square head profiles, while females were more evenly distributed across categories. Overall, the percentage patterns suggested that horn shape, horn color, and head shape contributed most strongly to visual differences between male and female animals, whereas traits such as muzzle color, ear-surface color, and ear shape appeared more uniform across sexes.

Table 2 illustrates that several body traits showed distinct distribution patterns between male and female Rambon cattle. Females tended to dominate the width and medium categories, while males appeared in medium chest-shape classes. Body shape, however, showed almost no diversity across the population; nearly all animals, regardless of sex, were grouped in the straight ribs category, indicating a highly consistent body form. A similar tendency was seen in the back profile, where both males and females were heavily concentrated in minimum height, suggesting that this trait remained stable across individuals. In contrast, rump coloration revealed clearer differences, as females were largely concentrated in the round with a smear, matching the body color of the rump, whereas males were distributed more evenly across several categories. Body color further reinforced this contrast: females were more frequently associated with brown color, while males tended to occupy smear categories.

Table 3: Discrimination measurement of qualitative morphological traits variables.

Variables	Dimension		Mean
	1	2	
Muzzle color	0.334	0.185	0.266
Horn shape	0.729	0.425	0.577
Horn color	0.653	0.448	0.553
Ear-surface color	0.520	0.265	0.391
Ear shape	0.746	0.528	0.636
Eye contour	0.439	0.173	0.308
Head shape	0.190	0.131	0.158
Head color	0.727	0.589	0.653
Chest shape	0.663	0.241	0.449
Body shape	0.169	0.106	0.140
Backline profile	0.141	0.185	0.162
Rump color	0.630	0.428	0.528
Body color	0.681	0.567	0.622
Cronbach's Alpha	0.920	0.828	0.884
Active total (Eigenvalue)	6.621	4.248	5.434
Inertia	0.509	0.327	0.418
% of variance	50.931	32.675	41.803

The findings of this study of Rambon cattle were in accordance with those reported in previous research on sexual dimorphism in bovine and livestock breeds. Prior work on the Sanmartinero Creole bovine, for example, documented significant differences in head size and shape between males and females, with males exhibiting broader and longer heads. In another investigation, skull measurements of Kuri cattle revealed that males had significantly greater maximum intercondylar widths and other cranial landmarks than females at middle age (Salamanca-Carreño *et al*., 2025). A comprehensive 2025 morphometric analysis of the head of the Sanmartinero Creole bovine found significant differences in head size and shape between sexes, with males having larger and broader cranial forms (Doyle *et al*., 2021). Moreover, a review of horn development across Bovidae detailed how horn morphology is under genetic regulation, including genes such as RXFP2 and HOXD1, and contributes to sexual dimorphism in headgear and cranial form (Allais-Bonnet *et al*., 2021). Finally, a recent review on horn formation in bovids emphasized that horn morphology is subject to sexual dimorphism, influenced by both genetic and developmental processes (Raidan *et al*., 2019). Collectively, these findings indicate that traits such as horn shape, horn color, and head shape exhibit significant sexual dimorphism, whereas others, including muzzle color and ear surface color/shape, do not. This aligns with the existing literature demonstrating sex-linked morphological divergence in head and horn characteristics in cattle, while certain traits remain stable across sexes (Xu *et al*., 2025). This study provided empirical evidence from a lesser-studied breed and supported the notion that sexual dimorphism was expressed more strongly in cranial/horn traits than in other external body features.

Multiple correspondence analysis

The discriminatory metrics for qualitative physical characteristics of Rambon cattle are delineated in Table 3. All Cronbach's alpha coefficients exceeded 0.70, signifying robust internal reliability of the qualitative data (Costa *et al*., 2013). The inertia values for Dimensions 1 and 2 were 0.509 and 0.327, respectively. Figure 1 depicts the spatial distribution of categories inside the MCA plot. The resulting two dimensions explain 83.6% of the variance in the data (dimension 1 = 50.931%, dimension 2 = 32.675%). The MCA scatterplot revealed significant overlap between male and female categories, suggesting that the attributes did not delineate into two distinctly separated groups. This indicates that although many individual characteristics exhibit considerable variation across sexes (as demonstrated by the Chi-square analysis), the overarching multivariate pattern is predominantly common, leading to only partial differentiation instead of total segregation.

Figure 1 showed that the male and female Rambon cattle were positioned slightly away from the centroid of the MCA plot, indicating that sex contributed modestly to the phenotypic dispersion but did not create a strong separation between groups. The position of male, which appeared toward the negative side of Dimension 1, aligned more closely with categories associated with lighter color, cush as smear body color (13d) and round with white circle rump color (12a), whereas Female, located slightly toward the positive side, tended to orient closer to light brown body color (13c) and round with smear circle (12b). Beyond sex, several qualitative traits formed clearer structural patterns across the biplot. Back-profile category 11b, placed at higher positive coordinates on Dimension 2, represented more distinct morphological expressions, while horn-shape 2b and horn-color 3a appeared at the lower negative area of the plot, marking them as divergent features within the population. Many remaining traits, including chest-shape categories 9a, 9c, and body-shape 10b, clustered near the central region, reflecting more homogeneous characteristics across individuals.

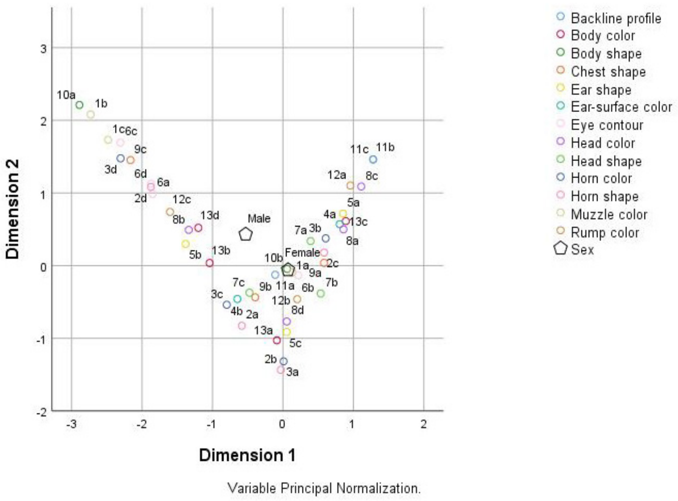

Figure 1: The joint plot of category points of qualitative traits in Rambon cattle (MCA).

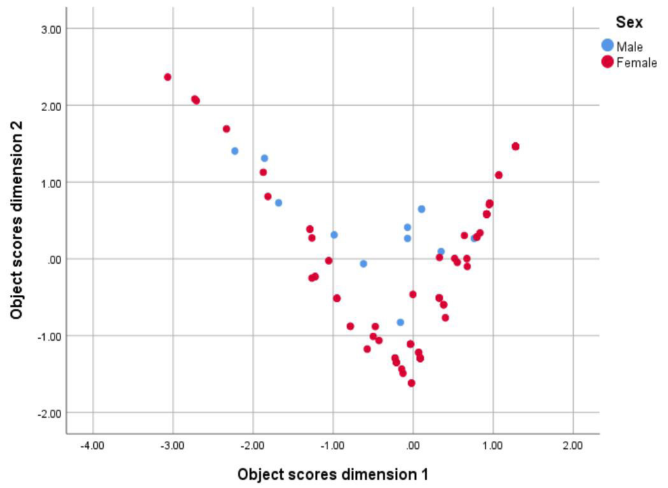

Figure 2: Bi-dimensional representation of the object scores the dimension variable associated with the individual sampled in male and female Rambon cattle.

The object score plot shown in Figure 2 indicated that male and female Rambon cattle were distributed across the same multidimensional space, indicating that individuals of both sexes shared similar qualitative morphological patterns. A key limitation of this study is the imbalance between male and female samples, which reflects the actual population structure of Rambon cattle in smallholder farming systems, where females predominate due to their importance in breeding and production. This imbalance may reduce statistical power for male-specific comparisons and influence the representation of sex categories in multivariate analyses. Although minor differences in the distribution of males and females were observed, the substantial overlap between groups and the absence of distinct sex-specific clusters indicate that sex contributed only modestly to overall morphological variation.

CONCLUSIONS

This study found modest qualitative morphological differences between male and female Rambon cattle, particularly in horn shape, head shape, chest shape, body and rump coloration. Most structural traits, however, were relatively uniform across sexes. Variation in body and rump color emerged as a stronger differentiator than traits of the head, ears, or eyes. The MCA map indicated that color- and body-shape attributes contributed most to individual dispersion, whereas many structural traits clustered near the center of the multivariate space. Nonetheless, object score pattern showed substantial overlap between males and females, indicating that sex did not produce a clear separation within the population. Overall, Rambon cattle could not be distinctly classified by sex, as both males and females exhibited broadly similar qualitative morphological characteristics, with observed variation driven mainly by specific color- and shape-related traits rather than sexual dimorphism. These results will be beneficial for future, more comprehensive investigations focused on formal breed characterization, selection, and conservation strategies.

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NOVELTY STATEMENTS

This study provides the first integrated phenotypic characterization of Rambon cattle using a combination of qualitative trait evaluation and multiple correspondence analysis (MCA). Unlike previous research that focused only on general phenotype or reproductive traits, this work systematically documents 13 head- and body-related morphological traits and quantifies their sex-associated differentiation. This study provides a structured description of 13 qualitative morphological traits in Rambon cattle, and although MCA is commonly used to identify morphological characteristics, this is the first time the method has been applied to Rambon cattle. These findings deliver new baseline phenotypic criteria that can support breed identification, formal description, and conservation planning for Rambon cattle as an Indonesian local genetic resource.

AUTHOR'S CONTRIBUTION

AD conceptualization, supervision, resources, project administration, writing original draft, PWP conceptualization, supervision, resources, funding acquisition, data curation, writing original draft, writing review and editing, ML data curation, investigation, writing review and editing, MA validation, writing original draft, writing review and editing, YSN formal analysis, methodology, software, writing original draft, DNHH validation, writing original draft, writing review and editing, APZNLS validation, writing original draft, writing review and editing, S validation, writing original draft, K validation, data curation, writing review and editing, AI conceptualization, formal analysis, investigation, methodology, validation, visualization, writing original draft, writing review and editing.

Data availability statement

Data are available from the corresponding author upon request.

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Ethical statement

All animal handling procedures were conducted in accordance with institutional and national guidelines for the care and use of livestock in research. Ethical approval for sample collection and observation was obtained from the Ethics Committee for Animal Care and Use, BRIN, under approval No. 033/KE.02/SK.02/2024.

Generative AI and AI-assisted technology statement

Artificial intelligence tools were used only for grammar correction and sentence editing. The authors affirm that all scientific content, data analysis, interpretations, and conclusions are solely their own.

Conflict of interest

The authors have declared no conflict of interest.

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