NUSANTARA BIOSCIENCE
Vol. 16, No. 1, pp. 104-110
May 2024

ISSN: 2087-3948
E-ISSN: 2087-3956
DOI: 10.13057/nusbiosci/n160113

The difference between Bali cattle and Limousin-Bali (Limbal) crossed cattle concerning their qualitative characteristics in Lombok Tengah District, Indonesia

ADI TIYA WARMAN[1], PANJONO[1,♥], GALIH TRIE FADHILAH[1], BAYU ANDRI ATMOKO[2], SIGIT BINTARA[1], TRI SATYA MASTUTI WIDI[1], ENDANG BALIARTI[1], ZAENAB NURUL JANNAH[1]

[1]Faculty of Animal Science, Universitas Gadjah Mada. Jl. Fauna No. 3, Bulaksumur, Sleman 55281, Yogyakarta, Indonesia. Tel.: +62-274-513363, Fax.: +62-274-521578, ♥email: panjono@mail.ugm.ac.id

[2]Research Center for Animal Husbandry, National Research and Innovation Agency, Cibinong Science Center. Jl. Raya Jakarta-Bogor, Bogor 16915, West Java, Indonesia

Manuscript received: 29 December 2023. Revision accepted: 26 February 2024.

Abstract. *Warman AT, Panjono, Fadhilah GT, Atmoko BA, Bintara S, Widi TSM, Baliarti E, Jannah ZN. 2024. The difference between Bali cattle and Limousine-Bali (Limbal) crossed cattle concerning their qualitative characteristics in Lombok Tengah District, Indonesia. Nusantara Bioscience 16: 104-110.* Crossbreeding is a potential approach that farmers might employ to improve the productivity of Bali cattle (*Bos javanicus* d'Alton, 1823). Exotic cattle breeds, such as Limousin cattle (*Bos taurus* Linnaeus, 1758), are frequently used for crossbreeding. This study aimed to determine the qualitative characteristic differences between Bali cattle and Limousin-Bali (Limbal) crossed cattle in the Lombok Tengah District of West Nusa Tenggara Province, Indonesia. Data sampling was conducted in 2 sub-districts, namely Pringgarata and Jonggat Sub-districts. The research used 80 adult female cattle, consisting of 40 Bali and 40 Limbal cattle. The average age of cattle was 4.24 years, and the average body weight was 236.66 kg for Bali cattle and 367.88 kg for Limbal cattle. Local farmers kept cattle using the same intensive methods. Phenotypic characterization included color and physical characteristics according to the guidelines provided by the Food and Agriculture Organization (FAO) and the Indonesian Institute of Sciences (LIPI). The Data were presented descriptively, and differences across variables were assessed using the chi-square method. The research indicated no significant difference in tail-tip color (P >0.05). The body and eyelid color showed a significant difference (P <0.05). Furthermore, legs color, buttocks color, dorsal line color, vulva color, muzzle color, horn color, face profile, backline profile, horn orientation, and ear orientation differed significantly (P <0.01). Thus, it can be concluded that crossbreeding caused changes in phenotypic characteristics in the next generation. Therefore, phenotypic characterization in the next generation of these crossbreeds must be conducted, and selection criteria must be established to achieve sustainable breeding goals.

Keywords: Characterization, crossing, native cattle, phenotypic

Abbreviations: Limbal: Limousin-Bali

INTRODUCTION

Indonesia is the second most biodiverse country in the world (Muhtadi et al. 2023). This is also reflected in the diversity of its livestock, as Indonesia has indigenous and local cattle (Widyas et al. 2022). Indonesia's indigenous cattle breed is Bali cattle. Bali cattle originated from the domestication of Banteng (*Bos javanicus* d'Alton, 1823) around 3500 years BC. Natural selection and climatic pressures in the wet tropics have adapted Bali cattle to low feed quality, parasites, and local diseases, giving rise to adaptive phenotypes (Mohamad et al. 2009; Sutarno and Setyawan 2015). These adaptive phenotypes include heat tolerance, resistance to tick-borne diseases, and survival in harsh environments with limited resources. The unique characteristics of Bali cattle make them well-suited for small-scale farming systems in Indonesia, where they are valued for their resilience and ability to thrive in challenging conditions.

Bali cattle have excellent adaptability and demonstrate high reproductive performance, capable of giving birth annually. The carcass percentage is high 54-55%, low-fat meat, and thin skin (Zulkharnaim et al. 2010; Tahuk et al. 2018). The existence of negative selection over a long period has caused Bali cattle a decrease in productivity. This can be observed in terms of body size, namely the shortened withers height, small body size, and decreased body weight, which cannot reach that of its ancestor, the Banteng. In addition to negative selection, existing Bali cattle have uncontrolled mating and even inbreeding (Sutarno and Setyawan 2015; Habaora et al. 2020).

The development of current mating technology provides breeders with the mechanism to increase productivity through artificial insemination. In this process, breeders can choose breeds for mating, whether for purification or crossbreeding. However, crossbreeding is favored among Bali cattle breeders to enhance productivity for its high economic value (Sumantri et al. 2022). Various exotic cattle breeds, such as Simmental and Limousin cattle, have been crossed with Bali cattle, as reported by Baliarti et al. (2023). One region where many Bali cattle have been crossbred with exotic cattle breeds is Lombok

Island, West Nusa Tenggara Province, as documented by Chusna et al. (2022).

These crossbreeds will undoubtedly change the genetic diversity that appears in the form of diverse phenotypic characteristics. Understanding livestock characteristics is necessary for managing genetic resources (Adinata et al. 2023). Phenotypic characterization is the initial stage in conserving cattle genetic resources (Bila et al. 2023); this in cattle breeds is the first concern to ensure unique genetic resources, becoming the basis for the formation of improvement strategies, conservation, selection criteria, and rational utilization (Heryani et al. 2016; King et al. 2022).

Phenotypic characterization of genetic resources generally refers to identifying populations of different breeds and describing them from external characteristics. Information on phenotypic characterization of livestock genetic resources can be used to measure and describe the genetic diversity of livestock to be understood further and utilized sustainably (FAO 2012). Characterization, inventory, and monitoring are critical in sustainable livestock genetic resource management. Information on breed characteristics is also important for effective planning to improve livestock genetic resources at the country level (Mekonnen and Meseret 2020).

Characterization is typically classified according to physical characteristics such as color, size, shape, and genetic history (Bhinchhar et al. 2017). Various studies on phenotypic characterization have been conducted on several cattle breeds in Indonesia, such as Jabres, Ongole Grade, Madura, Pasundan, Kebumen Ongole Grade, and Rambon cattle (Adinata et al. 2023). However, information on the phenotypic characterization of crossbreeds of Bali cattle with exotic cattle in Indonesia still needs to be improved because the crossbreeds have higher economic value than its Bali cattle. Based on these considerations, it is important to research the differences in phenotypic characteristics between Bali cattle and Limousin-Bali crossed cattle kept by smallholder farmers in Indonesia. This study intends to compare the phenotypic characteristics of Bali cattle and Limousin-Bali crossbred cattle in Lombok.

MATERIALS AND METHODS

Ethical clearance

The Research Ethics Commission of the Faculty of Veterinary Medicine at Universitas Gadjah Mada, Yogyakarta, Indonesia, approved the research under Number 00018/EC-FKH/Eks/2021, as it adhered to the ethical standards for animal research.

Research region

The research was conducted in Jonggat and Pringgarata, two sub-districts in the Lombok Tengah District of West Nusa Tenggara, Indonesia. This region is located between 8° 24' to 8° 57' South latitude, and 116° 05' to 116° 24' East longitude in the middle part of Indonesia. The region has a tropical climate with an average yearly temperature of 26.5°C, average humidity of 85.1%, and annual rainfall of 160.7 mm. The two sub-districts are 100-340 meters above sea level (BPS 2023).

Procedures

The sampling technique employed was purposive sampling. The research location was purposefully selected after consulted with the Department of Agriculture on Lombok Tengah District, as the area is known to be a source of Bali cattle and their crosses. The cattle breeds were determined based on the cattle's physical appearance and mating records provided by farmers and inseminators.

The 80 studied cattle consisted of 40 Bali and 40 Limousin-Bali (Limbal) cattle, selected using purposive sampling. The cattle used were adult females with an average age of 4.24 years, determined by interviewing the farmer and observing the incisor growth. The estimated average body weight of cattle based on the Lambourne formula between Bali vs Limbal cattle is 236.66 vs 367.88 kg. The cattle were kept by 63 smallholder farmers utilizing the same intensive-rearing system. The feed was native grass, rice straw, *Pennisetum purpureum*, *P. purpureum* cv. *Mott*, and *Sesbania grandiflora*. Drinking water was provided from wells and storage ponds. The cattle are tethered in enclosures throughout the day.

Assessments were conducted by the first author during daylight hours in the enclosure, with each of the cattle in a standing position to avoid bias refers to Traoré et al. (2015). Qualitative characteristics observed were color (body, legs, buttocks, tail tip, dorsal line, muzzle, horn, eyelid, and vulva) and physical (horn and ear orientation, face and backline profile). The phenotypic characteristics used refer to the FAO (2012) entitled "Phenotypic Characterization of Animal Genetic Resources" and the Indonesian Institute of Sciences (LIPI) (2015) Physical Appearance Filling Instructions.

Data analysis

The data were presented descriptively, and differences across variables were assessed using the chi-square test. This statistical analysis identified significant differences between the breeds, providing insights into their distinct qualitative characteristics. Additionally, the chi-square test helped determine whether these variations were statistically significant or simply due to chance. Software of Statistical Package for the Social Sciences (SPSS) version 25 (IBM USA) was employed to analyze the variations in qualitative characteristics.

RESULTS AND DISCUSSION

Color characteristics

The number and percentage of nine variables of body part color characteristics in Bali and Limbal cattle are presented in Table 1. It was found that muzzle color, horn color, legs color, buttocks color, dorsal line color, and vulva color were significantly different with significance ($P < 0.01$). Additionally, there were significant differences in body and eyelid color ($P < 0.05$). In contrast, no significant difference was observed in the color of the tail tip between the two groups (P >0.05). Based on phenotypic appearance, the body colors of Bali vs. Limbal cattle are dark red (52.50% vs. 42.50%), dark brown (5.00% vs. 17.50%), light brown (35.00% vs. 15.00%), and fawn (7.50% vs. 25.00%), respectively. The difference between Bali cattle and Limbal cattle is also in the muzzle color. The muzzle color in Bali cattle is black (pigmented) (100.00%), while Limbal cattle have black (pigmented) (82.50%) and light brown (unpigmented) (17.50%) (Table 1).

Eyelid color in Bali cattle is 100.00% pigmented, while in Limbal cattle, 15.00% do not have pigment. Horn color in Limbal cattle is more diverse than in Bali cattle, with three horn colors identified: black (62.50%), brown (2.50%), and brown-black (35.00%). Meanwhile, Bali cattle have 100.00% black horn color. The white color on the legs differs between Bali cattle and Bali cattle crosses, in this case, Limbal cattle. All Bali cattle studied have white on their legs with clearly distinct boundaries. However, 15.00% of Limbal cattle have legs with indistinct boundaries white, and 85.00% of Limbal cattle have legs that match their body color.

The white color on the buttocks of Limbal cattle is also different from that of Bali cattle, with 60.00% having white buttocks with indistinct boundaries and 40.00% having buttocks that are not white or mirror-shaped. Meanwhile, Bali cattle exhibit white buttocks with firm boundaries (62.50%) and white color without firm boundaries (37.50%). The tip tail color of Bali cattle, compared to Limbal cattle, was not significantly different, with the dominant color being black (60.00% vs. 57.50%), followed by brown (40.00% vs. 42.50%). The black color of the dorsal line between the two breeds differed; it was identified that 57.50% of Limbal cattle had a thin black dorsal line, and 35.00% had no dorsal line. Meanwhile, 100.00% of Bali cattle exhibited a thick black dorsal line color. Regarding vulva color, there was also a difference between Limbal and Bali cattle. Bali cattle have 100% black vulva color, while Limbal cattle have 77.50% black, 15.00% brown, and 7.50% a combination of black and brown vulva colors.

Table 1. Color characteristics between Bali cattle and Limbal crossed cattle

Variable	Bali (40)		Limbal (40)		X^2-Value	P-Value
	N	%	N	%		
Body color (%)					10.168	0.017
Dark Red	21	52.50	17	42.50		
Dark brown	2	5.00	7	17.50		
Light brown	14	35.00	6	15.00		
Fawn	3	7.50	10	25.00		
Muzzle color					7.671	0.006
Pigmented	40	100.00	33	82.50		
Not pigmented	-	-	7	17.50		
Eyelid color					6.486	0.011
Pigmented	40	100.00	34	85.00		
Not pigmented	-	-	6	15.00		
Horn color					18.462	0.000
Black	40	100.00	25	62.50		
Brown	-	-	1	2.50		
Brown-Black	-	-	14	35.00		
Legs color (%)					80.000	0.000
White with distinct boundaries	40	100.00	-	-		
White with indistinct boundaries	-	-	6	15.00		
Same as body color	-	-	34	85.00		
Buttock color (%)					43.077	0.000
White with distinct boundaries	25	62.50	-	-		
White with indistinct boundaries	15	37.50	24	60.00		
Same as body color	-	-	16	40.00		
Tail tip color (%)					0.052	0.820
Black	24	60.00	23	57.50		
Brown	16	40.00	17	42.50		
Dorsal line (%)					80.000	0.000
Thick Black	40	100.00	-	-		
Medium Black	-	-	3	7.50		
Thin Black	-	-	23	57.50		
Absence	-	-	14	35.00		
Vulva color					10.141	0.006
Black	40	100.00	31	77.50		
Brown	-	-	6	15.00		
Combination	-	-	3	7.50		

Note: N: Number of observations; %: Percentage of observations; X^2-Value: Chi-square value

Table 2. Physical characteristics between Bali cattle and Limbal crossed cattle

Variable	Bali (40)		Limbal (40)		X^2-Value	P-Value
	N	%	N	%		
Facial (head) profile					30.345	0.000
Straight	40	100.00	18	45.00		
Concave	-	-	22	55.00		
Backline Profile (%)					8.455	0.004
Straight	13	32.50	26	65.00		
Slopes down from withers	27	67.50	14	35.00		
Ear orientation					42.288	0.000
Erect	36	90.00	7	17.50		
Lateral	4	10.00	33	82.50		
Horn orientation					68.518	0.000
Upward	1	2.50	33	82.50		
Laterally	-	-	5	12.50		
Backward	38	95.00	2	5.00		
Downward	1	2.50	-	-		

Note: N: Number of observations; %: Percentage of observations; X^2-Value: Chi-square value

Physical characteristics

The physical characteristics of the female Bali and Limbal cattle are presented in Table 2. Bali and Limbal cattle face profiles, backline profiles, ear orientation, and horn orientation are significantly different ($p < 0.01$). The face profile of Bali cattle is 100.00% straight, while in Limbal cattle, the dominant face profile is concave (55.00%), followed by a straight face profile (45.00%). Concerning the backline profile, Bali cattle exhibit dominant slopes down from withers (67.50%), whereas, in Limbal cattle, the dominant backline profile is straight (65.00%). The ear orientation in Bali cattle is dominantly erect (90.00%), while in Limbal cattle, the ear orientation is dominantly lateral (82.50%). Furthermore, Bali cattle have dominant horns pointing backward (95.00%), while in Limbal cattle, the dominant horns point upwards (82.50%).

Discussion

The reddish-brown body color is the predominant color observed in local Indonesian cattle breeds especially Madura cattle (Kurniati et al. 2022), Aceh cattle (Widyaningrum et al. 2021), Katingan cattle (Utomo and Widjaja 2021), Pesisir cattle (Putra et al. 2018), and Pasundan cattle (Said et al. 2017). The increased yellowish-brown color in Limousin-Bali crossbred cattle is a characteristic inherited from Limousin, considering that Limousin belongs to the yellow-brown (chestnut) group of cattle, generally exhibiting yellow, red, and brown colors (Alderson 1992). Body color indicates genetic purity and is valuable for branding a cattle breed (Kimura et al. 2022; Kunene et al. 2022). Additionally, body color is a factor that influences an animal's ability to withstand heat stress and resist fly and tick attacks (Islam et al. 2022). Cattle with brighter colors demonstrate higher adaptability to heat stress than those with black fur, making them more suitable for extensive systems in hot climates (Anzures-Olvera et al. 2019; Isola et al. 2020). In addition to adaptability, cattle with lighter coat colors exhibit better weight gain than dark-colored cattle, as observed in Tharparkar cattle (*Bos indicus* Linnaeus, 1758) in India (Rashid et al. 2019).

Ongole Grade and Madura cattle are local Indonesian breeds with a black muzzle color, similar to Bali cattle (Hartatik et al. 2018; Kurniati et al. 2022). This characteristic is also evident in the crossbreeding of Limousin cattle with Madura cattle, resulting in a black and red muzzle color (Hartatik 2014), consistent with the muzzle color observed in Limbal cattle in this study. The melanocyte process influences the diversity in muzzle color, which melanocortin receptors regulate. This process involves the distribution of pheomelanin and eumelanin as color determinants in the fur and snout (Kim et al. 2014). Apart from serving as a means of livestock identification, muzzle color is now utilized in biometrics for identification purposes, analogous to fingerprints in humans (Li et al. 2022; Lee et al. 2023).

The black eyelid pigment in Bali cattle is also found in local Indonesian Pasundan cattle (Said et al. 2017). Then, the unpigmented eyelid color in Limousin-Bali cattle is also found in several cattle breeds in taurine in West Africa, namely N'Dama, Lagunaire, Lobi, and Somba (Grema et al. 2017). Similarly, Rarámuri Criollo cattle developed in the United States have unpigmented eyelids that account for 19% of the total population (McIntosh et al. 2020). The production of melanin pigment from melanocytes in the skin influences the pigmentation of the eyelids. Non-genetic factors such as environmental and physiological conditions cause differences in skin pigmentation in each cow (Jara et al. 2022). Low pigmentation of the eyelids can cause several eye diseases, such as squamous cell carcinoma and keratoconjunctivitis, which can affect cattle production (Jara et al. 2020).

The horn is a bony core surrounded by a sheath of cornified epithelium. It is present in livestock belonging to the Bovidae family, including buffalo (*Bubalus bubalis*), cattle (*Bos taurus* Linnaeus, 1758, *B. indicus*, and *B. javanicus*), goats (*Capra hircus* Linnaeus, 1758), and sheep (*Ovis aries* Linnaeus, 1758) (Knierim et al. 2015). The shape and length of horns are specific to each species and breed, exhibiting high variation between individuals (Grobler et al. 2021). Horn variation is evident in Bali and

Limbal cattle in Indonesia. The black color of horns in Bali cattle is also observed in Aceh cattle (Hartatik 2014), Madura cattle, and Jabres cattle (Adinata et al. 2023). The diversity of horn color in Limbal cattle is also found in Hungarian Grey cattle, albeit with different variants of horn color. In Hungarian Grey cattle, horns come in white, green, and cardy (a mixture of green and white) (Zsolnai et al. 2021). Regarding the orientation of horns, the dominant upward orientation observed in Limousin cattle crosses with Bali cattle is also found in Limousin cattle crosses with Madura cattle (Limura) (Hartatik 2014). While horns are not a trait directly impacting productivity, they hold significance as a physical trait employed as a selection criterion in Ankole cattle in Uganda (Kugonza et al. 2012) and Taccek (display) cattle on Madura Island, Indonesia (Herviyanto et al. 2020).

The white coloration on the legs and buttocks in Bali cattle is also observed in Madura and Pasundan cattle, where the white color exhibits indistinct boundaries (Maylinda et al. 2017; Said et al. 2017). Similarly, the black dorsal stripe identified in Bali cattle is found in the local Indonesian breed of Galekan cattle (Kuswati et al. 2022). Despite sharing some characteristics, a genetic distance exists between local Indonesian cattle breeds. There is a higher genetic similarity between local breeds such as Madura, Galekan, and Bali cattle. Still, Aceh, Ongole Grade, and Pesisir cattle have a genetic similarity closer to Indian zebu cattle (Mohamad et al. 2009). Cattle breeding in Indonesia has developed unique and adaptable genetic resources by merging the zebu ability to endure tropical and arid climates with the native Banteng adaptation to local environments and farms (Mohamad et al. 2012).

The characteristics observed in Limousin-Bali crossbred cattle are also evident in Simmental crossbred cattle with Bali cattle. These characteristics include legs sharing the same color as the body, buttocks color following the body color, and a white border on the buttocks with indistinct boundaries. However, Simmental crosses with Bali cattle still exhibit a thick black dorsal line (Chusna et al. 2022). In contrast, the crossbreeding of Limousin cattle with Madura cattle results in similar body, rump/buttock, and leg color as observed in the cross of Limousin cattle with Bali cattle. Notably, a distinction is found in the dorsal line, where Limousin crossbred Madura cattle lack a dorsal line (Hartatik 2014), while in Limousin crossbred Bali cattle, a thin to medium black dorsal line is still present.

The facial morphology characterized by a straight face, as seen in Bali cattle, corresponds to the results reported by Gelaye et al. (2022) in indigenous cattle from Southwestern Ethiopia and Getaneh et al. (2019) in Malle cattle. In contrast, Limbal cattle's predominantly concave facial profile reflects the facial shape inherited from their Limousin ancestors (Alderson 1992). Additionally, the predominantly straight-back profile of Limbal cattle is a physical characteristic shared with several taurine cattle breeds in Africa, such as Kuri, N'Dama, Lagunaire, Lobi, and Somba (Grema et al. 2017; Edouard et al. 2018).

The dominant upward ear orientation in Bali cattle is in line with the research of Karnuah et al. (2018) found in beef cattle in Liberia, West Africa, namely N'Dama and Muturu. The lateral ear orientation in Limbal cattle is similar to the results of research by Gelaye et al. (2022) on local cattle in Southwestern Ethiopia. The laterally oriented ear is composed of well-developed muscles that allow the ear to be moved even to listen to faint sounds from distant locations (Woldeyohannes et al. 2019).

These phenotypic characteristics facilitate the easy identification of cattle breeds due to the unique attributes inherent in each breed. Phenotypic variations within local livestock genetic resources signify the presence of genetic diversity that merits conservation efforts. A comprehensive understanding of phenotypic characteristics in local livestock is crucial for formulating conservation policies to preserve these valuable resources (Yakubu et al. 2022). In addition to phenotypic changes, crossbred cattle are anticipated to manifest heterosis effects in the subsequent generation, enhancing productivity and influencing the economic value generated (Chusna et al. 2022).

Crossbreeding is a process that aims to create new cattle breeds to meet the market’s demands. However, crossbreeding should not be done carelessly, as it may endanger the purity of local livestock (Sutarno and Setyawan 2015). Studies have shown that the crossbreeding program in Indonesia has failed because it is solely based on body weight selection, while other productive and adaptive traits are overlooked (Widyas et al. 2022). Therefore, it is crucial to formulate a crossbreeding and purification plan that will lead to genetic improvement.

Strategies that can be applied to achieve sustainable livestock breeding are at the policy, environmental, and farms level. The policy and ecological level includes the implications of government policies in agriculture, infrastructure, farmer involvement, setting breeding goals and production systems that take place based on the region and market targets. At the farm level includes breeding by purification or crossbreeding, livestock recording and data processing, reproduction methods, genetic analysis and estimation of breeding values, and selection and monitoring of genetic progress (Philipsson et al. 2006; Leroy et al. 2016). The strategy applied for crossbreeding Limousin cattle with Bali cattle certainly refers to the principles described above. The goal is for crossbreeding to continue at the breeder level with regular monitoring and evaluation by the local government and research institutions and to ensure that Indonesia's indigenous genetic resources are preserved.

The phenotypic characterization of Bali and Limousin-Bali cattle revealed significant differences between the two breeds in terms of body color, eyelid color, legs color, buttocks color, dorsal line color, vulva color, muzzle color, horn color, face profile, backline profile, horn orientation, and ear orientation. These findings conclude that crossbreeding induces changes in phenotypic characteristics in the subsequent generation. Consequently, it is imperative to conduct phenotypic characterization in the next generation of this crossbred and establish selection criteria to attain sustainable breeding goals. The results of this study are expected to be a basic reference in genetic improvement, conservation efforts, the development of new breeds, and in setting selection criteria for crossbred cattle in the future. Further research related to phenotypic adaptation and genotype testing needs to be conducted to obtain more comprehensive information on the development of crossbred cattle in the future.

ACKNOWLEDGEMENTS

The researchers wish to acknowledge the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia for their financial support for this study through the PMDSU (*Pendidikan Magister menuju Doktor untuk Sarjana Unggul*) research program. The contract with 2209/UN1/DITLIT/Dit-Lit/PT.01.03/20 is linked to the grant number 0217/E5/PG.02.00/2023. The authors express their gratitude to the farmers who participated in the research, as well as the Faculty of Animal Science at Universitas Gadjah Mada, Indonesia and the Agriculture Office of Lombok Tengah District, Indonesia for their valuable help in this study.

REFERENCES

Adinata Y, Noor RR, Priyanto R, Cyrilla L, Sudrajad P. 2023. Morphometric and physical characteristics of Indonesian beef cattle. Arch Anim Breed 66: 153-161. DOI: 10.5194/aab-66-153-2023.

Alderson L. 1992. The categorisation of types and breeds of cattle in Europe. Arch Zootec 41: 325-334.

Anzures-Olvera F, Véliz FG, de Santiago A, García JE, Mellado J, Macías-Cruz U, Avendaño-Reyes L, Mellado M. 2019. The impact of hair coat color on physiological variables, reproductive performance and milk yield of Holstein cows in a hot environment. J Therm Biol 81: 82-88. DOI: 10.1016/j.jtherbio.2019.02.020.

Badan Pusat Statistik (BPS). 2023. Lombok Tengah Regency in Figures. Badan Pusat Statistik, Praya. [Indonesian]

Baliarti E, Rozzaq MA, Warman AT, Bintara S, Widi TSM, Widayati DT, Atmoko BA, Nugroho T. 2023. Body morphometric characterization in conjunction with reproductive performance of Bali and Bali cross cattle in Indonesia. Adv Anim Vet Sci 11: 977-986. DOI: 10.17582/journal.aavs/2023/11.6.977.986.

Bhinchhar BK, Paswan VK, Yadav SP, Saroj, Singh P. 2017. Physical and morphometric characteristics of Gangatiri cattle. Indian J Anim Res 51: 1101-1104. DOI: 10.18805/ijar.11329.

Bila L, Malatji DP, Tyasi TL. 2023. Morphological characterization of Sussex cattle at Huntersvlei farm, Free State Province, South Africa. Plos ONE 18: e0292088. DOI: 10.1371/journal.pone.0292088.

Chusna RQ, Ramadhan YF, Fadhilah GT, Warman AT, Maharani D, Atmoko BA, Baliarti E. 2022. The difference in qualitative characteristics between Simmental-Bali (SIMBAL) crossed cows and Bali cows in West Nusa Tenggara, Indonesia. IOP Conf Ser: Earth Environ Sci 1114: 012059. DOI: 10.1088/1755-1315/1114/1/012059.

Edouard NK, Lacine BK, Cyrille KN, Etienne LN, Guiguigbaza-Kossigan D, Mamadou S, Valentine YGC. 2018. Multivariate analysis for morphological characteristics of N'Dama cattle breed in two agro-ecological zones of Côte d'Ivoire. Eur Sci J 14: 602-621. DOI: 10.19044/esj.2018.v14n3p602.

FAO. 2012. Phenotypic Characterization of Animal Genetic Resources. FAO Animal Production and Health Guidelines, Roma.

Gelaye G, Baye M, Masho W, Begna R, Admasu Z. 2022. Morphometric traits and structural indices of indigenous cattle reared in Bench Sheko zone, southwestern Ethiopia. Heliyon 8: e10188. DOI: 10.1016/j.heliyon.2022.e10188.

Getaneh D, Banerjee S, Taye M. 2019. Morphometrical traits and structural indices of Malle Cattle reared in the South Omo Zone of Southwest Ethiopia. Intl J Vet Sci Res 5: 32-47. DOI: 10.18488/journal.110.2019.52.32.47.

Grema M, Traoré A, Issa A, Hamani M, Abdou M, Fernández I, Soudré A, Álvarez I, Sanou M, Tamboura HH, Alhassane Y, Goyache F. 2017. Morphological assessment of Niger Kuri cattle using multivariate methods. S A J Anim Sci 47: 505-515. DOI: 10.4314/sajas.v47i4.9.

Grobler R, van Marle-Koster E, Visser C. 2021. Challenges in selection and breeding of polled and scur phenotypes in beef cattle. Livest Sci 247: 104479. DOI: 10.1016/j.livsci.2021.104479.

Habaora F, Fuah AM, Abdullah L, Priyanto R, Yani A, Purwanto BP. 2020. Importance-performance analysis toward productivity of Bali cattle based on agroecosystem in Timor Island. J Anim Vet Adv 19: 57-66. DOI: 10.36478/javaa.2020.57.66.

Hartatik T, Maharani D, Sidadolog JHP, Fathoni A, Sumadi. 2018. Haplotype diversity of partial cytochrome b gene in Kebumen Ongole Grade Cattle. Trop Anim Sci J 41: 8-14. DOI: 10.5398/tasj.2018.41.1.8.

Hartatik T. 2014. Analisis Genetik Ternak Lokal. Universitas Gadjah Mada Press, Yogyakarta. [Indonesian]

Herviyanto D, Kuswati, Ciptadi G. 2020. Identification characteristic Madura cattle female taccek type. J Trop Anim Prod 21: 83-92. DOI: 10.21776/ub.jtapro.2020.021.02.1. [Indonesian]

Heryani LGSS, Wandia IN, Suarna IW, Puja IK. 2016. Morphometric characteristics of the Taro White cattle in Bali. Glob Vet 16: 215-218. DOI: 10.5829/idosi.gv.2016.16.03.102116.

Islam MS, Yimer N, Haron AW, Abdullah FFJ, Han MHW, Mamat-Hamidi K, Zawawi HBM. 2022. First study on phenotypic and morphological characteristics of Malaysian Kedah-Kelantan cattle (*Bos indicus*) and method of estimating their body weight. Vet World 15: 728-736. DOI: 10.14202/vetworld.2022.728-736.

Isola JVV, Menegazzi G, Busanello M, dos Santos SB, Agner HSS, Sarubbi J. 2020. Differences in body temperature between black-and-white and red-and-white Holstein cows reared on a hot climate using infrared thermography. J Therm Biol 94: 102775. DOI: 10.1016/j.jtherbio.2020.102775.

Jara E, Peñagaricano F, Armstrong E, Ciappesoni G, Iriarte A, Navajas EA. 2022. Revealing the genetic basis of eyelid pigmentation in Hereford cattle. J Anim Sci 100: skac110. DOI: 10.1093/jas/skac110.

Jara E, Peñagaricano F, Menezes C, Tardiz L, Rodons G, Iriarte A, Armstrong E. 2020. Transcriptomic analysis of eyelid pigmentation in Hereford cattle. Anim Genet 51: 935-939. DOI: 10.1111/age.13004.

Karnuah AB, Dunga G, Wennah A, Wiles WT, Greaves E, Varkpeh R, Osei-Amponsah R, Boettcher P. 2018. Phenotypic characterization of beef cattle breeds and production practices in Liberia. Trop Anim Health Prod 50: 1287-1294. DOI: 10.1007/s11250-018-1557-z.

Kim SH, Hwang SY, Yoon JT. 2014. Microarray-based analysis of the differential expression of melanin synthesis genes in dark and light-muzzle Korean cattle. PLoS ONE 9: e96453. DOI: 10.1371/journal.pone.0096453.

Kimura S, Hatakeyama T, Koutaka T, Kubo K, Morita S, Eguchi K, Saitoh K, Yamauchi K, Imai S, Kashimura A, Inenaga T, Matsumoto H. 2022. PMEL p.Leu18del dilutes coat color of Kumamoto sub-breed of Japanese Brown cattle. BMC Genom 23: 694. DOI: 10.1186/s12864-022-08916-8.

King FJM, Banga C, Visser C. 2022. Morphological characterisation of three indigenous Mozambican cattle populations. J Agr Rural Dev Trop Subtrop 123: 225-234. DOI: 10.17170/kobra-202212057192.

Knierim U, Irrgang N, Roth BA. 2015. To be or not to be horned—Consequences in cattle. Livest Sci 179: 29-37. DOI: 10.1016/j.livsci.2015.05.014.

Kugonza DR, Nabasirye M, Hanotte O, Mpairwe D, Okeyo AM. 2012. Pastoralists' indigenous selection criteria and other breeding practices of the long-horned Ankole cattle in Uganda. Trop Anim Health Prod 44: 557-565. DOI: 10.1007/s11250-011-9935-9.

Kunene LM, Muchadeyi FC, Hadebe K, Mészáros G, Sölkner J, Dugmore T, Dzomba EF. 2022. Genetics of base coat colour variations and coat colour-patterns of the South African Nguni cattle investigated using high-density SNP genotypes. Front Genet 13: 832702. DOI: 10.3389/fgene.2022.832702.

Kurniati AD, Nugiartiningsih VMA, Kuswati, Suyadi S. 2022. Study of the physical and physiological response of the Madura as a breeding source (case study in Waru Sub-District, Pamekasan District). KnE Life Sci 2022: 292-299. DOI: 10.18502/kls.v0i0.11811.

Kuswati K, Ali MI, Wahyuni RD. 2022. Morphometric characteristics of Galekan cattle breed base on Principle Component Analysis (PCA). J

Ilmu-Ilmu Peternakan (Indonesian Journal of Animal Science) 32: 1-12. DOI: 10.21776/ub.jiip.2022.032.01.01.

Lee T, Na Y, Kim BG, Lee S, Choi Y. 2023. Identification of individual Hanwoo cattle by muzzle pattern images through deep learning. Animals 13: 2856. DOI: 10.3390/ani13182856.

Lembaga Ilmu Pengetahuan Indonesia (LIPI). 2015. Panduan Pengisian Form Penampilan Fisik. LIPI, Bogor. [Indonesian]

Leroy G, Baumung R, Boettcher P, Scherf B, Hoffman I. 2016. Review: Sustainability of crossbreeding in developing countries; definitely not like crossing a meadow. Animal 10: 262-273. DOI: 10.1017/S175173111500213X.

Li G, Erickson GE, Xiong Y. 2022. Individual beef cattle identification using muzzle images and deep learning techniques. Animals 12 (11): 1453. DOI: 10.3390/ani12111453.

Maylinda S, Nugroho H, Busono W. 2017. Phenotypic characteristics of local cattle in Madura Island. AIP Conf Proc 1844: 060002 DOI: 10.1063/1.4983442.

McIntosh MM, Gonzalez AL, Cibils AF, Estell RE, Nyamuryekung'e S, Almeida FAR, Spiegal SA. 2020. A phenotypic characterization of Rarámuri Criollo Cattle introduced into the Southwestern United States. Arch Latinoam Prod Anim 28: 111-119. DOI: 10.53588/alpa283406.

Mekonnen T, Meseret S. 2020. Characterization of Begait cattle using morphometric and qualitative traits in Western Zone of Tigray, Ethiopia. Intl J Livest Prod 11: 21-33. DOI: 10.5897/IJLP2019.0637.

Mohamad K, Olsson M, Andersson, Purwantara B, van Tol HTA, Rodriquez-Martinez H, Colenbrander B, Lenstra JA. 2012. The origin of Indonesian cattle and conservation genetics of the Bali cattle breed. Reprod Domest Anim 47: 18-20. DOI: 10.1111/j.1439-0531.2011.01960.x.

Mohamad K, Olsson M, van Tol HTA, Mikko S, Vlamings BH, Andersson G, Rodrı´guez-Martı´nez H, Purwantara B, Paling RW, Colenbrander B, Lenstra JA. 2009. On the origin of Indonesian cattle. PloS ONE 4: e5490. DOI: 10.1371/journal.pone.0005490.

Muhtadi A, Yulianda F, Boer M, Krisanti M, Desrita. 2023. Ichthyofauna diversity and its distribution in a Low-Saline Lake of Indonesia. Hayati J Biosci 30: 421-431. DOI: 10.4308/hjb.30.3.421-431.

Philipsson J, Rege JEO, Okeyo AM. 2006. Sustainable breeding programmes for tropical farming systems. Anim Genet Train Resour 2: 1-25.

Putra DE, Paul RC, Thu LNA, Okuda Y, Yurnalis, Ibi T, Kunieda T. 2018. Genetic characterization of Indonesian Pesisir cattle using mitochondrial DNA and Y-chromosomal haplotypes and loci associated with economical traits and coat color. J Anim Genet 46: 17-23. DOI: 10.5924/abgri.46.17.

Rashid SA, Tomar AKS, Verma MR, Mehrotra S, Bharti PK. 2019. Effect of skin and coat characteristics on growth and milk production traits in Tharparkar cattle. Indian J Anim Sci 89: 1251-1254. DOI: 10.56093/ijans.v89i11.95882.

Said S, Putra WPB, Anwar S, Agung PP, Yuhani H. 2017. Phenotypic, morphometric characterization and population structure of Pasundan cattle at West Java, Indonesia. Biodiversitas 18: 1638-1645. DOI: 10.13057/biodiv/d180443.

Sumantri I, Chang HSC, Widi TSM, Hadi NH, Rohaeni ES. 2022. Gross margin comparison of Bali and crossbred cattle in small holder beef cattle farming in South Kalimantan, Indonesia. Proceedings of the 9th International Seminar on Tropical Animal Production. Universitas Gadjah Mada, Yogyakarta, 21-22 September 2021. DOI: 10.2991/absr.k.220207.071.

Sutarno, Setyawan AD. 2015. Review: Genetic diversity of local and exotic cattle and their crossbreeding impact on the quality of Indonesian cattle. Biodiversitas 16: 327-354. DOI: 10.13057/biodiv/d160230.

Tahuk PK, Budhi SPS, Panjono, Baliarti E. 2018. Carcass and meat characteristics of male Bali cattle in Indonesian smallholder farms fed ration with different protein levels. Trop Anim Sci J 41: 215-223. DOI: 10.5398/tasj.2018.41.3.215.

Traoré A, Koudandé DO, Fernández I, Soudré A, Granda V, Álvarez I, Diarra S, Diarra F, Kaboré A, Sanou M, Tamboura HH, Goyache F. 2015. Geographical assessment of body measurements and qualitative traits in West African cattle. Trop Anim Health Prod 47: 1505-1513. DOI: 10.1007/s11250-015-0891-7.

Utomo BN, Widjaja E. 2021. Genetic resources of Katingan cattle and effort to conserve at the time in Katingan District, Central Kalimantan. Proceedings of the 3rd KOBI Congress, International and National Conferences (KOBICINC 2020). Universitas Bengkulu, Bengkulu, 24-25 November 2020. DOI: 10.2991/absr.k.210621.018.

Widyaningrum R, Budisatria IGS, Fathoni A, Maharani D. 2021. Profile and population dynamics of Aceh cattle in livestock breeding and forage centre, Indrapuri. IOP Conf Ser: Earth Environ Sci 667: 012033. DOI: 10.1088/1755-1315/667/1/012033.

Widyas N, Widi TSM, Prastowo S, Sumantri I, Hayes BJ, Burrow HM. 2022. Promoting sustainable utilization and genetic improvement of Indonesian local beef cattle breeds: A review. Agriculture 12 (10): 1566. DOI: 10.3390/agriculture12101566.

Woldeyohannes T, Hankamo A, Banerjee S. 2019. Morphological characterization and structural indices of indigenous cattle in Hadiya Zone, Southern Ethiopia. Glob J Anim Sci Res 7: 23-38.

Yakubu A, Jegede P, Wheto M, Shoyombo AJ, Adebambo AO, Popoola MA, Osaiyuwu OH, Olafadehan OA, Alabi OO, Ukim CI, Vincent ST, Mundi HL, Olayanju A, Adebambo OA. 2022. Multivariate characterisation of morphobiometric traits of indigenous helmeted Guinea fowl (*Numida meleagris*) in Nigeria. PLoS ONE 17: e0261048. DOI: 10.1371/journal. pone.0261048.

Zsolnai A, Kovács A, Kaltenecker E, Anton I. 2021. Identification of markers associated with estimated breeding value and horn colour in Hungarian Grey cattle. Anim Biosci 34: 482-488. DOI: 10.5713/ajas.19.0881.

Zulkharnaim, Jakaria, Noor RR. 2010. Identification of Genetic Diversity of Growth Hormone Receptor (GHR|AluI) Gene in Bali. Media Peternakan 33: 81-87. DOI: 10.5398/medpet.2010.33.2.81.