RESEARCH ARTICLE Indian Journal of Animal Research, Volume 56 Issue 8: 1041-1046 (August 2022)

Diversity of Qualitative Characteristics and Their Use to Distinguish the Origin of the Bali Cattle Population

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10.18805/IJAR.BF-1417

ABSTRACT

Background: The development of local Bali cattle in *ex-situ* areas allow for the formation of new qualitative phenotypic characteristics. The aim of this study is to characterize Bali cattle that have been created in Jambi Province's *ex-situ* environment in several of rearing areas.

Methods: A research sample of 478 Bali cattle from Muaro Jambi (MJB) district, Sarolangun (SLG) district, Tanjung Jabung Timur (TJT) District, Jambi City (KJB) and PTPN VI were surveyed. The qualitative phenotype characteristic observed were pattern of head color, dominant head color, inner-ear color, forehead color, side-lip color, horn shape, body-color pattern, dominant body color, back-line color, under-belly color, sock color, rump color and tail color. The frequency and percentage of each qualitative characteristic were calculated using the PROC FREQ function of SAS software version 9.0, resulting in a cross-tabulation of the qualitative characteristics observed in Bali cattle at various locations. Then, PROC CORESP performs multiple correspondence analysis (MCA) between the qualitative characteristics of the variables. The resulting plot depicts the graphical relationship between variables.

Result: Research results based on sex showed that only white lower lip and black inner ear were characteristic of the head found to be common, while black backline, light-brown underbelly, white rump and black tail hair were common characteristics for the body. Head phenotype based on district showed that white lower lip and white-black inner ear could be found in male Bali cattle while white lower lip and abnormal horn characteristic could be found in females. Body characteristic analysis showed three-color pattern to be common in male Bali cattle while black backline, white feet and white rump were common characteristics found in females. These characteristics can therefore be seen as differentiating characteristics between sex and district of origin of Bali cattle.

Key words: Bali cattle, Jambi, Phenotype.

INTRODUCTION

Bali cattle are a breed of livestock that has been purified and conserved (Diwyanto and Inounu 2009). Bali Province has been designated as the Bali cattle purification region. Bali cattle thrive and adapt outside of Bali Province (Matondang and Talib 2015) and it has been established that Bali cattle account for more than 60% of the cattle population in Jambi Province (Anonymous, 2011).

Due to the scarcity of male Bali cattle in Jambi Province, male Bali cattle are imported from the provinces of West Nusa Tenggara and Lampung for breeding, as well as artificial insemination. These strategies are thought to have influenced the diversity of the characteristics of Bali cattle (Srirattana *et al*., 2017). As a result, changes to specific characteristic such as color pattern (Mahmud 2014) and horn deformity (Nealm *et al*., 2014; Scheper *et al*., 2015) have occurred. Livestock rearing systems, particularly on small farms with uncontrolled crossbreeding, have a greater impact.

Bali cattle have qualitative characteristics that are similar to Bos javanicus and can be used to differentiate from other cattle breeds throughout the archipelago (Sujoatmodjo 1993; Mahdi and Wiyono 2013). Qualitative characteristic cannot always be used to measure the purity of Bali cattle (Setiawan *et al*., 2014); however, the deviation of qualitative phenotypic characteristic is an indication that cross breeding has occurred. Finding of specific qualitative phenotypic in one of the livestock rearing areas is one technique to differentiate these variations. The aim of this study is to characterize Bali cattle that have been created in Jambi Province's ex-situ environment in several rearing areas.

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How to cite this article: Hayanti, S.Y., Handiwirawan, E., Zubir, Bustami and Susilawati, E. (2022). Diversity of Qualitative Characteristics and Their Use to Distinguish the Origin of the Bali Cattle Population. Indian Journal of Animal Research. 56(8): 1041-1046. DOI: 10.18805/IJAR.BF-1417.

Submitted: 04-08-2021 **Accepted:** 26-10-2021 **Online:** 09-12-2021

MATERIALS AND METHODS

This study was conducted in the districts of Muaro Jambi (MJB), Sarolangun (SLG), Tanjung Jabung Timur (TJT), Jambi City (KJB) and PTPN VI in 2017. The survey site is working area of the Assessment Institute for Agricultural Technology of Jambi, Indonesia. The research material comprises 478 adult Bali cattle (125 males and 353 females).

Data collections

Qualitative variables observed and recorded were:

1. Sex, as 1= Male (JANTAN), 2= Female (BETINA).
2. Head color pattern, as 1= One color (Kp1wr), 2= Two colors mix (Kp2wr), 3= Three colors mix (Kp3wr), 4= Spots (Kptol).
3. Dominant head color, as 1= White (Kppt), 2= Light brown (Kpcomd), 3= Dark brown (Kpcotu), 4= Grey (Kpabu), 5= Black (Kpht).
4. Inner ear color, as 1= White (Tlpt), 2= Black (Tlht), 3= White and black (Tlptht), 4= Brown (Tlco).
5. Forehead color, as 1= Light brown (Dhcomd), 2= Dark brown (Dhcotua), 3= White (Dhpt), 4= Black (Dhht).
6. Lip edge color, as 1= White (Brpt), 2= Black (Bbht), 3= Brown (Bbco).
7. Horn shape, as 1= *Manggulgangsa* (Tdmgsa), 2= *Anoa* (Tdanoa), 3= *Congklok* (Tdcngkl), 4= *Pendang* (Tdpdg), 5= *Cono* (Tdcon), 6= *Bajeg* (Tdbajg), 7= Abnormal (Tdtdnrml).
8. Body color pattern, as 1= One color (Tb1wr), 2= Two colors mix (Tb2wr), 3= Three colors mix (Tb3wr), 4= Spots (Tbtol).
9. Dominant body color, as 1= Black (Tbht), 2= Dark brown (Tbcotu), 3= Light brown (Tbcomd).
10. Back line, as 1= Exist (Ada), 2= Does not exist (Tdada).
11. Under belly color, as 1= White (Prpt), 2= Black (Prht), 3= Dark brown (Prcotu), 4= Light brown (Prcomd).
12. Sock color, as 1= White (Kkpt), 2= White brown (Kkptco), 3= Grey (Kkabu), 4= Black (Kkht), 5= Brown (Kkco).
13. Rump color, as 1= White (Blpt), 2= Black (Blht), 3= Blackish white (Blptht), 4= Brownish white (Blptkeco).
14. Tail color, as 1= Black (Ekht), 2= White (Ekpt), 3= Light brown (Ekcomd), 4= Dark brown (Ekcotua).
15. Tail hair color, as 1= Black (Rbeht), 2= White (Rbept), 3= Light brown (Rbecomd).

Statistical analysis

The data was tabulated using Microsoft Office Excel 2016 software. The frequency and percentage of each qualitative trait were calculated using the PROC FREQ function of SAS software version 9.0 (2002), resulting in a cross-tabulation of the qualitative characteristics observed in Bali cattle at different locations. Then, for the qualitative characteristics, MCA between categorical variables was performed using PROC CORESP. The output data plotting that results depicts a graph of the relationship between the variable categories.

RESULTS AND DISCUSSION

Male Bali cattle in this study had a two-color pattern on their heads, while female Bali cattle had a three-color pattern, and both had a three-color pattern on their bodies (Fig 1A, B). Males and females have different color patterns (head and body) due to different sex-based color dominance for specific body parts. In general, animals have three basic color patterns for the body of black, red and white (Oslon 1999). Black color appearing in the head and body parts of males is caused by the dominant color carrier being for red and white in males, while in females red is codominant with white (Rolf 1999; Tabun, *et al*., 2013).

The analysis shows male and female Bali cattle there is similarity in the white color in the under lips, half of the inner ear, and white sock, as well as for the black back line (Fig 1 and 2). The formation of white color is caused by the

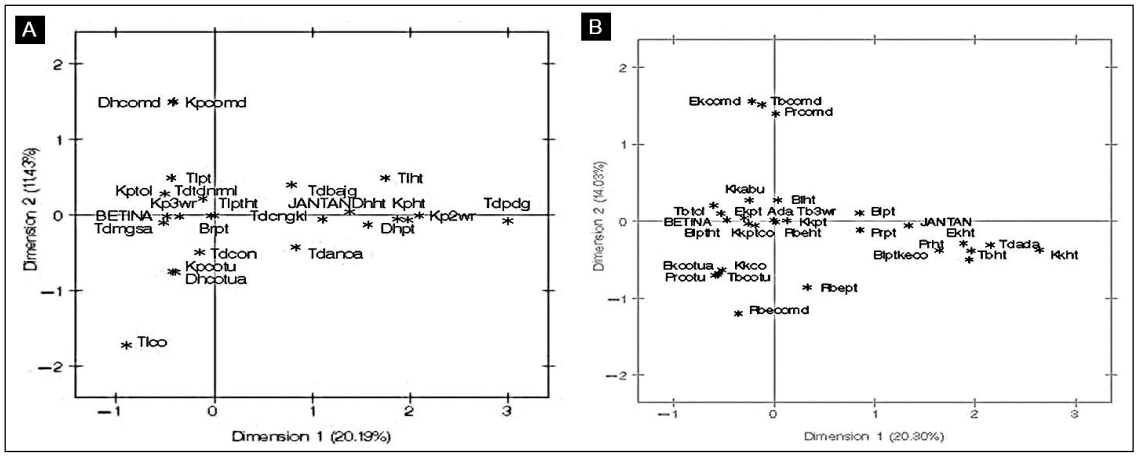

Fig 1: The relationship characteristic between sex with head phenotypic (A) and body phenotypic (B).

Tlpt= White ear, Tlht= White black ear, Tlco= Brown ear, Kp2wr= Two colors head, Kp3wr= Three colors head, Kptol= Spotty head, Kpcomd= Light brown head, Kpcotu= Dark brown head, Kpht= Black head, Brpt= White under lip edge, Dhcomd= Light brown forehead, Dhcotua= Dark brown forehead, Dhpt= White forehead, Dhht= Black forehead, Tdmgsa= *Manggulgangsa* horn, Tdanoa= *Anoa* horn, Tdcngkl= *Congklok* horn, Tdpdg= *Pendang* horn, Tdbajg= *Bajeg* horn, Tdtdnrml= Abnormal horn, Tb3wr= Three colors body, Tbtol= Spotty body, Tbht= Black body, Tbcotu= Dark brown body, Tbcomd= Light brown body, Ada= Backline exist, Tdada= No backline, Prpt= White belly, Prht= Black belly, Prcotu= Dark brown belly, Prcomd= Light brown belly, Kkpt= White socks, Kkabu= Grey socks, Kkht= Black socks, Kkco= Brown socks, Blht= Black back, Blpt= White back, Blptht= White black back, Blptkeco= White brown back, Ekht= Black tail, Ekpt= White tail, Ekcomd= Light brown tail, Ekcotua= Dark brown tail, Rbeht= Black tail hair, Rbept= White tail hair, Rbecomd= Light brown tail hair.

inhibition of melanocyte precursor-cell migration from the neural crest to specific parts of the body (Videira *et al*., 2013). White phenotype on lower lips, inner ears and feet and black backline are a normal signs (Charon and Lipka 2014). The characteristic of white lower lips and white feet as well as black back line on male and female Bali cattle in Jambi Province match the characteristics of Bali cattle specified (Anonymous 2010).

Female Bali cattle in Jambi Province exhibited qualitative characteristics that differed from those specified in the decree of Ministry of Agriculture of Republic Indonesia, characterized as brownish-white colored rump in female cattle but with a defined border (Fig 2). Other than this rump characteristic, gray, brownish-white, or brown socks can be found in female Bali cattle while in males, black socks are found instead. The color changes in Bali cattle in Jambi Province could be caused by the migration of melanocyte cells, which changes the color of previously white body parts (Seo *et al*., 2007; Videira *et al*., 2013). In a research conducted by Mansur *et al*. (2016), the formation of certain phenotypic characteristics of Bali cattle in Jambi Province can be expressed as a characteristic deviations. Deviating

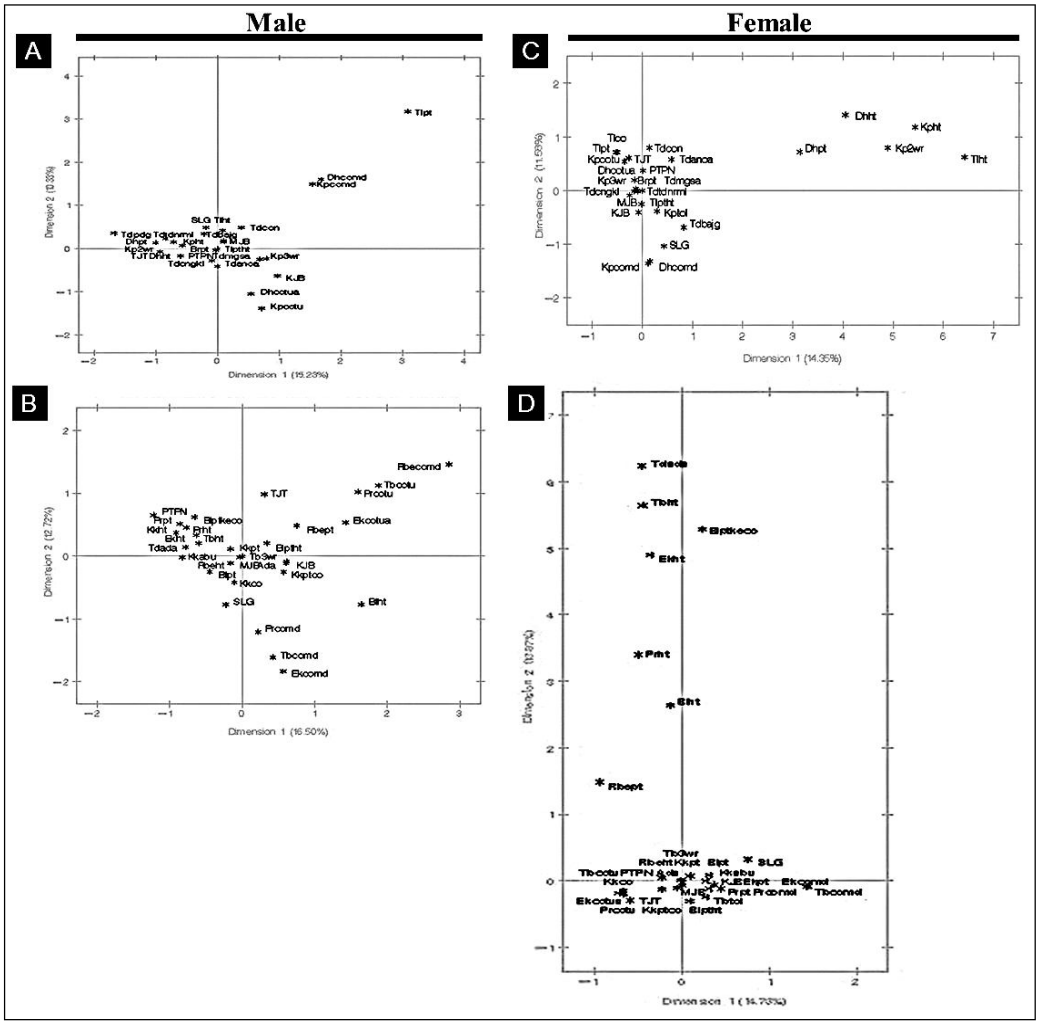

Fig 2: The relationship male and female between cow origin location with head and body phenotype.
(A, C)= Head, (B, D)= Body, SLG: Sarolangun, MJB: Muaro Jambi, KJB: Jambi City, TJT: Tanjabtim, PTPN: PTPN VI. Tlpt= White ear, Tlht= White black ear, Tlco= Brown ear, Tlptht= White-black ear, Kp2wr= Two colors head, Kp3wr= Three colors head, Kptol= Spots head, Kpht= Black head, Kpabu= Grey head, Kpcomd= Light brown head, Kpcotu= Dark brown head, Kpht= Black head, Brpt= White lower under lip, Dhcomd= Light brown forehead, Dhcotua= Dark brown forehead, Dhpt= White forehead, Dhht= Black forehead, Tdmgsa= *Manggulgangsa* horn, Tdanoa= *Anoa* horn, Tdcngkl= *Congklok* horn, Tdpdg= *Pendang* horn, Tdbajg= *Bajeg* horn, Tdtdnrml= Abnormal horn, Tb3wr= Three colors body, Tbht= Black body, Tbcotu= Dark brown body, Tbcomd= Light brown body, Ada= Back line exist, Tdada= Back line does not exist, Prpt= White belly, Prht= Black belly, Prcotu= Dark brown belly, Prcomd= Light brown belly, Kkpt= White socks, Kkptco= White brown socks, Kkabu= Grey socks, Kkht= Black socks, Kkco= Brown socks, Blpt= White rump, Blht= Black rump, Blptht= White black rump, Blptkeco= Brownish white rump, Ekht= Black tail, Ekcomd= Light brown tail, Ekcotua= Dark brown tail, Rbeht= Black tail hair, Rbept= White tail hair, Rbecomd= Light brown tail hair.

body color was also be found in other places, such as West Lombok (Sudrana *et al*., 2014).

Dominant body colors in male and female Bali cattle in Jambi Province were, respectively, black and light brown (Fig 1). According to Hardjosubroto (2004) and Purwantara *et al.* (2012), skin- and hair-phenotype change in male Bali cattle before and after adulthood is related to hormone. This agrees with research (Grymowicz *et al*., 2020) stating that hair-color change in male cattle is influenced by testosterone. Castration, which has no effect on body color, demonstrates the influence of testosterone on adult Bali cattle (Handiwirawan and Subandriyo 2004). The changing of body color into black in adult male Bali cattle causes the line on the back to not be visible (Fig 2). Some cattle breeds, such as Meghalaya State's native cattle, have a dark body color in bulls (Pundir *et al*., 2019).

Female Bali cattle, unlike males, had spots and black color patterns (Fig 2). Females with white spots are referred to as spotted cattle, while those with dark or black spots are referred to as Bali Injin cattle (Rahayu *et al*., 2009). Spotted pattern reflects a disturbance/discontinuation of melanocyte formation occurring in the hair and skin within the area of the spot (Rees 2003). Meanwhile, in female Bali cattle, black body color may be caused by DNA sequences which form eumelanin (Tabun *et al*., 2014).

The horn type in Bali cattle (Fig 1) is consistent with previous research into horn type and area of origin (Handiwirawan *et al*., 2003; Ris *et al*., 2012). One of the causes of sex differences in horn types is the expression of the RXFP2 gene, which is influenced by differences in INSL3 concentrations, which affect the growth of keratin to form horns (Allais-Bonnet *et al*., 2013). RXFP2 gene expression is linked to an increase in INSL3 production in male cattle during puberty (Pepe *et al*., 2009). The expression of this gene may be linked to male Bali cattle having larger diameter and length horns than females (Ris *et al*., 2012). However, no research has been conducted to explain the factors that influence the direction of horn development, resulting in the various horn phenotypes. Female Bali cattle have abnormal horns (Fig 1). Damage, such as broken horns, can be caused by a combination of impact strength and horn hardness, depending on the horn composition (Li *et al*., 2010).

Female Bali cattle have more characteristics than males in Jambi (Fig 2). Female Bali cattle have eleven distinct head characteristics, whereas males have only eight (Fig 2A, C). Male Bali cattle from SLG have the most distinguishing characteristics (5) when compared to those from other areas in terms of head characteristics (Fig 2A). Female Bali cattle from TJT, on the other hand, are the most distinct (5 characteristics) (Fig 2C).

Female Bali cattle have 12 differentiating characteristics based on body characteristics, whereas male Bali cattle only have eight (Fig 2B, D). Male and female Bali cattle from PTPN VI have the most distinct body characteristics, with 8 and 9 characteristics, respectively, when compared to male and female Bali cattle from other districts (Fig 2B, D). Because PTPN VI is a breeding site with a natural breeding system, it is expected to have a higher level of phenotypic diversity (Scheper *et al*., 2015). This means that using head or body characteristics to determine female sex is more likely. This is in line with the findings of Das *et al*. (2018), who discovered that sex influences differences in male and female cattle characteristics.

The similarities in phenotypic body characteristics between cows from MJB and other regions are thought to be the result of gene flow from MJB to other regions, as MJB is a source of Bali cattle for other regions (Fig 2B, D). MJB has the most population of any of the districts where Bali cattle samples were collected for this study (Anonymous 2011). This is consistent with Talib (2002) belief that Bali cattle from high-population areas have an impact on the quality of Bali cattle. Bali cattle migration between districts and from outside the province into Jambi Province influences the body characteristics of male and female Bali cattle (Gutiérrez-gil *et al*., 2007; Sutarno and Setyawan 2015). The environment influences body color changes in cattle (Seo *et al*., 2007; Heimbürge *et al*., 2020). This can result in qualitative differences between male and female body characteristics depending on the origin of the cattle. According to Singh *et al*. (2017), the environment can act as a triggering or restraining factor for qualitative phenotypic traits linked to genes, just as it has for quantitative phenotypic traits.

Conclusion

In Jambi Province, Indonesia, there are qualitative characteristics of Bali cattle that specifically correspond to sex and districts/cities of origin, which can be regarded as differentiating characteristics of Bali cattle for sex and location of origin. Female Bali cattle have more distinguishing features than male Bali cattle in both the head and the body.

Male Bali cattle from SLG have the most differentiating characteristics based on head characteristics, while male Bali cattle from PTPN VI have the most differentiating characteristics based on body characteristics. Female Bali cattle from TJT have the most distinguishing characteristics for the head, while those from PTPN VI have the most distinguishing characteristics for the body.

Acknowledgement

The author would like to thank Hasniarti and Kusningsih for their assistance during data collection in the field.

References

Allais-Bonnet, A., Grohs, C., Medugorac, I., Krebs, S., Djari A.S., *et al.* (2013). Novel insights into the Bovine polled phenotype and horn ontogenesis in Bovidae. PLOS ONE. 8(5): 1-14. DOI: 10.1371/journal.pone.0063512.

Anonymous, (2011). Livestock and Animal Health Statistics 2011. Ministry of Agriculture, Republic of Indonesia.

Anonymous, (2010). Determination of the Bali cattle. Ministry of Agriculture, Republic of Indonesia.

Charon, K.M., and Lipka, K.R. (2014). The effect of a coat colour-associated genes polymorphism on animal health-a review. Annals of Animal Science. pp. 1-28. DOI: 10.2478/aoas-2014-0066.

Das, S., Siddiqu, M.F., Ingle, V.S., Mishra, G. (2018). Physical and morphometric characterization of young Red Kandhari cattle in their breeding tract. Indian Journal Animal Research. 52(9): 1248-1252. DOI: 10.18805/ijar.B-3351.

Diwyanto, K. and Inounu, I. (2009). The impact of crossbreeding in the artificial insemination program on reproductive performance of beef cattle. WARTAZOA. 19(2): 93-102. DOI: 10.14334/wartazoa.v19i2.926

Grymowicz, M., Rudnicka, E., Podfigurna, A., Napierala, P., Smolarczyk, R., *et al*. (2020). Hormonal effects on hair follicles. International Journal Molecular Sciences. 21(5342): 1-13. DOI: 10.3390/ijms21155342.

Gutiérrez-gil, B., Wiener, P., Williams, J.L. (2007). Genetic effects on coat colour in cattle: Dilution of eumelanin and phaeomelanin pigments in an F2-Backcross Charolais × Holstein population. BMC Genetics. 8(56): 1-12. DOI: 10.1186/1471-2156-8-56.

Handiwirawan, E., Noor, R.R., Muladno., Schüler, L. (2003). The use of HEL9 and INRA035 microsatellites as specific markers for Bali cattle. Arch. Tierz., Dummerstorf. 46(6): 503-512. DOI: 10.5194/aab-46-503-2003.

Handiwirawan, E. and Subandriyo. (2004). Potency and genetic diversity of Bali cattle. WARTAZOA. 14(3): 50-60. DOI: dx.doi.org/10.14334/wartazoa.v14i3.802.

Hardjosubroto, W. (2004). Alternative policy in managing sustainable genetic resources of local beef cattle for national livestock breeding system. WARTAZOA. 14(3): 93-97. DOI: dx.doi.org/10.14334/wartazoa.v14i3.800.

Heimbürge, S., Kanitza, E., Tuchschererb, A., Otten, W. (2020). Within a hair's breadth-factors influencing hair cortisol levels in pigs and cattle. General and Comparative Endocrinology. 288(113359): 1-8. DOI: 10.1016/j.ygcen.2019.113359.

Li, B.W., Zhao, H.P., Feng, X.Q., Guo, W.W., Shan, S.C. (2010). Experimental study on the mechanical properties of the horn sheaths from cattle. The Journal of Experimental Biology. 213: 479-486. DOI: 10.1242/jeb.035428.

Mahdi, A. and Wiyono, H.T. (2013). Relationship Bali Cattle (*Bos sondaicus* Muller) and Banteng (*Bos bibosd'alton*) approach through the craniometric. Jurnal Ilmu Dasar. 14(2): 121-128.

Mahmud, A.T.B. (2014). Evaluation of the genetic purity of Bali cattle in Barru district using marker DNA microsatellite at the INRA 035 locus. Hasanuddin University, Makassar.

Mansur, M., Mahmud, A.T.B.A., Dagong, M.I.A., Rahim, L., Bugiwati, *et al*. (2016). Genetic diversity of Bali cattle in barru regency based on phenotype characteristics and microsatelite DNA identifier. JITP. 4(3): 104-111. DOI:10.20956/jitp.v4i3.1223.

Matondang, R.H. and Talib, C. (2015). Integrated Bali cattle development model under oil palm plantation. WARTAZOA. 25(3): 147-157. DOI: 10.14334/wartazoa.v25i3.1159.

Nealm, M., Batan, I.W., Suatha, I.K. (2014). The abnormal curvatura of horns in Bali cattle. Indonesia Medicus Veterinus. 3(2): 120-133.

Oslon, T.A. (1999). Genetics of Colour Variation. In the Genetics of Cattle. pp. 33-54. www.simmental.org/site/pdf/other/olsoncolor.pdf.

Pepe, A., Ferlin A., Gianesello, L., Facciolli, A., Agoulnik, A.I., Foresta, C. (2009). INSL3 plays a role in the balance between bone formation and resorption. Annals of the New York Academy of Sciences. 220: 219-220. DOI:10.1111/j.1749-6632.2008.03785.x.

Pundir, R.K., Singh, P. K., Dangi, P.S., Kumar, A., Borah, S., *et al*. (2019). Phenotypic characterization of indigenous cattle of Meghalaya State. Indian Journal Animal Research. 53(1): 59-62. DOI:10.18805/ijar.B-3466.

Purwantara, B., Noor, R.R., Andersson, G. (2012). Banteng and Bali Cattle in Indonesia/: Status and forecasts. Swedish Links Indonesia Symposia. 47: 2-6. DOI:10.1111/j.1439-0531.2011.01956.x.

Rahayu, S., Sumitro, S.B., Susilawati, T., Soemarno. (2009). The pattern of DNA amplification of Bali Injin cattle using a primer designed from the sry gen. Berk. Penel. Hayati. 3(b): 59-62.

Rees, J.L. (2003). Genetics of hair and skin color. Annu Rev. Genet. 37: 67-90. DOI:10.1146/annurev.genet.37.110801.143233.

Ris, A., Suatha, I., Batan, I.W. (2012). Variances of silak corn in female and male Bali cattle. Buletin Veteriner Udayana. 2(4): 87-93.

Rolf, M. (1999). Color patterns in crossbred beef cattle. The Oklahoma Cooperative Extension Service.

Scheper, C., Yin, T., König, S. (2015). Inclusion of Polled Geno- or Phenotype into Breeding Goals: Impact on Genetic Gain and Inbreeding. Procceding of the 66th Annual Meting of the European Federation of Animal Science.

Seo, K., Mohanty, T.R., Choi, T., Hwang, I. (2007). Biology of epidermal and hair pigmentation in cattle: A mini-review. Veterinary Dermatology. 18(6): 392-400. DOI:10.1111/j.1365-3164.2007.00634.x.

Setiawan, H., Ihsan, M., Dagong, A. (2014). Identification of genetic purity identification of genetic purity bali cattle in Bone Province using INRA035 locus mikrosatelite marker in Livestock Seminar Proceedings UNHAS, pp. 51-58.

Singh J., Singh V.K., Yadav A.K., Jha, A.K. (2017). Effect of genetic and non-genetic factors on age at first calving in Sahiwal cattle. Indian Journal Animal Research. 51(4): 635-639. DOI: 10.18805/ijar.8425.

Srirattana, K., McCosker, K., Schatz, T., St. John, J.C. (2017). Cattle phenotypes can disguise their maternal ancestry. BMC Genetics. 18(59): 1-11. DOI: 10.1186/s12863-017-0523-5.

Sudrana, I.P., Lestari, Jan, R., Rozy, T., Kasip, L.M. (2014). The other colour patern of Bali cattle in west Lombok regency. Jurnal of Research UNRAM. 18(1): 54-63.

Sujoatmodjo, M. (1993). Tracing the origin of Bali cattle using cytogenetic analysis methods. Hemera Zoa. 76(2): 40-44.

Sutarno and Setyawan, A.D. (2015). Review: Genetic diversity of local and exotic cattle and their crossbreeding impact on the quality of Indonesian cattle. Biodiversitas. 16(2): 327-354. DOI: 10.13057/biodiv/d160230.

Tabun, A.C., Hartatik,T., Sumadi, Volkandari, S.D., Suwandi, *et al*. (2014). Sequencing the Melanocortin 1 Receptor (MC1R) Gene in Kupang Female Bali Cattle. Proceedings of the 2nd National Science and Technology Seminar UNDANA, pp. 1-5.

Tabun, A.C., Hartatik, T., Sumadi. (2013). Identification of melanocortin 1 receptor (mc1r) gene based on coat color of Bali cows of Kupang by using the PCR-RFLP method. J. Indonesian Trop. Anim. Agric. 38(2): 86-91. DOI:10.14710/jitaa. 38.2.86-91.

Talib, C. (2002). Bali cattle in the breeding stock areas and their future development. WARTAZOA. 12(3): 100-107. DOI: 10.14334/wartazoa.v12i3.762.

Videira, I.F. dos S., Moura, D.F.L., Magina, S. (2013). Mechanisms regulating melanogenesis. An Bras Dermatol. 88(1): 76-83. DOI: 10.1590/S0365-05962013000100009.