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Assessment of coat colour variation and its effect on early growth and male fertility traits in the Kenya Boran cattle

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Abstract
Coat colour mediates and determines the extent of heat load on the animal with light coloured animals reflecting back most of the sun's heat hence less heat load and stress. On the other hand, dark coloured coats absorb more energy than the light coloured coats hence the former are likely to have higher thermal stress. The Kenyan Boran breed of cattle is characterized by a wide range of colours which include white, grey, golden, brown and red coat colours. However, the performance of different coat colour in terms of early growth and male fertility traits has not been determined. The objective of this study was therefore to assess coat colour variation and evaluate their effects on early growth and male fertility traits. The research was conducted on Kenyan Boran breed kept at Beef Research Institute (BRI) Lanet. Data collected included information on the animal's identity, coat colour, pedigree, parity, date of birth and weaning, birth weight, weaning weight, pre-weaning average daily gain and scrotal circumference, length and width. Genetic variance and heritability estimates were determined using probit mixed model and generalized linear mixed model. Variation in coat colour was evaluated using general linear model. Results revealed mean birth weight, weaning weight, average daily gain, scrotal circumference, width and length of 24.51 kg, 138.37 kg, 0.51 kg/day, 14.45 cm, 7.65 cm and 8.52 cm, respectively. Year of birth was significant for growth and male fertility traits ($p<0.001$) Season of birth had a significant effect on weaning weight and average daily gain ($p<0.05$). Colour of calf had a significant effect on average daily gain and scrotal circumference ($p<0.05$). Brown and white calves had faster growth rates compared to red calves whereas brown calves had larger scrotal circumference than white and mottled calves. Colour of dam of calf influenced birth weight, weaning weight and average daily gain significantly ($P<0.05$) where red dams gave birth to light calves but had higher weaning weight and pre-weaning daily gain compared to brown and white dams. Dam weight at birth significantly ($p<0.05$) influenced birth weight and average daily gain whereas weaning age had a significant effect on weaning weight. The significant effect of coat colour of calf or dam on growth and male fertility traits should be accounted for when estimating performance of animals in beef cattle.

Keywords: Coat colour, male fertility traits, Kenya Boran cattle

1. Introduction

The Kenyan Boran cattle is a *Bos indicus* breed kept primarily by pastoral and agro-pastoral communities for beef, subsistence milk production and traction in the ASALs of the country (Rewe *et al.*, 2009; Mutembei *et al.*, 2015) [36, 28]. The breed's genetic make-up comprises a complete blend of the founding genotypes, namely the local Zebu (*Bos indicus*) (64%), near East-European *Bos taurus* (24%) and native African *Bos taurus* (12%) (Abin, 2014) [3]. The Kenyan Boran breed of cattle is characterized by a wide range of colours that include white, grey, golden, brown and red coat colours (Haile *et al.*, 2011) [19]. Animal's coat colour is an adaptive trait of great importance as it affects their behaviour, existence and performance in different environments with varying climatic conditions (Ahmed *et al.*, 2015, Koseniuk *et al.*, 2018) [5, 23]. This is because an animal's ability to maintain body temperature or dissipate excessive heat to the surrounding environment depends on the morphological characteristics of hair coat (Mcmanus *et al.*, 2011) [26]. As solar radiation lands on the coat, coat colour mediates and determines the extent of heat load on the animal. The coat colour of an animal has been directly related to the amount of solar radiation that is absorbed or reflected, and therefore the heat exchange between the animal and the surrounding environment (Abdoun *et al.*, 2013) [1].

In zones of extreme temperatures, animals with dark coloured coats absorb more energy than the light coloured coats hence the former are likely to have higher thermal stress.
Heat stress leads to decreased growth, production and reproduction, compromises immunity making animals susceptible to diseases and may even result in animal's death (Sarangi, 2018) [38], and negatively affects milk quantity and quality (Pragna *et al.,* 2017) [33]. Many studies have demonstrated the importance of coat colour in influencing livestock performance in tropical zones, especially ASALs (Ahmed *et al.,* 2015; Decampos *et al.,* 2013; Foster, 2009) [5, 13, 15]. A study on heat tolerance traits of extensively reared goats of different coat colours revealed that white goats are more tolerant compared with goats of other coat colours (Adedeji, 2012) [4]. Cattle with lighter and thinner coats presented higher milk yields compared to their darker counterparts among the Tharparkar breed in India (Prabhakar *et al*., 2018) [32].
Genetic parameter estimates are essential for the implementation of breeding programmes as well as in assessing the progress of ongoing programmes (Liu *et al.,* 2016) [24]. Traits of economic importance in animals are of great concern to a breeder. Such characters are controlled by genes carried by the animal coupled with environmental effects (Baye *et al.,* 2011) [9]. The traits that are considered in beef cattle breeding programmes mainly include production and reproduction traits. Heritability and variance components of these traits have been evaluated forming the basis of current breeding programmes. However, health, management, adaptation and fitness traits are gaining significant consideration in the current breeding programmes.
Animal's coat colour is a fitness and adaptive trait that suits different animal species to the environment through camouflage, thermal adaptation and for aesthetics. Genetic parameter estimates for coat colour have been investigated in some species and the estimates varied from low through a medium to high heritability (Kasarda *et al.*, 2016; Prayaga *et al.*, 2009) [21, 35]. The wide range of heritability estimates confirms the complexity with which coat colour is inherited. The original Boran cattle from which the current breed was derived were white-grey in colour (Okeyo *et al.*, 2005) [30]. However, over time and through selection for improvement in growth and milk production performance, a wide range of colours aforementioned to date exist, all of which are accepted by the Kenyan Boran Cattle Breeders Society (BCBS). The genetic extent of this variation and its genetic parameters are unknown. The current study therefore envisaged to unravel the current scope of coat colour variation, variance components and the heritability estimates of the Kenyan Boran cattle to enable its inclusion in developing breeding programmes.

2. Methodology
2.1 Data source
The research was conducted in Beef Research Institute (BRI) Lanet, situated in Nakuru county of Kenya. The Institute is legally mandated with breeding and maintenance of an elite nucleus of the Kenyan Boran breed. Cattle were raised on natural pasture and kept in pasture fields throughout the day. Cow-calf system was practiced and weaning was done at seven months. Selection of breeding animals was done at weaning and at 24 months based on physical appraisal of growth performance and conformation. Natural mating was practiced. The best heifers in terms of performance and conformation were put in stud herds as a replacement while good heifers were put to commercial herds to breed stock for sale and slaughter. Animals with poor conformation contrary to Boran Cattle Breeders Society's (BCBS) standards were culled.

2.2 Data Collection
The performance records belonged to 1845 Kenyan Boran cattle born between 1999 to 2021. Data collected included information on the animal's identity, animal's coat colour, pedigree, date of birth and weaning. For each animal, coat colour was classified into red, brown, mottled, grey or white. Information on each animal in the 5 colour groups included identification number, calving date, age at first calving, birth and weaning weight. Included also was date of birth, date of weaning and parity.

2.3 Data Analysis
2.3.1 Effect of fixed factors on performance
Traits studied included birth weight, weaning weight, pre-weaning average daily gain and scrotal circumference, length and width. Variation in coat colour was assessed using general linear model procedures using SAS software. The model equation was:

$$Y_{ijklm} = \mu + x_i + a_j + s_k + m_l + e_{ijklm}$$

Where Y_{ijklm} = trait studied; μ = overall population mean value; x_i = effect of ith sex; a_j = effect of jth age; s_k = effect of kth season of birth; m_l = effect of lth year of birth and e_{ijklm} = error

2.3.2 Estimation of genetic parameters for coat colour
Genetic variance and heritability estimates were determined by use of probit mixed model. A generalized linear mixed model was used with probit link to model the outcomes. The general form of the model was:

$$\Pr\left(Y_{ijklm} = 1\right) = \theta\left(\mu + a_i + b_j + c_k + s_l + d_m + e_{ijklm}\right)$$

Where $\Pr\left(Y_{ijklm} = 1\right)$ denotes the probability of animal's coat colour phenotype, θ is the cumulative normal distribution function, which is the probit link between the linear predictor on the right-hand side to the probability for a specific outcome on the left-hand side, μ is a fixed model-intercept, a_i is the fixed effect of sex *i*, b_j is the fixed effect of age *j*, c_k is the fixed effect of season *k*, s_l is the random effect of sire *l*, d_m is the random effect of dam *m* and e_{ijklm} is the random residual error.
Random effects were collected in vectors to specify the variance covariance structure. These vectors, all sire and dam effects (vector u) and all residual errors (vector e) were inserted in the following matrix:

$$\begin{bmatrix} A\sigma_u^2 & 0 \\ 0 & I \end{bmatrix}$$

Where A was numerator-relationship matrix between sires and dams, I was the identity matrix and σ_u^2 was variance components associated with parental effects. Heritability was computed using variance component estimated from parental effects using the following formula:

$$\frac{4\sigma_u^2}{2\sigma_u^2 + 1}$$

This is because parental effects models only ¼ of genetic variance (hence the need to multiply by 4) and this was divided by the total variance. Genetic variances and heritability were evaluated for all the colors.

3. Results

The mean birth weight, weaning weight, average daily gain, scrotal circumference, width and length were 24.51 kg, 138.37 kg, 0.51 kg/day, 14.45 cm, 7.65 cm and 8.52 cm, respectively (Table 1). Year of birth was significant for growth and male fertility traits ($p<0.001$) (Table 1) whereas season of birth had a significant effect on weaning weight and average daily gain ($p<0.05$). Colour of calf had a significant effect on average daily gain and scrotal circumference ($p<0.05$). On the other hand, colour of dam of calf influenced birth weight, weaning weight and average daily gain significantly ($p<0.05$). Dam weight at birth significant influenced birth weight and average daily gain whereas weaning age had a significant effect on weaning weight (Table 1).

Table 1: Effect of fixed factors on juvenile growth traits in Kenyan Boran

	Trait					
Effect	**Birth weight, kg**	**Weaning weight, kg**	**ADG, kg/day**	**SC, cm**	**SW, cm**	**SL, cm**
Sex	ns	***	**	-	-	-
Year of birth	***	***	***	***	***	***
Month of birth		***		ns	*	*
Colour of calf	ns	ns	***	*	ns	ns
Colour of dam	*	**	**	ns	ns	ns
Dam weight at birth	*	ns	**	-	-	-
Dam weight at weaning	-	ns	ns	-	-	-
Weaning age	-	*		-	-	-
Parity	ns	ns	ns	ns	ns	ns
R^2	0.11	0.39	0.48	0.54	0.35	0.16
Mean	24.51	138.37	0.51	14.45	7.65	8.52
CV, %	10.19	17.40	28.59	20.94	31.56	52.25

Ns=Not Significant; *, ** and *** mean that the effect was significant at $p<0.05$, 0.01 and 0.001, respectively; SC=scrotal circumference; SL=scrotal length and; SW=scrotal width; ADG=pre-weaning daily gain

Least square means for growth and male fertility traits for each coat colour category are given in Table 2. In the analysis of coat colour, white animals accounted for 17.8% of the population, while grey, brown and red colored animals were 44.9%, 26.5% and 10.7%, respectively. The body weight at birth, weaning and scrotal circumference, width and length associated with different coat colour types are also shown in Table 2. White calves were significantly heavier at birth ($p<0.05$) compared to brown and red calves which had similar birth weights. At weaning, coat colour of calf did not influence body weight ($p>0.05$). At weaning, white and brown calves had similar body weights which were significantly higher ($p<0.05$) than that of red calves. Coat colour of calf had no effect on scrotal characteristics ($p>0.05$). To investigate the interaction between coat colour of dam and that of the calf, least square means for different colour combinations of the dam and calf were estimated.

Table 2: Least square means ± standard error for growth traits for different coat colours of calves and dams in Kenya Boran Cattle.

Trait	Birth weight, kg	Weaning weight, kg	ADG, kg/day	SC, cm	SL, cm	SW, cm
Colour of calf						
White	22.76±0.89	149.12±8.7	0.61±0.05[a]	8.18±1.14	14.63±0.78	8.01±0.62
Brown	23.18±0.88	151.00± 8.6	0.62±0.05 [a]	8.42±1.15	15.13±0.78	7.75±0.62
Red	23.42±0.89	148.00±8.8	0.54±0.05 [b]			-
Mottled	-	-	-	8.23±1.15	16.69±1.02	8.45±0.82
Colour of dam						
Brown	23.58±0.85[a]	152.27±8.29[a]	0.59±0.05[a]	8.25±0.77	15.39±0.52	7.09±0.42
Mottled	22.50±1.09[a]	133.82±10.40[b]	0.51±0.06 [b]	8.04±1.67	15.05±1.13	8.15±0.90
Red	22.77±0.91[b]	159.04±9.04[a]	0.67±0.06 [c]	-	-	-
Grey	-	-	-	8.07±3.32	16.15±2.26	10.22±1.80
White	23.67±0.86[a]	152.32±8.42[a]	0.60±0.05[a]	8.76±0.85	15.32±0.58	6.83±0.46
Colour of dam x calf						
Brownbrown	22.9±0.9 [a]	162.7±9.2				
BrownRed	23.9±1.1 [a]	151.0±11.7				
BrownWhi	23.1±1.0 [a]	160.6±9.3				
Mottled	22.2±1.1 [a]	143.4±11.1				
RedBrown	23.6±1.0 [a]	148.8±9.5				
RedRed	22.7±1.0 [a]	165.5±9.6				
RedWhite	24.5±1.1 [b]	176.7±11.1				
WhiteBro	22.6±1.0 [a]	159.6±9.3				
WhiteRed	22.7±1.1[a]	167.4±10.9				
whitewhite	22.5±1.0 [a]	158.9±9.4				

Within column, means with different superscript are different at $p<0.05$; SC=scrotal circumference; SL=scrotal length; SW=scrotal width; adg=pre-weaning daily gain

White calves born of red dams had significantly heavier birth weight ($p<0.05$) than calves born all the other dams, whereas brown calves of red dams were significantly heavier ($p<0.05$) than red calves born of red dams. Brown red calves were significantly heavier than red-white calves ($p<0.05$). For weaning weight, white calves born of red dams had the highest weaning weight (176.7±11.1), which was significantly different ($p<0.05$) all the other dam-calf colour combinations but was similar to red calves of white dams (167.4±10.9) and red calves of red dams (165.5±9.6). White calves had higher significantly higher weight ($p<0.05$) at weaning and yearling compared to brown and red calves. However, coat colour did not have any effect on birth weight (P>0.05). The phenotypic for coat colour for the Kenyan Boran was 3.74 with the genetic variance being 1.67 and a residual variance of 2.07. The heritability estimate was 0.53±0.11.

4. Discussion

Coat colour in cattle has been shown to influence body weight, body condition score and thermos-physiological variables (Katiyatiya *et al.*, 2017; Prayaga *et al.*, 2009) [22, 34]. In the present study, brown or red calves performed better than grey, white or mottled calves for birth, weaning, and pre-weaning daily gain traits. In a study among Boran and Nguni cattle in South Africa, red animals were also reported to have higher body weight, body condition scores, whereas white-red cattle had the highest rectal temperature or neck temperatures and higher body weights than light coloured animals, (Gwelo *et al.*, 2015; Katiyatiya *et al.*, 2017) [18, 22]. Heavy body weight under high ambient temperatures as the case in the hot tropics and ASALs may be a disadvantage under conditions of elevated temperatures because heavier animals have the tendency of losing heat at a lower rate due to reduced surface area (Castanheira *et al.*, 2010) [12]. Light coat coloured cattle tend to have longer grazing behaviour and subsequently, growth (Giblert & Bailey, 1991) [17]. Other studies have reported effect of coat colour on reproductive performance, physiological variable and milk yield in Holstein cows (Anzures-Olvera *et al.*, 2019; Isola *et al.*, 2020) [6, 20].
Heritability of coat colour in the current study based on an ordinal scale of 1=white to 5=red was found to be 0.52±0.11 and high like that of 0.61±0.12 reported by Prayaga *et al.* (2009) [35]. Other studies based on a similar scoring method reported estimates ranging from 0.42 to 0.61 for tropical cattle (Burrow, 2001; Prayaga & Henshall, 2005) [11, 34] and boxer dogs (Nielen *et al.*, 2001) [29]. Heritability estimates for coat colour in cattle have also been reported on the C*a*b* scale (Kasarda *et al.*, 2016) [21]. This scale measures the inheritance of the lightness of colour, shade and saturation. For the Slovak Pinzgau cattle, heritability of lightness, shade and saturation was reported to be 0.24, 0.57 and 0.17, respectively. Coat colour is recognized to be under the control of a few major genes (Olson, 1999) [31] with moderate heritability.
Acute heat stress has a negative effect on the cow's well-being. In response to environmental stresses such as heat stress, animals change their physiology through higher heart, breathing and respiration rates, increased sweating, increased core body temperature as well as other metabolic and endocrine-system changes which are important to well-being and productivity (Wheelock *et al.*, 2010) [40]. Sustained high ambient temperatures increase beyond an animal's comfort zone leads to impaired feed intake (Wheelock *et al.*, 2010) [40], post-pradial partitioning of nutrients (Baumgard & Rhoads, 2013) [8], metabolism (Rhoads *et al.*, 2009) [37], reduction in milk yield (Bohmanova *et al.*, 2007; West *et al.*, 2003) [10, 39] and milk components (Garner, 2017) [16], poor reproduction (Mellado *et al.*, 2013) [27] and reduced growth (López *et al.*, 2017) [25]. The current study has demonstrated significant differences between coat colours for birth and weaning weight and average daily gain. This means that among other mitigating strategies, coat colour of the dam or animal can therefore be used to modulate performance in beef cattle. The ability of an animal to adapt to environmental conditions influences its heat tolerance capabilities (Barbosa *et al.*, 2014) [7]. The Light or grey coloured animals are able to reflect 50% to 60% of direct solar radiation compared to darker animals (Abdulrahman *et al.*, 2019; Degafa, 2016) [2, 14] granting them an advantage in the hot tropics.

5. Conclusion

Coat colour of calf had a significant effect on average daily gain and scrotal circumference at weaning whereas coat colour of dam significantly influenced birth weight, weaning weight and average daily gain. Calves with brown or white coat colour had faster growth rates compared to red calves. Brown calves has significantly larger scrotal circumference than white and mottled calves. Calves born of red dams had significantly lower birth weight and higher weaning weight and pre-weaning daily gain. Therefore, coat colour of calf or dam need be considered when mitigating heat stress and estimating performance and male fertility in Kenyan Boran cattle.

6. References

1. Abdoun KA, Samara EM, Okab AB, Al-Haidary AA. The relationship between coat colour and thermoregulation in dromedary camels (*Camelus dromedarius*). Journal of Camel Practice and Research. 2013;20(2):251-255.
2. Abdurehman A. Physiological and anatomical adaptation characteristics of Borana cattle to pastoralist lowland environments. Asian Journal of Biological Science. 2019;12:364-372.
3. Abin SA. Animal recording as a tool for improved genetic management in African beef cattle breeds, MSc thesis in Animal Breeding and Genetics, University of Pretoria, South Africa; c2014. p. 106.
4. Adedeji TA. Effect of some qualitative traits and non-genetic factors on heat tolerance attributes of extensively reared West African Dwarf (WAD) goats. International Journal of Applied Agriculture and Apiculture Research. 2012;8(1):68-81.
5. Ahmed A, Tiwari RP, Mishra GK, Jena B, Dar MA, Bhat AA. Effect of environmental heat stress on reproduction performance of dairy cows: A review. International Journal of Livestock Research. 2015;5(4):10-18.
6. Anzures-Olvera F, Véliz FG, De Santiago A, García JE, Mellado J, Macías-Cruz U. The impact of hair coat color on physiological variables, reproductive performance and milk yield of Holstein cows in a hot environment. Journal of Thermal Biology. 2019;81:82-88. https://doi.org/10.1016/j.jtherbio.2019.02.020
7. Barbosa BRS, Santos SA, Abreu UGP, Egypt AA, Comastri Filho JA, Julian RS, *et al.* Heat tolerance in Nellore white, red and Nellore Pantaneira breeds in the Pantanal region, Brazil. Rev Brasileira Saúde Producao Animal. 2014;15:854-865.

8. Baumgard LH, Rhoads RP. Effects of heat stress on post absorptive metabolism and energetics. Annual Review of Animal Biosciences. 2013;1:311-337.
9. Baye TM, Abebe T, Wilke RA. Genotype–environment interactions and their translational implications. Personalized Medicine. 2011;8(1):59-70.
10. Bohmanova J, Misztal I, Cole JB. Temperature-humidity indices as indicators of milk production losses due to heat stress. Journal of Dairy Science. 2007;90:1947-1956.
11. Burrow HM, Moore SS, Johnston DJ, Barendse W, Bindon BM. Quantitative and molecular genetic influences on properties of beef. Australian Journal of Experimental Agriculture. 2001;41:893-919.
12. Castanheira M, Paiva ST, Louvandini H, Landim A, Fiorvanti MCS, Dallago BS, *et al.* Use of heat tolerance traits in discriminating between groups of sheep in central Brazil. Tropical Animal Health and Production. 2010;42:1821-1828
13. Decampos JS, Ikeobi CO, Olowofeso O, Smith OF, Adeleke MA, Wheto M, *et al.* Effects of coat colour genes on body measurements, heat tolerance traits and haematological parameters in West African Dwarf sheep. Open Journal of Genetics. 2013;3(4):280.
14. Degefa T. Ovarian follicular dynamics, super-ovulatory response, and *in vivo* embryo production potential of Boran (Bosindicus) and Boran *Holstein cross cattle in Ethiopia. Ph.D. Dissertation, FVM, Addis Ababa University; c2016. p. 93.
15. Foster LA, Fourie PJ, Neser FWC. Effect of heat stress on six beef breeds in the Zastron district: The significance of breed, coat colour and coat type. South African Journal of Animal Science. 2009;39(1):224-228.
16. Garner JB, Douglas M, Williams SRO, Wales WJ, Marett LC, DiGiacomo K, *et al.* Responses of dairy cows to short-term heat stress in controlled-climate chambers. Animal Production Science. 2017;57:1233-1241.
17. Gilbert RP, Bailey DR. Hair coat characteristics and post weaning growth of Hereford and Angus cattle. Jornal of Animal Science. Journal of Animal Science. 1991;69(2):498-506
18. Gwelo AF, Tefera S, Muchenje V. Temporal and spatial dynamics of mineral levels of forage, soil and cattle blood serum in two semiarid savannas of South Africa. African Journal of Range Forage Science. 2015;32:279-287.
19. Haile, A. Breeding strategy to improve Ethiopian Boran cattle for meat and milk production. ILRI (ILCA and ILRAD). 2011;26.
20. Isola JVV, Menegazzi G, Busanello M, Dos Santos SB, Agner HSS, Sarubbi J. Differences in body temperature between black-and-white and red-and-white holstein cows reared on a hot climate using infrared thermography, Journal of Thermal Biology; c2020. DOI: https:// doi.org/10.1016/j.jtherbio.2020.102775.
21. Kasarda R, Šidlová V, Pavlík I, Moravčíková N, Kadlečík O. Inheritance of coat colour in Slovak Pinzgau cattle. Journal of Central European Agriculture. 2016;17(1):48-55.
22. Katiyatiya CLF, Muchenj V. Hair coat characteristics and thermo physiological stress response of Nguni and Boran cows raised under hot environmental conditions. International Journal of Biometeorology. 2017;61:2183-2194. DOI: 10.1007/s00484-017-1424-z
23. Koseniuk A, Ropka-Molik K, Rubiś D, Smołucha G. Genetic background of coat colour in sheep. Archives Animal Breeding. 2018;61(2):173-178.
24. Liu, F, Yang Y, Li Y, Guo H, Dai H, Gao J, *et al.* Phenotypic and genetic parameter estimation of juvenile growth and bottom color traits in half-smooth tongue sole, *Cynoglossus semilaevis*. Acta Oceanologica Sinica. 2016;35(10):83-87.
25. López E, Mellado M, Martínez AM, Véliz FG, García JE, De Santiago A, *et al.* Stress-related hormonal alterations, growth and pelleted starter intake in pre-weaning Holstein calves in response to thermal stress. International Journal of Biometeorology. 2017;62:493-500.
26. McManus C, Louvandini H, Gugel R, Sasaki LCB, Bianchini E, Bernal FEM, *et al.* Skin and coat traits in sheep in Brazil and their relation with heat tolerance. Tropical Animal Health and Production. 2011;43(1):121-126.
27. Mellado M, Sepulveda E, Meza-Herrera C, Veliz F, Arevalo J, Mellado J, *et al.* Effects of heat stress on reproductive efficiency of high yielding Holstein cows in a hot-arid environment. Revista Colombiana de Ciencias Pecuarias. 2013;26:193-200.
28. Mutembei HM, Tsuma VT, Muasa BT, Muraya J, Erastus R.M. Bovine *in vitro* embryo production and its contribution towards improved food security in Kenya. African Journal of Food, Agriculture, Nutrition and Development. 2015;15(1):9722-9743.
29. Nielen, AL, Janss LL, Knol BW. Heritability estimations for diseases, coat color, body weight, and height in a birth cohort of Boxers. American Journal of Veterinary Research. 2001;62(8):1198-206.
DOI: 10.2460/ajvr.2001.62.1198. PMID: 11497438.
30. Okeyo AM, Mosi RO, Rege JE. Coat Colour: Its Relevance and Influence on Reproductive and Production Performance in Boran Cows. Kenya Veterinarian. 2005;28(1):37-45.
31. Olson TA, Chase Jr CC, Lucena C, Godoy E, Zuniga A, Collier RJ. Effect of hair characteristics on the adaptation of cattle to warm climates. Instituto Proci Ncia; c2006. p. 16–07.
32. Prabhakar A, Rashid SA, Tomar AKS, Channa GP. Effect of coat characteristics on milk production and milk composition traits in Tharparkar cattle. Journal of Entomology and Zoology Studies. 2018;6(5):939-941.
33. Pragna P, Archana PR, Aleena J, Sejian V, Krishnan G, Bagath M, Bhatta R. Heat stress and dairy cow: impact on both milk yield and composition. International Journal of Dairy Science. 2017;12(1):1-11.
34. Prayaga KC, Henshall JM. Adaptability in tropical beef cattle: genetic parameters of growth, adaptive and temperament traits in a crossbred population. Australian Journal of Experimental Agriculture. 2005;45:971-983.
35. Prayaga KC, Corbet NJ, Johnston DJ, Wolcott ML, Fordyce G, Burrow HM. Genetics of adaptive traits in heifers and their relationship to growth, pubertal and carcass traits in two tropical beef cattle genotypes. Animal Production Science. 2009;49(6):413-425.
36. Rewe TO, Herold P, Kahi AK, Zárate AV. Breeding indigenous cattle genetic resources for beef production in Sub-Saharan Africa. Outlook on Agriculture. 2009;38(4):317-326.
37. Rhoads, ML, Rhoads RP, VanBaale MJ, Collier RJ, Sanders SR, Weber WJ, *et al.* Effects of heat stress and

plane of nutrition lactating Holstein cows, I Production, metabolism, and aspects of circulating somatotropin. Journal of Dairy Science. 2009;92:1986-1997.
38. Sarangi S. Adaptability of goats to heat stress: A review. The Pharma Innovation Journal. 2018;7:1114-1126.
39. West JW, Mullinix, BG, Bernard, J. K. Effects of hot, humid weather on milk temperature, dry matter intake, and milk yield of lactating dairy cows. Journal of Dairy Science. 2003;(86):232-242.
40. Wheelock JB, Rhoads RP, VanBaale MJ, Sanders SR, Baumgard LH. Effects of heat stress on energetic metabolism in lactating Holstein cows. Journal of Dairy Science. 2010;93:644-655.