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Comparison of Growth Traits of Male Bali Cattle (*Bos javanicus*) with Different Adult Coat Colors

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ABSTRACT

Bali cattle have a distinct coloration that indicates the sexual dimorphism of adult cattle. However, coat color deviations are found in bulls due to either genetic impurity or inbreeding. Furthermore, information is needed to determine whether there is a relationship between coat color and cattle performance. This study aimed to evaluate the potential association between coat color deviation and the growth traits of male Bali cattle. A total of 99 adult male Bali cattle from Livestock Breeding and Forage Centre (BPTU) Denpasar, Bali, were used in this study to assess the possible association between coat color and growth capacity. Animals were grouped according to color patterns into full black (FBL), faded black (FDB), black sorel (BSR), and sorel (SRL). Periodically, growth traits of body weight (BW), wither height (WH), body length (BL), and chest circumference (CC) were measured at birth, weaning, and 365 and 730 days of age. The repeated measurement Anova analysis was used to evaluate the relation between coat color and growth traits over time. This study showed no correlation for both traits in calves due to the absence of color deviation in age. However, it turned out to be a significantly positive correlation ($p<0.05$) when Bali cattle reached puberty at 365 and 730 days. The black adult bulls (FBL & FDB) were significantly larger in growth traits ($p<0.05$) than their brown (BSR and SRL) counterparts. The coat color of male adult Bali cattle was associated with their growth traits.

Keywords: aberrant coat color; Bali cattle; full black; sexual dimorphism

INTRODUCTION

Eastern Indonesia's beef cattle population is dominated by Bali cattle, with South Sulawesi, East Nusa Tenggara, and West Nusa Tenggara hosting more Bali cattle than anyplace else in the world. Bali cattle farms can also be found in Malaysia, the Philippines, and Australia (Nijman *et al.*, 2003; Bradshaw *et al.*, 2006; Mohamad *et al.*, 2009). Bali cattle are widely reared and spread in tropical regions since they have advantages in heat tolerance, feed efficiency, meat quality, fair fertility, and low mortality (Purwantara *et al.*, 2012; Rahayu, 2014). For decades, there has been a growing tendency toward categorizing animals into distinct breeds, relying on their unique coat colors and patterns (Dreger *et al.*, 2019). Therefore, coat color and pattern were subjected to intense selection and became an identity of breeds (Gouveia *et al.*, 2014). The standard coat color for purebred adult male Bali cattle is black. However, more than 17% of Bali cattle exhibit abnormal color distortion, such as albino and *poleng* (Lindell, 2013). The finding of color deviation among Bali cattle varies in sorel (like a female), roan, and white spotted (Tabun *et al.*, 2013; Tabun *et al.*, 2022). This color distortion might be caused by inbreeding or genetic contamination. Intensive random crossing of breeds without keeping pedigree records results in a flood of crossbred calves with strange patterns and coat colors.

Bali cattle have sexual dimorphism (SD) in their coat color, completely separate for males and females (Hayanti *et al.*, 2021; Dahlanuddin *et al.*, 2014). The mane of lions, the dorsal crest of boars, the beard of baboons and humans, and the coat color of male Bali cattle are simply a couple of examples of sexual dimorphisms for hair coat that are designed in some regions of the body for males only. However, this SD is not owned by any other cattle breed. Bali cattle exhibit SD in their coat coloration, which is a completely distinguishing characteristic between males and females in the adult period of the species (Hayanti *et al.*, 2021; Dahlanuddin *et al.*, 2014). In general, male Bali cattle (bulls) tend to have darker coats than female Bali cattle (cows). Cows typically have a lighter coat or reddish-brown (sorel) color, while hocks, buttocks, and abdomen stripes are white. They have black patches along the back (Lindell, 2013). Bulls usually have black fur in their adulthood. However, if a bull is castrated, its black fur will return to its original brown color (Tabun *et al.*, 2013). This sexual dimorphism in coat coloration serves as a visual cue, making it easier to distinguish between male and female Bali cattle in the wild and on farms, aiding in breeding and herd management practices.

The sexual dimorphism in body size was also observed in cattle, with males having an average body size 1.48 times larger than females (Polák & Frynta, 2010). The color distortion of male Bali cattle turning sorel-like females might be related to their body size. The previous studies have explored the relationship between coat color and growth performances in goats (Arenas-Báez *et al.*, 2023), pigs (Hur *et al.*, 2013), and cattle (Rashad & EL-Hedainy, 2021; Rashid *et al.*, 2019; Goud *et al.*, 2021; Kunene *et al.*, 2022; Tabun *et al.*, 2022). The relationship between these traits in Bali cattle has been reported in cows and calves groups (Tabun *et al.*, 2022), but no study has been reported on bulls. Moreover, male Bali cattle are the only population that shows color alteration compared to their counterpart of cows and calves. There were occasional color deviations found within the population of male Bali cattle (Lindell, 2013); hence, its uniqueness warrants further investigation. Therefore, this study was designed to evaluate the potential association between coat color deviation and the growth capability of male Bali cattle.

MATERIALS AND METHODS

The research followed the guidelines established by the Animal Ethics Committee at Udayana University in Denpasar, Indonesia (Code ID: B/184/un14.2.9/pt.01.04/2021). A total of ninety-nine male Bali cattle from a breeding center herd in Livestock Breeding and Forage Centre (BPTU-HPT), Denpasar, Bali, were collected. The study was conducted between 2019 and 2021 to collect the growth traits of Bali cattle from birth to adulthood. In contrast, the color difference was observed in September 2021 when cattle reached sexual and physical maturity at 730 days of age. Cattle were categorized according to color and pattern into four groups: full black (FBL), faded black (FDB), black sorel (BSR), and sorel (SRL) (Figure 1). The coat color was classified based on field observations, which also referred to previous studies on variations in livestock coat color (Tabun *et al.*, 2022; Hur *et al.*, 2013).

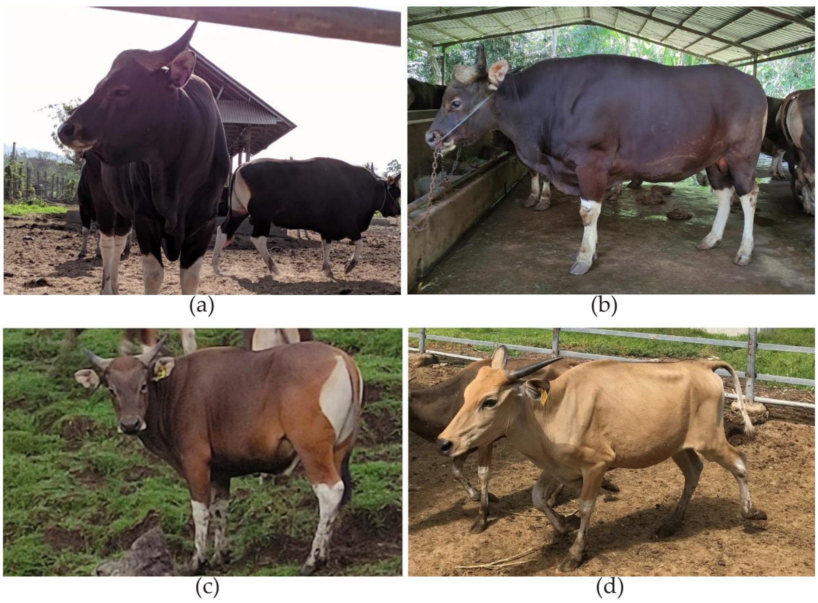
The animals were fed a standard regular diet for their weight requirements (14% crude protein and 65% total digestible nutrients) (NRC, 2015). Cattle were fed with a concentrate feed of 1%-1.5% for bulls and 2.5% for calves based on body weight. Also, forage and roughage are supplied at 10% of the average body weight. *Ad libitum* access to the water supply and pasture was always provided.

Animal growth traits were measured by adjusting their age at birth (0 days), weaning (205 days), yearling (365 days), and maturity (730 days). The variables of body weight, wither height, body length, and chest circumference were measured in a chute squeeze. The weight gain ratio in interval age estimates the weaning gain. Weights were adjusted to standard ages using the following formula (Simčič & Čepon, 2007):

$$BW_{adj} = BW_{initial} + \frac{BW_{final} - BW_{initial}}{interval\ days} \times interval\ adjusted\ days$$

where BW_{adj} is the body weight at the standard age (kg), BW_{final} is the final body weight (kg), $BW_{initial}$ is the initial body weight (kg), *interval days* are the number of days between weights. *Interval adjusted days* are the interval of standard age in days (205 days, 160 days, or 365 days). Only data from animals whose initial and final weights were measured at both ages were used to adjust these weight gains. This formula also adjusts the wither height, body length, and chest circumference.

Association analysis was designed to get an insight into the relationship between coat color and growth of Bali cattle, which was measured periodically at a



(a) (b) (c) (d)

Figure 1. Coat color variation of male Bali cattle with (a) full black, (b) faded black, (c) black sorel, (d) sorel.

particular growth time. The association analysis was evaluated with repeated measures Anova (RMA) in SAS® software (Mishra *et al.*, 2019). RMA measured multiple data taken on the same subject at different times. Mathematical model was:

$$Y_{ijk} = \mu + \alpha_i + \delta_{j(i)} + t_k + (\alpha * t)_{ik} + \varepsilon_{ijk}$$

where Y_{ik} was observations on the coat color i for each individual j and measurement time k, μ was mean, α_i was the fixed effect of coat color i, $\delta_{j(i)}$ was the random effect per individual j, t_k was the effect of measurement time k, $(\alpha * t)_{ik}$ was interaction, and ε_{ijk} was residual variance.

The repeated measurement of ANOVA only tolerates missing data; if there is a lack of at least one measurement, it will be equivalent to losing information about the entire case (Keselman *et al.*, 2001). Moreover, Statistical analysis for Person correlation was performed using RStudio® software with the package Corrplot (Wei *et al.*, 2013). The qualitative data regarding coat color used in correlation analysis was transformed into quantitative data, with categories assigned numerical values: sorel= 1, black sorel= 2, fading black= 3, and full black= 4. The order of coat color was a modification of previous studies (Hur *et al.*, 2013; Tabun *et al.*, 2022).

RESULTS

The association of coat color with their growth traits over time was illustrated in Table 1, in which the significant differences were denoted with the superscript. There was no significant association of coat color with birth and weaning age. FBL and FDB have superior morphology when they reach the age of 365 and 705 days. FBL and FDB Bali cattle were larger (p<0.05) for whole growth traits than BSR and SRL coat colors. 730-day-old FBL Bali cattle have the heaviest BW (271.17 kg) and the largest CC (159.54 cm), while SRL cattle are much smaller (BW 189.52 kg and CC 139.91 cm).

Figure 2 depicts that the traits were not significantly different between FBL and FDB but were significantly (p<0.05) different from BSR and SRL and became wider at 730 days of age. The steeper line of FBL and FDB was consistent with the more considerable daily weight gain in both traits (0.34 and 0.35, respectively), while BSR and SRL have lower weight gain (0.17 and 0.21, respectively) (Table 1).

Figure 3 illustrates the Pearson correlation between growth traits in each age cohort with coat color. The adult coat color was positively moderately correlated with body size from weaning through maturity, with the strongest association coming at 730 days (BL730 and Co= 0.47). There was a strong correlation for physical size in each age of 0, 205, 365, and 730 days. Body size at birth age was not correlated with any other traits at the age after. While growth traits at 205 days were positively correlated with almost all other variables.

DISCUSSION

The coloring of cattle ranges due to their natural environment. Numerous variables, including longevity,

Table 1. Growth traits at the different coat colors of male Bali cattle with repeated measures of ANOVA

Growth traits	Coat color				Descriptive statistics		
	FBL (43)	FDB (34)	BSR (10)	SRL (12)	Mean (99)	SE	CV (%)
Body weight (kg)							
Birth (0 days)	18.79	18.03	17.60	18.58	18.38	0.20	10.87
Weaning (205 days)	96.17	95.48	78.90	79.82	92.47	2.50	26.62
Yearling (365 days)	148.42^a	145.36^a	131.12^a	125.26^b	143.46	3.12	20.04
Mature (730 days)	267.10^a	265.89^a	185.72^b	189.52^b	255.62	6.70	21.15
Daily weight gain (kg)							
Weaning (205 days)	0.38	0.38	0.30	0.30	0.36	0.01	33.14
Yearling (365 days)	0.31	0.31	0.22	0.27	0.30	0.02	69.51
Mature (730 days)	0.34^a	0.35^a	0.17^b	0.21^b	0.32	0.01	36.21
Wither height (cm)							
Birth (0 days)	58.77	58.62	55.90	59.50	58.52	0.47	7.94
Weaning (205 days)	95.86	94.17	88.76	91.28	94.09	0.91	9.57
Yearling (365 days)	104.20^a	104.51^a	101.67^{ab}	102.49^a	103.88	0.63	5.99
Mature (730 days)	117.71^a	120.83^a	106.95^b	117.29^a	117.95	1.09	7.89
Body length (cm)							
Birth (0 days)	53.72	51.68	54.00	55.33	53.24	0.54	10.04
Weaning (205 days)	89.11	87.68	82.03	84.11	87.38	0.99	11.20
Yearling (365 days)	100.57^{ab}	103.32^a	99.77^{ab}	95.00^{ab}	101.69	0.88	8.55
Mature (730 days)	115.76^a	111.85^a	104.43^{ab}	102.62^b	111.68	1.44	11.02
Chest circumference (cm)							
Birth (0 days)	63.21	61.12	60.70	64.25	62.36	0.56	8.94
Weaning (205 days)	110.06	109.59	102.81	102.94	108.41	1.30	11.76
Yearling (365 days)	137.14^a	134.10^{ab}	126.07^{ab}	128.29^{ab}	134.04	1.42	10.47
Mature (730 days)	159.54^a	156.64^a	150.88^{ab}	139.91^b	156.14	2.07	11.31

Note: $^{a-b}$Means in the same row with different superscripts differ significantly (p<0.05). FBL= full black, FDB= faded black, BSR= black sorel, SRL= sorel, SE= standard error, CV= coefficient of variation.

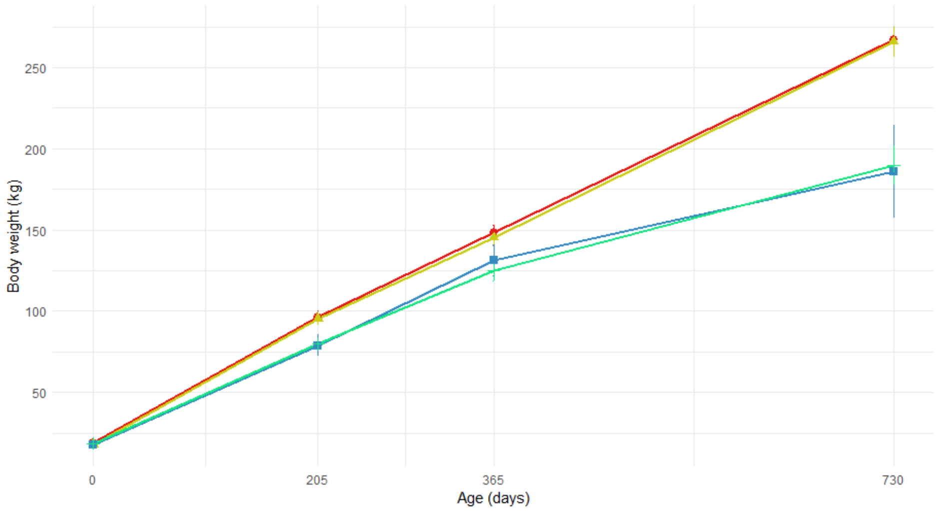


Figure 2. Graph line of body weight performance of male Bali cattle relative to their coat colors. Body weight was measured in the age of birth (0 days), weaning (205 days), yearling (365 days), and maturity (730 days). Bali cattle coat color was categorized into FBL ( )= full black, FDB ( )= faded black, BSR ( )= black sorel, and SRL ( )= sorel.

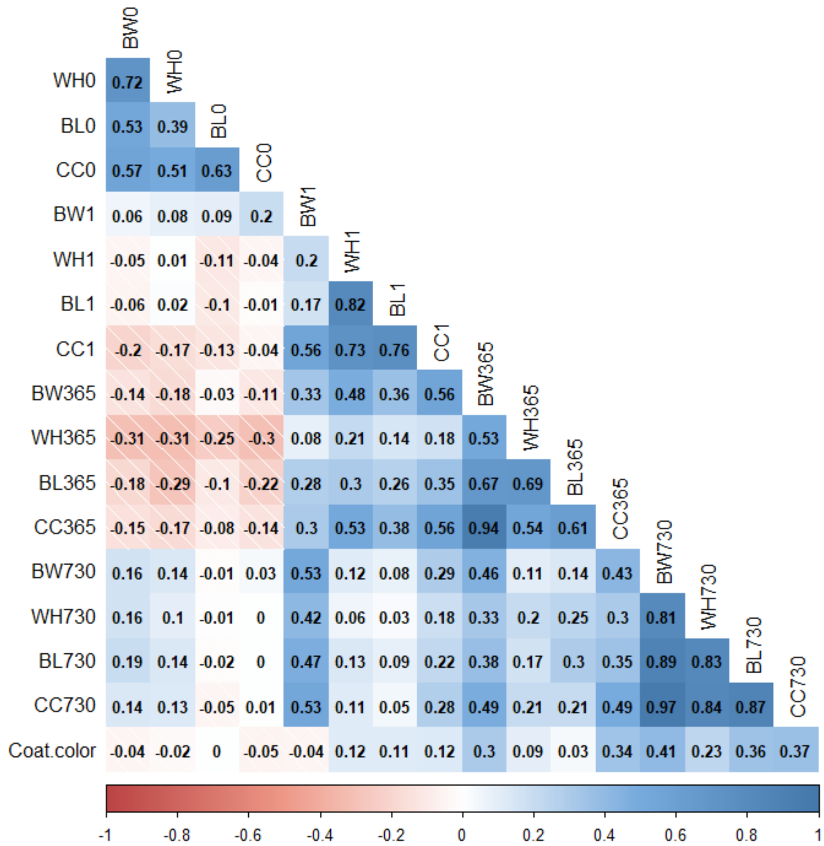


Figure 3. Pearson correlation between growth traits in every age period of Bali cattle. BW= body weight, WH= wither weight, BL= body length, CC= chest circumference, WG= weight gain, and the number after the variable denotes age in days. The blue color scale shows a positive correlation, and the red scale shows a negative correlation.

growth, and reproduction, are related to color diversity (Lee *et al.*, 2016; Sawicka-Zugaj *et al.*, 2023; Decampos *et al.*, 2013). This coat color diversity among cattle is not merely aesthetic; it holds advantages for various domains such as breed identification, market choice, cultural, and environmental adaptability (Sponenberg, 2021). Specific colors might be beneficial in particular climates or geographical areas. Bali cattle have a standard identification as a pure breed, mainly determined by their skin's unique color (SNI, 2020).

Moreover, Bali cattle also have a mark stature with slight to moderate size, which was in this study range for the second rank of SNI (SNI, 2020). However, growth traits in this study were lower than in the previous study of Bali cattle in the exact location (Arisasmita, 2018), but higher than in other studies in West Java (Said *et al.,* 2017) and Banyumulek (Agung *et al.,* 2018). Maintaining the purity of Bali cattle is crucial, as these cattle are among the tropical indigenous animals that are specifically protected and conserved in Bali Province (Kasa *et al.,* 2015). Therefore, color distortion might threaten the identity and integrity of Bali cattle over time. The loss affected the breed's physical appearance and drove its genetic heritage in danger, potentially compromising the critical traits of the breed's adaptability in certain situations. The coat color deviation could be due to crossbreeding contamination or side effects of inbreeding (Agung *et al.,* 2018; Lindell, 2013; Tabun *et al.,* 2022). Color variations in Bali cattle included roan, spotted, *poleng, injin*, and albino (Lindell, 2013). However, there were brown adult males, as observed in this study.

The classification of coat color in this study was due to a deviation of sexual dimorphism, where males in Bali cattle should be different from females, but instead, their coats were brown. Due to Indonesian national standards, pure adult male Bali cattle have a black coat in the main body and a white coat in the hocks, buttocks, and abdomen (SNI, 2020). This male variation could be related to impurity, which may lead to straying in growth, reproduction, or health quality. Interestingly, this study found that black adult bulls (FBL & FDB) were larger (of BW, WG, WH, BL, and CC at the ages of 365 and 730 days) ($p<0.05$) than their brown counterparts, which explains the predominance of black over brown. The higher growth performance of black Bali cattle compared with other brown sorrel found in this study aligns with the previous study. Dark-colored Egyptian crossbreed cattle had heavier body weight than brown ones (Rashad & EL-Hedainy, 2021); black West African dwarf sheep tended to have higher rumps than brown coats (Decampos *et al.,* 2013); black pigs of Korean crossbreed had a larger 140th day body, carcass weight, and backfat thickness than red coat (Hur *et al.,* 2013). Better growth and reproduction traits were also found in studies of small black ruminants (Maloney *et al.,* 2009; Durosaro *et al.,* 2014); the black coat color also tended to be higher EBV of birth and growth trait (Getachew *et al.,* 2020). However, the other studies were different from this finding. Darker cattle have adverse growth and behavior traits when exposed to heat stress (Finch *et al.,* 1984). Darker cattle also produced a lower 305-d milk yield (Anzures-Olvera *et al.,* 2019). Nevertheless, the difference remains unexplained.

The mechanism of coat coloration is determined by the melanin pigment accumulation (melanogenesis) in the basal layer of the epidermis, which is majorly produced by melanocyte cells (Bonaventure *et al.,* 2013). Differences in coat pigmentation are caused by the relative ratio of eumelanin (brown-black) to pheomelanin (yellow-red) (Schlessinger *et al.,* 2023). Pheomelanogenesis is stimulated by the antagonist mechanism of melanocyte-specific melanocortin receptor (MC1R) and agouti signaling protein (ASIP) genes (Videira *et al.,* 2013). Mutation of the MC1R and ASIP genes have been reported to have an association with coat coloration (Kunene *et al.,* 2022; Trigo *et al.,* 2021; Royo *et al.,* 2008; Goud *et al.,* 2021; Zhang *et al.,* 2014). However, no research has demonstrated an association of a gene with coat color in Bali cattle, either the MC1R or KIT genes (Jakaria *et al.,* 2023). The result indicates a challenge for studying Bali cattle coat color with a more comprehensive study like GWAS and RNA sequencing.

Bali cattle alter their color when they reach adolescence. Cattle begin to experience the puberty period when the sexual organs are functionally developed, which comes between 16 and 40 months in tropical conditions (Mc Dowell *et al.,* 1976). The age of puberty in cattle is moderately heritable, ranging from 0.16 to 0.57 (Martínez-Velazquez *et al.,* 2003). The onset of puberty is a series of complex events, including regulation of the endocrine system, reproductive system, and body alteration (Gupta *et al.,* 2016). The body alteration in male mammals during adolescence was seen in lions with new manes (West & Packer, 2002) and deer with antlers (Lemaître *et al.,* 2018); thus, male Bali cattle's coat color also changes at this age. Before reaching adolescence, male and female Bali cattle possess the same coloration. Moreover, this absence of color differences in the calves age showed no significant differences for growth traits between the color groups. In addition, this study also showed that there was no correlation for both traits before one year old. However, it then has a positive correlation ($p<0.05$) with their color alteration at later ages. A similar result was found in Bali cattle that color variation in calves has no differences in growth traits (Tabun *et al.,* 2022). The result describes how color alteration in Bali cattle over time might function as a contrast marker for growth traits between normal and improper development individuals.

Physical development in bulls has been reported to be related to hormonal alterations (Brito, 2021). The previous studies revealed a higher adrenal hormone in bulls and larger cattle (Chacur *et al.,* 2018; Kholghi *et al.,* 2020). Hormonal mechanisms were also evaluated in Korean brindle cattle with the hormones ACTH, DHEA, α-MSH, estradiol, and testosterone, which played an essential role in coat pigmentation during cattle development (Lee *et al.,* 2015). The hormone alteration in male Bali cattle is particularly noticeable in steers, whose coats turn black to brown after being castrated (Purwantara *et al.,* 2012). Moreover, it was discovered that testosterone has a role in transforming food into meat, and male cattle possess a higher percentage of muscle in their meat compared to cows and heifers (Reddy *et al.,* 2015). High testosterone levels were positively correlated with increased feed efficiency, as bulls found less trimmable fat and more meat than steers (Rossi *et al.,* 2022). The mechanism of the Bali cattle coat color is still unclear since no research has revealed a hormonal relationship. This issue unveils both challenges and opportunities to explore the fundamental mechanisms.

A moderate to strong correlation between growth traits in Bali cattle (Figure 3) was similar to a previous study (Jakaria *et al.,* 2017). Furthermore, the strong correlation between weaning age and further age highlighted the importance of maintaining nutrition at this age. Thus, body weight and other physical traits can be reached at a later age. This finding was consistent with the previous study that weaning weight is a determinant characteristic of maturing cattle (Tao *et al.,* 2017; Eckert *et al.,* 2015; Greenwood & Café, 2007) and may point to an assessment of coat pattern as an estimator of growth capacity since the estimated heritability of coat type was >0.55 (Maia *et al.,* 2005; Brenig *et al.,* 2013; Rashad & El-Hedainy, 2021).

The selection of FBL and FDB coat colors in the breeding system might produce progeny with enhanced growth traits. This finding could be utilized as a preliminary premise for selecting large cattle while preserving the genetic purity of male Bali cattle with dark coat color. In addition to the current study, investigating the gene association and hormonal mechanisms with coat coloration could further elucidate the variation of coat color in Bali cattle.

CONCLUSION

The coat color of male adult Bali cattle was associated with their growth traits. The darker coat color of Bali cattle (FBL and FDB) had heavier BW and larger WH, BL, and CC than BSR and SRL.

CONFLICT OF INTEREST

Jakaria and Wasmen Manalu serve as editors of the Tropical Animal Science Journal but have no role in the decision to publish this article. The authors also declare that there are no conflicts of interest.

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