



EVALUATION OF NON-GENETIC FACTORS AFFECTING PRE-WEANING AND POST-WEANING GROWTH TRAITS IN THE GUDALI AND WAKWA CATTLE REARED IN CAMEROON

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ABSTRACT

The study examined the non-genetic factors that affect growth traits in the Gudali and Wakwa beef cattle reared in the Adamawa Region, Cameroon. Data used for this study were collected from, the Institute of Agricultural Research and Development Centre, Wakwa, Ngaoundere, Cameroon. The data consisted of pedigree information and performance records. Traits under study were birth weight (BW), 3- month weight (3MWT), 4- month weight (4MWT), 6-month weight (6MWT), weaning weight (WWT), 12-month weight (12MWT), yearling weight (YWT), 18-month weight (18MWT), 24-month weight (24MWT), 30-month weight (30MWT) and 36-month weight (36MWT). General linear model with sire effect considered as random, birth month and birth year of calf, season of birth, sex of calf, herd, sire year, dam month and year of birth and dam's age at calving and herd-year-season, herd-year-season (HYS) and covariation of age at weighing was used to analyse the data. The result showed that all non-genetic factors: calf month and year of birth, season, sex, herd and herd-year-season had a highly significant ($p < 0.0001$) effects on all the growth traits studied in both breeds of cattle. In the Gudali, cow age group was highly significant ($p < 0.01$) for all the pre-weaning traits and not significant ($p > 0.05$) for post-weaning traits. This result was similar in the Wakwa breed cattle. In general, the factors included in linear models for growth traits affects growth traits significantly, which is in agreement with the findings reported in literature. It is therefore necessary to take into account these significant effects to better assess calf performance.

KEYWORDS beef cattle; pre-, post-weaning growth traits; environmental factors.

INTRODUCTION

Genetic improvement through selection in a breeding programme depends on the accuracy of identifying genetically superior animals. However, breeding for excellent growth traits has become an important part of selection programmes of beef cattle. Many papers aimed at the study of factors affecting growth traits can be found: Herd, region, year and month of calving, calving number, type of mating, sex of born calves, muscularity of calves, weaning age, dam's body conformation and dam's age (Řiha *et al.*, 1999; Ebangi *et al.*, 2002a, Goyache *et al.*, 2003 and Jakubec *et al.*, 2003) are the main effects on growth traits (weight). Among environmental effects, the most frequently used herd-year-season effect, which represents especially management practices, accounts for the highest proportion of variability of beef growth traits (Přibyl *et al.*, 2000). Specification and potential quantification of the influence of factors affecting growth traits are useful for formulating management and selection decisions. This requires that non-genetic factors (fixed effects) influencing the accuracy of predicted breeding values be either controlled experimentally or eliminated statistically (Van Wyk *et al.*, 1993). Therefore the objective of this study was to evaluate the non-genetic (environmental) factors affecting pre-weaning and post-weaning growth traits in the Gudali and Wakwa cattle reared in the Adamawa region, Cameroon.

METHODOLOGY

This study was conducted in the Institute of Agricultural Research and Development Wakwa Station, in the

Adamawa region of Cameroon. The region is situated at latitude 6° and 8°N and longitudes 10° and 16° E, at an altitude of 1100m above sea level (Ndofor-Foleng *et al.*, 2010). Weather conditions have been reported by Pamo and Yonkeu (1986). Natural vegetation is woody savannah. Major grasses have been described by Piot and Rippstein (1975).

Gudali cattle is a short-horned Zebu cattle and the Wakwa cattle is a two-breed synthetic derived from the *inter se* mating of American Brahman X Gudali F₁ females (Prewakwa). The experimental animals (Gudali and Wakwa) breeds have been described by, Ebangi *et al.* (2002) and Ndofor-Foleng *et al.* (2010). The management of these animals was described in detail by Abassa *et al.* (1993). Data for this study were obtained from the Institute of Agricultural Research and Development Wakwa Station, in the Adamawa region of Cameroon. Data were collected from 1968 and 1988 from compiled herd books. The data that were collected included pedigree information and performance records from birth to 36-months weight for both the Gudali and Wakwa breed. The original data file was checked and corrected for erroneous information. The data set consisted of records of 3788 and 2276 animals for the Gudali and Wakwa cattle respectively. Animals were arranged in contemporary groups, based on sire identity, dam identity, birth month and birth year of calf, season of birth, sex of calf, herd, sire year, dam month and year of birth and Cow age group. The raw data were edited such that the utilized records gave complete information on calf identity, sire identity, dam identity, sex of animal, dates of birth, season of birth,

herd and weights at birth, 3- month weight (3MWT), 4- month weight (4MWT), 6-month weight (6MWT), weaning weight (WWT), 12-month weight (12MWT), yearling weight (YWT), 18-month weight (18MWT), 24- month weight (24MWT), 30-month weight (30MWT) and 36-month weight (36MWT).

Statistical Model and Analysis.

The general linear model procedure of SAS (2002) was used to test the significance of non-genetic (fixed) effects, with sire effect considered as random, birth month and birth year of calf, season of birth, sex of calf, herd, sire year, dam month and year of birth and cow age group and herd-year-season fitted as fixed effect and exact ages at 3-, 4- 6-, Weaning, Yearling, 18-, 24-, 30- and 36- months weights as linear covariates. The following model was fitted for Birth weight, 3MWT, 4MWT, WWT, YWT, 18MWT, 24MWT, 30MWT and 36MWT

$$Y_{ijklmnopq} = \mu + A_i + B_j + C_k + D_l + E_m + F_n + G_o + H_p + HYS_q + e_{ijklmnopq}$$

Where $Y_{ijklmnopq}$ = an observation of a trait on the i^{th} sire of the j^{th} breed, of the k^{th} sex, born in the l^{th} season, of the m^{th} herd, of the n^{th} year of birth of the dam, of the o^{th} calf year of birth, of the p^{th} cow age group and of the q^{th} herd-year-season.

- μ = Overall mean,
- A_i = Random effects of the i^{th} sire,
- B_j = Fixed effects of the j^{th} breed,
- C_k = Fixed effects of the k^{th} sex ($K= 1, 2$),
- D_l = Fixed effects of the l^{th} season ($l = 1, 2$),
- E_m = Fixed effects of the m^{th} herd ($m = 1, 2, 3, \dots, 21$),
- F_n = Fixed effects of the n^{th} year of the birth of dams ($n= 52, 53 \dots 83$),
- G_o = Fixed effects o^{th} calf birth year ($n= 67, 68, 69, \dots, 88$).
- H_p = Fixed effect of the p^{th} cow age group ($p= 1, 2, \dots, 5$),
- HYS_q = Fixed effects of k^{th} herd-year-season, $e_{ijklmnopq}$ = Residual error variance, assumed to be normally, identically and independently distributed with a zero mean and variance (σ^2) (niid).

There were two levels of sex effect (males and females), two levels of breed effect (Gudali and Wakwa), five levels of dam's age at calving (2-4 years old, 5-7 years old, and 8-10 years old, 11-13 years and 14 years and above). The composite herd-year-season effect (HYS) included herd, year and season effects (with 2 levels of season, where 1 = rainy season and 2 = dry season).

RESULTS AND DISCUSSION

The non-genetic factors that affected pre-weaning and post-weaning growth performance of Gudali and Wakwa calves are shown on Table 1.

Breed effect

The estimates of least square means for all the growth traits studied (Table 1) showed a highly significant difference between the breeds. In all the performance characters studied, the Wakwa calves had highly significantly ($p < 0.01$) higher weights than the Gudali cattle. Calves of Wakwa showed a great potential for growth intensity traits. This report is in agreement with studies by Tawah *et al.* (1993) and Abassa *et al.* (1993) who reported significant ($p < 0.05$) higher pre-weaning

and post-weaning weights in favour of Wakwa. This could be attributed to hybrid vigour and complementarities genes from the parental breeds (Brahman and Gudali). The significant effect of breed on all the traits studied is a good indication that genotype plays an important role in the growth performance of both the Gudali and Wakwa cattle. This point is further enhanced by the fact that these two breeds are reared, broadly speaking, under the same environmental conditions with little differences in management. This result is also in agreement with that of Jakubec *et al.* (2003) who reported high weights for Blonde d'Aquitaine and Charolais that were higher in comparison with indigenous calves raised in Slovakia (except for birth weights).

Season of birth

The general linear model (GLM) indicated that, the fixed effect of season of birth had a significant effect ($p < 0.001$ or $p < 0.01$ or $p < 0.05$) on all the performance traits studied in both the Gudali and Wakwa cattle. Significant season variations may be due mainly to variations in feed and fodder availability as well as disease incidence (Bell, 2006) in different seasons. Animals born during the main rains were the heaviest at birth. This was probably because annual rainfall pattern was expected to be translated into a clear pattern in milk production of dams and in calf growth (Pico, 2005). Calves born in dry season had lower birth weights than those born in the rainy season in both breeds. The reason being that during this period, the pastures are usually depleted and less nutritious. This state of nutritional stress results in weight loss and poor body condition of the pregnant dams, a state that is passed on to the calf through the prenatal developmental environment. The inherent nutritional stress is then reflected in the calf by a lower weight at birth in the dry season. Ebangi *et al.* (2002) reported a highly significant effect of season and attributed it to seasonal variations in the total physical environment due to changes in the weather, which affected feed availability and disease incidence.

The tendency was reversed for WWT, 18MWT and 36MWT in the Gudali breed. The dry season calves outperformed the rainy season calves by 10.73 kg, 12.78 kg and 2.10 kg in weight at weaning, 18-months and 36-months respectively while the rainy season calves outperformed the dry season calves by 0.79 kg, 4.18 kg, 3.92 kg, 15.66 kg, 6.34 kg, 13.51 kg and 22.92 kg in weight at birth, 3-months, 4-months, 6-months, yearling, 24-months, 30-months and 36-months respectively in the Gudali breed. The reason for this is probably because calves born during the dry season are often weaned during the rainy season. Secondly, seasonal differences in growth traits indicated an advantage for dry-season calves which had had higher WWT and 18MWT. Similar results have been reported by Ebangi *et al.* (2002) and Szabo *et al.* (2006). They concluded that, late dry season calves and their dams are, however, exposed to the earlier part of the rainy season, characterized by young nutritious pastures, favorable for better body condition for the dam and higher milk production for calf consumption. The consequence is a higher calf growth leading to a higher weaning weight. This advantage was passed on to the post-weaning performance of the calf.

On the other hand, in the Wakwa calves, the rainy season calves outperformed the dry season calves by 0.48 kg,

6.73 kg, 6.18 kg, and 3.19 kg in weights at birth, 3-months, 4-months and 36-months respectively while the dry season calves outperformed the rainy season calves by 11.33 kg, 12.16 kg, 6.47 kg, 12.42 kg, 9.92 kg and 19.08 kg in weights at 6-month, weaning, yearling, 18-months, 24-months and 30-months weights. The significant season effects obtained in this study is in agreement with the results obtained by Ebangi *et al.* (2002) for the same Gudali breed, by Kassa-Mersha and Arnason (1986) in Ethiopian Boran cattle, Kahi *et al.* (1995) and Dadi *et al.* (2002) in Hereford cattle. It is therefore advantageous to have calving during the end of the dry season and start of the rains because of supplementary feeding may not be necessary. The fact that heavier calves were born towards the end of the rainy season indicated that such calves benefited from better maternal (uterine) environment, as the gestating dams had better nutrition from the abundant and relatively rich pastures during the proceeding four months.

Sex of the animal

Sex was a highly significant ($p < 0.001$) source of variation on the various growth traits studied (Table 1). In both breeds, male calves were consistently heavier ($p < 0.001$), than female calves. The male calves were 0.67 kg, 5.98 kg, 6.35 kg, 9.84 kg, 23.41 kg, 14.85 kg, 10.35 kg, 8.98 kg and 26.77 kg heavier than the females for birth, 3-months, 4-months, 6-months, weaning, yearling, 18-months, 24-months, 30-months and 36-months weights in the Gudali breed, respectively. On the other hand, male calves were 0.89 kg, 5.45 kg, 6.29 kg, 7.20 kg, 8.77 kg, 11.48 kg, 20.84 kg, 9.98 kg, and 28.19 kg heavier than the females for birth, 3-months, 4-months, 6-months, weaning, yearling, 18-months, 24-months, 30-months and 36-months weights in the Wakwa breed respectively. It is generally recognized that males of most species of domestic animals grow more rapidly and reach a greater mature weight than females (Koger and Knox, 2009). The higher weights for male calves obtained in the present study may be attributed to hormonal differences in their endocrinological and physiological functions and to selection pressure that was more intense on males than female calves.

The significant difference between male and female calves for pre-weaning and post-weaning growth performance was expected (Tawah *et al.*, 1993; Ebangi *et al.*, 2002a and Crews, 2006). These findings emphasized those factors such as sex of calf and season or month of calving need to be corrected for in order to improve the efficiency of selection. Similar results was also obtained by Ebangi *et al.* (2002) for the pre-weaning growth traits in both breeds. The result in the present study agrees with those reports for pre-weaning weights for different beef cattle breeds, Jakubec *et al.* (2003) for Blonde d'Aquitaine breed and Goyache *et al.* (2003) for Asturiana da los Valles beef cattle. Koger and Knox (2009) reported that sex of calf and year of birth had significant effects on weaning weight in Hereford cattle in range of the New Mexico Agricultural Experiment Station. The differences in the weights of males and females encountered in these breeds are large enough to necessitate correction for sex in a genetic study.

Calf month and year of birth

From Table 1 below, the effects of calf month and year of birth were important ($p < 0.01$) in all the performance traits studied. Significant effect of year of calving on growth traits have been reported by Oudah and Mehrez (2000) and Jakubec *et al.* (2003) for Friesian calves. The significant ($p < 0.001$) month effect obtained in this study is also in agreement with reports by Pico *et al.* (2004) for Brahman calves and Szabo *et al.* (2006) for Hungarian Fleckvieh cattle. The significant effect of year on pre-weaning and post-weaning growth performance traits may be explained in terms of rainfall pattern in the Adamawa Region and the quality and quantity of forage which usually influence the quality and quantity of milk production in the dam, an essential component for calf growth. Improvement in pastures and herd management as a result of improvement in herdsman skills over the years could equally contribute to the significant year effect (Tawah *et al.*, 1993).

Sire year of birth

The effects of year of birth of sire on BWT, 3MWT, 4MWT, 6MWT, WWT, YWT, 18MWT, 24MWT were highly important ($p < 0.001$) in both breeds (Table 1). Ebangi *et al.* (2002) reported a significant year of birth of sire effect ($p < 0.05$ or $p < 0.001$) on BWT, WWT, and YWT in Gudali breed, but a non-significant effect on EMWT in the same breed. The significant effect obtained in this result is in agreement with the reports of Oudah and Mehrez (2000) and Lengyel *et al.* (2002), who worked on different breeds of cattle and reported that the effect of sire was highly significant on growth traits. On the other hand the effect of year of birth of sire on 30-months and 36-months weights were not important ($p > 0.05$) in both the Gudali and Wakwa beef breed. Abassa *et al.* (1993) however obtained non-significant effects ($p > 0.05$) of sire and parity on weaning weight in the Gudali and Wakwa beef cattle while Trail and Gregory (1981) reported a significant ($p < 0.01$) sire effect on weaning weight for Ayrshire and Sahiwal breeds of cattle.

Dam's month and year of birth

The effect of month and year of birth of cow had no significant effect ($p > 0.05$) except on weight at 3-months, 4-months, and 6-months in the Gudali breed. Similarly, year of birth of cow had no significant effect except on weight at 3-months, 4-months, 6-months, 24-months and 30-months in the Wakwa breed. This was in disagreement with the findings of Lengyel *et al.* (2002) who reported significant effects of dam's year of birth on pre-weaning growth traits. Also, significant effect of year and month of calving of dam on growth traits were reported by several studies on different breeds of cattle (Oudah and Mehrez, 2000) in Friesian cattle and Sottie *et al.* (2009) in the Sanga and Friesian-Sanga crossbred calves.

Dam's (cow's) age group

Dam's (Cow's) age group: Dam's age group affected all the early growth traits (BWT, 3MWT, 4MWT, 6MWT, WWT and YWT) highly significantly ($p < 0.001$) or significantly ($p < 0.05$). Dams aged 5–7 years produced calves of highest BWT for both the Gudali and Wakwa calves. BWT of calves of the youngest Dams (2–4 years old) were lower by 0.71 kg and 0.69 kg for Gudali and Wakwa calves respectively, than BWT of calves of 5–7 years old dams. The oldest dams (14 years and above)

produced calves of lowest BWT (by 0.90 kg, and 0.75 kg for Gudali and Wakwa respectively less than BWT of calves of 5–7 years old dams). Statistically significant differences were found in BWTs between calves of oldest and youngest cows and cows aged 5–7 years, respectively. However, generally, older dams gave birth to heavier calves than younger dams. The trend in this study for BWT was in an increase with an increase in age of dam up to eleven years of age. First-calf heifers account for the majority of calving difficulty and associated calf losses. This is true despite the fact that most first-calf heifers are observed more closely, and assisted more readily at calving than mature cows. High rates of dystocia among first-calf heifers and young cows are mostly due to the fact that they are smaller at first parturition than at subsequent calving. This could be explained by the fact that young dams need an additional energy for finishing their own growth. In comparison with mature dams, cows of higher age (above eleven years) usually produce calves of lower BWT as production ability decreases along with the increasing age of dam. This results gotten for birth weight is in agreement with the findings of Tawah *et al.* (1993), Abassa *et al.* (1993) but was not in agreement with findings of Ebangi *et al.* (2002) with respect to the same breeds. Cassell (2007) reported a significant effect on age of dam on BWT in Kenana cattle in northern Sudan though calf birth weights declined from dams more than 10 years old. The influence of dam's age on weaning was significant in both breeds.

Calves of dams aged 5–7 years had the highest WWT. On the contrary, calves of the youngest cows had the lowest WWT. According to dam's age, differences in WWT were significant only between calves of 5–7 years old and 2 years old or younger cows. Weaning weights of calves increased along with increasing age of dams until the age of 5–7 years. Calves of the youngest cows had the lowest WWT (by 13.25 kg and 10.71 (Gudali and Wakwa respectively) less than WWT of 5–7 years old dams). When WWTs of the oldest cows were compared with WWTs of 5–7 years old dams, the difference was 10.54 kg, 10.20 (for Gudali and Wakwa respectively) in favour of calves of 5–7 years old dams. Goyache *et al.* (2003) also reported the highest weaning weight for calves descending from 5-9 years old cows. This is in agreement with findings of Řiha *et al.* (1999), Ebangi *et al.* (2002) and Jakubec *et al.* (2003). Except for birth weight, Přibyl *et al.* (2000) reported highest weights and fastest growth for calves of 5-7 years old dams. In general, the highest weights were reported for calves descending from mature dams aged 5-8 years, which is in accordance with the analyses of calves raised in Adamawa region.

Cassall (2001) reported that dam age showed no significant effect on WWT in Kenana cattle but however, there was a slight but non-significant increase in WWT as dam age increased. Generally, age of dam has a profound effect on the incidence of dystocia. First-calf, two-year-old heifers represent the greatest source of trouble to the beef herd owner. Difficulty in two-year-olds is three to four times as high as in three-year-olds, and three-year-olds have about twice as much difficulty as four-year-olds. By the time a cow reaches 4 - 5 years of age, dystocia problems are minimal (Cassall, 2001). Rumph and Van Vleck (2004) also reviewed findings about the influence of

dam's age on birth weight and weaning weight. According to their study, both traits are affected by dam's age and therefore adjustment factors are necessary for accurate genetic evaluation. The effect of age of dam on weaning weights in Zebu cattle in the tropics may be less pronounced than in temperate countries because of the late age at first calving (Sottie *et al.*, 2009).

However, in both breeds, calves of the oldest cows had the highest YWT. YWT of calves coming from 5–7 years old cows was insignificantly lower. Calves of 2 year- 4 years old cows had the lowest YWT and differed significantly from the groups of the oldest cows. This result is similar to findings of Krupa *et al.* (2005), who study factors affecting growth traits of purebred calves of six beef breeds (Aberdeen Angus, Blonde d'Aquitaine, Charolais, Hereford, Limousine and Beef Simmental). On the other hand, 6MWT, 24MWT, 30MWT, and 36MWT were however not significantly affected by dam's age at calving.

Herd

Differences between herds constitute the most important source of identifiable random variation affecting growth traits in the Gudali and Wakwa cattle. The effect of herd on the growth traits studied were highly significant ($p < 0.001$) in both breeds. This observation is consistent with earlier reports on Gudali and Wakwa cattle by Tawah *et al.* (1993) and Ebangi *et al.* (2002). Ebangi *et al.* (2002) however, reported that the significant difference observed in herd was because the herds were located within two main ecological zones, Young Basalt (Vina zone) and Ancient Basalt (plateau zone). The Vina zone is a swampy woody area in which the grazing areas were fenced, thereby limiting grazing space for the animals. Although the swampy nature and thick forest of this zone provided the animals with forage all year round, it was at the same time a natural habitat and breeding ground for tsetse flies, the main trypanosomosis vectors.

On the opposite, grazing areas found within the Ancient Basalt (plateau zone) were not fenced resulting in animals having access to more grazing land. Although the zone did not provide forage to the animals all year round, annual preparations of hay supplementation during the dry season partly compensated for the difference. Most of the herds with the best performance were located in the Ancient plateau zone. Consequently, the significant herd effect could be attributed to variations in herd location, variations in the degradation level of grazing areas, stocking effect, variations in soil composition and pastures, variations in tsetse fly infestation and overall differences in herd management and herdsman skills across seasons and years.

Herd-year-season interaction

The interaction of herd with season of birth with year of birth was very important ($p < 0.001$) for all the growth traits studied in both Gudali and Wakwa breeds. The significant effect of herd x year x season interaction could be attributed to seasonal variations and management differences across years. The results are in accordance with findings of Dadi *et al.* (2002), Goyache *et al.* (2003) and Gutiérrez *et al.* (2006) who analysed growth traits of beef calves raised in South Africa and Spain, respectively and Krupa *et al.* (2005) who studied factors affecting growth traits of beef cattle raised in Slovakia. These

effects are brought about by variations in forage availability caused by marked differences in rainfall during the dry and wet seasons which have a profound influence on performance of beef cattle in the tropics. Pico (2005) using the analysis of variance method indicated that fixed effect of herd-year-season, had a significant effect ($p < 0.001$) on all traits, except BWT for where age was excluded. The inclusion of herd-year-season interaction in the model for estimating variance components and genetic evaluation in field data seems justifiable as the Wakwa breed of cattle are bred in different ecological regions of the country, under very different management levels.

CONCLUSIONS

The results presented in this study does not only show the influence of non-genetic (environment) factors on the performance character, but also identifies the models of choice to be used in analyses of growth traits in the Gudali and Wakwa cattle breeds. In general, most of the factors (breed, season of calving, sex, herd, calf birth month and year effects, sire year, dam month and year of birth, dam's age group and herd x year x season) included in general linear model for pre-weaning and post-weaning performance traits were significant in both breeds and as such should be taken into considerations when designing a breeding programme for beef cattle. Therefore, for reliable genetic parameter estimations of growth traits of the Gudali and Wakwa animals for selection, these sources of variation should be taken into consideration in other to get the real breeding value of the animals. When estimating genetic parameters and breeding values, adjustment should be made for these non-genetic factors. Based on the data available for analyses, the obtained results will serve as a relevant set-up in developing the model for genetic study of growth traits in beef breeds raised in the Adamawa region of Cameroon.

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TABLE 1: Least Square Means (Kg) for fixed effects (non-genetic) factors affecting growth performance of Gudali and Wakwa beef cattle

Trait (Gudali)	BWT	3MWT	4MWT	6MWT	WWT	YWT	18MWT	24MWT	30MWT	36MWT
Breed effect	***	***	*	*	*	*	**	***	*	***
Season of birth	**	**	*	***	*	*	*	*	*	*
Dry season	23.43 ± 0.48	79.26 ± 3.09	98.40 ± 3.53	121.86 ± 15.02	166.35 ± 4.44	163.86 ± 5.26	210.03 ± 6.43	223.89 ± 9.00	264.63 ± 8.83	332.04 ± 9.56
Rainy season	24.22 ± 0.45	83.44 ± 2.86	102.32 ± 3.35	137.52 ± 4.66	155.62 ± 4.13	170.20 ± 4.93	197.25 ± 6.06	237.40 ± 5.26	287.55 ± 8.36	329.94 ± 8.98
Sex	**	***	***	***	***	***	***	***	***	***
Male	25.01 ± 0.42	84.34 ± 2.69	103.54 ± 3.09	134.29 ± 4.31	159.91 ± 3.93	173.74 ± 4.61	209.56 ± 5.76	235.82 ± 7.75	275.58 ± 7.90	344.38 ± 8.61
Female	24.34 ± 0.43	78.36 ± 2.69	97.19 ± 3.11	125.09 ± 4.32	150.07 ± 3.93	150.33 ± 4.62	194.71 ± 5.76	225.47 ± 7.72	266.60 ± 7.98	317.61 ± 8.61
Calf birth month	***	***	***	***	***	**	***	***	***	***
Calf birth year	***	***	***	***	***	***	***	***	***	***
Herd	**	*	**	**	*	***	***	***	*	*
Sire year of birth	*	*	*	*	*	*	*	*	Ns	Ns
Dam month of birth	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
Dam year of birth	Ns	*	***	**	**	Ns	Ns	Ns	Ns	Ns
Cow age group	*	**	**	*	*	*	Ns	Ns	Ns	Ns
Herd x year x season	***	*	*	***	***	***	***	*	***	**
Wakwa breed										
Season of birth	***	*	**	*	*	*	**	*	**	**
Dry season	24.43 ± 0.56	88.26 ± 3.08	108.43 ± 0.56	155.85 ± 2.02	162.24 ± 6.18	169.71 ± 6.42	211.81 ± 7.60	244.49 ± 8.94	316.63 ± 4.83	324.72 ± 1.41
Rainy season	24.91 ± 0.44	94.99 ± 2.86	114.61 ± 0.44	144.52 ± 0.86	150.08 ± 5.42	163.24 ± 4.82	199.39 ± 5.64	234.57 ± 6.83	297.55 ± 1.38	327.91 ± 9.03
Sex	**	***	**	***	*	*	*	**	**	**
Male	25.67 ± 0.41	96.81 ± 2.69	116.67 ± 0.41	155.29 ± 1.31	159.54 ± 5.14	170.53 ± 4.69	212.29 ± 5.46	249.95 ± 6.69	304.58 ± 2.90	340.41 ± 8.37
Female	24.78 ± 0.41	91.36 ± 2.69	110.38 ± 0.41	148.09 ± 1.33	150.77 ± 5.16	154.41 ± 4.64	200.81 ± 5.41	229.11 ± 6.63	294.60 ± 1.98	312.22 ± 8.34
Calf birth month	***	***	***	***	***	***	***	***	***	***
Calf birth year	***	***	***	***	*	***	***	***	**	***
Herd	**	*	*	*	*	***	*	**	*	*
Sire year of birth	*	*	*	*	*	*	*	*	Ns	Ns
Dam month of birth	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
Dam year of birth	Ns	***	***	***	Ns	Ns	Ns	**	*	Ns
Cow age group	*	**	*	*	*	*	Ns	Ns	NS	Ns
Herd x year x season	***	*	*	***	*	*	*	**	***	***

*: P < 0.05, **: P < 0.01, ***: P < 0.001