Comparison of growth pattern for body weight in Brakmas and Bali cattle using non-linear regression models

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Abstract

The objective of this study was to compare the growth curve parameters derived from non-linear regression models using body weight data of Brakmas and Bali cattle. Four non-linear models, namely Brody, von Bertalanffy, Gompertz and Logistic, were fitted to the body weight data collected from 279 Brakmas (range in age from 1 to 15 y) and 74 Bali (range in age from 1 to 10 y) cows. Coefficient of determination (R^2), residual mean square (MSE) and mean of absolute deviation (MAD) were used to determine the best model to describe the growth pattern of the cattle. For both cattle breeds, the Logistic model showed the highest R^2 value at 0.967, followed by Gompertz, von Bertalanffy and Brody with R^2 values at 0.966, 0.966 and 0.964, respectively. Logistic model also showed the lowest MSE at 1057.1, followed by Gompertz, von Bertalanffy and Brody that yielded 1080.5, 1094.7 and 1138.7 of MSE, respectively. Supporting these results, Logistic model showed the lowest MAD at -6.17 compared to Gompertz (-5.78), von Bertalanffy (-1.65) and Brody (1.82). Brakmas cattle showed higher mature weight compared to Bali cattle of 328.8±4.917 kg and 270.4±4.419 kg, respectively, as estimated by Logistic model. However, Bali cattle showed higher rate of maturing at 0.109±0.011 compared to Brakmas cattle (0.089±0.005) which indicated that Bali cattle would likely attain its mature weight earlier than Brakmas cattle. This was further explained by the negative correlation between mature weight and rate of maturing where Brakmas cattle showed higher negative correlation coefficient compared with Bali cattle. The correlation between mature weight and maturing rate of Brakmas and Bali cattle were -0.528 and -0.170, respectively. It is concluded that the use of non-linear model is useful as it could summarize the weight-age relationship into several biologically interpreted parameters compared to the entire lifespan weight-age data points that are difficult to interpret.

Keywords: Growth, Non-linear functions, Brakmas, Bali

Introduction

Breed characterization for productivity, maternal and calf performance is important as a basis to synchronize genetic resources with other production resources and need to be done comprehensively (Gregory *et al.,* 1985). Breed selection is essential to be used either in straight breeding or crossbreeding programs for herd improvement. Some selection parameters might be able to be evaluated at young ages such as birth weight, weaning weight and average daily gain, but the evaluation of mature size, optimal body weight for production, maternal and reproductive traits will take a longer period to evaluate. The measurements of cattle's body dimension are widely used for genetic improvement of meat production performance in live beef cattle because they objectively could improve selection for growth by enabling the breeder to recognize early and late maturing animals of different sizes (Brown *et al.,* 1974), as the mature size impacts the profitability of beef enterprises (Marco *et al.,* 2010). Mature size of cows affects many aspects of production, including maintenance requirements (McMorris and Wilton, 1986; Montano-Bermudez *et al.,* 1990), reproduction (Buttran and Willham, 1989; Owens *et al.,* 1993) and culled cow value, and therefore the profitability of the cow calf operation (Rumph *et al.,* 2002). Information regarding the growth event in livestock is useful in developing a genetic improvement program to produce the most efficient biological type for a particular feeding environment in a specific market situation (Stobart *et al.,* 1986). Evaluation of growth by using a long series of body weight or body size changes observed throughout the life of animals is very difficult to explain (Kratochvilova *et al.,* 2002; Berry *et al.,* 2005), therefore fitting the entire life body measurements such as body weight, height and length to non-linear functions offers an opportunity to summarize the entire growth events into several parameters that can be interpreted biologically (Perotto *et al.,* 1992; Berry *et al.,* 2005).

Brakmas cattle were developed from the crossing of Brahman and local indigenous Kedah-Kelantan (KK) cattle which began in 1978 at MARDI Kluang Research Station Johor Malaysia. Purebred KK cattle have the advantages in fertility and adaptability; however their low growth rate is not economical for commercial beef production (Johari and Jasmi, 2009). The crossbreeding program resulted in superior Brakmas crossbred offspring compared to purebred KK. A study by Dahlan (1985) showed an improvement in body weight at birth, weaning and post weaning of Brakmas compared to crosses of KK-Hereford and Friesian-KK. Brakmas crossbred calves had the highest birth weight (20.2 kg) compared to KK (15.4 kg). A continuous systematic breeding and selection scheme of Brakmas cattle has resulted in the stabilization of the Brakmas breed at 50% Brahman and 50% KK bloodline. They have shown great potential for commercial beef cattle production in oil palm plantations as they have good adaptability, high tolerance to heat stress, tick and parasites, and low maintenance (Johari and Jasmi, 2009).

Bali cattle (*Bos/Bibos javanicus*) are the domesticated strain of Banteng, and have long been domicile in Java and Bali islands (Bell *et al.,* 1990). It is one of Indonesian local cattle breeds, besides Aceh, Pesisir and Madura breeds (Martojo, 2012). These humpless cattle are relatively large-framed and well-muscled. They are well adapted to the tropics and indigenous to Southeast Asia. Chamdi (2005) indicated that Bali cattle have superiorities in fertility rate, production performance, adaptability to local environment, carcase dressing percentage, resistance to parasites and work capability. They also have the ability to survive on low quality fodder (McCool, 1992). Bali cattle are suitable for intensive village-based management, plowing paddy fields, but their hoofs are too soft for draught on paved roads. Several factors known to contribute to its wide distribution are traditional resettlement, colonial and government programs (Panjaitan *et al.,* 2003). Most Bali cattle are raised traditionally by the farmers with feed resources mainly from native grasses and agricultural by-products (Hasan *et al.,* 2005). These cattle are particularly important to the smallholder farming enterprises of the eastern islands of the Indonesian archipelago where they comprise approximately 80% of the cattle population and are an important source of capital to meet major household needs (Talib *et al.,* 2003). However, over the past decade, the number of Bali cattle has declined in most areas of Eastern Indonesia due to high slaughter rates in female animals and the shortage of breeding bulls. Farmers tend to sell the bulls due to their high stock price. Bali cattle become favourite among the farmers due to their capability to utilize low quality feed efficiently, high fertility and conception rate and early maturing (Purwantara *et al.,* 2012). Entwistle *et al.* (2012) reported the birth weight and mature weight of female Bali cattle were 16.8 kg and 303.3 kg, respectively. It also showed high calving rate of 83% and low calf mortality of 7% (Talib, 2002). The objective of this study was to compare the mature weight and rate of maturing of Brakmas and Bali cattle using non-linear regression models.

Materials and Methods

Research location

This study was conducted at MARDI Muadzam Shah, Pahang research station. Bandar Muadzam Shah is located in the South Eastern Region of Pahang State at latitude of 3.031 and longitude of 103.1295 and it has an elevation of 44 m above sea level.

Animal management

The animals were a part of the ongoing breed evaluation study of beef cattle breeds conducted in MARDI Muadzam Shah Research Station. The animals were maintained to be in average body condition score of 3 out of 5-point body condition score (5=animals being in excess fat cover; 3=in moderate fat cover; 1=emaciated, based on Ariff *et al.* (2010) and free from Brucellosis and Foot and Mouth Disease. Breeding soundness evaluation was conducted on bulls prior to mating. Only bulls with good vision, moderate body condition score, free from contagious diseases such as Brucellosis and Foot and Mouth Disease, and had passed semen quality evaluation were included in this breed evaluation study.

Animals were controlled and separated using barbed-wire fencing and left to graze on *Brachiaria decumbens* pasture throughout the day. Supplementary feed in the form of palm kernel cake pellet were given at 1% of body weight two weeks prior to breeding. Animals were mated for 60-d breeding period and rectal palpation was conducted 45-60 d after the removal of bulls. New-born calves were given identification number (ear tag and tattoo) and weighed within 24 h (Chase *et al.,* 2000). Other information such as sex of calf, pedigree identification, birth date and body measurements at various ages were also recorded. Calves were weaned at six mo of age. Body weight was taken using a digital weighing scale and recorded in kilogram. The data were distributed over four age groups as shown in Table 1. The age of the animal was determined from farm recordswhere date of birth and date of weighing were available.

Table 1. The number of female Brakmas and Bali cattle by age groups in months

Age group (months)	Brakmas	Bali
0-12	166	16
13-24	34	7
25-36	47	11
>36	32	40
Total	279	74

Fitting of non-linear functions

Cross-sectional data of body weight were collected from 279 heads of Brakmas and 74 heads of Bali cows.

Four nonlinear models: Brody, Gompertz, von Bertalanffy and Logistic, were chosen for their ease in calculating the growth curve parameters (Brown *et al.*, 1976) and were fitted to the Brakmas and Bali cattle body weights. The four 3-parameter growth models were as described below:

Brody : $W=A(1-Be^{-kt})$
Gompertz : $W=Ae^{-Be^{-kt}}$
von Bertalanffy : $W=A(1-Be^{-kt})^3$
Logistic : $W=A/(1+Be^{-kt})$

where W is the observed body weight, at age t in mo, A is the asymptote for the body weight, B is constant of integration and k is rate of maturing per day interpreted as daily rate of growth relative to asymptotic size. The coefficient of determination (R^2), residual mean square (MSE) and mean of absolute deviation (MAD) were used to determine the model with the best goodness of fit to describe the growth pattern for body weight in Brakmas and Bali cows as suggested by Malhado *et al.* (2009). It was contended that a model which yielded higher R^2 and lower MSE and MAD was considered a better fit model since it could explain a bigger proportion of the variation in body weight than a model with lower R^2 and higher MSE and MAD.

Results and Discussion

Based on R^2 values, all models showed high representation of the variation of the pooled dataset of Brakmas and Bali cattle as the R^2 values ranged from 0.964 to 0.967 (Table 2). Logistic model accounted 96.7% of the pooled dataset, followed by Gompertz, von Bertalanffy and Brody models with R^2 values of 0.966, 0.966 and 0.964, respectively. To choose the best model to compare the growth curve parameters between these two breeds, the model that yielded the lowest MSE and MAD was chosen as suggested by Malhado *et al.* (2009).

Table 2. Estimates of the parameters A, B and k, coefficient of determination (R^2), residual mean square (MSE) and mean of absolute deviation (MAD) derived from Gompertz, von Bertalanffy, Brody and Logistic models for all genetic groups

Model	Parameters			R^2	MSE	MAD
	A	B	k			
Gompertz	311.7±4.18	1.958±0.054	0.060±0.004	0.966	1080.5	-5.78
von Bertalanffy	315.6±4.64	0.493±0.010	0.053±0.003	0.966	1094.7	-1.65
Brody	329.8±6.52	0.900±0.010	0.034±0.002	0.964	1138.7	1.82
Logistic	305.4±3.55	5.192±0.271	0.102±0.006	0.967	1057.1	-6.17

Residual mean square values ranged from 1057.1 to 1138.7. Logistic model yielded the lowest MSE value followed by Gompertz, von Bertalanffy and Brody where the MSE values were reduced to 1057.1, 1080.5, 1094.7 and 1138.7, respectively. The result was supported by the lowest MAD yielded by Logistic model; therefore it was the best model to describe the growth pattern of both cattle breeds. Freitas (2005) and Bilgin *et al.* (2004) found that Logistic model was more versatile in describing the growth pattern in sheep and growth of Awassi lamb scrotal circumference, respectively. Malhado *et al.* (2009) found that Brody model yielded the highest residual mean square in crosses of Dorper sheep and local Brazilian breed, therefore might not be suitable to describe the growth pattern of other sheep breeds. However, Gbangboche *et al.* (2011) found that Brody model was the best model to describe the growth pattern of Lagune cattle and was selected for its computational simplicity and the ability to accommodate missing data (Bullock *et al.,* 1993; Kaps *et al.,* 2009; Arango *et al.,* 2002; Forni *et al.,* 2009).

The comparison of growth curve parameters of Brakmas and Bali cows estimated by Logistic model is presented in Table 3. The mature weight of Brakmas cows as estimated by Logistic model was significantly higher ($p<0.05$) compared to that of Bali cows where the estimated mature weights were 328.8±4.917 kg and 270.4±4.419 kg, respectively. The mature weight of Brakmas cattle estimated from this study was higher than that of the local indigenous Kedah-Kelantan cattle of 227.8±2.30 kg (Ariff *et al.,* 1993) and lower than Brahman cattle (343.0±4.0 kg) as reported by Freetly *et al.* (2011). The estimated mature weight of Bali cattle was higher than those reported by Martojo (2012), where the mature weight of Bali cows sampled from Bali, Nusa Tenggara Timur, Nusa Tenggara Barat and South Sulawesi were 303.3, 221.5, 241.9 and 211.0 kg respectively. This variation could be influenced by the environmental factors (Martojo, 2012) such as management system (extensive, semi-intensive of intensive), feed and temperature (Sri Rachma *et al.,* 2011). Devendra *et al.* (1973) reported the mature weight of Bali cows in Malaysia was 264 kg, which was lower than that reported in this study. The variation of body weight reflected the impact of environmental and management system, particularly nutrition (Entwistle *et al.,* 2012). Bali cattle were also characterized by a higher rate of maturing of 0.109±0.011 compared to Brakmas, with maturing rate of 0.089±0.005. This indicates that Bali cattle grow at a faster rate as they attain lower mature weight at earlier ages than Brakmas cattle. The maturing rate of Brakmas cattle was higher than Kedah-Kelantan and Brahman-KK cattle at 0.05±0.004 and 0.04±0.002, respectively (Ariff *et al.,* 1993). Animals with heavier mature weight tended to be slower maturing compared to those with lighter mature weight (Ariff *et al.,* 1993; Taylor and Fitzhugh, 1971). It was found that the correlation between mature weight and rate of maturing was negative for both breeds where Brakmas cattle showed higher negative correlation between these two parameters of -0.528 compared to -0.170 for Bali cattle, thus explaining the slower maturing rate of Brakmas cattle with heavier weight at maturity. The negative correlation between A and k growth curve parameters indicate that animals with slower maturing rate tend to attain heavier mature weight. Cattle with higher maturing rate will grow to lower mature weight (Kratochvílová *et al.,* 2002; Fitzhugh, 1976), therefore the animals are older at similar degree of maturity compared to cattle of higher mature weight.

Table 3. Parameter estimates of A, b and k derived from Logistic model and correlation coefficient (r) of parameters A and k for Brakmas and Bali cattle

Breed	Growth curve parameters (±SE)			r
	A*	b	k*	
Brakmas	328.8±4.917	5.057±0.295	0.089±0.005	-0.528
Bali	270.4±4.419	4.799±0.372	0.109±0.011	-0.170

*Significant at p<0.05

From the Logistic model it was indicated that Brakmas cattle met its inflection point at the age of 18 mo, while at 14 mo for Bali cattle (Figure 1). After the age of 48 mo, the growth of Bali cattle started to slow down and plateau from the age of 78 mo. As slower maturing animals, Brakmas cattle continued to grow to maturity at a slower rate after 48 mo of age.

While considering altering the growth pattern of the animals, it's imperative to examine the relevant growth curve parameters as animals which grow at lower rate towards maturity tend to attain their higher mature weight at later ages. The earliness to attain its mature weight will become the benchmark for the animals to be slaughtered or to be used as replacement stocks.

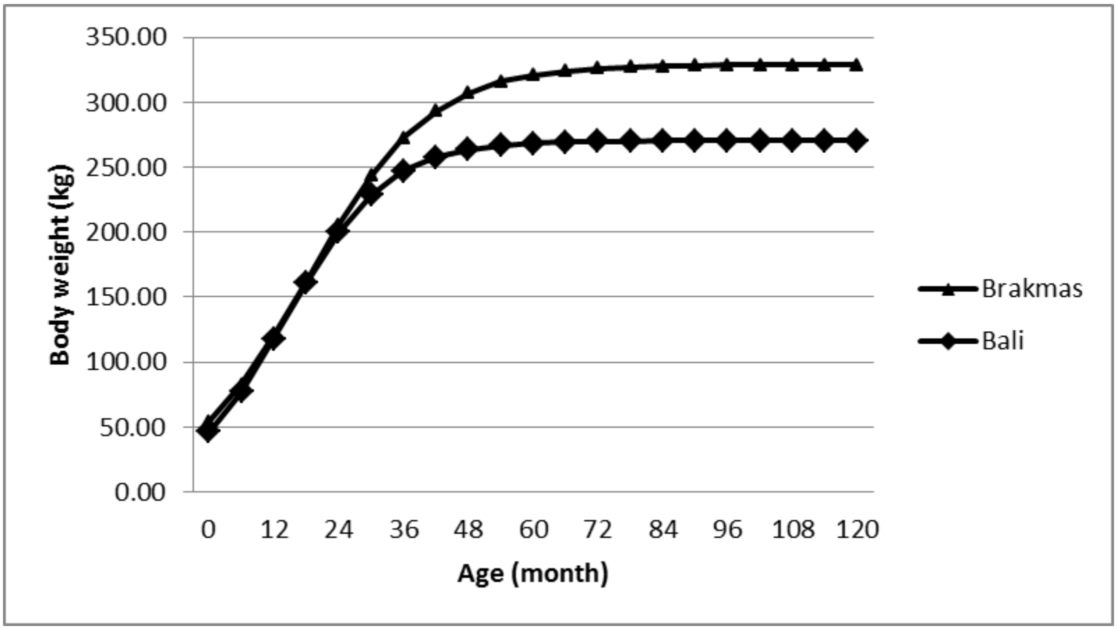

Figure 1. Growth pattern of Brakmas and Bali cattle as estimated by Logistic model

Conclusion

In this study, Logistic model showed the best goodness for growth pattern data of Brakmas and Bali cattle as shown by the highest coefficient of determination and the lowest residual mean square and mean of absolute deviation. This study also revealed that Brakmas cattle had higher mature weight compared to Bali cattle, however Bali cattle showed higher rate of maturing , indicating that Bali cattle will attain its mature weight earlier than Brakmas. This phenomenon caused by the negative relationship between rate of maturing and mature weight in both cattle breeds, explaining why Bali cattle had lower mature weight compared to Brakmas. As a cattle breed with high maturity rates, Bali cattle seems to be potentially developed as alternative beef cattle breeds in Malaysia as it can be slaughtered or served as replacement stock at younger age.

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