Describing growth pattern of Brakmas cows using non-linear regression models

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Abstract

The objective of this study was to evaluate the best fit non-linear regression model to describe the growth pattern of Brakmas cows. Estimates of asymptotic mature weight, rate of maturing and constant of integration were derived from Brody, von Bertalanffy, Gompertz and Logistic models which were fitted to cross-sectional data of body weight taken from 279 Brakmas cows raised in MARDI Muadzam Shah. Coefficient of determination (R^2) and residual mean squares (MSE) were used to determine the best fit model in describing the growth pattern of Brakmas cows. Logistic model was the best model among the four growth functions evaluated to determine the mature weight of Brakmas cattle as shown by the highest R^2 and lowest MSE values (0.973 and 1037.4, respectively), followed by Gompertz (0.973 and 1050.4, respectively), von Bertalanffy(0.972 and 1067.1, respectively) and Brody (0.912 and 1037.4, respectively) models. The correlation between rate of maturing and mature weight was found to be negative in the range of -0.528 to -0.874 for all models, indicating that animals of heavier mature weight had lower rate of maturing. The use of non-linear model 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 pattern, body weight, Brakmas cows

Introduction

Brakmas cattle as a breed were developed from the initial crosses derived from the crossing of purebred Brahman and local indigenous Kedah-Kelantan (KK) breeds. The source of the Brahman genetic materials were young bulls and semen imported by MARDI from Texas, USA and Australia. The first cross progeny were inter se mated until the fourth filial generation and selection of the Brahman crosses was done with the aim at developing a Brahman-KK crossbred herd of uniform phenotype of white grey coat colour. Purebred KK cattle have advantages in terms of fertility and adaptability although their growth rate was reported to be low (Johari and Jasmi, 2009). The Brakmas crossbreeding programme produced superior offspring compared to purebred KK showing improvement in terms of body weight at birth, weaning, yearling and 24 mo of age over KK cattle (Dahlan, 1985).

From the initial evaluation of various KK crosses involving Friesian (FK), Hereford (HK) and Brahman (BK) sires, FK recorded high calf mortalities, thus leaving HK and BK for further evaluation. The HK crosses were more superior compared to BK in terms of weaning weight, yearling weight and weight at 24 mo. They also demonstrated early maturity with earlier first calving than the BK crossbreds (33.7±1.70 mo vs. 37.5±0.85 mo) as reported by Johari *et al.* (1994). However, the BK crossbred demonstrated better adaptation for breeding in oil palm plantations compared to HK crossbreds (Daud *et al.,* 1996) with a higher survival rate. The main causes of death in HK crossbreds were naval ill, septicaemia, pneumonia, *E. coli* infection and internal parasitic infestation. A continuous systematic breeding and selection scheme among the BK crossbreds has resulted in the creation of new composite breed, Brakmas which was officially declared in 1999. Brakmas cattle have a genetic make-up of 50% Brahman and 50% KK bloodline. They have great potential for commercial beef cattle production in oil palm plantations since they have been reported to exhibit good adaptability, high tolerance to heat stress, ticks and parasites, and are easy to maintain with minimum health problems (Johari and Jasmi, 2009).

Selection of animals is important for breeders in order to decide which individuals are to be selected as parents to produce the progeny in the next generation. There are many ways of selection; however the most efficient method is the one which would result in the maximum genetic improvement per unit of time and effort expended (Hazel and Lush, 1942). The selection objectives of animals may consist of high reproductive efficiency (calving rate, weaning rate, mothering ability) and faster and efficient growth (birth weight, weaning weight, yearling weight, and relative and absolute growth rate). Growth plays a significant role to ensure the sustainability of a beef cattle operation alongside the reproductive efficiency, thus it is an important criterion to look into during the animal selection. Growth is defined as the increments in size and number of cells and the accumulation of extracellular substances (Aguilar *et al.,* 1983). It is important to understand the animals' growth in order to decide the optimum age and body weight to breed and slaughter. Furthermore, strategic feeding management can be implemented to achieve the desired body weight without adding too much cost. However, the study of growth often takes a long period; therefore non-linear algebraic models are used widely in order to describe the growth events of the animals. Non-linear algebraic models are an effective method of describing individual growth patterns in a small number of biologically interpretable parameters. Such models tend to reduce the effect of temporary environment and random variation as well as adjusting for the non-linear relationship between age and live weight or body size (Berry *et al.,* 2005). Relative and absolute growth rates, maturing rate, and mature size are the important traits that can be estimated by using growth functions (Kaps *et al.,* 2000). Sigmoidal growth curve can be divided into a segment of increasing slope (the self-accelerating phase) and a segment of decreasing slope (the self-inhibiting phase) (Goonewardene *et al.,* 1981). The meeting point between these two phases is known as the point of inflection.

One of the main advantages in using a mathematical model to describe growth is that it consolidates the information contained in the weight-age data into three or four biologically interpretable parameters and used to derive other relevant growth traits (Perotto *et al.,* 1992; Nešetřilová, 2005). These parameters could then be compared between populations and breed groups. The fitted parameters of these growth functions could also be used to calculate and predict growth rates (absolute, relative, instantaneous or life-time) and maturing rates of animals or breed groups (Goonewardene *et al.,* 1981) and degree of maturity (Fitzhugh and Taylor, 1971). Growth functions were first described by Brody (1945) and Richards (1959) to model the growth in cattle. Brody, Gompertz, Logistic, von Bertalanffy and Richards growth functions are the most commonly used non-linear functions to describe sigmoidal growth patterns in dairy and beef cattle (Berry *et al.,* 2005). These growth models have been used to summarize important growth characteristics such as growth rate, mature body size and weight, and the interval between birth and maturity (Gbangboche *et al.,* 2011). Beltrán et al. (1992) reported that Brody model gave adequate predictions of weights from 18 mo of age to maturity, but early weights were slightly overestimated. The growth functions differ in a fixed position of the inflection point (y*, t*) related to the asymptotic weight (A). It is located approximately at a third of A in von Bertalanffy function (y*/A = 0.296) and in Gompertz function (y*/A = 0.368), while at a half of A in Logistic function (Kratochvílová *et al.,* 2002). Although the 4-parameter Richard's model fitted the data more accurately, it required more iterations for convergence. Richard's function was found to be problematic during convergence and did not fit the dataset to study the growth curves of Santa Ines sheep (da Silva *et al.,*2012). The parameter A is the asymptotic limit for the body size measurement interpreted as mature size and not an estimate of the largest measurement or largest size reached by an animal (Brown *et al.,* 1976). The constant of integration (b) has no biological interpretation while k is the growth rate after birth relative to the mature measure of size (Ariff *et al.,* 2010). Topal *et al.* (2004) and Malhado *et al.* (2009) suggested that the goodness of fit of the models were determined by the highest R^2 and the lowest MSE.

Information regarding the growth pattern of different breeds of livestock is useful in developing a genetic improvement programme to produce the most efficient biological type for a particular feeding environment in a specific market situation. Cattle body measurement affects efficiency, maintenance requirements, profitability, reproduction, and culled cattle value. The characterization of some body measurements of beef cattle that are related to growth will lead to a more efficient utilization of genetic resources (Sri Rachma *et al.,* 2011). Interest in modelling the animal growth is caused by its economic implications as an early estimation of these parameters are important for selection purpose (Beltran *et al.,* 1992). The objective of this study was to determine the best fitted non-linear model to estimate the mature weight and growth curve parameters of Brakmas cattle.

Materials and Methods

The cross-sectional data of body weight were collected from 279 Brakmas cows using a digital weighing scale. The data were distributed over four age groups as shown in Table 1. The age of the animal was determined from farm records where date of birth and date of weighing were recorded.

Table 1. The number of female Brakmas cattle by age groups

Age group (mo)	No. of animals
0-12	166
13-24	34
25-36	47
>36	32
Total	279

Four nonlinear models, namely Brody, Gompertz, von Bertalanffy and Logistic, were fitted to the Brakmas body weight dataset to determine the growth pattern of Brakmas cattle. The 3-parameter growth models were chosen of their ease of calculation (Brown *et al.,* 1976). The four growth models used were described below (Brown *et al.,* 1976):

Brody: $Y=A(1-Be^{-kt})$

Gompertz: $Y=Ae^{-Be^{-kt}}$

von Bertalanffy: $Y=A(1-Be^{-Kt})^3$

Logistic: $Y=A/(1+Be^{-kt})$

where Y is the observed measurement of size, at age t in mo, A is the asymptote for the measure of size, 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) and residual mean square (MSE) were used to determine the model with the best goodness of fit to describe the growth pattern for body weight in Brakmas cows. A model which yielded higher R^2 and lower MSE was considered a better fit model since it could explain a higher proportion of the variability in body weight than a model with lower R^2 and higher MSE.

Results and Discussion

The growth curve parameters for body weight as derived from Gompertz, Brody, von Bertalanffy and Logistic models for Brakmas cows are presented in Table 2. Mature weights as derived by all four models were in the range of 328.8±4.91 to 364.0±9.69 kg. The mature weight of Brakmas cattle estimated by Logistic model (328.8±4.9 kg) was higher than that of the local indigenous Kedah-Kelantan cattle of 227.8±2.3 kg (Ariff *et al.*, 1993) but lower than that of Brahman cattle of 343.4±4.0 kg obtained from Brody model (Freetly *et al.*, 2011). The Brody model gave the highest estimate of mature weight for Brakmas cows, followed by von Bertalanffy, Gompertz and Logistic models. The R^2 value of the models used in this study ranged from 0.912 to 0.973. Logistic and Gompertz models provided the highest R^2 value for Brakmas cows, followed by von Bertalanffy. The R^2 value for Logistic and Gompertz models were comparable with the same models to estimate live body weight for Lagune cattle (Gbangboche *et al.*, 2011) and Nellore cattle (Lopes *et al.*, 2012). The result on R^2 was supported by the lowest estimate for MSE derived by Logistic model, followed by Gompertz and von Bertalanffy, while higher estimate of MSE was derived by the Brody model. A similar study was done by Lopes *et al.* (2012) on Nellore cattle, but the ranking was in the order of von Bertalanffy, Logistic, Brody and Gompertz, in terms of goodness of fit, however, Gbangboche *et al.* (2011) ranked in the order of Brody, Gompertz and Logistic in their study of growth curve for Lagune cattle. It indicated that body weight data of different cattle breeds raised in different environments would likely affect the goodness of fit for the models in explaining the variation in body weight in cattle.

The rate of maturing (k) ranged from 0.025 to 0.089 and the Logistic model estimated the highest rate of maturing, followed by the Gompertz, von Bertalanffy and Brody models. The value k indicates the growth speed of the animals relative to their mature size. Animals with high k value showed a precocious maturity compared to the animals with lower k value but similar initial weight (Malhado *et al.*, 2009). The analysis showed that Brody model estimated the lowest rate of maturing, therefore this model tended to estimate the highest mature weight and the animals were older at maturity compared to other models. Gbangboche *et al.* (2011) indicated that Brody model tended to overestimate the mature weight during the growing phase and thus this could be a disadvantage of the model. Similar findings were also found in Dorper crossbred sheep (Malhado *et al.*, 2009), Barbarine sheep (Hamouda and Atti, 2011), Blackbelly rams for the evaluation of testicular growth pattern (Jimenez-Severiano *et al.*, 2010), Lagune cattle (Gbangboche *et al.*, 2011) and Santa Ines sheep (da Silva *et al.*, 2012) where Brody model estimated the lowest rate of maturing and highest parameter A. Brown *et al.* (1976) explained that this larger estimate of A was associated with smaller k value. Correlation between the mature weight and rate of maturing was negative for all models ranging from -0.874 to -0.528 where Brody model provided the highest negative correlation between mature weight and rate of maturing. The negative correlation between parameters A and k would indicate that animals with slow maturing rate attain their mature weight at later ages and are heavier. Cows with higher maturing rate will take shorter time to attain its mature weight (Kratochvílová *et al.*, 2002; Fitzhugh, 1976), therefore the animals are older at the time of maturity than the animals with lower mature weight.

Table 2. Estimates of growth curve parameters from Gompertz, Brody, von Bertalanffy and Logistic models and residual mean square for body weight in Brakmas cows

Model	Growth curve parameter[1]			r	R^2	MSE
	A (kg)	b	k			
Gompertz	339.3±6.075	1.955±0.060	0.056±0.007	-0.704	0.973	1050.4
Brody	364.0±9.690	0.902±0.011	0.025±0.004	-0.874	0.912	1132.5
von Bertalanffy	345.1±6.834	0.493±0.012	0.042±0.005	-0.764	0.972	1067.1
Logistic	328.8±4.917	5.057±0.295	0.089±0.005	-0.528	0.973	1037.4

[1]A estimated mature size; b constant of integration; k rate of maturing; r the correlation of A and k; R^2 coefficient of determination; MSE residual mean square

Logistic and Gompertz models fitted the body weight data closer to the sigmoidal pattern compared to von Bertalanffy and Brody models (Figure 1). At a similar age prior to the growth plateaux the two models of Logistic and Gompertz were at higher body weight estimates than the other two models. At earlier ages before the inflection point Brody model did not show extremely higher estimates of body weight as reported by Gbangboche *et al.* (2011), however the Brody model showed slower growth after the inflection point. It also did not meet the interception point where other models met at approximately 72 mo of age and continued to grow slowly explaining why Brody model gave the highest estimate of mature weight.

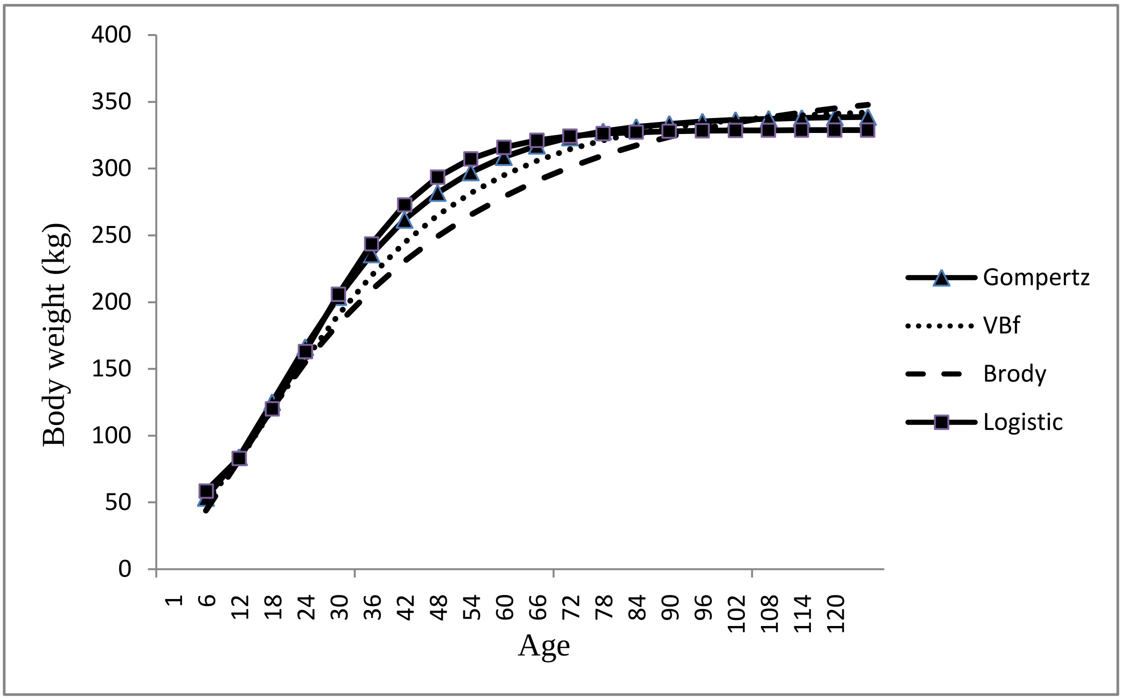

Figure 1. Growth pattern of Brakmas cows estimated by Gompertz, von Bertalanffy (vBf), Brody and Logistic models

Conclusion

Among the four competing models, Logistic and Gompertz models showed the highest R^2 indicating that these models were the best fitted models to describe the growth pattern for body weight of Brakmas cows. However, the Logistic model showed the lowest MSE value; therefore it gave the best goodness of fit to the dataset and was the best model to describe the weight-age relationship or growth pattern of Brakmas cattle. The correlation of mature weight and rate of maturing was found to be negative for all models, indicating that animals with low rate of maturing would take longer time to attain their mature weight.

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References

Aguilar, C., Friedli, C., and Cañas, R. 1983. The growth curve of animals. *Agric. Systems*, 10(3):133-147.

Ariff, O.M., Hifzan, R.M., Zuki, A.B.M, Jiken, A.J. and Lehan, S.M. 2010. Maturing pattern for body weight, body length and height at withers of Jamnapari and Boer goats. *Pertanika J. Trop. Agric. Sci.* 33(2):269-276.

Ariff, O.M., Johari, J. A., and Ismail, D. 1993. Growth pattern for body weight of straightbred and crossbred Kedah-Kelantan cattle. *MARDI Res.J.* 21(2):129-134.

Beltrán, J. J., Butts, W. T., Olson, T. A., and Koger, M. 1992. Growth patterns of two lines of Angus cattle selected using predicted growth parameters. *J. Anim. Sci.* 70(3):734-741.

Berry, D. P., Horan, B., and Dillon, P. 2005. Comparison of growth curves of three strains of female dairy cattle. *Animal Science*, 80:151-160.

Brown, J. E., Fitzhugh, H. A., and Cartwright, T. C. 1976. A comparison of nonlinear models for describing weight-age relationships in cattle. *J. Anim. Sci. 42*(4):810-818.

da Silva, L. S. A., Fraga, A. B., da Silva, F. D. L., Beelen, P. M. G., de Oliveira Silva, R. M., Tonhati, H., and da Costa Barros, C. 2012. Growth curve in Santa Inês sheep. *Small Rum. Res*, 105(1):182-185.

Dahlan, I. 1985. Growth performance, body conformation, carcass characteristics and palatability of KK cattle and its crossbred. *MSc. Thesis*, UPM

Daud, E., Johari, J.A. and Ariff,O.M. 1996. Cow productivity in Brakmas and Hereford-KK multiplier herd. In *Proc. Silver Jubilee MSAP Conf.*, 28-31 May 1996, Kuching, Sarawak pp138-139.

Fitzhugh, H. A. 1976. Analysis of growth curves and strategies for altering their shape. *J. Anim. Sci 42*(4):1036-1051.

Fitzhugh, H. A., and Taylor, S. 1971. Genetic analysis of degree of maturity. *J. Anim. Sci 33*(4):717-725.

Freetly, H.C., Kuehn, L.A and Cundiff, L.V. 2011. Growth curves of crossbred cows sired by Hereford, Angus, Belgian Blue, Brahman, Boran, and Tuli bulls, and the fraction of mature body weight and height at puberty. *J. Anim. Sci.* 89:2373-2379.

Gbangboche, A. B., Alkoiret, T. I., Toukourou, Y., Kagbo, A., and Mensah, G. A. 2011. Growth curves of different body traits of Lagune cattle. *Res.J. Anim. Sci.* 5(2):17-24.

Goonewardene, L. A., Berg, R. T., and Hardin, R. T. 1981. A growth study of beef cattle. *Canadian J. Anim. Sci.*, 61(4):1041-1048.

Hamouda, M. B., and Atti, N. 2011. Comparison of growth curves of lamb fat tail measurements and their relationship with body weight in Babarine sheep. *Small Rum. Res. 95*(2):120-127.

Hazel, L. N., and Lush, J. L. 1942. The efficiency of three methods of selection. *J.Heredity*, 33(11):393-399.

Jiménez-Severiano, H., Reynoso, M. L., Román-Ponce, S. I., and Robledo, V. M. 2010. Evaluation of mathematical models to describe testicular growth in Blackbelly ram lambs. *Theriogenology*, *74*(7):1107-1114.

Johari, J. A., and Jasmi, Y. 2009. Breeds and breeding program for beef production in Malaysia. In *Proceedings of the 8th Malaysia Congress on Genetics*, 4-6 August 2009, Genting Highlands p22-28.

Johari, J.A., Ariff, M.O. and Adnan, S. 1994. Reproductive performance of KK crossbred cattle. *MARDI Res. J.* 22(1):91-95.

Kaps, M., Herring, W. O., and Lamberson, W. R. 2000. Genetic and environmental parameters for traits derived from the Brody growth curve and their relationships with weaning weight in angus cattle. *J. Anim. Sci.* 78(6):1436-1442.

Kratochvílová, M., Hyánková, L., Knížetová, H., Fiedler, J., and Urban, F. 2002. Growth curve analysis in cattle from early maturity and mature body size viewpoints. *Czech J. Anim. Sci*., 47(4):125-132.

Lopes, F. B., da Silva, M. C., Marques, E. G., and McManus, C. M. 2012. Analysis of longitudinal data of beef cattle raised on pasture from northern Brazil using nonlinear models. *Trop. Anim. Health and Prod. 44*(8):1945-1951.

Malhado, C. H. M., Carneiro, P. L. S., Affonso, P. R. A. M., Souza, A. A. O., and Sarmento, J. L. R. 2009. Growth curves in Dorper sheep crossed with the local Brazilian breeds, Morada Nova, Rabo Largo, and Santa Inês. *Small Rum.Res. 84*(1):16-21.

Nešetřilová, H. 2005. Multiphasic growth models for cattle. *Czech J. Anim. Sci*., 50(8), 347-354.

Perotto, D., Cue, R. I., and Lee, A. l. 1992. Comparison of nonlinear functions for describing the growth curve of three genotypes of dairy cattle. *Canadian J. Anim. Sci.* 72:773-782.

Sri Rachma, A. B., Harada, H., and Ishida, T. 2011. The estimation of growth curve of Bali cattle at Bone and Barru districts, South Sulawesi, Indonesia using ten body measurements. *J. Indonesian Trop. Anim. Agric*., 36(4):228-236.

Topal, M., Ozdemir, M., Aksakal, V., Yildiz, N., and Dogru, U. 2004. Determination of the best nonlinear function in order to estimate growth in Morkaraman and Awassi lambs**.** *Small Rum. Res.* 55(1):229-232.