Describing Growth Pattern of Bali 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 Bali 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 74 Bali cows raised in MARDI Research Station Muadzam Shah Pahang. Coefficient of determination (R^2) and residual mean squares (MSE) were used to determine the best fit model in describing the growth pattern of Bali cows. Von Bertalanffy model was the best model among the four growth functions evaluated to determine the mature weight of Bali cattle as shown by the highest R^2 and lowest MSE values (0.973 and 601.9, respectively), followed by Gompertz (0.972 and 621.2, respectively), Logistic (0.971 and 648.4, respectively) and Brody (0.932 and 660.5, respectively) models. The correlation between rate of maturing and mature weight was found to be negative in the range of -0.170 to -0.929 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 and time consuming to interpret.

Keywords: growth pattern, body weight, Bali cows

Introduction

Bali cattle *(Bos javanicus)* is one of Indonesian local breeds, other than Aceh, Pesisir and Madura (Martojo, 2012). It is considered as one of the most beautiful of all wild cattle species as it originates from Banteng cattle. They are most likely be the ancestors of the domestic cattle of South-East Asia. Purwantara *et al*. (2012) and Lisson *et al*. (2010) estimated that Bali cattle represented approximately 25-27% of the total cattle population in Indonesia. Bali cattle is an important cattle breed that contributes to the Indonesian beef industry (Sri Rachma *et al*., 2011). Bali cattle dominate the beef cattle population primarily in eastern Indonesia such as East and West Nusa Tenggara islands and South Sulawesi and the numbers there now exceed those in Bali. It is also distributed in some areas of Sumatera such as Lampung, Bengkulu and South Sumatera as well as south and central Kalimantan (Purwantara *et al*., 2012). Several factors known to contribute to its wide distribution are traditional resettlement, colonial and government programs (Panjaitan *et al*., 2003).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. The selection objectives may be directed at high reproductive efficiency encompassing traits such as calving frequency, calving interval and initial breeding age and efficient growth in preweaning and finishing phases. Growth plays a significant role to ensure the sustainability of a beef cattle operation alongside reproductive efficiency, thus it is an important criterion to emphasize in animal selection. Growth is defined as the incremental increase in size and cell number 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 then 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 growth parameters that can be estimated by using growth functions (Kaps *et al.*, 2000). Sigmoidal growth curve is often characterized by an increasing slope, named the self-accelerating phase and a segment of decreasing slope of the self-inhibiting phase (Goonewardene *et al.*, 1981). The meeting point between these two phases is known as the point of inflection where the peak accelerated growth tends to decline towards a growth plateau. Studies in animals' growth by using growth models were reported in goats (Ariff *et al.*, 2010), sheep (Topal *et al.*, 2004; Jimenez-Severiano *et al.*, 2010; da Silva *et al.*, 2012), beef cattle (Kaps *et al.*, 2000; Freetly *et al.*, 2011), dairy cattle (Perotto *et al.*, 1992; Berry *et al.*, 2005), chicken (N'dri *et al.*, 2006), mouse (Koops *et al.*, 1987; Kurnianto *et al.*, 1999) and pig (Koops and Grossman, 1991). The objective of this study was to determine the best fit non-linear model to estimate the mature weight and growth curve parameters of Bali cows.

Materials and Methods

The cross-sectional data of body weight were collected from 74 Bali 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 available.

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

Age group (mo)	No. of animals
0-12	16
13-24	7
25-36	11
>36	40
Total	74

Four nonlinear models, namely Brody, Gompertz, von Bertalanffy and Logistic, were fitted to the Bali body weight dataset to determine the growth pattern of the Bali cows. These models are determined by 3 parameters of A, k and b representing the asymptote, rate of growth towards maturity and integration constant, respectively. These 3-parameter growth models were chosen for their ease of calculation and biological interpretation of the model parameters (Brown *et al.*, 1976). The four growth models used were described below (Brown *et al.*, 1976):

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

where Y_t 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 highest goodness of fit to describe the growth pattern for body weight in Bali cows. A model which yields higher R^2 and lower MSE is 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 Bali cows are presented in Table 2. Based on the coefficient of determination, the von Bertalanffy model showed the highest R^2 value and presented the best goodness of fit attaining 97.3 % in explaining the variability in body weight while the Brody model was least fit for the dataset to estimate the Bali cow mature weight based on the lowest value of R^2. Supported by lowest MSE, the von Bertalanffy model was the best model to describe the body weight of Bali cows followed by Logistic and Gompertz models. A similar study was conducted by Lopes *et al.* (2012) on Nellore cattle, but the R^2 rank for the models fell in the order of von Bertalanffy, Logistic, Brody and Gompertz, while Gbangboche *et al.* (2011) ranked Brody, Gompertz and Logistic models in the study of growth curve of Lagune cattle. It indicated that different datasets, breeds and environmental factors presented different goodness of fit for the models. The estimated mature weights derived by all models ranged from 270.4 to 307.3kg. The Brody model gave the highest estimated mature weight for Bali cattle (307.3±12.63 kg). Similar trend was reported by Perotto *et al.* (1992) for dairy cattle, Malhado *et al.* (2009) for crossbred Dorper sheep and Gbangboche *et al.* (2011) for beef cattle, where the Brody model yielded higher estimate of mature weight. The range of mature weight for Bali cattle raised in MARDI Muadzam Shah was higher than those reported by Martojo (2012), where the mature weight of Bali cows in Bali, Nusa Tenggara Timur, Nusa Tenggara Barat and South Sulawesi were 303.3, 221.5, 241.9 and 211.0 kg, respectively. Devendra *et al.* (1973) reported the mature weight of Bali cows in Malaysia was 264 kg, lower than that reported in this study. The variation of body weight reflected the impact of environmental and management system particularly the nutrition (Entwistle *et al.*, 2012).

For the rate of maturing, Brody model showed the lowest maturing rate at 0.030±0.002 while Logistic model gave the highest estimate of the parameter k at 0.109±0.011. The correlation coefficients between parameter A and k were negative for all models with the parameters derived from Brody model had the highest negative correlation (-0.929). This correlation coefficient between the parameter k and the estimate of mature size A estimated by Brody model in Bali cattle is similar to that reported for Brakmas cattle (Mohd. Hafiz, *et al.*, 2015) and explained why Brody model tended to estimate higher mature weight compared to the other models. Brown *et al.* (1976) explained that the larger estimate of mature weight was associated with smaller rate of maturing. The negative correlation between A and k indicates that animals tend to grow slowly relative to their mature weight in their development to attain heavier mature weight. Cows with higher mature weight will also take a longer 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, coefficients of determination and residual mean square for body weight in Bali cows

Model	Growth curve parameter[1]			r	R^2	MSE
	A (kg)	b	k			
Gompertz	277.6± 5.54	1.78±0.065	0.06±0.004	-0.61	0.972	621.2
Brody	307.3±12.63	0.86±0.010	0.03±0.002	-0.93	0.932	660.5
von Bertalanffy	285.8± 7.37	0.45±0.011	0.05±0.003	-0.79	0.973	601.9
Logistic	270.4± 4.42	4.79±0.372	0.11±0.011	-0.17	0.971	648.4

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

Growth patterns of Bali cattle as derived by Gompertz, von Bertalanffy, Brody and Logistic models are presented in Figure 1. Gompertz and Logistic models showed the same point of inflection that was at 12 mo, while the inflection point of von Bertalanffy was at 8 mo. It also showed a different pattern for body weight from that of Brakmas cattle where all models met the interception point at the age of 72 mo (Mohd. Hafiz *et al.*, 2015). Logistic model already met the mature size at the interception point, while the other models showed a continued trend to grow before plateauing towards maturity.

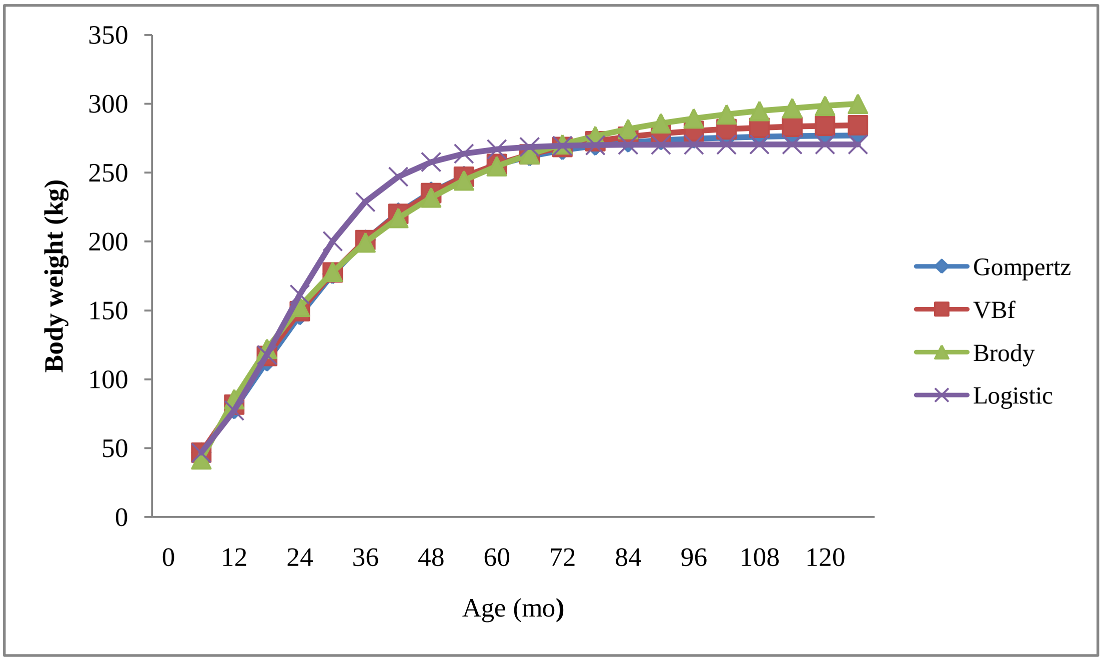

Figure 1. Growth patterns of Bali cows estimated by Gompertz, von Bertalanffy (VBf), Brody and Logistic models

Conclusion

Among the four competing growth models, von Bertalanffy model was found to explain most of the variation in body weight and it is the best fit model to describe the growth pattern for body weight of Bali cows. The inverse relationship between mature weight and rate of maturing indicates that animals with lower rate of maturing tend to be heavier at maturity and take longer time to attain their mature weight.

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