Estimation of body weight growth curve parameters of Katjang-Boer crossbred

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Abstract

The objective of this study was to determine the best non-linear regression model to describe the growth pattern of male Katjang-Boer crossbred goat, a new synthetic goat breed. Estimates of mature weight (A), rate of maturing (k) and constant of integration (B) as growth curve parameters were derived from four non-linear regression models, namely Brody, Logistic, von Bertalanffy and Gompertz. Monthly body weight data were collected from 66 male Katjang-Boer crossbred from birth to 48-mo of age and fitted with the above non-linear regression models. Coefficient of determination (R^2) and residual mean squares (MSE) were used to determine the best non-linear model to estimate the growth curve parameters. Von Bertalanffy model showed the best goodness of fit in describing the growth pattern as shown by the highest R^2 and the lowest MSE (0.951 and 22.42, respectively), followed by Gompertz (0.948 and 26.79, respectively), Logistic (0.941 and 30.32, respectively) and Brody (0.873 and 23.56, respectively). The correlation between parameters A and k were found to be negative, ranging from -0.87 to -0.52, indicating that animals with lower rate of maturing tended to be heavier at maturity. The use of non-linear model is useful in summarizing the entire lifespan weight-age data points that is usually time consuming in their analysis. The study of growth pattern is important to determine the optimum weight and age for replacement does and slaughter.

Keywords: growth pattern, body weight, crossbred, Katjang-Boer goats

Introduction

Growth plays a significant role to ensure the sustainability of a livestock operation alongside reproductive efficiency, thus it is an important criterion to emphasize in animal selection. Growth is defined as the net accretion of protein and fat in respective tissues controlled by nutrition, environment and the genetic capacity to grow (Breever et al., 1992). It is important to understand the animals' growth in order to decide the optimum age and body weight for breeding or slaughtering purposes. Furthermore, strategic feeding management can then be implemented to achieve the desired body weight without incurring too much cost.

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. Using non-linear algebraic models is an effective method to describe the growth pattern 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). Rate of maturing 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 three phases namely preparing where growing starts at a specific point and increases gradually, secondly the increasing phase where the curve adopts linear shape up to distortion point and quietness phase where the curve reaches asymptote (Waheed et al., 2011).

Kambing Katjang (KK) goats are indigenous to Malaysia, Southern Thailand and Indonesia. They possess good natural characteristics of tick tolerance and high fecundity under harsh circumstances, however the growth performance is relatively low (Tsukahara et al., 2008) and considered as non-economical in commercial production (Johari and Jasmi, 2009). Crossbreeding of animals provides an opportunity to increase productivity (Johari and Jasmi, 2009; Hirooka et al., 1997), thus a crossbreeding program between Katjang bucks and Boer does was conducted to develop a synthetic goat breed by combining the hardiness of KK goats and well-muscled Boer goats. Following a structured breeding and selection program, a flock of Katjang-Boer crossbred was established in MARDI Kluang that will meet farmers' preferences towards low maintenance goat breed yet still produce higher meat yield compared to local indigenous KK goat breed. The objective of this study was to determine the best non-linear model to estimate the mature weight and growth curve parameters of male Katjang-Boer goat crossbred.

Materials and Methods

Data of body weight were collected from 66 male Katjang-Boer goats from birth to 48 months old using a digital weighing scale in MARDI Kluang. The age of the animals were determined from farm records where date of birth and date of weighing were available.

Four nonlinear models, namely Brody, Gompertz, von Bertalanffy and Logistic, were fitted to the male Katjang-Boer goats body weight dataset to determine the growth pattern. These models are determined by the three parameters of A, k and b representing the asymptote, rate of maturing and constant of integration, respectively. These 3-parameter growth models were chosen for their ease of calculation and biological interpretation of the model parameters (Hafiz et al., 2015; Brown et al., 1976). The four growth models used were described in Table 1.

Table 1. Nonlinear model equations for growth curve parameters fitting and their point of inflection

Model	Equation	Point of inflection
Brody	$Y_t=A(1-Be^{-kt})$	not exist*
Gompertz	$Y_t=Ae^{-Be^{-kt}}$	0.368*A
von Bertalanffy	$Y_t=A(1-Be^{-kt})^3$	0.296*A
Logistic	$Y_t=A/(1+Be^{-kt})$	A/2

*Goshu and Koya (2013)

where Yt 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 (R2) was used to determine the model with the highest goodness of fit to describe the growth pattern for body weight in Katjang-Boer goat. A model which yields higher R2 and lower MSE is considered a better model since it could explain a higher proportion of the variability in body weight than a model with lower R2 and higher MSE (Malhado et al., 2009).

Results and Discussion

The growth curve parameters for body weight as derived from Gompertz, Brody, von Bertalanffy and Logistic models for male Katjang-Boer crossbred 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 reaching up to 95.1% while the Brody model was least fitted for the dataset to estimate the male Katjang-Boer mature weight based on its lowest value of R^2. Supported by lowest MSE, the von Bertalanffy model was the best model to describe the body weight of male Katjang-Boer goats followed by Gompertz and Logistic models. The rank of non-linear models was similar to a study by Hafiz et al. (2019) where the goodness of fit for non-linear model to describe the growth pattern of selected Kedah-Kelantan cows was Von Bertalanffy, Gompertz, Logistic and Brody. A similar study was done by Malhado et al. (2009) ranked Gompertz, Logistic, von Bertalanffy, Richards and Brody for Dorper crossbreds, while da Silva et al. (2012) ranked Logistic, von Bertalaffy, Brody and Gompertz for the growth pattern of Santa Ines sheep. Study by Lopes et al. (2012) on Nellore cattle ranked von Bertalanffy, Logistic, Brody and Gompertz while Gbangboche et al. (2011) ranked Brody, Gompertz and Logistic in the study of growth curve of live body weight in Lagune cattle as shown by the highest R^2 and lowest MSE. Tsukahara et al. (2008) reported the rank of non-linear models for Katjang female goats was Brody, von Bertalanffy, Gompertz and Logistic while Hafiz et al. (2015) reported that the rank of non-linear models was Logistic, Gompertz, von Bertalanffy and Brody in female Brakmas cattle. It indicates that different datasets, breeds and environmental factors could yield different goodness of fit for the models. This is supported by Malhado et al. (2009) where same functions may vary in results based on breed, population and features tested.

The estimated mature weights derived by all models ranged from 40.61±1.19 to 45.11±1.74 kg. The Brody model gave the highest estimated mature weight for male Katjang-Boer goats of 45.11±1.74 kg while Logistic model yielded the lowest estimate of mature weight at 40.01±1.19 kg. A similar trend was found by Malhado et al. (2009) for crossbred Dorper sheep, Jimenez-Severiano et al. (2010) in the testicular growth of Blackbelly ram lambs and da Silva et al. (2012) in Santa Ines sheep, where the Brody model yielded higher estimate of mature weight compared to the other models. A study by Hamouda and Atti (2011) also showed Brody model estimated the highest mature weight and several fat tail characteristics namely lower fat tail circumference, lower fat tail width and fat tail length in Barbarine sheep. The range of mature weight for Katjang-Boer goats was higher than local indigenous Katjang goat as reported Tsukahara et al. (2008) where the range of mature weight of Katjang goats was 27.0 to 31.8 kg. As a result of crossbreeding, the mature weight of Katjang-Boer goats was lower than Boer goat reported by Ariff et al. (2010) where the estimated mature weight of Boer goats ranged from 58.23 to 59.31 kg. The variation of body weight reflects the impact of environmental factors and management system, particularly the nutrition (Entwistle et al., 2012). The rate of maturing ranged from 0.07±0.01 to 0.19±0.02 where Brody model showed the lowest rate of maturing and Gompertz model showed the highest value. Animals with high maturing rate will attain their mature weight earlier than the animals with low rate of maturing. Kratochvílová et al. (2002) and Fitzhugh (1976) explained that animals with higher mature weight will also take a longer time to attain mature weight as reflected in their lower rate of maturing, therefore the animals are older at the time of maturity than the animals with lower mature weight. The rate of maturing of Katjang-Boer goats was higher than the local Katjang goats (Tsukahara et al., 2008), but lower than the Boer goats reported by Ariff et al. (2010). The correlation between mature weight and maturing rate is the most important biological relationship in a function (McManus et al., 2003). The correlation coefficients between parameters A and k were negative for all models ranging from -0.52 to -0.87 with Brody model gave the highest negative correlation. These highly negative correlation coefficients between the parameter k and the estimate of mature size A estimated by Brody model was also found in Katjang and Katjang-German Fawn crossbreds (Tsukahara et al., 2008), Boer and Jamnapari goats (Ariff et al., 2010), Santa nines sheep (da Silva et al., 2012) and dorper crossbreds (Malhado et al., 2009). Brown et al. (1976) explained that the larger estimate of mature weight is associated with smaller rate of maturing. For livestock producers, it is very important to have animals with fast maturing rate as it will reflect the earliness of the animals to be used for breeding and slaughtering purposes. Malhado et al. (2009) reported that Dorper x Santa Ines sheep were possible to be slaughtered earlier as they have faster growth rate compared to Dorper x Rabo Largo and Dorper x Morada sheep.

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 male Katjang-Boer goats

Model	Growth curve parameter[1]			r	R^2	MSE
	A (kg)	b	k			
Gompertz	41.76±1.30	1.91±0.09	0.13±0.01	-0.69	0.948	26.79
von Bertalanffy	42.42±1.37	0.49±0.02	0.11±0.01	-0.75	0.951	22.42
Brody	45.11±1.74	0.91±0.01	0.07±0.01	-0.87	0.873	23.56
Logistic	40.61±1.19	4.55±0.41	0.19±0.02	-0.52	0.941	30.32

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

Growth patterns of male Katjang-Boer goats derived from Gompertz, von Bertalanffy, Brody and Logistic models are presented in Figure 1. From the graph, all models met the interception point at 30 mo with the body weight of 40 kg. After the interception point, all models showed increasing trend to mature weight at 33 mo (Gompertz), 39 mo (von Bertalaffy), 63 mo (Brody) and 27 mo (Logistic).

Point of inflection is where the increasing- and self inhibiting-phase met. For female animals, it is important to manipulate and strategize the feeding regime to alter the sigmoidal curve, so the animals will grow faster and achieve 60% of their mature weight for breeding purpose (Bhatti et al., 2007), while in male animals, the alteration of sigmoidal curve is important to determine the optimum body weight for slaughtering purpose. In Katjang-Boer crossbred, the point of inflections estimated by von Bertalanffy, Gompertz and Logistic models were three-, five- and eight-month, respectively. Therefore, strategic management especially in feeding aspect need to be done before the age at point of inflection in order to achieve their maximum weight at two years old as the main market demand for goats are for festive seasons (Hifzan et al., 2018).

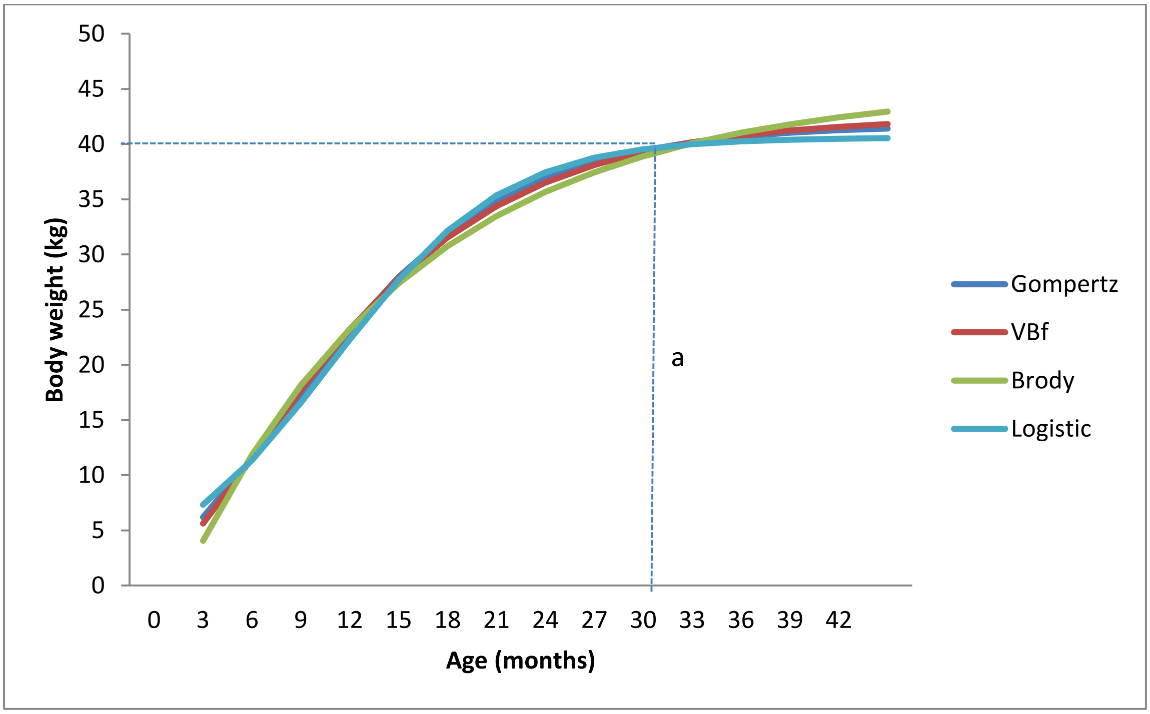

Figure 1. Growth patterns of male Katjang-Boer goats estimated by Gompertz, von Bertalanffy (VBf), Brody and Logistic models; a=the interception point for all models

Conclusion

Three out of four non-linear models showed high representative of growth pattern for body weight of the male Katjang-Boer goats where von Bertalanffy, Gompertz and Logistic accounted 95.1%, 94.8% and 94.1%, respectively, of the total variation. Von Bertalanffy model showed the best model to describe the growth curve of male BK goats as indicated by the highest R^2 and lowest MSE values. The correlation between mature weight and rate of maturing was found to be negative and this inverse correlation indicates that animals with lower rate of maturing tend to be heavier at maturity and take longer time to attain their mature weight. The male Katjang-Boer goats showed slight improvement in term of mature weight compared local indigenous Katjang goats but lower to the Boer goats that were used as foundation breeding stock. The size of Katjang-Boer crossbred are suitable for Malaysian market demand especially for festive seasons. The study of growth curve is important in order for the animal breeders to decide the optimum body weight and age for replacement does and ideal weight to slaughter for maximum profit.

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