

## Conference Paper

# Determination of the Best Nonlinear Function in order to Estimate Brahman Female Cattle Growth

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### Abstract

Growth can be described by using a mathematical model. The appropriate mathematical model which is biologically and analytically easy to interpret is the nonlinear model. This research aimed to evaluate the nonlinear mathematical model in predicting Brahman female cattle growth. Data used in this research were the body weight recording of 738 Brahman female cattle, with age ranging from early birth (< 1 mo) to mature (60 mo), collected by *Balai Pembibitan Ternak Unggul dan Hijauan Pakan Ternak* (BPTU-HPT) [Breeding Center for Good Livestock and Animal Feed] Sembawa from 2012 to 2015. Data were analyzed using four nonlinear mathematical model: Brody, Bertalanffy, Logistic, and Gompertz. Results showed that the degree of goodness fit of the four models classifies high in the category ( $R^2 > 0.84$ ). Brody model was most appropriate in describing the Brahman female cattle growth curve. Logistic and Gompertz models were most appropriate in predicting Brahman female cattle mature weight.

**Keywords:** Breeding, Brody, Growth curve, Mature weight, Nonlinear

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## 1. Introduction

Brahman cattle have been developed in the United States by crossing three cattle breeds namely Gir, Guzerat, and Nellore. Brahman cattle have been accepted for their environmental adaptability, longevity, mothering ability, and efficient beef production. *Balai Pembibitan Ternak Unggul dan Hijauan Pakan Ternak* (BPTU-HPT) [Breeding Center for Good Livestock and Animal Feed] Sembawa has begun to develop Brahman cattle since 2012. Since the beginning of the Brahman cattle breeding program, little research has been made to improve its biological and genetic potential.

Body weight is believed to be the most important trait in evaluating cattle producing capacity [1]. Growth can be described by using a mathematical model. The appropriate

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mathematical model which is biologically and analytically easy to interpret is the nonlinear model [2]. Mathematical models that are commonly used are Brody, Von Bertalanffy, Gompertz, and Logistic [3].

The application of nonlinear mathematical model had been done on some researches such in the growth of Dhofari cattle [4], Brakmas cattle [3], Lagune cattle [5], and Nellore cattle [5]. In Indonesia, the application of nonlinear mathematical models was growth and age puberty of Brahman cross cattle [2] and Frisian Holstein cattle growth [6]. The application of nonlinear mathematical model to predict growth of Brahman female cattle has never been done. Therefore, this study aimed to evaluate the application of the nonlinear mathematical model in predicting Brahman female cattle growth in *Balai Pembibitan Ternak Unggul dan Hijauan Pakan Ternak (BPTU-HPT) Sembawa*.

## 2. Material and Methods

### 2.1. Material

The data used in this study were a form of 738 Brahman female cattle body weight, from the age of early birth (< 1 mo) to mature (66 mo). The data were collected by *Balai Pembibitan Ternak Unggul dan Hijauan Pakan Ternak (BPTU-HPT) Sembawa* from 2012 to 2015.

### 2.2. Methods

#### 2.2.1. Data collecting

The data used consisted of body weight and the age of the cattle. Cattle age data were obtained from *Balai Pembibitan Ternak Unggul dan Hijauan Pakan Ternak (BPTU-HPT) Sembawa* recordings, which were then calculated to determine the age of each cattle. Body weight data were obtained from cattle weighing recording from 2012 to 2015. The body weighing was done using a cattle scale with a 1 000 kg capacity and an error margin of 1 kg. The type of data used is cross-sectional data, in which data collection was done by measuring the weight of individual cattle in certain age group, followed by the measurement of other individual samples from within the same population [7].

### 2.2.2. Mathematical model

The mathematical model used in this study were Brody, Von Bertalanffy, Logistic, and Gompertz as explained by [4].

$$\text{Brody: } Y_t = A(1 - Be^{-kt}) \quad (1)$$

$$\text{Bertalanffy: } Y_t = A(1 - Be^{-kt})^3 \quad (2)$$

$$\text{Logistic: } Y_t = A/(1 + Be^{-kt})^{-1} \quad (3)$$

$$\text{Gompertz: } Y_t = A \exp(1 - Be^{-kt}) \quad (4)$$

$Y_t$  is the body weight on  $t$  age;  $A$  is a mature body weight;  $B$  is the proportion of mature weight which will reach after birth weight formed by  $Y_0$  and early  $t$  (the value of integral constants);  $k$  is the animal growth rate reach on mature body weight,  $e$  is basic of logarithm (2.718282)

### 2.2.3. Goodness of fit

The coefficient of determination ( $R^2$ ) and mean square error (MSE) were used to determine the model with the best fit [8]. The smaller MSE value and the bigger  $R^2$  value (> 70 %) indicate more fit the mathematical model used in predicting the studied variable.

### 2.2.4. Statistical analysis

One-way ANOVA was used to determine whether there is a difference in value between  $A$ ,  $B$ , and  $k$  from each tested mathematical model. Duncan multiple range tests (DMRT) was used to determine whether the  $A$ ,  $B$ , and  $k$  coefficient for every model was significantly different [8].

## 3. Result and Discussion

### 3.1. Bodyweight

There were body weight variations between Brahman cattle age group. Variations of body weight in individual animal were caused by birth season, year of birth, and the mating season [9]. Indonesia has two seasons: the rainy season and dry season, there

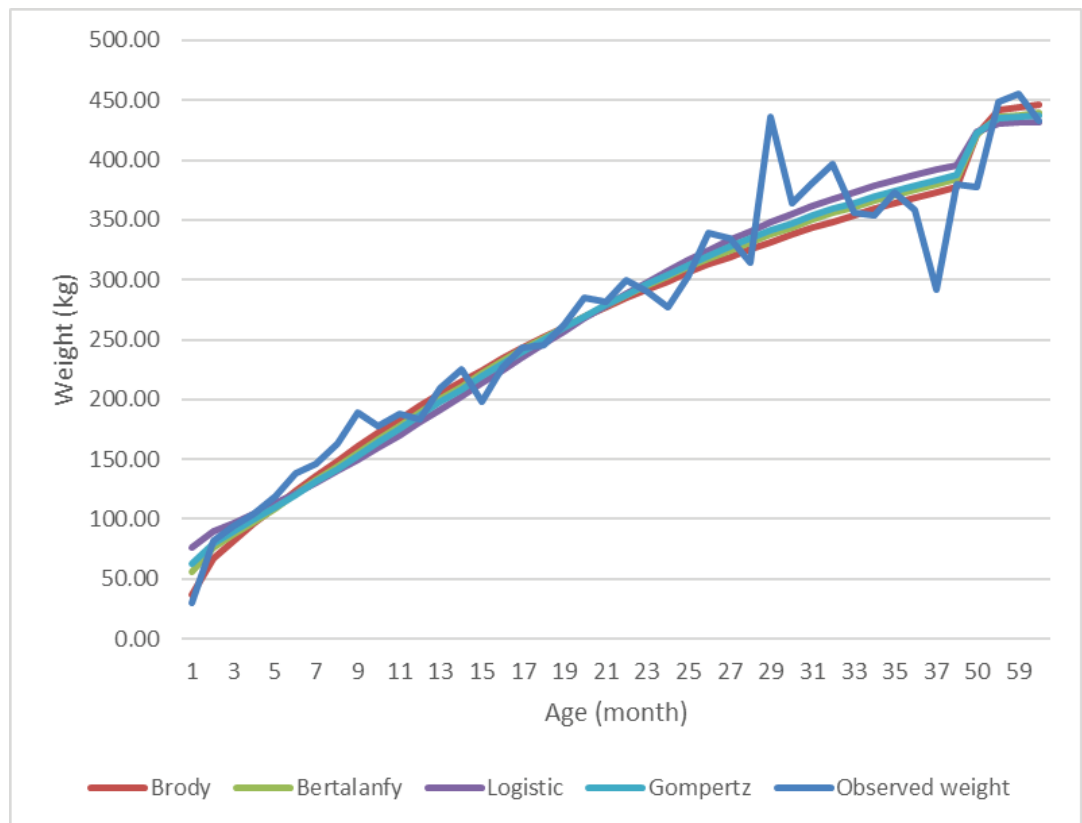
is a significant difference in cattle feed availability between these two seasons. The weaning age of Brahman cattle was 3 mo to 4 mo, in which the weaning age will affect the growth of calves after weaning [10].

Figure 1 shows the curve graph that connects between body weight and age of observed data, as well as body weight prediction results from the four mathematical models. The curve describes the pattern of growth Brahman female cattle in BPTU-HPT Sembawa. The growth curve depicted by each mathematical models followed the nonlinear growth curve patterns with depiction accuracy ( $R^2 > 0.88$ ). In general, all the points of curve depicted by each mathematical models were coinciding with the actual curve, except in some age experiencing underestimate and overestimate in predicting body weight. Brody model was more appropriate in predicting birth weight than other mathematical models. Each mathematical model underestimates in predicting body weight at the age 59 mo, and weight at ages 29 mo to 32 mo, as well as overestimate in predicting body weight at the ages 22 mo to 24 mo.

Model Brody was the most appropriate model in describing the growth curve of Brahman female cattle because it has the highest determination coefficient ( $R^2 = 0.90$ ) and the lowest value of MSE (1 429.86). The same results were obtained by [5] which states that the Brody models were more appropriate in describing the growth of Laguna cattle. The different results were obtained [3] which stated that Logistic and Gompertz models were more appropriate in describing Brakmas cattle growth. [4] stated that the Bertalanffy model was more appropriate in describing Dhofari cattle growth.

### 3.2. Growth parameter

The result of parameter analysis based on Brody, Bertalanffy, Logistic, and Gompertz mathematical models are shown on Table 1. Brody models had the highest value in predicting A parameter, followed by Bertalanffy, Logistic, and Gompertz models. There are significant differences ( $P < 0.05$ ) of A (adult weight) parameter between each model. The value of A parameter in Logistic models has significant ( $P < 0.05$ ) difference compared to Brody, Bertalanffy, and Logistic models, while the value of A parameter in Brody, Bertalanffy, and Gompertz models do not show significant ( $P < 0.05$ ) differences. The result of [3] in Brakmas cattle, showed that the Brody models ( $364.00 \pm 9.69$ ) had the highest value of A parameter followed by Bertalanffy ( $345.10 \pm 6.83$ ), Gompertz ( $339.30 \pm 6.07$ ) dan Logistic ( $328.80 \pm 4.92$ ) models. Different results were obtained by [4] in Dhofari cattle, which stated that the highest A parameter achieved by Bertalanffy



**Figure 1:** Brahman cattle growth curve by Brody, Bertalanffy, Gompertz, and Logistic models.

( $322.0 \pm 1.32$ ) models followed by obtained by Gompertz ( $319 \pm 1.31$ ), and Logistic ( $317 \pm 1.30$ ) models.

The highest B (the proportion of mature weight which will reach after birth weight) value is achieved by Logistic models, followed by Brody, Bertalanffy, and Gompertz models. There are significant differences ( $P < 0.05$ ) on B parameter value between each model. The value of B parameter in Logistic models has significant ( $P < 0.05$ ) difference compared to Brody, Bertalanffy, and Gompertz models. The value of B parameter also has significant ( $P < 0.05$ ) difference in Gompertz models compared to Bertalanffy and Brody models, while B parameter value shows no differences between Bertalanffy and Brody models. The same results were obtained by [8] which states that the estimated value of B was significantly ( $P < 0.05$ ) difference between all models.

The value of k (growth rate reach on mature body weight) ranged from 0.035 to 0.101. The highest value of k achieved by Logistic models followed by Brody, Bertalanffy, and Gompertz models. There is no significant ( $P > 0.05$ ) differences on the value of k parameter between all models. The same results were obtained by [4] in Dhofari cattle, which stated Logistic ( $0.127 \pm 0.002$ ) models had the highest k parameter value followed

by Gompertz ( $0.106 \pm 0.002$ ), Bertalanffy ( $0.127 \pm 0.002$ ) models [3] stated that Brody models predict the lowest value of the k parameter. Therefore this model tends to predict the value of A parameter highest compared with other models. [5] stated that Brody models tend to overestimate in predicting the value of A parameter during the growth phase.

TABLE 1: The value of A, B, k,  $R^2$ , and MSE

Model	A	B	$K^{ns}$	$R^2$	MSE
Brody	$507.19 \pm 8.27^b$	$0.928 \pm 0.050^a$	$0.034 \pm 0.001$	0.900	1429.786
Bertalanffy	$465.29 \pm 5.51^b$	$0.510 \pm 0.005^a$	$0.056 \pm 0.002$	0.892	1530.501
Logistic	$438.23 \pm 4.20^a$	$4.810 \pm 0.128^b$	$0.101 \pm 0.002$	0.877	1744.960
Gompertz	$454.81 \pm 4.94^b$	$1.990 \pm 0.028^c$	$0.067 \pm 0.002$	0.889	1585.188

*a,b,c* different superscript in the same column indicate significantly different ( $P < 0.05$ )

Brahman female cattle weight 446.85 kg at the age 4 yr to 5 yr [2] stated that cattle at the age 4 yr to 5 yr would reach mature weight. The most appropriate model in predicting the mature weight of Brahman female cattle was Logistic and Gompertz. Same results achieved by [4] and [3] which stated that the Logistic model was the most appropriate model in predicting mature weight in Dhofari and Brakmas cattle.

The  $R^2$  and MSE value between four mathematical models ranged from 0.877 to 0.900 and 1 429.786 to 1 585.188. Brody models have the highest determination coefficient value ( $R^2 = 0.90$ ) and the lowest MSE (1 429.86) value, while the Logistic models have the lowest  $R^2$  value (0.877) and the highest MSE value (1 744.96). The  $R^2$  value obtained from the four models in this study were smaller than those found in [3–5, 11], with each shows  $R^2$  value (0.96), (0.93), and (0.90) respectively. Those differences are thought to be caused by the high data variety in each age group, although the relatively large sample size. The body weight data from different breeds reared in different environments would influence the goodness of fit of the mathematical models in explaining the variations in cattle body weight [3].

## 4. Conclusion

All the evaluated mathematical nonlinear models in this study have a high level of  $R^2$  ( $R^2 > 0.84$ ) in describing curve Brahman female cattle growth. Brody models were appropriate in describing the Brahman female cattle growth curve. Logistic and Gompertz models were suitable in predicting Brahman female cattle mature weight.

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