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RESEARCH ARTICLE

Predicting The Growth Curve of Body Weight in Madura Cattle

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Abstract

The growth curve of livestock animals is important to evaluate the biological development managed with a farming management system. This study aimed to estimate the growth curve of body weight (BW) in Madura cattle *(Bos indicus)* kept at the breeding management. Three non-linear models of Logistic (L), Gompertz (G) and Von Bertalanffy (B) were performed in this study using 186 records data and computed with SPSS 16.0 package. Research showed that the asymptotic weight (male/female) was reached of 220.80/218.02 kg (L), 277.72/274.13 kg (G) and 333.92/329.83 kg (B). The weight of inflection (male/female) was reached of 110.40/109.01 kg (L), 102.10/100.78 kg (G) and 98.94/97.73 kg (B). The time of inflection (male/female) was reached of 10.89/10.47 months (L), 10.09/10.23 months (G) and 9.80 months (B). Moreover, the coefficient of determination (R2) in all models included of high category i.e. 0.68 (male) and 0.70 (female). However, three goodness-of-fit parameters of root mean squared error (RMSE), Akaike's (AIC) and Beyesian (BIC) values revealed that G and B models were more accurate than the other models for male and female, respectively. It can be concluded that about 68-70% of body weight of animals in a study can be explained by non-linear models of L, G and B.

Keywords: *Body weight, Growth curve, Inflection, Madura cattle, Non-linear models*

Madura Sığırlarında Vücut Ağırlığı Büyüme Eğrisinin Tahmini

Öz

Çiftlik hayvanlarının büyüme eğrisi, bir çiftlik yönetim sisteminde biyolojik gelişimin değerlendirilmesi için önemlidir. Bu çalışmada, damızlık amaçlı yetiştirilen Madura sığırlarında *(Bos indicus)* vücut ağırlığının (BW) büyüme eğrisinin tahmin edilmesi amaçlanmıştır. Bu çalışmada, 186 veri kaydı ve SPSS 16.0 paket programı eşliğinde doğrusal olmayan üç model, Lojistik (L), Gompertz (G) ve Von Bertalanffy (B), kullanılmıştır. Çalışma, asimptotik ağırlığın (erkek/dişi), 220.80/218.02 kg (L), 277.72/274.13 kg (G) ve 333.92/329.83 kg (B)'a ulaştığını göstermiştir. Büküm ağırlığı (erkek/dişi), 110.40/109.01 kg (L), 102.10/100.78 kg (G) ve 98.94/97.73 kg (B)'a ulaşmıştır. Büküm zamanı (erkek/dişi), 10.89/10.47 ay (L), 10.09/10.23 ay (G) ve 9.80 ay (B) olarak belirlenmiştir. Ayrıca, tüm modellerde determinasyon katsayısı (R2), yüksek, 0.68 (erkeklerde) ve 0.70 (dişilerde) saptanmıştır. Bununla birlikte, Hata Kareler Ortalamasının Karekökü (RMSE), Akaike Bilgi Kriteri (AIC) ve Bayesci Bilgi Kriteri (BIC) üçlü uyum indeks analiz değerleri, G ve B modellerinin sırasıyla erkek ve dişiler için diğer modellere göre daha doğru olduğunu ortaya koymuştur. Hayvanların vücut ağırlığının yaklaşık %68-70'inin doğrusal olmayan L, G ve B modelleri ile tahmin edilebileceği sonucuna varılabilir.

Anahtar sözcükler: *Vücut ağırlığı, Büyüme eğrisi, Büküm, Madura sığırı, Doğrusal olmayan modeller*

INTRODUCTION

Madura cattle is one of Indonesian native cattle that originated from Madura Island and is a composite breed that has undergone hundreds of years of selection and domestication. Based on its history, Madura cattle were formed from product cross mating between *Bos javanicus* (wild banteng) and *Bos indicus* that occurred thousands of years ago. Until now, Madura cattle had diverged into 3 functions: sonok, karapan and commercial Madura cattle. Sonok cattle are female Madura cows that have beautiful body shape, coat color, conformation and skills which are the result of selection and specific maintenance from generation to generation. Karapan cattle is a bull that has the ability to run fast and has a lighter and smaller body. Karapan cattle are widely used for the traditional arts of the Madura community [1].

The Madura cattle was kept for meat production and

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drought by smallholders. The weaning weight (205 days of age) and yearling weight (365 days of age) of Madura cattle were 97.00±13.77 kg and 120.00±10.86 kg, respectively [2]. Despite the slaughter weight, carcass weight and carcass percentage of Madura bull were 248.00±71.00 kg; 128.90±45.16 kg and 51.08±4.50%, respectively [3]. In addition, the reproductive traits of Madura cow such as service per conception, conception rate and gestation length were 1.46 time, 58.80%, and 283.35±17.15 days, respectively [4]. According to Cytochrome Oxidase I (COI) gene (mtDNA), the Madura cattle had similar genetic characterization with Zebu *(Bos indicus)* cattle [5].

Madura cattle had good of genetic potency as the beef cattle in Indonesia. The genetic improvement in these cattle is being carried out through a selection program. The early selection in Madura cattle can be performed with growth curve of body weight. The growth curve of body weight was used to evaluate the growth performance in several Indonesian cattle breeds i.e. Friesian Holstein [6-12], Bali [13], Brahman cross [14], Madura [15,16], Aceh [17] and Ongole grade [18]. In addition, the growth curve was also used in many cattle breeds such as Belgian Blue [19], N'Dama [20], Nellore [21,22], Dhofari [23], Parda de Montana [24], Aberdeen Angus [25], Podolica [26] and Friesian Holstein [27,28] to evaluate the growth performance in the world.

The growth in livestock can be defined as an increase of body size per time unit [29]. Growth is a continuous function during the animal's life from embryonic stages up to adult age and it is mathematically explained by growth curve models. Growth curve for poultry generally have the characteristics: an accelerating phase of growth from hatching, a point of inflection in the growth curve at which the growth rate is maximum, a phase where growth rate is decelerating and a limiting value (asymptote) mature weight [30]. In addition, the growth curve is to describe the regular change generated by the live weight or some part of the animal with the age increasing, which commonly is a S-shaped (sigmoid) curve [31].

The application of mathematical model on growth curve will provide a set of parameters that could be used to describe growth pattern overtime. Furthermore, it will enable the breeders to expect the weight of animals at a specific age and to detect the stage that associated with the reduction in growth rate [32]. Moreover, growth curves of livestock have been used to dynamically observe the growth course, to forecast the poultry growth law and to instruct the feeding and management programs to improve the selection and breeding effects [33].

The growth curve of livestock can be estimated with several nonlinear regression model of Brody, Von Bertalanffly, Gompertz, Logistic, Richards and Weibull. However, the Logistic, Gompertz and Von Bertalanffy models have fixed growth forms with point of inflection at about 50%, 30% and 30% of the asymptote in animals, respectively [34]. Moreover, many models were used to obtain the growth curve model in cattle [10,12]. Unfortunately, the study of growth curve estimation in Madura cattle using non-linear models so far is not reported. This study was aimed to estimate the growth curve of body weight with non-linear model of Logistic, Gompertz and Von Bertalanffy. The result of this study can be used as the basic information to keep Madura cattle for breeding or feedlot purposes.

Material and Methods

Ethical Approval

The following experiment was conducted under the guidelines of the Indonesian Code of Practice for the Care and Use of Animals for Scientific Purposes and was approved by the Indonesian Ministry of Agriculture Animal Ethics Committee (Balitbangtan/Lolitsapi/Rm/14/2019).

Animals Data and Research Site

The records of body weight (BW) in Madura cattle (*Bos indicus)* were collected from 186 animals (95 males and 91 females) between the year 2014 to 2019. The weighing time of each animal was performed every month from birth to 20 month of age using electronic digital weight scale. The animals were kept in the colony stall at Indonesian Beef Cattle Research Station *(Loka Penelitian Sapi Potong Grati)*. This station located at longitude112°33'55" to 113°30'37" E and latitude 70°32'34" to 80°30'20" S. This area located at 2 to 2770 m above the sea level with air temperature of 24-32°C and rainfall of 0.2-30.9 mm/year.

Animals Management

The animals were kept in the colony stall with natural mating system. Each stall consisted of 1 bull and 15 to 20 cows. The forages feed consisted of 97.98% of Elephant grass *(Pennisetum purpureum)* and 2.02% of rice straw. Thus, the concentrate feed consisted of chalk (1.89%), salt (1.89%), rice bran (24.75%), slamper corn (20.51%), coffee peel (4.98%), palm kernel cake (9.70%), copra cake (10.16%), cassava flour (10.16%), destillers dried grains with soluble (7.98%) and corn gluten feed (7.98%). Thus, the standard nutritional content of feed for Madura cattle was presented in *Table 1*. Moreover, the fresh water was given *ad libitum* with regular medical examination and vaccination.

Data Analysis

The individual BW data in male (1.876 datasets) and female

Table 1. *The standard nutritional content (DM) of feed for Madura cattle*

Physiological Status	CP (%)	TDN (%)	CF (%)
Birth to weaning	9-10	58-60	19-22
Weaning to adult	10-11	58-60	17-19

DM: *dry matter;* ***CP:*** *crute protein;* ***TDN:*** *total digestible nutrient;* ***CF:*** *crude fiber*

(1.737 datasets) cattle were used to estimate the growth curve with Logistic (L), Gompertz (G) and Von Bertalanffy (B) models using SPSS 16.0 software. The non-linear regression equations that used in the present study were presented in *Table 2*. The goodness-of-fit model in this study was selected based on coefficient of determination *(R^2)* and mean root squared error (*RMSE)*, Akaike's information criterion *(AIC)* and Beyesian information criterion *(BIC)* using the mathematical formula as follow [35]:

$$R^2 = 1 - \left(\frac{SSE}{SST}\right)$$

$$RMSE = \sqrt{\frac{SSE}{n-p-1}}$$

$$AIC = NLn\left(\frac{SSE}{N}\right) + 2p$$

$$BIC = NLn\left(\frac{SSE}{n}\right) + pLn(n)$$

where, R2 is the coefficient of determination; *SSE* is the sum of square error; *SST* is the total sum of square; *AIC* = Akaike's information criterion; *BIC* = Beyesian information criterion; N is number of observations (data points); p is the number of parameters.

Results

The average of body weight in Madura cattle from birth to adult ages were presented in *Table 3* (male) and *Table 4* (female). Mostly, the CV value in each age group were included of high category (>20%). Therefore, the growth parameters in Madura cattle were presented in *Table 5*. According to *Table 5*, the A value in B model was higher than the other models in both sexes. Thus, the highest of W_i and t_i values were reached by L model. Meanwhile, the lowest of W_i and t_i values were reached by B model. In addition, A, W_i and t_i values in male were higher than female animals. In general, the A value in animals in the study was 218.02-333.92 kg. The W_i value in animals in the study was 97.73-110.40 kg. While, the t_i value in animals

Table 2. *The growth curve function of Logistic, Gompertz and Von Bertalanffy models (24)*

Model	Y_t	W_i	t_i
Logistic	$A(1+Be^{-kt})^{-1}$	A/2	(Ln.B)/k
Gompertz	$A\exp(-Be^{-kt})$	A/e	(Ln.B)/k
Von Bertalanffy	$A(1-Be^{-kt})^3$	A(8/27)	(Ln.3B)/k

Y_t: *body weight (kg) of cattle at t week of age;* ***A:*** *the asymptotic weight (kg) when times goes to infinity;* ***B:*** *scaling parameters (constant of integration);* ***k:*** *maturing rate (kg/month);* ***e:*** *constanta (2.72);* ***t:*** *time (month);* ***W_i:*** *weight of inflection (kg);* ***t_i:*** *time of inflection (month)*

Table 3. *The descriptive statistics of body weight in male Madura cattle at different ages*

Age (month)	N	Mean (kg)	SD	CV (%)	Min.	Max.
0 (birth)	95	16.81	3.51	20.88	11.00	25.00
1	95	25.86	4.52	17.48	16.80	33.62
2	95	34.93	7.08	20.27	20.72	50.85
3	94	43.99	10.07	22.89	24.58	68.27
4	91	53.00	13.26	25.02	28.44	85.69
5	91	61.08	15.82	25.90	32.30	103.12
6	89	69.94	18.92	27.06	36.00	120.54
7	87	78.36	22.05	28.14	39.10	137.96
8	87	86.90	25.41	29.25	41.25	155.38
9	87	95.67	28.59	29.88	43.41	172.81
10	87	104.43	31.77	30.42	45.57	190.23
11	87	113.20	34.96	30.88	47.73	207.65
12	87	121.97	38.15	31.27	49.88	225.08
13	87	130.74	41.34	31.62	52.04	242.50
14	87	139.51	44.53	31.92	54.20	259.92
15	87	148.27	47.72	32.19	56.35	277.35
16	87	157.04	50.92	32.42	58.51	294.77
17	87	165.81	54.12	32.64	60.67	312.19
18	87	174.58	57.32	32.83	62.82	329.62
19	87	183.35	60.51	33.01	64.98	347.04
20	87	192.11	63.71	33.16	67.14	364.46

N: *number of animals;* ***SD:*** *standard deviation;* ***CV:*** *coefficient of variation;* ***Min.:*** *minimum;* ***Max.:*** *maximum*

Table 4. *The descriptive statistics of body weight in female Madura cattle at different ages*

Age (month)	N	Mean (kg)	SD	CV (%)	Min.	Max.
0 (birth)	91	15.85	2.92	18.43	11.00	25.00
1	91	24.74	4.41	17.83	15.97	37.53
2	91	33.74	7.04	20.87	20.91	51.25
3	91	42.74	9.95	23.29	23.87	66.87
4	91	51.74	12.96	25.04	26.82	82.49
5	86	59.82	15.75	26.33	29.78	98.12
6	85	68.34	18.67	27.32	32.73	113.74
7	84	76.89	21.72	28.25	35.69	129.36
8	79	85.53	24.76	28.95	38.64	144.99
9	79	94.28	27.79	29.47	41.60	160.61
10	79	103.04	30.82	29.92	44.55	176.23
11	79	111.79	33.86	30.29	47.51	191.86
12	79	120.54	36.90	30.61	50.46	207.62
13	79	129.30	39.94	30.89	53.42	223.92
14	79	138.05	42.98	31.13	56.37	240.22
15	79	146.80	46.02	31.35	59.33	256.52
16	79	155.56	49.07	31.54	62.28	272.82
17	79	164.31	52.11	31.71	65.24	289.12
18	79	173.06	55.15	31.87	68.19	305.42
19	79	181.81	58.20	32.01	71.15	321.73
20	79	190.57	61.24	32.14	74.10	338.03

N: *number of animals;* ***SD:*** *standard deviation;* ***CV:*** *coefficient of variation;* ***Min.:*** *minimum;* ***Max.:*** *maximum*

Table 5. *The growth curve parameters for body weight of Madura cattle*

Model	Sex	A	B	k	W_i	t_i	Iteration
Logistic	Male	220.80±8.12	7.10±0.33	0.18±0.01	110.40	10.89	6
	Female	218.02±7.92	7.31±0.34	0.19±0.01	109.01	10.47	6
Gompertz	Male	277.72±18.85	2.48±0.05	0.09±0.01	102.10	10.09	5
	Female	274.13±18.40	2.51±0.05	0.09±0.01	100.78	10.23	5
Bertalanffy	Male	333.92±33.08	0.60±0.01	0.06±0.01	98.94	9.80	5
	Female	329.83±32.35	0.60±0.01	0.06±0.01	97.73	9.80	5

A: *the asymptotic weight (kg) when times goes to infinity;* ***B:*** *scaling parameters (constant of integration);* ***k:*** *maturing rate (kg/month);* ***t:*** *time (month);* ***W_i:*** *weight of inflection (kg);* ***t_i:*** *time of inflection (month)*

Table 6. *The goodness-of-fit criteria for the studied growth models*

Sex	Model	R^2	RMSE	AIC	BIC
Male	Logistic	0.68	36.80	13.531.09	13.547.70
	Gompertz	0.70	35.23	13.518.02	13.534.63
	Bertalanffy	0.68	36.67	13.514.44	13.531.05
Female	Logistic	0.70	35.09	12.376.97	13.393.35
	Gompertz	0.68	36.64	12.363.37	12.379.75
	Bertalanffy	0.70	35.05	12.359.64	12.376.02

R^2: *coefficient of determination;* ***RMSE:*** *root mean squared error;* ***AIC:*** *Akaike's information criterion;* ***BIC:*** *Beyesian information criterion*

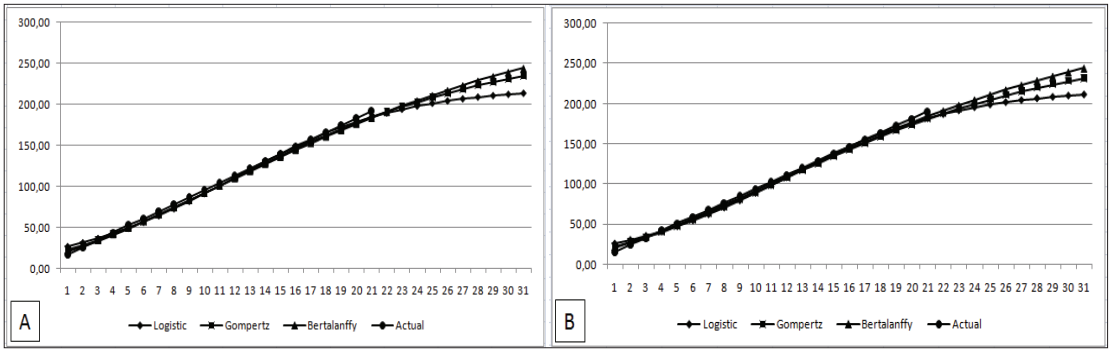

Fig 1. The growth curve of body weight in Madura cattle. A-male, B- female

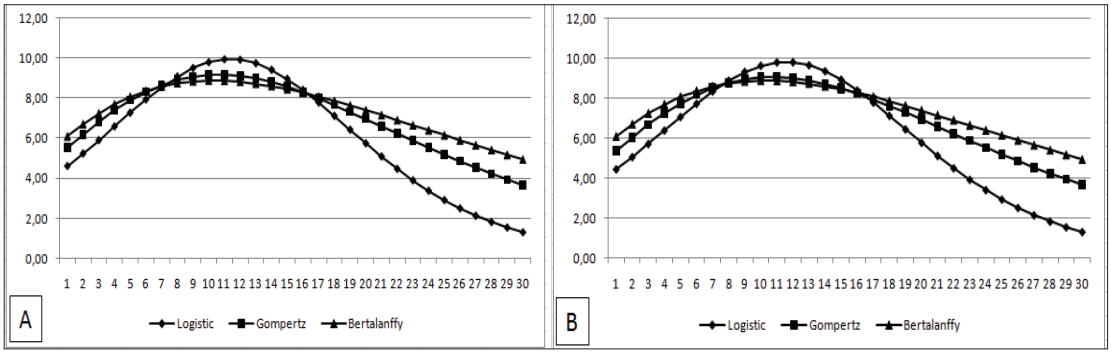

Fig 2. The growth rate of body weight in Madura cattle. A- male, B- female

in the study was 9.80-10.89 months. The R^2 value in each model included of high category ($0.60<R^2<0.80$). However, the goodness-of-fit criteria showed that the G model ($R^2=0.70$) can be selected as the best function to describe growth of male Madura cattle with the lowest of RMSE, AIC and BIC values *(Table 6)*. Meanwhile, the B model as the best function to describe growth of female Madura cattle with the lowest of RMSE, AIC and BIC values. The growth curve and the growth rate of BW in Madura cattle were presented in *Fig. 1* and *Fig. 2,* respectively. According to the growth curve and the growth rate illustration, both sexes have similar growth characteristics. In addition, the number of iterations in the estimated non-linear model were reached of 5 (L) to 6 (G and B),

Discussion

The A values (L/G/B) in dairy cows *(Bos taurus)* were 343.60/354.50/369.90 kg [8], 213.00/543.40/1084.00 kg [27] and 672.94/986.44/1565.60 kg [28]. In addition, the A values (L/G/B) in several *Bos taurus* cattle breeds were 431.00/481.00/517.00 kg in Belgian Blue [19]; 437.10/444.70/448.90 kg in Angus [25] and 778.50/936.90/1098.00 kg in Podolica [26]. Meanwhile, the A values (L/G/B) in some *Bos indicus* cattle breeds were 306.60/311.52/314.04 kg in Brahman cross [14] and 317.00/319.00/322.00 kg in Dhofari [23]. In general, the A value of L model in Madura and Turkish Holstein (TH) cows [27] were under similar range (218.02 vs 213.00). Therefore, the A value of B model in Madura and Dhofari cattle [23] were under similar range (329.83 vs 322.00 kg). The mature weight of cattle can be influenced by farming system and genetics factor.

The W_i value (L/G/B) in Indonesian Holstein (IH) and TH cows were 145.45/130.41/109.60 kg [8] and 336.47/362.89/463.88 kg [28], respectively. Hence, the W_i value in observed Madura cattle was lower than IH and TH cows. Moreover, the W_i values (L/G/B) in several *Bos taurus* cattle breeds were 215.50/176.84/153.19 kg in Belgian Blue [19]; 218.55/163.49/133.01 kg in Angus [25] and 389.30/344.70/325.30 kg in Podolica [26]. Therefore, the W_i values (L/G/B) in some *Bos indicus* cattle breeds were 153.30/143.03/93.05 kg in Brahman cross [14]; 174.00/132.00/108 kg in Ongole grade [18] and 158.00/117.00/95.40 kg in Dhofari [23]. The W_i value of B model in Madura and Dhofari cattle [23] were under similar range (98.84/97.73 vs 85.40). The W_i value in cattle can be influenced by farming system and genetics factor.

The t_i values (L/G/B) in IH and TH cows were 7.55/6.45/4.99 months [8] and 10.92/10.23/13.22 months [28], respectively. Therefore, the t_i value (L/G/B) in some *Bos taurus* cattle breeds were 8.25/6.61/5.56 months in Belgian Blue [19]; 13.24/7.36/19.57 months in Angus and 13.87/12.39/11.70 in Podolica [26]. Therefore, the t_i values (L/G/B) in some *Bos indicus* cattle breeds were 7.81/6.57/2.33 months in Brahman cross [14]; 10.90/6.32/7.26 months in Ongole grade and 7.00/5.00/9.00 months in Dhofari [23]. The t_i value of L modelin Madura, TH [28] and Ongole grade [18] were under

similar range (10.89/10.47vs 10.90 vs10.92). The inflection point indicates several things of the presence of maximum growth of livestock, age at puberty and the lowest point in mortality.

The t_i value in observed Madura cattle reveals that the puberty age of Madura cattle was reached at about 11 months (L) or about 10 months (G). A previous study reported that the puberty age in cattle was reached at 8-12 months [36]. Puberty age in cattle indicates that the sexual organs of cattle developed and signed by sexual behaviors of estrous (female) and flehmen libido (male). In addition, cattle at 11 months of age were mentioned as yearling age and used as the selection criteria for breeding cow and bull. Hence, the heritability (h^2) value of yearling weight (YW) in Madura cattle was 0.54±0.18 (high category) and suggested that the YW trait can be increased with selection program [37]. In cattle, the body weight at puberty age was about 40% of adult weight [38]. Commonly, the puberty age in *Bos indicus* cattle was higher than *Bos taurus* cattle [39]. Puberty age can be affected by genetic (breed) and environmental (climate, nutrition, season) factors [40]. However, the puberty age in cattle can be increased by selection, crossbreeding, and feed (nutrition) improvement [41].

The G and B models are able to describe the growth of observed male and female Madura cattle accurately with high R^2 value (0.70) and lowest of RMSE, AIC and BIC. A similar finding has been reported in Brahman cross cows with B model as the best function rather than L and G models [14]. In conclusion, the non-linear G and B models can be used to predict the body weight of male and female Madura cattle.

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Conflict of Interest

Authors declares that there is no conflict of interests.

Author Contributions

HH and WPBP planned and designed the study, methods, data analysis and manuscript preparation. All authors participated in the study and concurred with the submission and subsequent revisions submitted by the corresponding author.

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