

Predicting the growth curve of body weight in Ettawa Crossbred Goats with Logistic and Gompertz mathematical models

Prediksi kurva pertumbuhan berat badan pada Kambing Peranakan Ettawa dengan model matematika Logistik dan Gompertz

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Abstract. Ettawa crossbred goat is one of Indonesian native goat that kept for meat and milk productions. This research was aimed to predict the growth curve of body weight in Ettawa crossbred goat at 1 - 24 months of age with Logistic (L) and Gompertz (G) mathematical models. The number of 48 goats (24 males and 24 females) were used in this study and collected from Tambang District, Kampar Regency, Riau Province of Indonesia. Research showed that L and G models have the very high coefficient determination (R^2) value ($R^2 > 0.90$). The asymptotic weight (A) in animal studies was 53.34 kg (L) / 55.20 kg (G) for male and 36.99 kg (L) / 39.86 kg (G) for female. The inflection of weight (I_w) in animal studies was 26.67 kg (L) / 20.29 kg (G) for male and 18.49 kg (L) / 14.65 kg (G) for female. The inflection of age (I_A) in animal studies was 8.54 months (L) / 6.74 months (G) for male and 9.80 months (L) / 7.00 months (G) for females. In conclusion, the growth curve of body weight in Ettawa crossbred goats can be predicted with L and G models accurately.

Keywords: body weight, inflection, coefficient determination, growth curve, Ettawa crossbred

Abstrak. Kambing Peranakan Ettawa merupakan salah satu kambing asli Indonesia yang dipelihara untuk produksi daging dan susu. Penelitian ini bertujuan untuk memprediksi kurva pertumbuhan berat badan kambing Peranakan Ettawa umur 1 - 24 bulan menggunakan model matematika Logistik (L) dan Gompertz (G). Sebanyak 48 kambing (24 jantan dan 24 betina) digunakan pada penelitian ini yang dikoleksi dari Kecamatan Tambang, Kabupaten Kampar, Provinsi Riau, Indonesia. Hasil penelitian menunjukkan bahwa model L dan G memiliki nilai koefisien determinasi (R^2) yang sangat tinggi ($R^2 > 0.90$). Berat asimtotik pada kambing sebesar 53,34 kg (L) / 55,20 kg (G) pada jantan dan 36,99 kg (L) / 39,86 kg (G) pada betina. Berat infleksi (I_w) pada kambing sebesar 26,67 kg (L) / 20,29 kg (G) pada jantan dan 18,49 kg (L) / 14,65 kg (G) pada betina. Umur infleksi (I_A) pada kambing sebesar 8,54 bulan (L) / 6,74 bulan (G) pada jantan dan 9,80 bulan (L) / 7,00 bulan (G) pada betina. Disimpulkan bahwa kurva pertumbuhan berat badan pada kambing Peranakan Ettawa dapat diprediksi secara akurat dengan model L dan G.

Kata kunci: berat badan, infleksi, koefisien determinasi, kurva pertumbuhan, Peranakan Ettawa

INTRODUCTION

Ettawa crossbred goat is one of Indonesian native goat that kept for meat and milk productions. This goat has been decided into Indonesian native goat since year 2013 through the decision of Indonesian Ministry of Agriculture No: 695/Kpts/PD.410/2/2013 (Amin et al., 2021). As the native goat of Indonesia, selection of Ettawa grade goat is important for genetic improvement. The growth curve of livestock can be used for livestock selection. The process of growth measured as body weight on a longitudinal time frame has often been summarized using mathematical models fitted to growth curves. One of the objectives of curve fitting is to describe the course of body weight increase over time with mathematical parameters that are biologically interpretable (Lawrence & Fowler, 2002; Cak et al., 2017).

Growth curve is a reflection of the ability of an individual or population to actualize themselves as a measure of the development of body parts to the maximum size (adult) in the existing environmental conditions. Generally, growth in the form of sigmoid or "S". The "S" curve represents a form of acceleration and deceleration that is limited by turning points or inflection points. The inflection point is the maximum point of growth in body weight (Lawrence & Fowler, 2002). In models of animal production systems, growth curves are used to provide estimates of daily feed requirements for growth. These estimates are used in providing total feed requirements, which sets an upper limit to feed intake when animals are given ad libitum access to feeds (Lopez et al., 2000). The mathematical models for describing growth kinetics are important tools to examine biological parameters, such as body weight at specific time, maximum growth response, and body weight at maturity, growth rates, inflection point, and body weight at the inflection point. Numerous growth functions have been developed to describe and fit the nonlinear sigmoid relationship between growth and time or age (Lucena et al., 2019).

Two growth curve models of Logistic and Gompertz have been used to predict growth curve of body weight in many goat breeds such as Kacang (Tsukahara et al., 2008; Wiradarya et al., 2020), Angora (Özdemir & Dellal, 2009), Alpine (Kume & Hajno, 2010), Beetal (Waheed et al., 2011), Damascus (Gaddour et al., 2012), Saanen (Regadas Filho et al., 2014), Repartida (Pires et al., 2017), Raeini Cashmere (Ghiasi et al., 2018), Markhoz (Kheirabadi & Rashidi, 2018), Sirohi (Waiz et al., 2019), Boer (Garcia-Muniz et al., 2019) and native Mexican (Maldonado-Jaquez et al., 2021). Recently, study of determining the growth pattern in Ettawa grade goat is not reported. Hence, this study was carried out to predict the growth curve of body weight in Ettawa grade goat with Logistic and Gompertz mathematical models. The results of this study can be used as the early information to describe the growth model in Ettawa grade goat that usefull for the selection program.

MATERIALS AND METHODS

The number of forty-eight (48) Ettawa crossbred goats (24 males and 24 females) were used in the present study. The goats were grouped into 24 age groups with the ratio of 1 animal/age group. The goats in this study were collected from Tambang District, Kampar Regency, Riau Province of Indonesia from October to November year 2011. The goats that used in this study were kept by smallholders with traditional management system. The research site located at latitude 01°00'40" N to 00°27'00" S and longitude 100°28'30" E to 101°14'30" E. The average air temperature was about 20 - 30 °C with the rainfall about 2000 - 2200 mm/year and latitude about 26 - 100 m above sea level. The body weight (BW) of goats were obtained with the animal weighing scale. Therefore, two non-linear regression models of Logistic (L) and Gompertz (G) were computed in this using CurveExpert Professional 2.3. package (Hyams, 2020).

The mathematical formula to describe the growth characteristics with L and G models as follow (Tutkun, 2019):

$$\text{Logistic} : Y_t = \frac{A}{1 + B^{-kt}} ; I_w = 0.5(A) ; I_A = \frac{\text{Ln}(B)}{k} ; \text{MGR} = 0.50(I_w \times k)$$

$$\text{Gompertz} : Y_t = Ae^{-e^{-b-kt}} ; I_w = A/e ; I_A = B/k ; \text{MGR} = I_w \times k$$

where, Y_t is the predicted body weight at t^{th} age; A is the asymptotic weight (kg); B is the scale parameter; k is the average rate of body growth until the animal reaches body maturity; e is the logarithm base (2.72); t is the animals age (months); I_w is the inflection of weight (kg) I_A : is the inflection of age (months); MGR is the maximum growth rate (kg/month).

RESULTS AND DISCUSSION

Body Weight

The body weight (BW) in male goats was higher than female goats as shown in Table 1. In ruminant animals, the androgen hormone of males was given the sex dimorphism effect and signed with higher performance in males rather than in females (Soeparno, 2005). In the breeding station at South Kalimantan Province, the average BW in Ettawa crossbred goat at 18 months of age reached of 50.41 ± 1.08 kg for male and 47.20 ± 1.13 kg for female (Hasan et al., 2014). In the breeding station at West Java Province, the average BW in Ettawa crossbred goat at 18 -24 months of age reached of 45.30 ± 4.70 kg for male and 37.70 ± 1.90 kg for female (Anggraeni & Praharani, 2017). Compared to this study, the BW of female Ettawa grade at the breeding station was higher. Meanwhile, the BW of male Ettawa crossbred in South Kalimantan was closed to the Ettawa grade at 18 months of age in this study (45.30 vs 48.00). The different results between present study and previous studies can caused by the different of management system, feed nutrient or feed composition and the enviromental factors (climate, humidity and air temperature).

Tabel 1. The body weight of Ettawa crossbred goat at 1 - 24 month of age

Age (month)	Body weight (kg)		Age (month)	Body weight (kg)	
	Male	Female		Male	Female
1	3.70	3.20	13	52.70	23.00
2	6.30	5.40	14	55.00	27.20
3	11.40	6.20	15	54.40	24.80
4	13.60	9.80	16	50.30	23.90
5	14.90	11.70	17	53.70	26.60
6	15.40	13.00	18	48.00	29.10
7	17.00	16.50	19	55.70	31.40
8	19.80	18.70	20	53.30	37.70
9	22.30	20.10	21	49.70	34.50
10	27.00	21.80	22	50.80	32.70
11	38.80	19.90	23	46.00	36.30
12	44.30	22.40	24	51.30	33.40

Growth Parameters

The growth parameters for BW in Ettawa crossbred goat was presented in the Table 2. According iner similar to Table 2, the asymptotic weight (A), inflection of weight (I_w) and inflection of age (I_A) in L model was higher than G model. In addition, all the growth parameters in males were higher than females. The A value in male Ettawa grade was 53.34 kg (L) and 55.20 kg (G) and close to mixed-sex goat of Alpine *i.e.* 50.30 kg (L) / 51.70 kg (G) and Saanen *i.e.* 53.30 kg (L) and 54.90 kg (G) as shown in Table 3. Thus, the inflection of weight (I_w) in male Ettawa crossbred was 26.67 kg (L) and 20.29 kg (G) and cose to mixed-sex goat of Boer *i.e.* 24.75 kg (L) and 20.11 kg (G); Alpine *i.e.* (25.15 kg (L) and Saanen *i.e.* 26.50 kg (L) and 20.18 kg (G) as shown in Table 3. Therefore, the Inflection of age (I_A) in female Ettawa crossbred goat with L model was 9.80 months and close to mixed-sex Malaysian Kacang goat (9.23 months) in the similar model (Table 3). Meanwhile, the I_A value in female Ettawa crossbred goat with G model was 7.00 months and close to male Beetal (7.28 months) and mixed-sex Markhoz (7.23 months) in the similar models (Table 3). The growth curve of body weight in goat can be affected by breed, sex, nutrition and farming management system. In the breeding system of goat, an inflection point is important to determine the optimum weight and age for reproduction (Devendra & Burns, 1983). The k

parameter influences the maturation rate of the animal, indicating the growth rate to reach the asymptote weight. Carneiro et al. (2009) reported that animals with a higher k value matured earlier than animals of a similar weight with a smaller k value. In this study, the k value in L model was higher than G model.

Table 2. The growth parameters in body weight of Ettawa crossbred goat

Sex	Model	A	B	k	I_W	I_A	MGR
Male	Logistic	53.34	25.69	0.38	26.67	8.54	5.07
	Gompertz	55.20	1.55	0.23	20.29	6.74	4.67
Female	Logistic	36.99	5.84	0.18	18.49	9.80	1.66
	Gompertz	39.86	0.84	0.12	14.65	7.00	1.76

A: asymptote weight (kg); B: scaling parameter; k: maturing rate; I_W : inflection of weight (kg); I_A : inflection of time (month); MGR: maximum growth rate (kg/month)

Table 3. The weight and age inflections in several goat breeds based on Logistic and Gompertz mathematical models

Breed	Sex	Model	A	I_W	I_A	R^2	Reference
Angora	Mixed	L	20.70	10.35	2.67	0.96	Ozdemir & Dellal (2009)
		G	23.39	8.60	4.33	0.96	
Beetal	Male	G	24.02	8.83	7.28	0.99	Waheed et al. (2011)
	Female	G	22.94	8.43	8.33	0.99	
Boer	Mixed	L	49.50	24.75	2.63	-	Garcia-Muniz et al. (2019)
		G	54.70	20.11	13.27	-	
Indonesian Kacang	Male	L	30.60	15.30	15.57	0.98	Wiradarya et al. (2020)
		G	42.90	14.59	14.41	0.98	
	Female	L	26.31	13.16	12.95	0.98	
		G	31.12	12.76	12.71	0.98	
Malaysian Kacang	Mixed	L	27.00	13.50	9.23	0.93	Tsukahara et al. (2008)
		G	28.10	10.33	15.83	0.94	
Markhoz	Mixed	L	22.99	11.50	3.09	0.96	Kheirabadi & Rashidi (2018)
		G	24.67	9.07	7.23	0.97	
Mexican	Mixed	L	73.40	36.70	15.95	0.85	Maldonado-Jaquez et al. (2021)
		G	84.59	31.10	11.78	0.88	
Raeini Cashmere	Male	G	18.28	9.14	1.16	-	Ghiasi et al. (2018)
	Female	G	18.27	6.72	3.32	-	
Repartida	Mixed	L	22.31	11.66	1.16	0.91	Pires et al. (2017)
		G	24.50	9.01	2.40	0.91	
Alpine	Mixed	L	50.30	25.15	8.36	-	Regardaz Filho et al. (2014)
		G	51.70	19.01	15.83	-	
Saanen	Mixed	L	53.30	26.50	8.36	-	(2014)
		G	54.90	20.18	15.83	-	
Sirohi	Male	L	26.13	13.07	0.40	0.96	Waiz et al. (2019)
		G	27.37	10.06	0.80	0.98	
	Female	L	22.86	11.43	0.37	0.96	
		G	23.74	8.73	0.70	0.98	
Damascus	Mixed	G	15.74	5.78	0.33	0.71	Gaddour et al. (2012)

L: Logistic; G: Gompertz; A: asymptote weight (kg); I_W : inflection of weight (kg); I_A : inflection of age; R^2 : coefficient of determination

In addition, Ghiasi et al. (2018) reported that the growth parameters (A and k) of body weight in Raeini Cashmere goat have the low heritability (h^2) value (<0.30). Sunwasiya et al. (2019) has

been worked with Brody model to describe the growth patterns of Sirohi goat and obtains the high (>0.30) and low categories of h^2 value in A and k values, respectively. High h^2 value indicated that the observed traits can be improved with the selection program.

Growth Curve Model

The growth curve of body weight in Ettawa grade goats with L and G models were illustrated in Figure 1. According to the Figure 1, the growth curve of L and G models were similar with the coefficient of determination (R^2) more than 0.90 (very high category). Gaddour et al. (2012) obtained the high category of R^2 value (0.71) in the growth curve of BW with G model for Damascus goat. High R^2 value in this study indicated that the growth curve of L and G models can be used to predict BW of goats from 1 to 24 months of age accurately. However, the growth curve in female Ettawa crossbred goat has the lower of standard error (SE) and Akaike's information criterion (AIC) values rather than male goat (Table 4). Hence, a growth curve model with higher R^2 and lower SE / AIC values than the others indicated that this model is accurate for describing the growth pattern of animal. In this study, the R^2 value in L and G models for female goat was similar (0.95). Previous studies were obtained the similar R^2 value in both models on Angora (0.96), Indonesian Kacang (0.98) and Repartida (0.91) goats (Table 3). In addition, the growth rate of BW in male goats were higher than female goats (Figure 2) and mainly affected by sex dimorphism effect (Soeparno, 2005). In the inflection point of male goats, the maximum growth rate was ranged from 4.67 (G) to 5.07 (L) kg/month. Meanwhile, the maximum growth rate in female goats at the inflection point was 1.66 (L) and 1.76 (G) kg/month. The growth rate at inflection point in the male Ettawa crossbred goat was closed to the Indonesian Kacang goat (male/female) *i.e.* 1.23/1.06 kg/month (L) and 1.10/1.02 kg/month (G) as reported by Wiradarya et al. (2020).

Table 4. Goodness-of-fit criteria for the growth model of Logistic and Gompertz

Sex	Model	R^2	SE	AIC
Male	Logistic	0.94	4.62	74.83
	Gompertz	0.92	5.48	83.01
Female	Logistic	0.95	2.44	44.09
	Gompertz	0.95	2.24	40.06

R^2 : coefficient of determination; SE: standard error; AIC: Akaike's information criterion

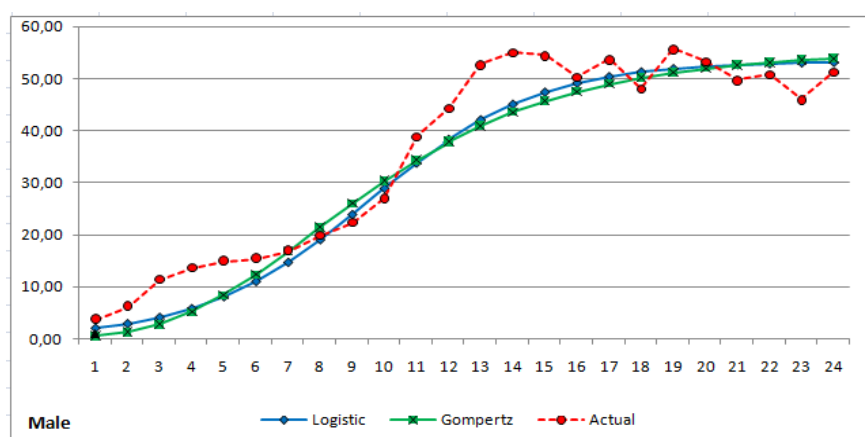
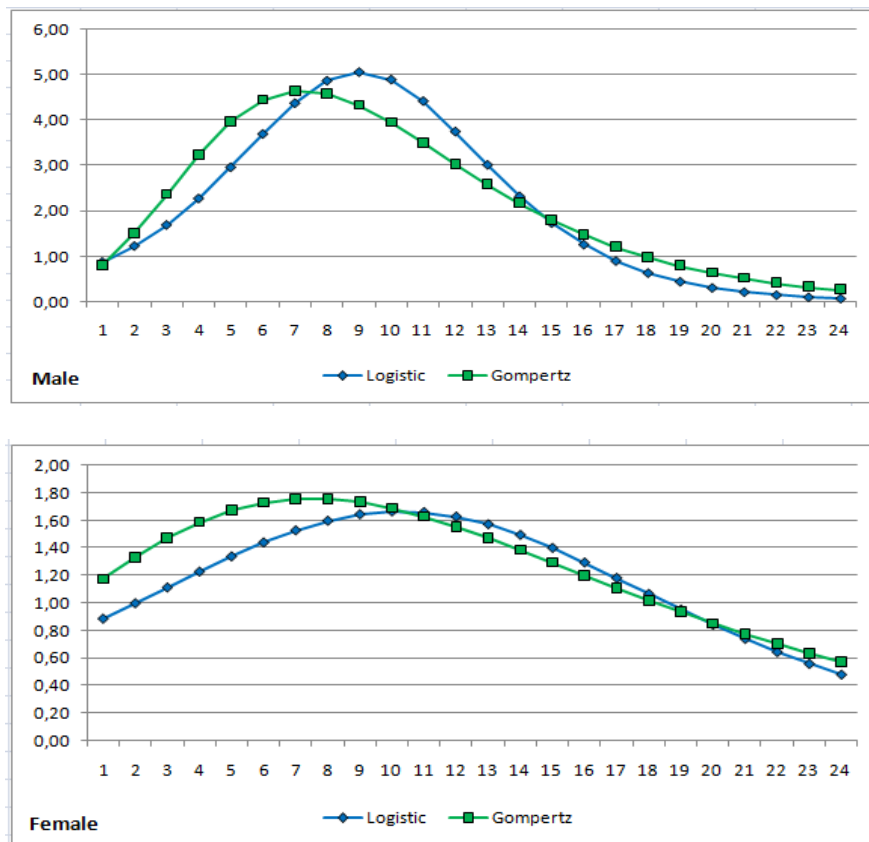


Figure 1. The growth curve of body weight in Ettawa crossbred goats based on Logistic and Gompertz mathematical models



Gambar 2. The growth rate of body weight in Ettawa crossbred goats based on Logistic and Gompertz mathematical models

CONCLUSION

It can be concluded that the Ettawa crossbred goat in the present study has the adult weight about 53-55 kg (male) and 36-39 kg (female). In addition, the inflection point in Ettawa crossbred goats at Tambang District were about 20-26 kg at about 6-8 months of age for male and about 14-18 kg at about 7-9 months of age for female. Therefore, upper 90% of the L and G mathematical models able to describe the BW in goats.

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