GROWTH ANALYSIS IN RABBIT USING GOMPERTZ NON-LINEAR MODEL

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ABSTRAK

Penelitian ini bertujuan untuk membandingkan pola kurva pertumbuhan tiga bangsa kelinci. Tiga bangsa kelinci yang digunakan dalam penelitian ini adalah satu bangsa kelinci lokal (IL), dua bangsa kelinci impor Flamish Giant (FG) dan Rex (R). Bobot badan sebagai parameter penelitian dicatat pada masing-masing bangsa dari lahir sampai umur 63 hari dengan selang waktu tiga hari. Data dikelompokkan berdasarkan jenis kelamin, kemudian dirata-ratakan untuk analisis pola pertumbuhan. Data bobot badan dianalisis mengunakan rumus Gompertz. Parameter kurva pertumbuhan digunakan untuk menduga pertumbuhan. Hasil analisis menunjukkan bobot badan antara kelinci jantan dan betina dalam satu bangsa tidak berbeda nyata, sedangkan hasil analisis bobot badan antar bangsa menunjukan perbedaan (P<0.05). Pertumbuhan relatif tiga bangsa kelinci menunjukkan berbeda nyata (P<0.05) baik pada jenis kelamin jantan maupun betina. Pendugaan bobot badan dewasa pada FG memiliki nilai tertinggi diikuti R dan IL dengan nilai terendah. Koefisien determinasi analisis Gompertz model pada pertumbuhan kelinci sangat tinggi (R^2 = 0.999).

Kata kunci: Gompertz model, kurva pertumbuhan, bobot badan, kelinci

ABSTRACT

An experiment was conducted to compare the growth curve of rabbit. Three breeds of rabbit, namely Indonesian Local Rabbit (IL), Flamish Giant (FG) and Rex (R) were used in the study. Individual body weights of each breed was measured from birth to 63 days of age with 3-days interval. Those periodical data were separated into different sex, be then it was averaged to analysis growth pattern. Growth curve parameters were estimated to fit growth data. There was no difference in body weight between sexs within breed. Indonesian local rabbit had the lowest body weight. The results showed that growth curve paramaters among three breeds were significantly different (P<0.05) for both sexes. FG had the highest value of asymptotic mature weight, followed by R and IL. In conclusion, Gompertz model was excellent fit for the growth data in rabbit with a high coefficient determination (R^2 = 0.999).

Keywords : Gompertz model, growth curve, body weight, rabbit

INTRODUCTION

In the tropic, rabbit became important small livestock and meat source. They have high productivity on reproduction but in Indonesian, rabbit development is less than poultry and ruminant. Breeding and genetic were the vital aspects of rabbit production which urgently needed in tropics to ensure a high success rate of rabbit development program. Unfortunately, there was preference in Indonesian farmers to raise exotic breed of rabbit. They had a notion that local breeds are genetically inferior. A serious consequence of this practice was the possibility loss of local germplasm. In other side, potential of imported breeds could not be optimised because their ability to adapt to tropic environment was low. Lebas *et al.* (1997) reported that low productivity of imported breeds as a result of unsuccessful environmental adaptation. In all cases, breed evaluation tests (local versus imported breed) should be priority to be carried out. Attention has been given to the body weight as a consequence of the growth.

Growth curve is a figure of individual ability to express its genetic potential to maximum size under the existing environmental condition. Some studies on growth curve have been reported. Suparyanto (2001) used three non-linear growth curves of Von Bertalanffy, Logistic and Gompertz to analysis the relationship of body weight and age. One of non-linear model have been used to describe growth patterns is Gompertz model. According to Lenart (2011), the Gompertz distribution was widely used to describe the distribution of adult body. This model based on the exact central moments and defined with higher accuracy approximations. By solving the maximum-likelihood estimates analytically, the dimension of the optimization problem can be reduced, both in the case of discrete and continuous data. Gompertz model has been used to analysis the growth of mice (Kurnianto *et al.*, 1998), dog (Helmink *et al.*, 2000) sheep (Suparyanto *et al.*, 2001), rabbit (Blasco *et al.*, 2003), lamb (Lambe *et al.*, 2006), pig (Strathe *et al.*, 2010) and cattle (Forni *et al.*, 2009; Budimulyati *et al.*, 2012). Several researches about growth of rabbit were analysed with Logarithmic model (Rao *et al.*, 1997), Stochastic model (Sampaio *et al.*, 2005) and General Linear Mixed Model (McNitt and Lukehfar, 2005).

The objective of this study was to compare growth curve of rabbit between imported and Indonesia local breeds.

MATERIALS AND METHODS

Materials

Three breeds of rabbit were used in this study, namely Flamish Giant (FG), Rex (R) and Indonesian local rabbits (IL). The number of rabbit used in each genetic group of the male FG, R and IL rabbits were 16, 16 and 9 heads, respectively. Meanwhile, the female number of respective breed was 16, 12 and 8, respectively. The study was conducted in Temanggung Regency – Central Java, under temperature ranging from 18 to 25°C.

Methods

The offsprings were obtained from mating of two buck and six doe for each breed (mating ratio 1:3). After weaning, feeding was provided *ad libitum* by automatic feeder and drink was given by nipple. They were fed a complete, pelletized diet containing 19.71% of crude protein, 23.46% of fiber and 1.77% of fat throughout the experiment. Body weights were recorded individually at 3-days interval from birth to 63 days of age.

Data analysis

SAS (1990) was used to analyze the data of body weights on three breed using General Linear Model (GLM). Differences between male and female body weight were tested by t-test. Growth curve parameters were estimated from average of body weights using Gompertz model (Dastidar, 2006) and analyzed using Gauss-newton method of SAS (1990). Gompertz model was chosen based on an earlier study suggesting this model provided a fit for weight data in mice compared to logistic and asymptotic models (Kurnianto *et al.*, 1997). Growth curve parameters were used in expecting weight data within each breed. The Gompertz model was formulated as:

$$y_t = A\ exp\ [-B\ exp\ (kt)]$$

where,

y_t: body weight (g) at age of t (weeks); A: asymptotic (mature) weight; B: intregration constant, time scale parameter of no specific biological significance; k: growth rate constant, which a logarithmic function of degree of maturity in body weight changes linearly time unit; exp: base of natural logarithm (2.7183).

Other parameters derived from the model used were age and weight at the point of inflection designated as t_i and y_i, respectively.

$$t_i = 1nB/ k \text{ and } y_i = A / exp$$

The deferences in mean growth parameters between sexes within breed was tested using t-test, whereas mean comparison for similar sex among breeds was tested by Duncan’s range multiple test.

RESULTS AND DISCUSSION

Body Weight

Preliminary analysis showed that there was no significantly difference of body weights between male and female at all breeds. Body weights of three breeds of rabbit from birth to 63 days of age is presented in Table 1. The average birth weight of FG was 56.16 g, IL was 53.49 g and R was 96.42 g. Birth weights showed lower body weight than the previous experiment that was 66.7 g (Sartika *et al.*, 1998), 49.78 g (Suc *et al.*,1996) and 61.3 g (Rahardjo, 1988), for Flamish giant, Indonesian local rabbit and Rex, respectively.

Body weights of male were not significant different in 0 until 3 days of age, while from 6

Table 1. Body Weights of Three Breeds of Rabbit

Age (day)	Male			Female		
	Flamish Giant	Local	Rex	Flamish Giant	Local	Rex
	…………………………………	……… (g) ………	…………………………………			
0	52.00±6.06	46.67±11.77	49.00±5.56	60.31±14.09^{K}	45.25±12.37^{L}	47.42±5.50^{L}
3	62.31±11.15	55.00±13.13	61.50±8.94	71.50±20.09^{K}	55.88±11.88^{L}	60.00±8.830^{KL}
6	79.69±15.22^{A}	65.56±15.68^{B}	84.62±9.54^{A}	86.56±21.50^{K}	68.38±13.90^{L}	80.42±10.05^{KL}
9	96.44±18.87^{AB}	86.89±14.58^{B}	104.62±8.72^{A}	102.69±22.35	87.50±15.11	101.00±9.67
12	129.00±22.78^{A}	111.11±16.27^{B}	127.06±13.74^{A}	142.44±31.14^{K}	113.38±14.09^{L}	123.58±13.98^{KL}
15	151.12±27.37^{AB}	133.56±19.50^{B}	156.06±18.23^{A}	167.56±32.05^{K}	136.12±17.22^{L}	151.17±24.19^{KL}
18	180.75±37.98^{A}	138.67±21.48^{B}	184.19±22.64^{A}	195.94±52.96^{K}	146.12±17.30^{L}	179.33±20.71^{KL}
21	211.25±43.83^{A}	158.22±23.84^{B}	210.56±23.48^{A}	230.12±66.65^{K}	166.50±19.24^{L}	204.58±23.21^{KL}
24	257.81±45.78^{A}	184.33±18.87^{B}	242.12±25.13^{A}	267.00±49.84^{K}	189.88±15.26^{L}	243.17±19.66^{K}
27	296.00±41.93^{A}	211.11±20.26^{B}	278.75±34.90^{A}	302.69±53.82^{K}	215.12±15.85^{L}	281.58±29.12^{K}
30	321.06±50.79^{A}	246.78±29.60^{B}	312.69±39.19^{A}	328.31±51.05^{K}	245.00±29.03^{L}	318.83±30.25^{K}
33	368.94±63.43^{A}	271.44±20.67^{B}	364.50±51.18^{A}	376.62±57.37^{K}	274.00±19.71^{L}	361.67±33.54^{K}
36	408.12±69.57^{A}	294.22±22.57^{B}	379.88±54.66^{A}	408.69±70.31^{K}	297.00±21.28^{L}	389.50±41.60^{K}
39	440.25±72.64^{A}	316.89±24.52^{B}	407.88±55.57^{A}	445.56±70.45^{K}	319.75±25.48^{L}	410.58±48.51^{K}
42	472.94±81.97^{A}	352.67±32.54^{B}	435.50±68.10^{A}	483.25±62.65^{K}	356.75±29.28^{L}	453.17±62.37^{K}
45	482.19±71.68^{A}	383.89±32.51^{B}	452.31±80.28^{A}	496.44±48.68^{K}	383.38±36.14^{L}	478.08±76.10^{K}
48	526.44±92.30^{A}	384.33±25.98^{B}	490.75±86.61^{A}	537.19±71.17^{K}	386.12±25.38^{L}	514.42±92.15^{K}
51	564.25±100.80^{A}	392.88±21.09^{B}	530.38±91.67^{A}	581.38±82.88^{K}	395.12±19.43^{L}	556.58±110.67^{K}
54	606.69±110.75^{A}	407.22±20.74^{B}	573.50±89.62^{A}	627.44±97.39^{K}	408.50±16.88^{L}	605.08±113.69^{K}
57	650.25±124.99^{A}	419.22±17.82^{B}	613.12±86.14^{A}	674.44±111.85^{K}	419.38±15.22^{L}	643.50±114.84^{K}
60	694.25±141.24^{A}	431.89±14.62^{B}	644.19±96.91^{A}	723.31±126.76^{K}	439.00±19.20^{L}	684.91±130.49^{K}
63	750.12±144.10^{A}	443.33±12.79^{B}	674.69±111.25^{A}	779.06±121.59^{K}	444.50±9.55^{L}	714.92±136.57^{K}

Different superscripts in the same rows shows significant different (P< 0.05):
- A,B,C : different superscripts in the same rows shows significant different within male between breed.
- K,L,M : different superscripts in the same rows shows significant different within female between breed.
- a,b : different superscripts at the FG breed between male and female indicate significantly different.
- r,s : different superscripts at the IL breed between male and female indicate significantly different.
- x,y : different superscripts at the R breed between male and female indicate significantly different.

days to 63 days of age showed significant difference (P<0.05). FG show similarity to R, but not similar to IL. Except in 9 and 15 days of age, FG was similar to IL and R but did not show similarity between IL and R. In female, body weights showed significant different among three breeds (P<0.05) from birth until 63 days of age, except in 9 days of age. Birth weight of FG is differed to IL and R, but IL show similarity to R. R was similar to FG and IL, but did not showed similarity between FG and IL in 12 until 21 days of age. Meanwhile, in 24 until 63 days of age IL show significantly difference with FG and R, but FG was similar with R. IL had the lowest body weight. According to Farrell and Raharjo (1984) local rabbit was smaller than the imported breed.

Growth Curve Paramaters

Means of growth curve paramaters for each breed are presented in Table 2. Asymptotic weight (A) among three breed were significantly different (P<0.01) for both sexes. The highest of A value was achieved by FG, in which for males and females were 1249.77 and 1521.78, respectively. Meanwhile, the smallest of A value was attained by IL, that was 558.21 for males and 559.19 for females. According to The American Rabbit Breeders Association (2011), body weight of FG achieved 5.890 g for male and 6.350 g for female. The research indicated that flamish giant was adapted with the tropic. It was stated by Brahmantiyo (2008) that FG which raised by Indonesian farmers was diverged from the pure breed character.

The growth rate constant (k) among three breed were high significantly different (P < 0.01) for both sexes. The highest and smallest k value for both sexes were IL and FG respectively. The results demonstrated that Indonesian Local Rabbit matured earlier than other breeds. It was stated by Kurnianto *et al.* (1998) that large of k values indicated early maturing individuals, whereas small k values indicated late maturing individuals. Point of inflection was corresponds to two parameters, namely age at point inflection (t_i) and weight at point of inflection (y_i). Autoacceleration stage was replaced be autoretardation stage in this point. This analysis showed that FG was the oldest and the largest at the point of inflection for both sexes as shown the highest t_i and y_i values, 41.32 days and 459.76 g; 48.12 days and 559.83 g, respectively for male and female. There was relationship between the k value and t_i. The rabbit breed with higher k value reached the t_i at a younger age. It was found IL had point inflection at the youngest age among three breeds.

Fitting of Growth Model

Illustration of growth patterns of this study was based on a set of data by averaging individual estimated from body weights. Mean of body weight was computed at each age for each breed. Fitted Gompertz model to body weight is illustrated in Figure 1 for male and Figure 2 for

Table 2. Estimated Growth Curve Parameters of Gompertz Model (A, B, K, t_i and y_i) for Each Breed

Estimated Parameter	Breed		
	Flamish Giant	Local	Rex
Male	(16)	(9)	(16)
A	1249.77 ± 100.5[a]	558.21 ± 23.44[c]	1107.38 ± 74.18[b]
B	3.16 ± 0.06[a]	2.74 ± 0.08[c]	3.00 ± 0.05[b]
K	0.0279 ± 0.002[c]	0.04 ± 0.002[a]	0.03 ± 0.001[b]
t_i	41.32[a]	24.91[b]	39.02[c]
y_i	459.76[a]	205.35[b]	407.38[c]
R^2	0.999	0.999	0.999
Female	(16)	(8)	(12)
A	1521.78 ± 150.4[a]	559.19 ± 20.47[c]	1258.87 ± 74.38[b]
B	3.17 ± 0.06[b]	2.69 ± 0.07[c]	3.18 ± 0.04[a]
K	0.02 ± 0.002[c]	0.04 ± 0.002[a]	0.03 ± 0.001[b]
t_i	48.12[a]	24.55[c]	42.60[b]
y_i	559.83[a]	205.71[c]	463.11[b]
R^2	0.999	0.999	0.999

Different superscripts in the same rows shows significant different (P< 0.05)

Number in bracket is the number of sample

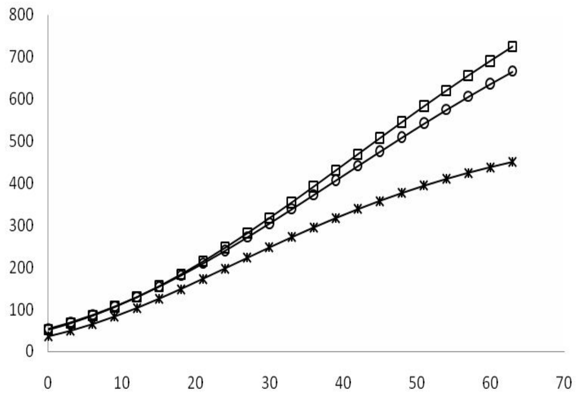

Figure 1. Gompertz growth curves fitted to body weight at male, Flamish Giant (□) Local (∗) Rex (○).

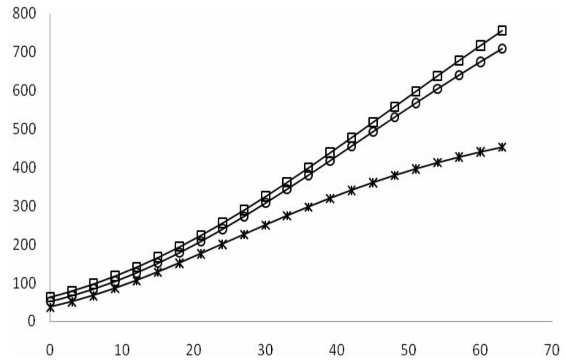

Figure 2. Gompertz growth curves fitted to body weight at female, Flamish Giant (□) Local (∗) Rex (○).

female. Growth model to weight data showed that FG had the fastest growth performance, followed with R and IL was slowest. It indicated that type of breed was influence growth performance. Reported by McNitt and Lukefahr (2005) that growth performance of Californian, New Zealand White, Palomino and White Satin were difference one another. The growth performance of rabbits reported from tropical countries was in contrast to observed in temperate regions (Lukefahr and Cheeke, 1991). The lower result might due to the heat stress factor.

The means residual of estimated body weight from observed data is illustrated in Figure 3 for male and Figure 4 for female. The figures showed FG's residual was similar to R, but IL had the opposigh the Gompertz model tended to over

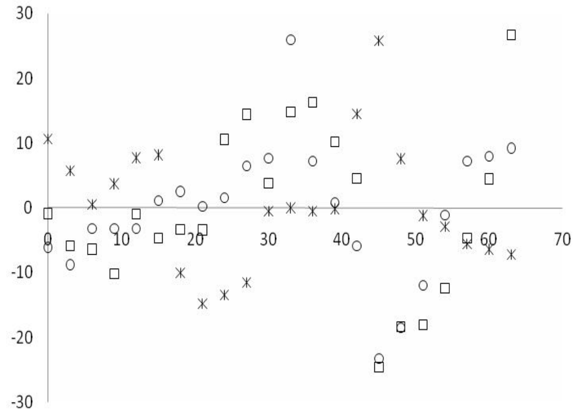

Figure 3. Residual plot of the estimated body weight from the observed body weight from birth to 63 days at male Flamish Giant (□) Local (∗) Rex(○).

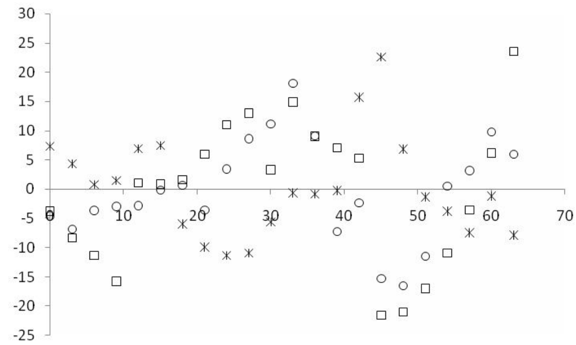

Figure 4. Residual plot of the estimated body weight from the observed body weight from birth to 63 days at female Flamish Giant (□) Local (∗) Rex (○).

estimated and underestimated, it provided an excellent fit for growth data as shown by the high coefficient of determination (R^2 = 0.999). According to Khan *et al.* (2013), the high coefficient of determination was reliable on estimation.

CONCLUSION

Indonesian local rabbit had the lowest growth performance, whereas Flamish Giant had the fastest. The import rabbit grew faster than the local rabbit of Indonesia. Gompertz model was excellent fit for the growth data with a high coefficient determination.

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