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Original Research Paper

The Growth Curve of Gompertz Model in Body Weight of Mixed-sex Goose Breeds in Slovakia

Hrncar C[1], Bujko J[1], Widya P.B.P[2]

[1]Slovak University of Agriculture, Nitra, Slovak Republic 94676
[2]Research Center for Biotechnology, Indonesian Institute of Science, Cibinong, Indonesia 16911

Corresponding Author: Widya PBP, Research Center for Biotechnology, Indonesian Institute of Science, Cibinong, Indonesia; Email: widya.putra.lipi@gmail.com

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Abstract
The growth curve in poultry is important to evaluate the performance and farming management system. This study was aimed to estimate the growth curve of body weight in goose. The growth curve in this study was estimated with non-linear Gompertz model through CurveExpert 1.4. software. Three goose breeds in Slovakia i.e. Landes (L), Pomeranian (P) and Steinbacher (S) were used in this study. Total of 28 geese (10 L, 8 P and 10 S) were used to estimate the growth curve. Research showed that the asymptotic weight (A) in those geese were reached at 5332.51 g (L), 6186.14 g (P) and 5048.27 g (S). Thus, the maturing rate (k) in each breed were similar (0.05 g/day). The weight of inflection was reached at 1960.48 g (L), 2274.32 g (P) and 1855.98 g (S) respectively. The time of inflection (t_i) was reached at 25.6 days (L), 26.2 days (P) and 27.80 days (S) respectively. The maximum growth rate (MGR) was reached at 98.02 g/day (L), 113.72 g/day (P) and 92.80 g/day (S). According to the CurveExpert 1.4. software, the coefficient of determination (R^2) with Gompertz model was 0.99 for each breed. It can be concluded that Pomeranian geese had highest of growth rate than the other breeds.
Keywords: Body weight, Growth curve, Inflection, Slovak geese, Gompertz model

Introduction

Growth in poultry is very important for feed management evaluation, determine obtaining the harvest time and selection program. Growth is an economic trait in poultry production that is influenced by genetic and environmental factors. Growth can be defined as an increase in body size per time unit (Lawrence and Fowler 2002). Growth is a continous function during the animal's life from embryonic stages up to adult age. Growth curve of poultry generally has the following 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 (Fitzhugh 1976). In addition, the growth curve which commonly is a S-shaped (sigmoid) curve describes the regular change generated by the live weight or some part of the animal with increasing age (Ersoy *et al*. 2006).

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 is associated with the reduction in growth rate (Yakupoglu and Atil, 2001). Morever, growth curve of livestock has been used to observe dynamically growth course, to forecast the poultry growth pattern and instruct the feeding and management programs to improve the selection and breeding effects (Yang *et al.* 2006).

The Gompertz model is one of non-linear regression model which has been used to estimate the growth curve in poultry animals such as turkey (Ersoy *et al.* 2006), chicken (Yakupoglu and Atil 2001), quail (Beiki *et al.*

2013), Peking duck (Maruyama *et al.* 2002), Muscovy duck (Susanti and Purba, 2017), ostrich (Ramos *et al.* 2013), pigeon (Gao *et al.* 2016) and geese (Onder *et al*. 2017). Hence, the Gompertz function has fixed growth forms with point of inflection at about 50% and 30% of the asymptote in birds respectively (Rickleft, 1968).

Recent study on growth curve in Slovak goose breeds are limited. Three goose breeds (*Anser anser*) in Slovakia i.e. Landes, Pomeranian and Steinbacher (Fig. 1) were under critically endangered. These breeds were kept by the farmers in Slovakia for meat production, feathers and fatty liver. The adult weight of Landes and Pomeranian geese were 5 kg for male and 6 kg for female respectively. Moreover, the annual egg production is 40 eggs/female/year with average egg weight of 170 g. Hence, the adult weight of Steinbacher geese were 5-6 kg (female) and 6-6.5 kg (male) with with annual egg production of 12-15 eggs/female/year (Buckland and Guy, 1997). This study was aimed to estimate the growth curve of body weight in mixed-sex of three goose breeds in Slovakia (Landes, Pomeranian and Steinbacher) with non-linear Gompertz model. The results from this study can be used as a basic information to develop farming management system in endangered goose breeds of Slovakia.

Figure. 1. The phenotypic characteristics of Landes (A), Pomeranian (B) and Steinbacher (C) geeses

Materials and Methods

Birds and management system

Twenty eight of mixed-sex geese were used in this study and consisted of 10 Landes geese (L), 8 Pomeranian geese (P) and 10 Steinbacher geese (S). These breeds were under critically endangered in Sovakia. The geese were kept in free-range management conditions. Goslings were individually weighed electronic weighing tool (Sartorius, capacity 6 kg, readability 100 g) at the ages of 1, 14, 28, 42, 56, 70, 84, and 98 days. One day old goslings were placed into brooder batteries until 14 days of age. Thus, the mixed-sex goslings were raised into shelter run pens until 98 days of age in free-range conditions.

Nutrition

During rearing, goslings were fed *ad libitum* with a feed mixture including 17 % crude protein, 3.3% crude fat, 3.4% crude fibre, 4.9% crude ash matter, 0.76% lysine, 0.38% methionine, 0.8% calcium, 0.56% phosphorus, 0.15% sodium, 12020 IU vitamin A, 3005 IU vtamin D_3 and vitamin E (α-tocopherol).

Data analysis

The records data of body weight (BW) in geese were used to estimate growth curve with non-linear Gompertz model through CurveExpert 1.4. computer program (Hyams, 2010). Thus, the mathematical formula in non-linear Gompertz model and some growth parameters refering to Ibtisham *et al.* (2017) are as follows:

$$W_t = Ae^{-e^{B-kt}}$$

$W_i = A/et_i = B/k$

$MGR = k \times W_i$

where, W_t is the body weight (g) of goose at t dayy of age; A is the asymptotic weight (g) when time goes to infinity; B is the scaling parameters (constant of integration); k is the maturing rate (g/day); e is the constant (2.72); t is the time unit (days); W_i is the weight of inflection (g); t_i is the time of inflection (day); MGR is the maximum growth rate (g/day).

Results and Discussion

The average body weight (BW) in Pomeranian (P) goose was highest than those of Landes (L) and Steinbacher (S) geese as presented in Table 1. Thus, the asymptotic weight (A) value in studied geese was reached of 5332.51 g (L), 6186.14 g (P) and 5048.27 g (S) as presented in Table 2. With the similar method (Gompertz model), Shi Tou (ST) geese had A values of 6357.71 g (male) and 5412.49 g (female) as reported by Ibtisham *et al.* (2017). Thus, the A value in Sichuan White (SW) geese with similar method was 3947.34 g (male) and 3166.70 g (female) as reported by Ibtisham *et al.* (2017). Morever, Onder *et al.* (2017) reported that the A value in Turkish native (TN) geese with similar model reached 5044 g (male) and 4179 g (female). The A value in growth curve indicates maximal life weight increase reached by livestock. It is highly influenced by genetic factor (Brody, 1945).

Table 1. Means of body weight (g) in mixed-sex of goose breeds of Slovakia

Age (day)	Breed		
	Landes (N=10)	Pomeranian (N=8)	Steinbacher (N=10)
1	105.20±8.93^{ac}	118.63±4.93^{b}	106.80±12.55^{ac}
14	774.40±114.62^{ac}	797.38±186.38^{a}	561.00±53.93^{bc}
28	2456.40±214.49^{ac}	2428.75±311.73^{a}	1942.00±318.64^{bc}
42	3489.20±225.35^{ac}	3812.13±271.82^{b}	3202.20±384.03^{ac}
56	4220.00±492.84^{ac}	4643.75±375.54^{a}	3840.00±245.86^{bc}
70	4740.00±609.55^{ab}	5287.50±664.27^{a}	4325.00±190.86^{ab}
84	4940.00±597.59^{ab}	5700.00±787.40^{a}	4825.00±265.92^{ab}
98	5433.33±524.09^{ab}	6140.00±606.63^{a}	5225.00±409.70^{ab}

N: number of goslings

Table 2. The growth parameters for body weight (g) in mixed-sex of goose breeds of Slovakia

Parameter	Breed		
	Landes	Pomeranian	Steinbacher
A	5332.51	6186.14	5048.27
B	1.28	1.31	1.39
k	0.05	0.05	0.05
W_i	1960.48	2274.32	1855.98
t_i	25.6	26.2	27.80
MGR	98.02	113.72	92.80
R^2	0.997	0.998	0.998
SE	177.36	142.71	132.39

A: asymptotic weight (g) when time goes to infinity; B: scaling parameters (constant of integration); k: maturing rate (g/day); W_i: weight of inflection (g); t_i: time of inflection (day); MGR: maximum growth rate (g/day); R^2: coefficient of correlation; SE: standard error of regression

The maturing rate (k) in Slovak geese in this study was 0.05 g/day and higher than that of ST geese (0.04 g/day) but was similar to female SW geese (0.05 g/day) with similar model (Ibtisham *et al*. 2017). In addition, the k value in TN geese (0.06 g/day) with similar model (Onder *et al*. 2017) was higher than that in Slovak geese in this study. In addition, the k value in Canada geese (*Branta canadensis minima*) with similar model was 0.08 g/day (male) and 0.07 g/day (female) as reported by Sedinger (1986). The k value is not a genetic affect, but is highly affected by environmental factor (Susanti and Purba, 2017).

The weight of inflection (W_i) in this study was reached of 1960.48 g (L), 2274.32 g (P) and 1855.98 g (S). The

W_i values in ST geese with similar model were 2338.87 g (male) and 1991.14 g (female). Thus, the W_i values in SW geese with similar model was 1452.15 g (male) and 1164.96 g (female) as reported by Ibtisham *et al*. (2017). In addition, the W_i values in TN geese with similar model were 1856 g (male) and 1538 g (female) as reported by Onder *et al*. (2017). The W_i value in male ST geese showed close to P geese. In addition, the W_i value in S geese showed close to male TN geese.

The time of inflection (t_i) in Slovak geese was 25.6 days (L), 26.2 days (P) and 27.8 days (S). The t_i values in ST and SW geese with similar model were more than 30 days (Ibtisham *et al*. 2017) thus higher than that in Slovak geese in this study. In addition, the t_i values in TN geese with similar model were 26.6 days (male) and 25.6 days (female) and close to that in Slovak geese in this study. Hence, the maximum growth rates (MGR) in Slovak geese were 98.02 g/day (L), 113.72 g/day (P) and 92.80 g/day (S). Onder *et al*. (2017) reported that the MGR values in TN geese with similar model were 102 g/day (male) and 87.7 g/day (female), and showed lower than that in Slovak geese in this study. The growth parameters of B and k were used to estimate the inflection point (W_i and t_i) from the derivative of equation function of the Gompertz curve.

The growth rate in livestock can be improved through selection program to obtain the animal that has fast growth rate for optimum slaughtering weight in a relatively short period as expected by most farmers (Pingel, 1993). The growth curve of BW in Slovak geese from 1 until 121 days of age is sigmoid (Fig. 2) with the inflection point occuring at less than 30 days (Fig. 3). Morever, the coefficient of determination (R^2) value in Gompertz model was 0.99 (very high) and suggests that the growth curve in this study was accurate to explain the growth profile in Slovak mixed-sex goose breeds from day old duck (DOD) to adult age.

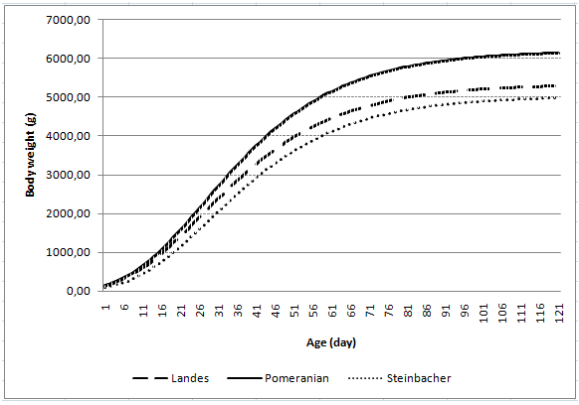

Figure. 2. The growth curve of Gompertz model in body weight of mixed-sex goose breeds of Slovakia

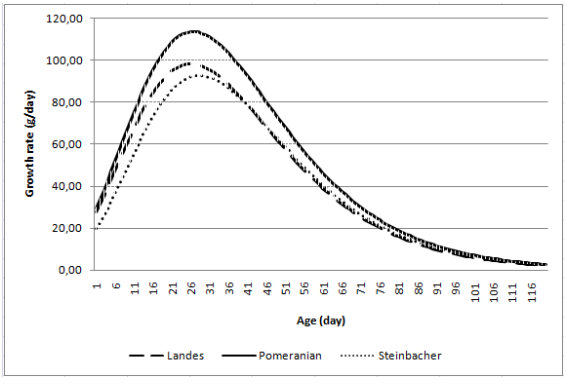

Figure. 3. The growth rate of body weight in mixed-sex goose breeds of Slovakia based on Gompertz model

Conclusion

The growth curve of Gompertz model was accurate (R^2=0.99) to explain BW in mixed-sex goose breeds of Landes, Pomeranian and Steinbacher in Slovakia from DOD to adult age. However, in depth study with large sample size, more mathematical model and sex factor are important to obtain accurate estimates of growth curve parameters.

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