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Gomperzt non-linear model for predicting growth performance of commercial broiler chickens

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ABSTRACT

An experiment was conducted to estimate growth parameters for commercial broiler chickens in Indonesia. The data was collected from July 2021 to June 2022. A total of 1,570 samples consisting of four strains of broiler chickens were collected from 74 houses. The samples were daily weighed from 0 to 7 days of age, and they were weekly weighed from 1 to 5 weeks of age. A nonlinear Gompertz growth model was fitted to the observed body weights (BW). The results for five growth parameters were as follows: the asymptotic value (A) of the mature live weight ranged from 3.733 to 5.044 kg; the turning point of growth (B) ranged from 4.499 to 4.561; the value growth rate constant (K) ranged from 0.049 to 0.059 kg/week; Inflection points in ranged from 25.292 – 30.970 days, and 1.373 – 1.855 kg for inflection age (IA) and inflection weight (IW), respectively. The model was an excellent fit for the growth data in the commercial broiler with a low Akaike information criterion (AIC), and high coefficient determination (R^2).

Keywords: Asymptotic value, Growth rate constant, Inflection point, Slaughter age, Strains

INTRODUCTION

Modern broiler production is a large and rapidly developing sector that provides the market with a relatively inexpensive, and high-quality protein source. The contemporary selection programs have achieved significant improvements in weight gain, feed conversion, slaughter performance, and carcass traits over the past decades (Chambers *et al.*, 1981; Le Bihan-Duval *et al.*, 1999; Zhang and Aggrey, 2003; Aggrey *et al.*, 2010; Siegel, 2014). Advances in

broiler selection have resulted in significant shorter fattening times, less than 35 days at slaughter weights of 2 kg (Hristakieva *et al.*, 2014).

Regarding the genetic improvement and expansion of the broiler industry in Indonesia, there were several strains of broiler chicken produced by the breeders. Strains with large populations were CP 707, Lohmann, Cobb, and Ross. Each strain has a specific performance of growth, feed efficiency, and carcass quality (Abdullah *et al.*, 2010). The growth of body weight is an easi-

er indicator for farmers to make an evaluation of their chicks. Growth is an economic trait for animals, defined as a change in body size, such as weight or height per unit of time. Knowledge of animal growth is critical for improving management and feeding methods to maximize the profits of broiler farms (Narinç *et al.*, 2017). The appropriate method is required to make a proper decision about when should farmers harvest or slaughter the chickens.

Mathematical models have been successful in characterizing growth patterns and visualizing the shape of growth over time. Among these models, the most commonly used are non-linear models that allow for the interpretation and understanding of the underlying growth patterns during the growing season (Schnute, 1981). Gompertz model is one of the non-linear models that are generally used to describe growth patterns. The Gompertz distribution is based on exact central moments and is defined with a more accurate approximation (Lenart, 2011). The objective of this study was to estimate growth curve parameters for specific strains of commercial broiler chicken in Indonesia.

MATERIALS AND METHODS

Data Collection

The data was collected from commercial broiler farms in the Central Java province of Indonesia. Chickens were raised intensively in closed houses with *ad libitum* access to feed and water. The period of collecting data was from July 2021 to June 2022. A total of 1,570 samples of four strains of broiler chickens were collected from 74 houses. The detailed data used in the study was presented in Table 1. The samples were individually daily weighed until 7 days of age and then weekly weighed until 35 days of age.

Statistical Model

General linear model with Duncan multiple range test was performed as preliminary analysis to differentiate the data of body weights on four strains. The Gompertz model was fitted on the

observed BW of broiler chickens by using NLIN procedure of Statistical Analysis System (SAS OnDemand, 2021). The model was as follows:

$$w(t) = A \times \exp(-B \times \exp(-K \times t))$$

Where $w(t)$ is observed BW of chickens t days of age in kg, t is the age of weighed in days. The growth parameters consist of A as the predicted mature life weight of asymptotic value; B as turning point of growth and K as growth rate constant to achieve an adult weight. \exp is the value-based of the natural logarithm (2.718). The model was performed for individual data. The inflection of age and weight (IA and IW), respectively were calculated according to the pattern of Lupi *et al.* (2016) as follows:

$$IA = \ln(B)/K$$

and

$$IW = A/\exp$$

RESULTS AND DISCUSSION

Least squares mean (LSM) and standard deviations (SD) of body weights for four strains are presented in Table 2. The LSM of observed data showed the highest BW of day-old chicks (DOC) was 0.047 kg for CP 707 and Cobb, and the lowest was Ross (0.044 kg). Therefore, that for Lohmann was 0.041. Mehmood *et al.* (2013) categorized the BW of DOC boiler chick into four groups 1) small ranging from 0.031 to 0.034 kg; 2) medium ranging from 0.035 to 0.038 kg; 3) A-grade ranging from 0.039 to 0.042 kg; 4) A+ grade ranging from 0.043 to 0.046 kg. Recently, Hidayat *et al.* (2021) reported BW of DOC in Indonesia was 0.048 kg. There was no significant difference among strains for BW of DOC to 7 days old chicks. The BW of 7 days of chicks observed in this study was higher than 0.125 kg for Lohmann reported by Mueller *et al.* (2018); 138.9 kg for Cobb reported by Masoudi and Azarfar (2017) and 146.88 kg for Ross reported by Al-Samarai (2015).

The differences in BW among strains were observed at 14 and 21 days old of broiler. Cobb

Table 1. Number of sample used in the study

Sources	Number of houses	Cumulative	Means
Populations	74	1,132,716	15,306.97
Samples	74	1,570	21.22
CP 707	21	595	28.33
Lohmann	19	440	23.16
Cobb	24	405	16.87
Ross	10	130	13.00

showed slightly lower BW than the other strains. The BW of twenty-eight and thirty-five days old were not significant differences among the four strains. The BW of 28 and 35 days of Cobb and Ross observed in the study were in range with the BW reported by Demuner *et al.* (2017) for the same strain in Brazil. They observed the BW for Cobb ranged from 1.352 - 1.556 kg, and 1.876 - 2.219 kg for 28 and 35 days, respectively. Meanwhile, that for Ross ranged from 1.454 - 1.651 for 28 days and ranged from 2.043 - 2.309 kg for 35 days. A significant difference has been reported for weekly BW of different strains of broiler chicken raised in tropical conditions (Udeh *et al.*, 2015). The results indicated that genetic factor has an impact on the growth performance of broiler chicks (Smith and Pesti, 1998).

The results of five growth parameters and predicted body weights for commercial broilers chicks are presented in Table 3 and Table 4, respectively. The asymptotic value of the mature live weight of commercial broiler chicks ranged from 3.733 to 5.044 kg. The value of B estimated in this study ranged from 4.499 to 4.561. The strain of broiler chicks sequentially from the smallest values of A and B were Ross, Lohmann, Copp, and CP 707. The previous study of growth parameters for broiler chicks using the Gompertz growth model conducted in Turkey estimated higher values ranging from 5.454 - 6.282 kg, and 4.916 - 5.313, respectively for A and B (Topal and Bolukbasi, 2008).

The observed value of K ranged from 0.049 to 0.059 kg/week. Mata-Estrada *et al.* (2020) reported a value of 0.021 kg/week for K param-

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Table 2. Least squares mean and standard deviation for body weight at different ages of commercial Broiler chickens

Age (d)	Body weight (kg)			
	CP 707	Lohmann	Cobb	Ross
0	0.047 ± 0.012	0.041 ± 0.011	0.047 ± 0.011	0.044 ± 0.021
1	0.063 ± 0.023	0.059 ± 0.024	0.065 ± 0.029	0.061 ± 0.033
2	0.081 ± 0.031	0.076 ± 0.033	0.080 ± 0.036	0.074 ± 0.041
3	0.099 ± 0.040	0.095 ± 0.042	0.100 ± 0.045	0.093 ± 0.050
4	0.121 ± 0.046	0.116 ± 0.048	0.120 ± 0.055	0.108 ± 0.060
5	0.146 ± 0.059	0.137 ± 0.062	0.142 ± 0.065	0.133 ± 0.084
6	0.172 ± 0.042	0.169 ± 0.038	0.165 ± 0.046	0.167 ± 0.068
7	0.197 ± 0.080	0.192 ± 0.084	0.191 ± 0.082	0.185 ± 0.102
14	0.527 ± 0.204 ^a	0.514 ± 0.214 ^a	0.466 ± 0.202 ^b	0.514 ± 0.261 ^a
21	1.010 ± 0.401 ^a	1.008 ± 0.421 ^a	0.914 ± 0.398 ^b	1.007 ± 0.489 ^a
28	1.622 ± 0.716	1.608 ± 0.727	1.506 ± 0.718	1.608 ± 0.764
35	2.267 ± 0.966	2.198 ± 0.929	2.048 ± 1.057	2.207 ± 1.111

^{a,b}P<0.05

Table 3. Estimated Growth Parameters of Gompertz Model for commercials Broiler chickens

Estimated parameter	CP 707	Lohmann	Cobb	Ross
A	5.044	4.372	4.437	3.733
B	4.561	4.537	4.483	4.499
K	0.049	0.054	0.050	0.059
IA	30.970	28.005	30.005	25.292
IW	1.855	1.608	1.632	1.373
AIC	-224.096	-247.935	-193.167	-199.838
R ²	0.999	0.999	0.999	0.999

A, predicted mature life weight of asymptotic value; B, turning point of growth; K, growth rate constant to achieve an adult weight; IA, inflection of age; IW, inflection of weight; AIC, Akaike information criterion; R², coefficient determination.

Table 4. Predicted body weight at different ages of commercials broiler chickens

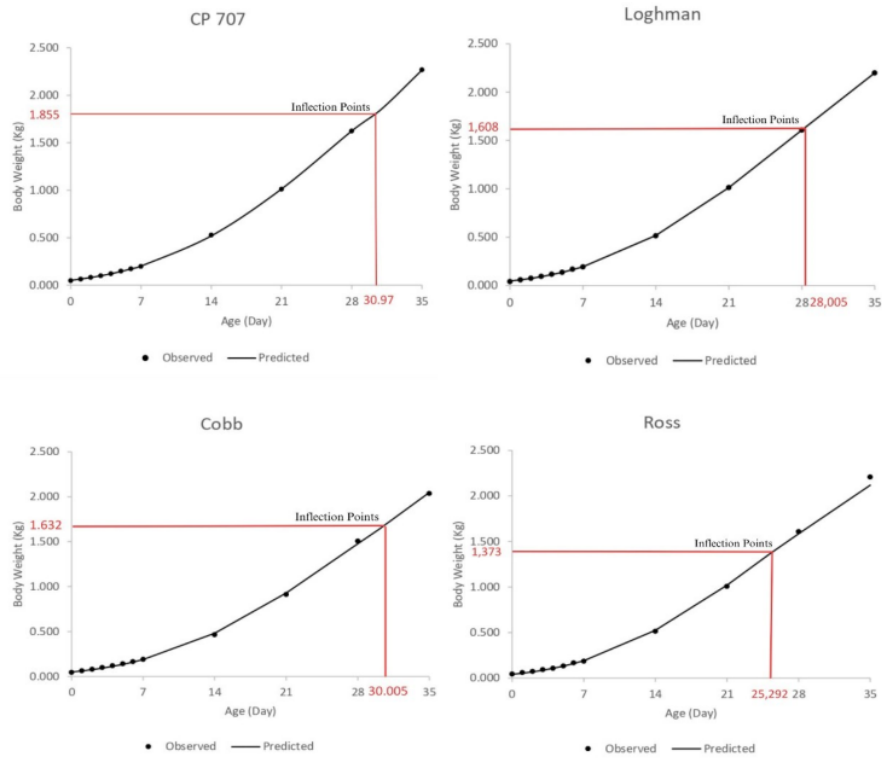
age	CP 707	Lohmann	Cobb	Ross
	kg			
0	0.052	0.047	0.050	0.041
1	0.065	0.059	0.062	0.054
2	0.081	0.074	0.077	0.068
3	0.099	0.092	0.094	0.086
4	0.120	0.113	0.113	0.107
5	0.144	0.137	0.136	0.131
6	0.171	0.164	0.161	0.159
7	0.201	0.195	0.189	0.191
14	0.519	0.518	0.482	0.524
21	1.013	1.013	0.930	1.019
28	1.624	1.608	1.478	1.584

eters in Creole chickens of Mexico, applying the Gompertz Model. The low value (0.15 g/week) obtained by Nguyen Hoang *et al.* (2020) in Vietnamese indigenous Mia chicken. Strains with the highest and smallest values of K were Ross and CP 707, respectively. The result demonstrated that Ross attain mature weight earlier than other strain. It was stated by Lupi *et al.* (2016) that animal with high value of K matured earlier than animals with low value for this parameter.

The value of K is important for choosing the chicken for the breeding and marketing goals. Early and lower weight of maturity may be preferred if the breeding program is aimed to produce animals with lower energy needs, but later maturity should be taken into account if the goal of the breeding program is to produce animals with higher mature weights to meet market demand (Fitzhugh and Taylor, 1971). Commer-

cial broilers have been raised for the purpose of efficient production as part of the meat industry. Chicken with higher mature weights and delayed maturation were therefore favored.

Obtained value of inflection points in the present study ranged from 25.292 – 30.970 days, and 1.373 – 1.855 kg for IA and IW, respectively. Masoudi and Azarfah (2017) reported values of 1.334 for IW in Ross, which is similar to obtained IW of the present study, but they reported later AI of 29.28. The value of AI was expected beginning sexual maturity, but Pittroff *et al.* (2008) stated that AI of growth curve was not associated with the onset of puberty. The AI and IW might be appropriate to assign slaughter time. Generally, broiler farm holders in Indonesia slaughter their chickens less than 5 weeks of age with approximately a body weight of 1.70 kg (Hafid, 2022). The specific values of IW and AI



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 Figure 1. Growth curve of four strains broiler chickens predicted by Gompertz growth models in comparison with the observed data

estimated in this study are applicable for estimation of optimal slaughter age and weight in the broiler industry. The illustration of observed and predicted growth curves for each strain are shown in figure 1.

The values of AIC ranged from -247.935 to -193.167, and R² (0.999) for all strains. Based on that values, the Gompertz model provided an excellent fit for growth of commercial broiler chickens. According to Köhn *et al.* (2007) and Khan *et al.* (2013), the model with low value of Akaike information criterion (AIC), and high value of coefficient determination (R²) was reliable on estimation.

CONCLUSION

The AI and IW of Gompertz growth curve model expected could be used to assign the optimum slaughter time of broiler chickens. The model could help define feeding programs and marketing strategies that meet nutritional needs from hatching to maximal growth of commercial broiler chickens.

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collection

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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