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Research Article

Mathematical Models of Growth and Feed Intake in Rambon Ducks

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Abstract

Objective: This study evaluated the growth and feed intake of Rambon ducks, a type of local Indonesian ducks. **Materials and Methods:** This study evaluated growth using 6 models, including the Brody, Gompertz, Logistic, Morgan Mencer Flodine (MMF), Richards and von Bertalanffy models. The feed intake model was estimated using the rational function equation. A total of 80 selectively-bred layer ducks (40 males and 40 females) were reared for 22 weeks. **Results:** All growth models applied were a good fit for both female and male ducks. The Logistic model with three parameters had the best fit with the highest correlation beween actual and predicted values and lowest standard error of estimation. High correlations also indicated that the rational function model had a good fit and successfully predicted feed intake of the ducks from hatching to 22 weeks. **Conclusion:** The Brody, Gompertz, Logistic, Morgan Mencer Flodine, Richards and von Bertalanffy models had a good fit and successfully predicted the growth of Rambon ducks from hatching to 22 weeks, however, the Logistic model had the best fit. The rational function model also had a good fit and successfully predicted feed intake of the ducks from hatching to 22 weeks.

Key words: Growth model, feed intake model, rambon ducks, laying ducks

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Growth is defined as an increase in the number and size of cells. The growth process is generally measured in live animals. Growth patterns are of particular importance to the animal production industry, due to its practical implications for feeding and management. The age of an animal's sexual maturity in flock, for example, is greatly affected by the growth and size of the animals.

Growth curves are the most appropriate models for describing growth patterns and can be used to predict growth rate and estimate body weight or body part changes over time. Growth curves are sigmoidal with an inflection point where the rate of growth is maximal with an upper asymptote[1,2]. There are many mathematical models that can be used to determine age-live weight relationships, such as the Gompertz function[3], Logistic function[4], Richards function[5], Brody function[6], von Bertalanffy function[7] and Morgan Mencer Flodine (MMF)[8]. These growth curves are characterized by different features and limitations and are specific for different species. Therefore, choosing the right model for a specific animal requires careful consideration.

Feed intake is an economically important factor in the poultry industry as feed is very costly, feed is linked to growth and growth is limited by feed intake[9,10]. Predicting feed intake at various ages is necessary to determine an optimal diet[11]. Thus, the nutrient content in feed relies on the intake of the animal. Although a study by Goliomytis used a polynomial cubic function to predict feed intake, very few studies have been conducted on the subject[12].

The Rambon duck is a local, layer duck that originates from Java, Indonesia. Its eggs are an important source of a farmer's income. Although the Rambon duck provides an adequate number of eggs, it has not been selected for economic traits. Determining growth and feed intake patterns are very important for management purposes, to identify optimal feeding and to plan for sexual maturity, growth patterns also provide important information to help to formulate breeding plans. The purpose of this study was to evaluate the best fit of different mathematical models to describe growth and feed intake in the Rambon duck.

MATERIALS AND METHODS

This study was conducted from April-October, 2015 at the duck breeding center in the Faculty of Animal Husbandry at Universitas Padjadjaran and was supported by the Directorate General of Research and Higher Education of Indonesia. All procedures and protocols were approved by the Panel Research Selection (reference number: 353/UN6.R/PM/2015).

Table 1: Composition of diet in starter and grower Rambon ducks across days 1-22

Ingredients	Starter (%)	Grower (%)
Yellow corn	59.00	55.00
Wheat bran	7.00	22.50
Soybean meal	14.00	7.00
Coconut meal	5.75	6.00
Fish meal	11.00	7.00
Bone meal	1.25	2.50
Coconut oil	1.50	1.50
Mineral premix	0.50	0.50
Calculated value		
Crude Protein	20.02	16.01
ME (Kcal kg^{-1})	3.006	2.716
Crude fat	5.93	5.84
Crude fiber	3.83	5.16
Total calcium	1.03	1.05
Total phosphorus	0.61	0.62

Table 2: Growth models

Models	Formula
Brody[6]	Y = a*(1-b*exp(-c*x))
Gompertz[13]	Y = a*exp(-exp(b-c*x))
Logistic[4]	Y = a/(1+b*exp(-cx))
MMF[8]	Y = (a*b+c*x^d)/(b+x^d)
Richards[5]	Y=a/(1+exp(b-c*x))^(1/d)
Von Bertalanffy[7]	Y = a*((1-b*exp(-c*x)))**3

Forty male and 40 female of day-old ducks (DOD) from the 2nd generation of selective breeding for egg production were reared to 22 weeks of age in a 3 m×6 m animal house divided into 16 pens (80 cm×100 cm) bedded with rice hull litter. Each pen consisted of 5 ducks. The ducks were fed starter and grower rations as shown in Table 1. The models that were used to predict intake and growth are presented in Table 2.

The feed intake was estimated with rational function[14]:

$$y = \frac{(a + bx)}{(1 + cx + dx^2)}$$

where, y is the body weight (g), x is age (week), a is the asymptotic or maximum growth response, b is a scale parameter related to initial weight, c is the intrinsic growth rate and d represents shape parameters. The parameter estimates were calculated using proc-nlin with SAS 9.0. The best fit was indicated with a correlation between observed and predicted data (r) and standard error of prediction (SE).

RESULTS

Body weight and average daily gain: Growth in the Rambon duck was sigmoidal shaped (Fig. 1). Weights at hatching were 40.95 and 43.83 g, while weights at 22 weeks were 1,508 and

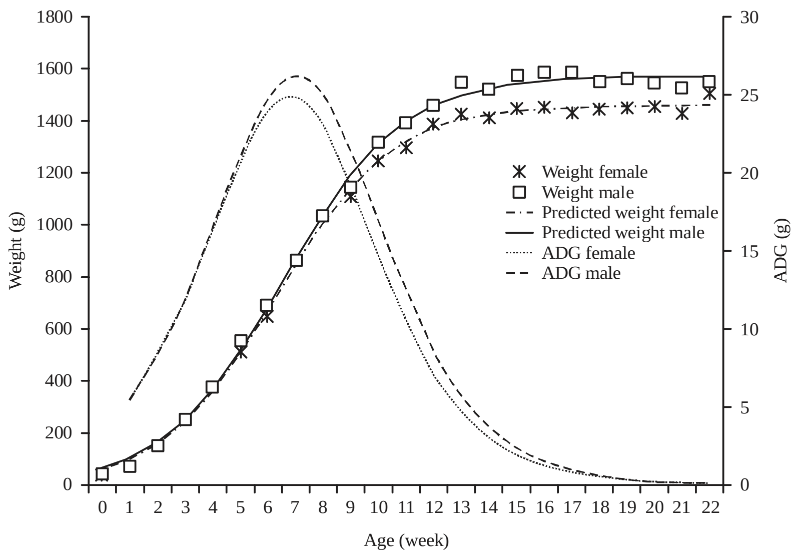

Fig. 1: Growth curve based on logistic model

Table 3: Correlation between actual and predicted values (r) and standard errors of prediction (SE)

		Female		Male	
Models	Formula	r	SE	r	SE
Brody[6]	Y = a*(1-b*exp(-c*x))	0.9808	107.82	0.9787	123.09
Gompertz[13]	Y = a*exp(-exp(b-c*x))	0.9982	34.24	0.9977	41.80
Logistic[4]	Y = a/(1+b*exp(-cx))	0.9995	22.21	0.9990	27.26
MMF[8]	Y = (a*b+c*x^d)/(b+x^d)	0.9980	34.05	0.9970	44.94
Richards[5]	Y = a/(1+exp(b-c*x))^(1/d)	0.9992	22.52	0.9990	27.78
Von Bertalanffy[7]	Y = a*((1-b*exp(-c*x)))**3	0.9969	45.95	0.9963	54.27

Table 4: Parameter estimates across models

		Female				Male			
Models	Formula	a	b	c	d	a	b	c	d
Brody[6]	Y = a*(1-b*exp(-c*x))	1717.20	1.09	0.12	-	1862.10	1.10	0.11	-
Gompertz[13]	Y = a*exp(-exp(b-c*x))	1493.20	1.58	0.32		1606.60	1.62	0.31	
Logistic[4]	Y = a/(1+b*exp(-cx))	1461.80	20.78	0.48		1574.08	21.60	0.47	
MMF[8]	Y = (a*b+c*x^d)/(b+x^d)	0.22	585.50	1383.90	3.36	0.19	694.20	1494.20	3.40
Richards[5]	Y = a/(1+exp(b-c*x))^(1/d)	1466.93	2.42	0.44	0.77	1576.58	2.78	0.45	0.45
Von Bertalanffy[7]	Y = a*((1-b*exp(-c*x)))**3	1511.00	1.05	0.27		1625.40	1.09	0.26	

1,553 g, for females and males, respectively. The correlation between actual and predicted values (r) and standard errors of prediction (se) are presented in Table 3, while parameter estimates are presented in Table 4. The correlations were generally high, ranging from 0.9808-0.9995 for females and 0.9787-0.9990 for males. The standard errors of prediction ranged from 22.21-107 g for females and between 27.26 and 123.09 g for males. The Logistic model had the highest correlation and the lowest standard error.

Average daily gain (ADG) was estimated from the predicted values of the Logistic model (Fig. 1). The ADG reached its peak at 7 weeks and then decreased gradually by 20 weeks until it nearly reached zero. From hatching to 4 weeks, both females and males had similar accelerations in growth but thereafter, the males grew faster than the females.

Feed intake: Parameter estimates, correlations between actual and predicted values (r) and the standard error of prediction for feed intake are presented in Table 5. The correlations were high, ranging between 0.9432 and 0.9566, for females and males, respectively. The trend of intake is illustrated in Fig. 2. Intake increased until approximately 10 weeks and then decreased gradually.

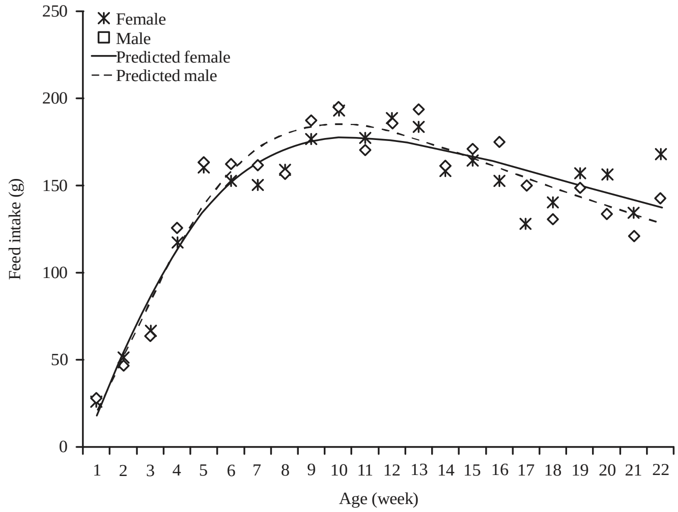

Fig. 2: Feed intake curve based on rational function

Table 5: Parameter estimates by gender

	Sex	
Parameters	Female	Male
a	-20.816	-12.486
b	39.230	31.553
c	0.006	-0.047
d	0.010	0.011
r	0.9432	0.9566
se	15.711	14.318

Rational function: $y = (a+bx)/1+cx+dx^2)$

DISCUSSION

The Rambon duck is a local Indonesian layer duck that originated from Java Island. The male has dark brown around the head, while the female has light brown around the head, chest, back, wings and neck. Rambon duck eggs are a blue-green color.

Although there have been very few studies on Rambon ducks, the weights of the mature ducks in this study were in line with those reported by the Agricultural Ministry of Indonesia (females: 1.4 and 1.5 kg, males: 1.6 and 1.7 kg)[15]. The ducks reached sexual maturity at 180 days (25 weeks).

All applied models had high correlations and as a consequence, they all had a good fit both for females and males, however, the Logistic model with three parameters had the best fit. Therefore, the Logistic model is the most appropriate model to successfully predict the growth of Rambon ducks.

Several studies have compared different growth models in chickens and have shown that the Brody, Gompertz, Logistic, MMF, Richards and von Bertalanffy models successfully predict growth patterns by age[1,12,15-22]. Other studies showed similar results in quails and Turkeys[8,23-26]. Models are very specific for different strains and populations. ADG, for example, is very specific for different breeds of duck, since different breeds perform differently. There have few studies that have evaluated ADG in the Rambon duck.

Feed intake affects production cost and egg-laying performance. Thus, it is important to predict information on the size of the animals before they enter the laying period. Feed intake is affected by age, sex, health, temperature and energy concentration in the diet and is also affected by feed pellet quality and managerial factors, such as feed and water availability, environmental management, stocking density and disease control[10,27]. Therefore, feed intake is linked to growth rate and growth rate is limited by feed intake[9,10]. Goliomytis[12] studied feed intake in broiler chicken using cubic polynomial function and his results were consistent with the findings of the current study.

In this study, the correlations between actual and predicted values were 0.9432 and 0.9566 for females and males, respectively. High corelations indicated that the Rational Function model had a good fit in predicting feed intake in ducks from hatching to 22 weeks. Farmers and the breeding industry can successfully predict the efficient feeding program to obtain optimal egg production using the Logistic model.

CONCLUSION

The Brody, Gompertz, Logistic, Morgan Mencer Flodine, Richards and von Bertalanffy models had a good fit and successfully predicted the growth of the Rambon duck from hatching to 22 weeks of age, however, the Logistic model had the best fit. The Rational Function model had a good fit and successfuly predicted feed intake from hatching to 22 weeks of age.

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REFERENCES

1. Yang, Y., D.M. Mekki, S.J. Lv, L.Y. Wang, J.H. Yu and J.Y. Wang, 2006. Analysis of fitting growth models in jinghai mixed-sex yellow chicken. Int. J. Poult. Sci., 5: 517-521.
2. Vitezica, Z.G., C. Marie-Etancelin, M.D. Bernadet, X. Fernandez and C. Robert-Granie, 2010. Comparison of nonlinear and spline regression models for describing mule duck growth curves. Poult. Sci., 89: 1778-1784.
3. Gompertz, B., 1825. On the nature of the function expressive of the law of human mortality and on a new mode of determining the value of life contingencies. Philos. Trans. R. Soc. London, 115: 513-585.
4. Nelder, J.A., 1961. The fitting of a generalization of the logistic curve. Biometrics, 17: 89-110.
5. Richard, F.J., 1959. A flexible growth function for empirical use. J. Exp. Biot., 10: 290-300.
6. Brody, S., 1945. Bioenergetics and Growth. Reinhold Publishing Co., UK., Pages: 1023.
7. Von Bertalanffy, L., 1957. Quantitative laws in metabolism and growth. Quart. Rev. Biol., 32: 217-231.
8. Sengul, T. and S. Kiraz, 2005. Non-linear models for growth curves in large white turkeys. Turk. J. Vet. Anim. Sci., 29: 331-337.
9. Scott, T.A., 2005. Variation in feed intake of broiler chickens. Recent Adv. Anim. Nutr. Aust., 15: 237-244.
10. Ferket, P.R. and A.G. Gernat, 2006. Factors that affect feed intake of meat birds: A review. Int. J. Poult. Sci., 5: 905-911.
11. Morel, P.C.H., J.A. Timmers, T.A.T.H. de With, G.R. Wood, R. Sheriff, B.J. Camden, D.V. Thomas and V. Ravindran, 2001. Prediction of feed intake in modern broilers. Proc. Aust. Poult. Sci. Sym., 13: 152-155.
12. Goliomytis, M., E. Panopoulou and E. Rogdakis, 2003. Growth curves for body weight and major component parts, feed consumption and mortality of male broiler chickens raised to maturity. Poult. Sci., 82: 1061-1068.
13. Winsor, C.P., 1932. The gompertz curve as a growth curve. Proc. Natl. Acad. Sci., 18: 1-8.
14. Saxena, A., B.M. Gupta and M. Jauhari, 2007. Exploring models for the growth of literature data. DESIDOC Bull. Inform. Technol., 27: 3-12.
15. AMI., 2013. Keputusan meneri pertanian nomor: 700/kpts/PD.410/2/2013. Agricultural Ministry of Indonesia (AMI), Indonesia.
16. Grey, T.C., D. Robinson and J.M. Jones, 1982. Effect of age and sex on the eviscerated yield, muscle and edible offal of a commercial broiler strain. Br. Poult. Sci., 23: 289-298.
17. Grossman, M., B.B. Bohren and V.L. Anderson, 1985. Logistic growth curve of chickens: A comparison of techniques to estimate parameters. J. Hered, 76: 397-399.
18. Knizetova, H., J. Hyanek, B. Knize and H. Prochatzova, 1991. Analysis of growth curves of fowl. II. Ducks. Br. Poult. Sci., 32: 1039-1053.
19. Duan-Yai, S., B.A. Young, A. Lisle, J.A. Coutts and J.B. Gaughan, 1999. Growth data of broiler chickens fitted to Gompertz function. Asian Aust. J. Anim. Sci., 12: 1177-1180.
20. Aggrey, S.E., 2002. Comparison of three nonlinear and spline regression models for describing chicken growth curves. Poult. Sci., 81: 1782-1788.
21. Norris, D., J.W. Ngmbi, K. Benyi, M.L. Makgahela, H.A. Shimelis and E.A. Nesamvuni, 2007. Analysis of growth curves of indigenous male Venda and Naked Neck chickens. S. Afr. J. Anim. Sci., 37: 21-26.
22. Zhao, Z., S. Li, H. Huang, C. Li, Q. Wang and L. Xue, 2015. Comparative study on growth and developmental model of indigenous chicken breeds in China. Open J. Anim. Sci., 5: 219-223.
23. Karaman, E., D. Narinc, M.Z. Firat and T. Aksoy, 2013. Nonlinear mixed effects modeling of growth in Japanese quail. Poult. Sci., 92: 1942-1948.
24. Kizilkaya, K., M.S. Balcioglu, H.I. Yolcu, K. Karabag and I.H. Genc, 2006. Growth curve analysis using nonlinear mixed model in divergently selected Japanese quails. Archiv. Geflugelkunde, 70: 181-186.
25. Raji, A.O., S.T. Mbap and J. Aliyu, 2014. Comparison of different models to describe growth of the Japanese quail (Coturnix Japonica). Trakia J. Sci., 12: 182-188.
26. Raji, A.O., N.K. Alade and H. Duwa, 2014. Estimation of model parameters of the Japanese quail growth curve using Gompertz model. Arch. Zootecn., 63: 429-435.
27. Leeson, S. and J.D. Summers, 2000. Commercial Poultry Nutrition. 2nd Edn., University Books, Guelph, Ontario.