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Research Article

Comparing The Effects of Environmental Enrichment on Growth in Geese with Some Nonlinear Models

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Abstract

The aim ofthe present study is to determine the time-dependent changes in the live weights of the geese, for which environmental enrichment was applied (Turkish local goose genotype), between the days 7 and 98. For this purpose, nonlinear Brody, Gompertz, Logistic, von Bertalanffy, and Richards growth models, which are used commonly, were used to determine the growth and development of poultry. Geese were divided into 3 groups (control group (C), broom group (B), mirror group (M)) based on their enrichment characteristics. The success status of the models applied in the present study was assessed based on mean square error (MSE) and coefficient of determination (R2) values. It was found thatR2 value was be 96.86 in the Logistic model, 96.82 in Brody model, 96.16 in vonBertalanffy model, 95.04 in Gompertz model and 93.85 in Richards model, respectively, and MSE value was 0.2368 in Logistic model, 0.2004 in Brody model, 0.1992 in von Bertalanffy model, 0.3567 in Gompertz model and 0.3711 in Richards model, respectively. As a result, it was concluded that the most suitable models with high coefficient of determination but low mean square error were Brody, Gompertz, and von Bertalanffy models, respectively, in determining the time-dependent live weight change in the geese (Turkish local goose genotype), for which environmental enrichment was applied, and it was suitable to use these three models in determining the effect of environmental enrichment on live weight.

Key words: Goose, Environmental enrichment, Body weight, Growth model

Kazlarda Çevresel Zenginleştirmenin Büyüme Üzerine Etkilerinin Bazı Doğrusal Olmayan Modellerle Karşılaştırılması

Öz

Bu çalışmanın amacı, çevresel zenginleştirme uygulanan kazlarının (Türk yerel kaz genotipi) canlı ağırlıklarında 7 ile 98. günler arasındaki zamana bağlı değişimleri belirlemektir. Bu amaçla kanatlı hayvanların büyüme ve gelişimlerini belirlemek için yaygın olarak kullanılan doğrusal olmayan Brody, Gompertz, Logistic, von Bertalanffy, ve Richards büyüme modelleri kullanılmıştır. Kazlar zenginleştirme özelliklerine göre 3 gruba (kontrol grubu (C), süpürge grubu (B), ayna grubu (M)) ayrıldı. Bu çalışmada uygulanan modellerin başarı durumu hata kareler ortalaması (MSE) ve belirleme katsayısı (R2) değerlerine göre değerlendirildi. R2 değeri sırasıyla Logistic model de 96.86, Brody model de 96.82, von Bertalanffy model de 96.16, Gompertz model de 95.04, Richards model de 93.85 olduğu, MSE değerleri sırasıyla Logistic model de 0.2368, Brody model de 0.2004, von Bertalanffy model de 0.1992, Gompertz model de 0.3567, Richards model de 0.3711 olarak bulunmuştur. Sonuç olarak çevresel zenginleştirme uygulanan kazlarda (Türk yerel kaz genotipi) zamana bağlı canlı ağırlık değişiminin belirlenmesinde belirleme katsayısı yüksek fakat ortalama hata karesi düşük olan en uygun modellerin sırasıyla Brody, Gompertz ve von Bertalanffy modelleri olduğu sonucuna varılmış, canlı ağırlık üzerine çevresel zenginleştirme etkilerinin belirlenmesinde bu üç modelin de kullanımının uygun olacağı sonucuna varılmıştır.

Anahtar kelimeler: Kaz, Çevresel zenginleştirme, Vücut ağırlığı, Büyüme modeli

Introduction

Nutrition is one of our most important vital activities. A sufficient and balanced diet is required to maintain a healthy and qualified life. And this is possible with qualified foods to be obtained within the daily diet. The unpredictable increase of population and quality of life make the provision of qualified nutrients which should be taken with the daily diet more difficult. This has caused the development of the sources in the poultry sector, which is among the important animal protein sources, and the development of new breeds and species. And this has especially caused an increase in the interest towards goosebreed.

Geese, which have an important place in the Anatidae population, are herbivores (Taskin et al., 2020a;Taskin et al., 2020b). They have big and strong ventriculum. This property gives geese advantage in terms of roughage consumption compared to other poultry. Also, geese are durable animals with high adaptation skills and they are raised for other reasons such as security and weed control (Boz et al., 2014; Karadavut and Taskin, 2014).

The time-dependent numeric and dimensional increases in living creatures are described as growth (Sahin et al., 2014). Morphological, physiological and behavioural changes are observed in living creatures during growth. These changes cause the body rates of living creatures to shape and their structural systems to gain functionality and develop. Genotype and environment are the most important factors affecting development and growth in living creatures. Poultry are also affected by environmental factors positively or negatively like all living creatures (Schmidt-Nielsen, 1997). Environmental enrichment methods are used to eliminate these environment-based problems. Environmental enrichment is defined as rearrangement of habitats using several objects to enhance quality of life of animals and improve their normal behavioural expressions (Belz et al., 2003).Various images, audible sounds, structures, plastic materials, and odours used in hencoops are the basic environmental enrichment instruments (Yildirim and Taskin, 2017; Branch et al., 2015; Fernandes et al., 2015; Bizeray et al., 2002). In environmental enrichment method, it is aimed to display species-typical behaviour in animals in a wide range and increase animal welfare (Van de Weerd, 2009). It has been reported that the increase of behaviour and welfare in poultry cause the improvement of biological functions and this affects production (Regmi et al., 2016; Blatchford et al., 2016; Genhardt-Henrich et al., 2017; Pickel et al., 2011; Stratmann et al., 2015).

To express the growth in living creatures better, it is required to perform biological interpretation and mathematical assessment together (Karadavut et al., 2013). For this purpose, many mathematical growth models have been established. These models enable to assess the data collected in different dates, biological processes and growth better (Behr et al., 2001). Also,these models are used in breeding to have information about the situations such as performing predictions about future, selecting broods and evaluating health (Colak et al., 2006). To model the growth in poultry, the growth curve models such as Brody, Gompertz, Logistic, vonBertalanffy and Richards are used commonly (Zhao et al., 2015; Alkan and Birgul, 2017; Michalczuk et al., 2016; Demuner et al., 2017; Eleroglu et al., 2018).

The aim of this study was to predict the time-dependent changes in the live weights of the Turkish local geese raised in the environment establishedthrough some environmental enrichment tools (Broom, mirror) by using some nonlinear mathematical growth models.

Material and Method

The present study was conducted with the ethics committee approval from Kırşehir Ahi Evran University Animal Experiments Local Ethics Committee (Decision dated 27.01.2016 and numbered 01/12) in April and July in Kırşehir Ahi EvranUniversity, Agricultural Faculty, Animal Science Department application coop (39°8'45" N and 34°9'34" E).

In the present study, totally 72 (3x 3x 8) one-day goose chicks (Turkish local goose genotype) obtained from brood goose establishment of Yozgat Bozok University were used as the animal material. Natural photoperiod was applied for the geese and they were fed ad libitum by means of the automatic drinkers and feeders hanging on the coop ceiling. At the beginning, the geese were fed with the feed containing 28% HP and 2800 kcal/kg ME in the first 0-2ndweeks and 20% HP and 3000 kcal/kg ME in the 4th-14thweeks (NRC, 1994; Tilki and Inal, 2004; Onk and Kirmizibayrak, 2019). As the raising environment, the geese were collectively kept in the climate controlled environment up to the first 7thday (37 °C) and in the environment without any air conditioning until the end of the 4thweek by decreasing temperature gradually. Also, at the end of the 7thday, numbered anklets were attached to the goose chicks and they were setindividually and all the processes were performed with these numbers.

The geese were put in 9 attached coops (4 birds/m^2 with floor area of 2.5 m^2) prepared without a ceiling (8 goose chicks in each coop) at the end of 4 weeks. Thus, the study design was formed with totally 3 groups including 1 control group (C) and 2 treatment groups (B, M) and 3 repetitions (8 goose chicks per repetition) for each group. In the present study, a strict cleaning was applied, wood shavings were used as mat providing that theyhad a minimum height of 10 cm and they were cleaned and replaced every 5 days.

These objects used for environmental enrichment were designed upon the review of the previous studies conducted on poultry (Yildirim and Taskin, 2017). In the present study, mirrors and broom objects were used to encourage the pecking sense and locomotor activities of the geese for the purpose of environmental enrichment. Four-faced mirror (20x10cm) and red-handled green (Uçtem LUX004 Plastic Broom Lux No 4) brooms were used. Environmental enrichment objects (mirrors and brooms), two in each coop, were hung on wires hanging down the coop ceiling with a ground height of 30 cm considering the accessibility of the geese (Jones et al., 2000). Then, this height was increased 5 cm gradually in every 2 weeks considering the growth of the geese.

In determining the growth curves, the weekly live weight increases determined between the days 7 and 98 in every 7 days were used in the present study. Live weights were determined by means of the electronic precision weighing device (0.01 g) individually and assessed in groups. Brody, Gompertz, Logistic, von Bertalanffy and Richards growth curve models were used in the present study to determine the model which defines growth best (Draper and Smith, 1981).

The growth curve models used in the study are as follows:

Brody Model: $Y = a\ (1- be^{(-kt)})$

Gompertz Model: $Y = ae^{-be^{(-kt)}}$

Von Bertalanffy Model: $Y = a(1 - be^{-kt})^3$

Logistic Model: $Y = a(1 + be^{(-kt)})^{-1}$

Richards Model: $Y = a(1 - be^{(-kt)})^m$

In the above equations:

Y refers to "live weight"; *a* and L_∞ refer to the theoretical upper asymptote value; *b*refers to the first weight when growth begins; *k* represents the instant growth amount; *e* represents the natural log base of 2.718; m represents the inflection point parameter of the model, and *t* represents time. When comparing the models, Coefficient of determination (**R^2**) and mean square error (**MSE**) were used (Narinc et al., 2017). In selecting the most suitable model, it was paid attention that the coefficient of determination was high (close to one) and mean square error was low (close to zero). The models were determined in accordance with this. Also, it is confirmed whether there is any correlation between the successive values of the error term. The data of the study wereanalysed by Statistica 6.0 V statistical software.

Results and Dıscussıon

In the present study, all the groups for which environmental enrichment was applied were assessed together and the parameter predictions and the coefficients of determination calculated by Brody, Gompertz, Logistic, vonBertalanffy and Richards models are presented in **Table 1**.

Table 1. The table of the assessment of all groups together.

	Brody	Gompertz	Logistic	Von Bertalanffy	Richards
$\underline{A} \pm S_{\underline{A}}$	171.41±0.259	169.37±0.045	92.02±0.015	207.84±0.017	5501.30±26.800
$\underline{B} \pm S_{\underline{B}}$	1.01±0.001	6.13±0.017	-1.01±0.003	0.904±0.001	-4.013±0.027
$\underline{K} \pm S_{\underline{K}}$	0.000348±0.001	0.00584±0.001	0.000655±0.001	0.00252±0.001	0.0056±0.001
$\underline{M} \pm S_{\underline{M}}$					-5.78±0.0177
R^2	0.9682	0.9504	0.9686	0.9616	0.9385
MSE	0.2004	0.3567	0.2368	0.1992	0.3711

When all the treatments were assessed, it was found in Brody, Gompertz, Logistic, von Bertalanffy and Richards models that the parameter **$\bar{A}$±$S_{\bar{A}}$** was 171.41±0.259, 169.37±0.045, 92.02±0.015, 207.84±0.017, and 5501.30±26.8, respectively, the parameter $\underline{B} \pm S_{\underline{B}}$ was 1.01±0.001, 6.13±0.017, -1.01±0.003, 0.904±0.001, and -4.013±0.027. The parameter $\underline{K} \pm S_{\underline{K}}$ was

0.000348±0.001, 0.00584±0.001, 0.000655±0.001, 0.00252±0.001, and 0.0056±0.001, respectively.
In addition, in Richards model, the parameter $\underline{M} \pm S_{\underline{M}}$ was calculated to be -5.78±0.0177.

Also, when we assessed all the models based on MSE and R^2 values, the highest R^2 value was determined in the Logistic, Brody and vonBertalanffy models and these values were found to be 96.86, 96.82, and 96.16, respectively. MSE value was 0.2368 in the Logistic model, 0.2004 in the Brody model, 0.1992 in the von Bertalanffy model, 0.3567 in the Gompertz model, and 0.3711 in the Richards model.

Table 2 shows the parameter predictions and the coefficients of determination calculated for C, B, and M groups.

In C group, R^2 value was found in ascending order to be 0.94576 in Gompertz model, 0.94370 in Richards model, 0.96576 in von Bertalanffy model, 0.97145 in Logistic model, and 0.97177 in Brody model, respectively. Also, in the other two groups, it was 0.93423 in Richards model, 0.94576 in Gompertz model, 0.95794 in von Bertalanffy model, 0.96974 in Logistic model, and 0.96996 in Brody model in M group and 0.93713 in Richards model, 0.93713 in Brody model, 0.95044 in Gompertz model, 0.96063 in von Bertalanffy model, an 0.96480 in Logistic model in B group, respectively.

MSE value was found,in ascending order, to be 0.1545 in Brody model, 0.1563 in Logistic model, 0.1841 von Bertalanffy model, 0.3000 in Richards model, and 0.411 in Gompertz model in C group, and 0.1813 in Brody model, 0.1827 in Logistic model, 0.2465 in vonBertalanffy model, 0.3127 in Gompertz model, and 0.3799 in Richards model in M group, and 0.2570 in Logistic model, 0.2636 in Brody model, 0.2809 in von Bertalanffy model, 0.3417 in Gompertz model, and 0.4342 in Richards model in B group, respectively.

Table 2. The table of assessing growth models based on the groups (B, M, C)

			B		
	Brody	**Gompertz**	**Logistic**	**Von Bertalanffy**	**Richards**
$\underline{A} \pm S_{\underline{A}}$	170.00±0.547	169.36±0.0789	92.082±0.0304	207.84±0.0242	5541.9±5.76
$\underline{B} \pm S_{\underline{B}}$	1.006±0.0003	6.155±0.0332	1.0115±0.000450	0.90638±0.00206	3.9772±0.00486
$\underline{K} \pm S_{\underline{K}}$	0.00037±0.000009	0.006046±0.000083	0.000699±0.000016	0.002638±0.000043	0.005692±0.000066
$\underline{M} \pm S_{\underline{M}}$					-5.7972±0.0175
R^2	0.93713	0.95044	0.96480	0.96063	0.93713
MSE	0.2636	0.3417	0.2570	0.2809	0.4342
			M		
	Brody	**Gompertz**	**Logistic**	**Von Bertalanffy**	**Richards**
$\underline{A} \pm S_{\underline{A}}$	172.01±0.272	169.17±0.0547	91.990±0.0210	207.78±0.0161	5543.3±5.73
$\underline{B} \pm S_{\underline{B}}$	1.0052±0.000204	6.0354±0.0163	-1.0098±0.000376	0.89853±0.00118	-3.9716±0.00638
$\underline{K} \pm S_{\underline{K}}$	0.000345±0.000009	0.005659±0.000065	0.000651±0.000016	0.002452±0.000040	0.005426±0.000055
$\underline{M} \pm S_{\underline{M}}$					-5.7715±0.0123
R^2	0.96996	0.94576	0.96974	0.95794	0.93423
MSE	0.1813	0.3127	0.1827	0.2465	0.3799
			C		
	Brody	**Gompertz**	**Logistic**	**Von Bertalanffy**	**Richards**
$\underline{A} \pm S_{\underline{A}}$	172.27±0.268	169.56±0.0739	91.991±0.0222	207.91±0.0352	5422.7±75.8
$\underline{B} \pm S_{\underline{B}}$	1.0050±0.000168	6.1865±0.0256	-1.0096±0.000310	0.90614±0.00245	-4.0866±0.0768
$\underline{K} \pm S_{\underline{K}}$	0.000326±0.000008	0.005780±0.000061	0.000616±0.000014	0.002462±0.000036	0.005584±0.000050
$\underline{M} \pm S_{\underline{M}}$					-5.7633±0.0477
R^2	0.97177	0.95457	0.97145	0.96576	0.94370
MSE	0.1545	0.411	0.1563	0.1841	0.3000

Also, although R2 value was ranked number four when ordered ascending in the von Bertalanffy model in the B group due to the treatments, it was ranked three based on MSE value of this model. Similarly, there were differences in the ranking of Gompertz and Brody models in terms of R2 and MSE values. Figure 1 shows the time-dependent growth curves drawn of all the treatments.

Determining the characteristics such as growth and live weight increase affecting production directly is very important economically in poultry breeding. Various models are used in the studies to analyse the growth and live weight increase in poultry. It has been reported that the most preferred ones among these models are Gompertz, Logistic, Richards, and von Bertalanffy models (Narinc et al., 2017). Gompertz model, which is the mostly used one, is well known and it is used frequently to identify the number or the volume of the bacteria and cancer cells as well as the growth of animals and plants (Tjørve and Tjørve, 2017).

R2 value obtained from Brody model in C group was similar with R2values obtained in local female and male geese. However, R2 values obtained with different models significantly distinguished from the results we obtained (Onder et al., 2017). Also, R2 values obtained in the study conducted with Chinese local geese using Logistic, Gompertz, Von Bertalanffy and Richards models were higher than the R2 values we found (Ibtisham et al., 2017).

In a similar study conducted with quails, Gompertz, Logistic, Morgan-Mercer-Flodin (MMF) and Richards models were used and R2 value was determined to be 0.9974, 0.9933, 0.9993 and 0.9969 in males and 0.9975, 0.9937, 0.9993 and 0.9966 in females (Sengul and Kiraz, 2005).

In the study conducted on chicken, Gompertz, Richards, Lopez, Logistic and Von Bertalanffy models were used and R2 was reported to be 0.984 and 0.998 (Faraji-Arough et al., 2019).

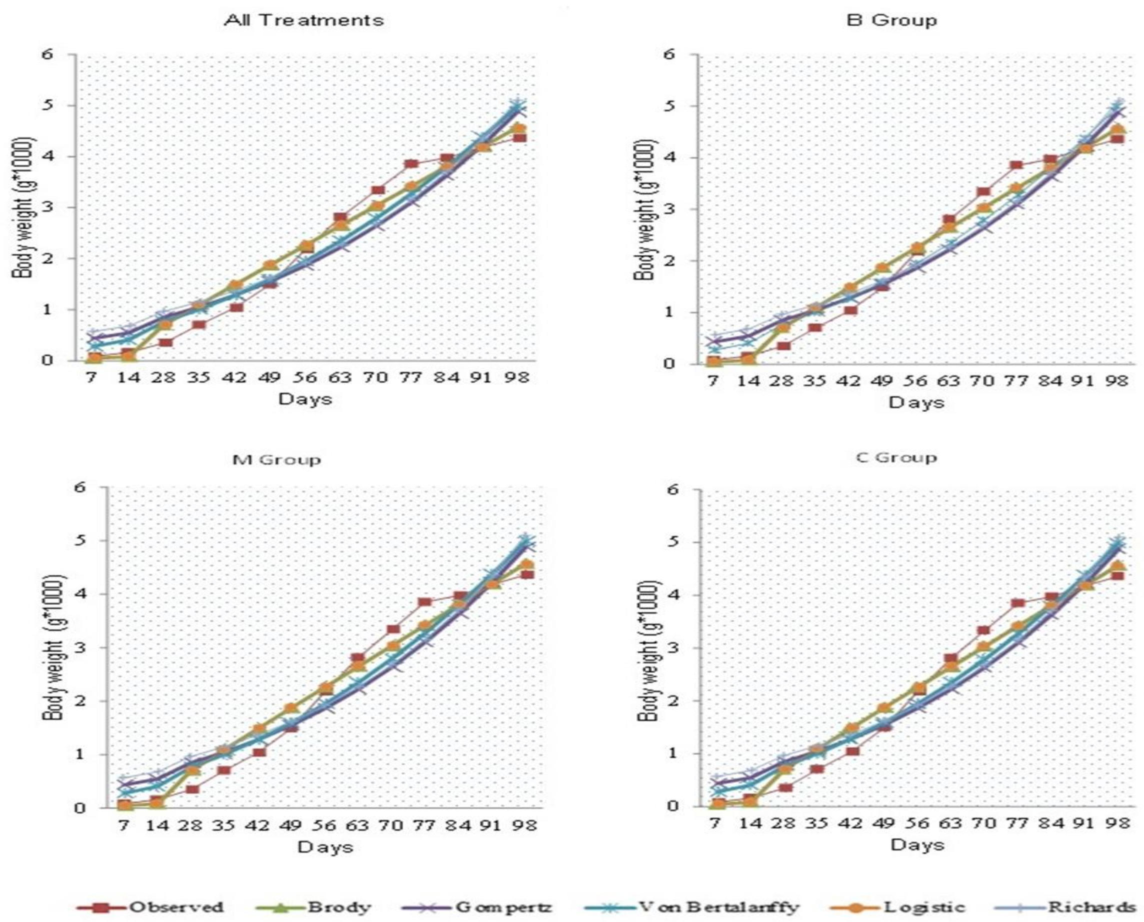

Figure 1. Time-dependent growth curves

Consequently, Gompertz, Logistic, Richards, von Bertalanffy and Brody models were used to determine the time-dependent live weight change in the geese (Turkish local geese genotype) for which environmental enrichment was applied in the study. It was concluded that the models used were affected by the treatment differences in the study groups and it will be suitable to use Brody, Gompertz, and von Bertalanffy models in terms of stating similar studies. The change in live weight is greatly under the effect of environmental factors as well as genetical structure. Mathematical growth curves demonstrate us the course of growth and they also give valuable information about the biological change. Because growth is not only a mathematical event but also a biological event. For this reason, it becomes important to explain biologically the changes, occurring mathematically

Conclusions

The parameters of the models used in this study have become biologically interpretable. So, it was found to be valuable and significant in terms of demonstrating that the data of the geese eroded due to time were successful both in time and the sensitivity of the measurements made. Environmental enrichment studies are one of the ways of getting higher production by increasing animal welfare. But such studies are needed to see how and in what direction environmental enrichment affects growth and development while increasing production. The results of the present study would add valuable contributions to future related studies.

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