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Growth Curve of Commercial Broiler as Predicted by Different Nonlinear Functions

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Abstract: This study was carried out to identify the better function that fit the growth curve in broiler depending on some criteria [coefficient of determination (R^2), Adjusted R^2 and mean square error (MSE)]. Eighty day-old unsexed broiler chicks (Ross 308) were used in this study for the period from 6/4/2015 to 17/5/2015. The growth data of broiler through 6th weeks were subjected to three nonlinear functions (Weighted Least Square (WLS), Gompertz, and Logistic). Results revealed that the WLS function was the best for fitting the growth curve in the broiler as compared with the two functions. The estimated values of asymptotic weight (β_0), the integration constant (β_1) and maturity rate (β_2) parameters according to WLS model were 2088, -3.68 and 0.14 respectively. In conclusion: The results confirmed that WLS function was more appropriate to describe the growth curve in the broiler (Ross 308) as compared with other functions.

Keywords: Growth curve, nonlinear functions, broiler

1. Introduction

World poultry meat consumption consists of three major segments: broilers, turkeys, and other poultry. Broilers clearly dominate the world poultry consumption contributing about 70 percent of the total poultry meat consumption (Roenick, 1998).

The broiler industry requires birds with the ability to grow very fast and to produce a good quality carcass in the shortest time frame (Prince, 2002).

Growth can be defined as an increase in body size per time unit. It represents an important economic trait in broiler industry (Schulze et al., 2001). The diet of broiler consists different types of additives and the effect of additives could not limit to the final weight,but it may extend to include the shape of growth. When the growth curve varied, this will increase their importance in recognizing the changes through the different stages of raising broiler. The growth curve was the main subject of many studies in domestic animals because the knowledge of the growth curve has practical applications and will lead to increasing the economic revenue of the project. (Sabbioni et al., 1999; Abbas et al., 2014).

The application of nonlinear equations on growth curve will provide a set of parameters that could be used to describe growth pattern over time. Furthermore, it will enable the breeders to expect the weight of animals at a specific age and to detect the stage that associated with the reduction in growth rate (Tzeng and Becker, 1981; Yakupoglu and Atil, 2001).

In bioeconomical studies, the using of mathematical growth model in combination with food consumption data is important because the cumulative food consumption up to slaughter is dependent not only on growth but also on the shape of the growth curves (Knitztova *et al.,* 1992).

Several equations have been used in broiler for instance: Logistic, Gompertz, Bertalanffy, Richards (Yang et al., 2006; Topal and Bolukbasi, 2008; Moharrery and Mirzaei, 2014; Mohammed, 2015).

The objective of the present study is to identify the better nonlinear function that could be used to describe the growth curve of broiler under the conditions of Iraq.

2. Materials and Methods

The experiment was conducted in one of the private sector poultry farms in Baghdad for the period from 6/4/2015 to 17/5/2015 day-old unsexed broiler chicks (Ross 308), purchased from a local commercial hatchery. Birds were housed in a floor pen. The lighting regimen provided 22 h of continuous light per day. Birds were vaccinated against Newcastle disease and infectious bronchitis on the 10th day of age and against Gambaro disease on 17 days of age.

A commercial basal diet was given to the birds. The ingredient and the nutrient composition of the basal diet are presented in Table 1. Feed and drinking water were offered *ad libitum*. Birds were weighed at fixed intervals of one week for 6 weeks.

Table 1. *Nutrient composition of the basal diet of broiler (Ross 308).*

Ingredient %	Starter 1-21 days	Finisher 22-42 days
Yellow corn	51	53.3
Soybean meal(45%protein)	30	25
Wheat	13.8	15
Premix*	2.5	2.5
Salt	0.3	0.3
Methionine	0.1	0.1
Lysine	0.1	0.1
Di calcium phosphate	1.2	1.2
Calculated chemical analysis		
ME(Kcal/kg)	3000	3086
Crude protein%	21.3	19.5
Calcium %	0.69	0.52
Available phosphore	0.74	0.69
Methionine	0.33	0.31
Lysine	1.19	1.08

*(2.5%) provided the following per kg of complete diets:36700IUvit.D_3, 1920 mg vit.E, 83.42 vit.K_3 50 mg vit B1,150 vit. B2, 500mg vit.B3,1775 mg vit.B6, 0.8 mg vit. B12, 600 mg vit.pp, 24.5 mg folic acid, 27 mg Biotin, 5767.5 mg choline, 2667 mg Fe, 333.75 mg Cu, 3334 mg Mn,203 mg Co, 2334 mg Zn, 100 mg Ca, 10 mg Se, 65446 mg Ph, 36667 mg methionine, 200 mg ethoxyquin, 50 mg flavophospholipol, 30 g fish meal, 1800 g wheat bran

3. Growth Curve Functions

The growth functions were carried out from the weekly body weight.

Three functions were used (Weighted Least Square (WLS), Gompertz, and Logistic) to identify the better function that describe the growth curve in the broiler. The functions and their mathematical notations are presented in Table (2). In all functions, β_0 is the asymptotic (mature) weight parameter, β_1 is the scaling parameter (constant of integration) and β_2 is the instantaneous growth rate (per day) parameter (Yang et al. 2006).

Table 2. *Growth curve functions.*

	Function
WLS	$\beta_0/(1+\exp(-\beta_1- \beta_2*x))$
Gompertz	$\beta_0*\exp-\beta_1\exp(-\beta_2*at)$
Logistic	$\beta_0*(1+\beta_1*\exp(-\beta_2*x))**-1$

4. Statistical Procedures

All parameters estimated by the Levenberg-Marquardt iteration method using NLIN procedure in SAS program (SAS, 2010). Several criteria are used to determine the goodness of fit: coefficient of determination (R^2), adjusted R^2 and mean square error (MSE) (Table 3).

Table 3. *The criteria of Goodness of fit for functions.*

Criteria	Equation
R^2	(SSE/SST)
MSE	SSE/df
Adjusted R^2	r^2- (k-1)(1-r^2)/n-k

Where: RSS – the residual sum of square, SST – the total sum of squares. *n* – the number of observations, *k* – the number of parameters included in the function.

5. Results and discussions

Table (4) showed the estimated body weight and the predicted body weight by three functions in broiler during sex weeks. While figures 1, 2, 3 showed the fitting of WLS, Gompertz and Logistic functions.

Table 4. *stimated body weight and predicted body weight by three functions.*

Estimated body weight	Predicted body weight /WLS	Predicted body weight / Gompertz	Predicted body weight / Logistic
43.00	58.57	29.84	72.14
146.88	135.44	122.99	154.48
377.55	336.68	371.34	354.63
710.83	725.82	759.03	721.96
1228.55	1245.05	1205.34	1217.03
1650.00	1678.24	1625.97	1665.54
1955.10	1919.17	1973.34	1947.38

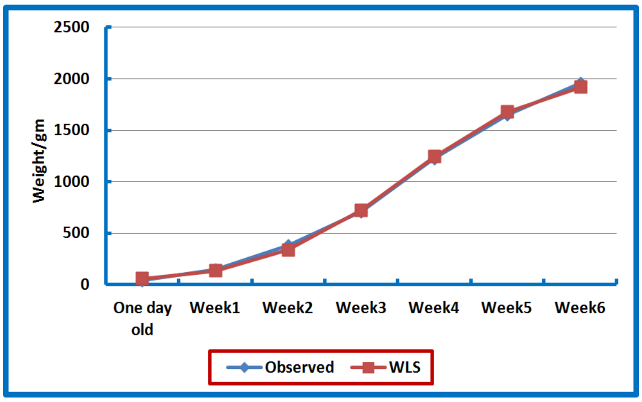

Figure 1: *Fitting growth curve of broiler (Ross 308) by Weighted least square function.*

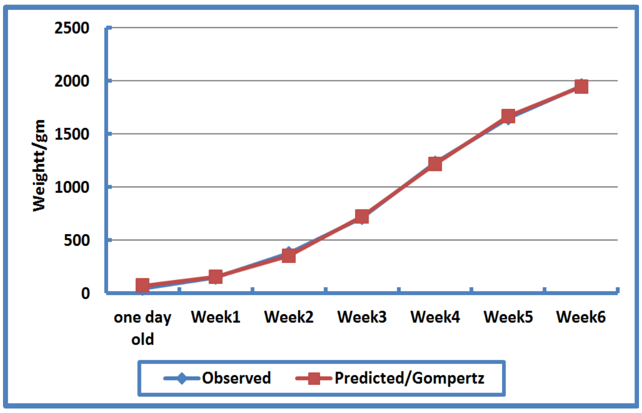

Figure 2: *Fitting growth curve of broiler (Ross 308) by Gompertz function.*

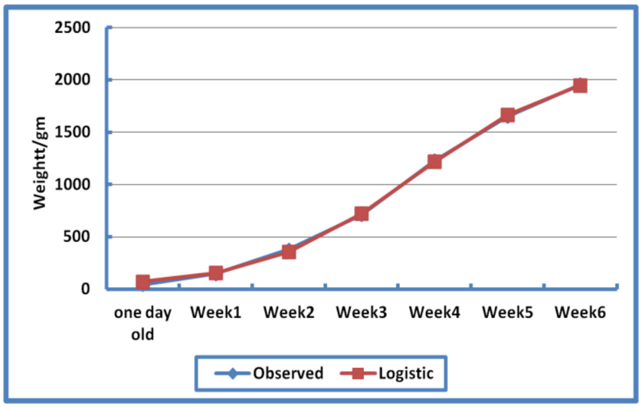

Figure 3: *Fitting growth curve of broiler (Ross 308) by Logistic function.*

Table (5) shows the parameters of WLS, Gompertz, and Logistic growth curve functions. Concerning with the mature weight (β_0) the value of Gompertz was the highest (2814) whereas the lowest (2088) was found in WLS. For the β_1 values, the highest values were found in Gompertz (4.83) and the lowest values were found in WLS function (-3.68). On the other hand, the highest value of β_2 was found in Logistic (33.49) and the lowest in Gompertz (0.06).

Table 5. *Parameters of Growth curve models, correlations among parameters and coordinates of inflection points.*

Model	β_0	β_1	β_2	$r\ \beta_0\ \beta_1$	$r\ \beta_0\ \beta_2$	$r\ \beta_1\beta_2$
WLS	2088	-3.68	0.14	0.12	-0.71	-0.71
Gompertz	2814	4.83	0.06	-0.72	-0.95	0.88
Logistic	2186	0.13	33.49	-0.82	-0.54	0.90

The correlations between the growth curve parameters were found negative for β_0-β_2 for all functions whereas the correlation was positive between β_0-β_1 and β_1-β_2 for Gompertz and Logistic. The results are in contrast for WLS function.

The results of goodness of fit for WLS, Gompertz and Logistic functions are presented in Table 6.

Table 6. *Goodness of fit criteria results for models.*

Model	Adjusted R^2	R^2	MSE
WLS	0.995	0.999	3.19
Gompertz	0.989	0.997	1137.5
Logistic	0.981	0.994	497.6

In all models, the value of the coefficient of determination was high for all three functions. Similar results obtained by Kuhi et al., (2003) who found that growth functions, the Lopez, the Richards, the France, the von Bertalanffy, the Gompertz and the logistic gave a suitable fit to the profiles. The comparison based on R^2 values, $R^2 > 0.98$ showed that it is difficult to identify the model which is significantly better than the others to fit growth curve based on this criterion. Tompić et al., (2011) found that the R^2 values of the Gompertz, Richards and Logistic function were ranged from 0.988 to 0.995 in Ross 308 broiler.

In the present study results showed that the adjusted R^2 values were parallel to R^2. These results agree with results reported by Moharrery and Mirzaei, (2014) who found that the adjusted R^2 values of Gompertz, Logistic, Lopez, Richards, and Weibull functions ranged from 0.979 to 0.995.

The value of MSE of WLS function was the lowest 3.19, as compared with the values of MSE for the Gompertz (1137.5) and Logistic (497.6). This result confirmed that WLS function was fit the growth curve better than other functions.

The results of the present study disagreed with the previous results reported by several researchers (Gous et al., 1999; Santos et al., 2005) who confirmed that the Gompertz function is the best function for describing growth curve in broiler. On the other hand, some studies found that the Richards function gave the best fit for growth curve in broiler (Kuhi et al., 2003; Tompić et al., 2011; Moharrery and Mirzaei, 2014).

These differences among studies could be attributed to differences in the environment in which the broiler were reared. According to Yalcin et al., (1997) the continuous selection for increased growth rate may increase broiler sensitivity to hot climate. High environmental temperature decreases body protein growth for broilers and decreases the time required to reach the point of inflection for broiler

(Hruby *et al*., 1996). Thus, broilers reared at higher temperatures reach the end of the asymptote sooner and at a lower growth rate. These differences could lead to disagreement about the better function that describes the growth curve in the different environments.

Although, Logistic, Gompertz and Bertalanffy are the three main models, but different researches implied different models (Aggrey, 2002).

Due to the difference of breeds, environment conditions and other errors, obtaining a good comparison among different research results was difficult (Wang et al., 2004; Sun et al., 2006).

It is concluded that the description of the growth patterns using mathematical models allows an exact comparative analysis. Mathematical models of growth are useful to provide means for visualizing growth patterns over time. The equation can be used to predict the expected weight of a group of animals at a specific age. The results of the present study confirmed that WLS function was more appropriate to describe the growth curve in the broiler (Ross 308) in a tropical climate as compared with other functions.

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