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Analyzing Growth Curves of Turkeys Reared in Different Breeding Systems (Intensive and Free-Range) with some Nonlinear Models

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Breeding system, growth models, large white turkey, live weight.

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ABSTRACT

The objective of this study was to identify the growth curve of live weight of turkeys reared in different systems (intensive and free- range) with the best mathematical model. To achieve this goal, the live weight of male and female turkeys (Large White) reared for 0-18 weeks were used. Logistic, Gompertz, Von Bertalanffy, and Gauss were used to determine the best model for the turkeys. In comparison of the models, values of Coefficient of Determination (R^2), Mean Squares of Error (MSE) and Model Efficiency (ME) were used. In Von Bertalanffy model, the coefficient of determinations for males and females were found as 0.9974 and 0.99915 in intensive system and 0.9794 and 0.9804 in Free-Range system, respectively.

As a result of this study, because the highest R^2 and the lowest MSE were observed in Von Bertalanffy model, it was the best among the models to identify growth curve of the turkeys.

INTRODUCTION

Growth is the change in weight and body sizes of the living organism, and it is an economically important feature in livestock breeding (Alpan and Arpacık, 1998; Akçapınar and Özbeyaz, 1999). Exposure of the economic importance of the features about live weight and growth rate has aroused of scientist´s and grower´s interest, and it has increased their interest in analyzing the weight-age relationship (Ngeno *et al.* 2010; Rizzi *et al.* 2013; Eleroglu *et al.* 2014).

The growth of the animals is showed up as a result of complex metabolic activities thus, researchers have tried to explain numerically the growth characteristics by improving various mathematical models to express this complex biologic situation better. Obtaining the expected performance of the animals at mature ages is related to these animal´s growth and development. The changes related to the age in the growth of an animal is called the growth curve (Akbaş and colleagues, 1999; Malhado et. al., 2008; Agudelo-Gomez, 2009; Bayram and Akbulut, 2009; Prestes, 2012). Briefly, the changes shown in living growth and body sizes, based on the age, can be defined as growth curve (Goonewardene et. al. 198: Kocabaş *et al.*, 1997). In the process of time that growth ends and the animal reaches the weight of mature living, biologic parameters which have an important place in explaining growth physically can be guessed (Behr et. al., 2001). Şengül and Kiraz (2005) have examined the growth curves of Large White turkeys, and have determined that Gompertz´s, Logistic´s, Richards´s, and Morgan-Mercer-Flodin´s models, gave nearly the same coefficient of determinations (99%).

In livestock-breeding, growth curves are used in subjects to identify the best slaughtering age, to get information about the general state

of health of the living, to identify the age that it can be used in breeding, to identify the age of sexual maturity (Doğan, 2003), to investigate the effects of selection on growth curve parameters, etc. (Bilgin *et al.* 2004; Tariq *et al.* 2011; Tariq *et al.* 2013).

The growth orbit measured as body mass and body weight is defined with proper mathematical methods relevant to growth curves, especially of poultry (Aggrey, 2002; Reddish and Lilburn, 2004; Norris *et al.*, 2007).

Growth is an important economic feature in broiler industry, and it can be defined as the increase of body size per unit, in time (Schulze *et al.*, 2001). The estimation of growth curve parameters can be of importance to the economy of production. Biological implications of the model parameters, and their relationship with other production features, provide a sound basis for developing a breeding strategy to modify the growth curve (Lambe *et al.* 2006; Abegaz *et al.* 2010; Ayied *et al.* 2011; Saghi *et al.* 2012). The growth, influenced by genetic and environmental factors, is explained by some non-linear models (Brody, Von Bertalanffy, Gompertz, Logistic, and Richard's) (Kum *et al.* 2010). Briefly, studies on nonlinear growth models provide useful information for breeding intentions (Topal *et al.* 2004; Keskin and Daşkıran 2007; Kucuk *et al.* 2008). Bayram *et al.* (2004) has examined the growth features of Brown Swiss and Friesian cows with only Richard´s model. Eyduran *et al.* (2008) reported that Gompertz´s model was more effective than Logistic´s, monomolecular´s and Richard´s at early phases of Kivircik and Morkaraman Breeds. Aksoy *et al.* (2011) denoted that the log-linear model was more appropriate than the linear model in Holstein and Brown Swiss Calves. Şahin *et al.* (2014) reported that the growth performance, sexual maturity age, breeding age and appropriate slaughtering age in male and female Anatolian buffalo calves, could be estimated by using Richard´s model.

The objective of this study was to examine the live weight of Large White turkeys in both genders, reared in intensive and Free-Ranged systems by some nonlinear models and, to determine the best model.

MATERIAL AND METHOD

This research was carried out in poultry facilities of Agriculture Faculty in Bingol University-Turkey. Totally 60 Large White turkey poults were divided into 2 groups (intensive and Free-with 3 replicates (10 in each).

All the groups were kept inside from 0 to 8 weeks and fed with the feed including 26-28% crude protein and 2800-2900 kcal/kg ME (NRC, 1994). The birds were fed and watered *adlib*. The groups reared in Intensive system were kept on the ground with litters until the end of 18 weeks fattening period. The lightening program was 23L:1D through the fattening period. Nutritional values and the values of protein and energy of feeds used in the study is shown in Table 1.

Table 1 – Values of protein and energy of feeds used in the study

Feed Type	Week	Protein (%)	ME (kcal/kg)
Starter Feed	0-8	26-28	2800-2900
Grower Feed	9-14	20-23	2900-3000
Finisher Feed	15 - 18	16-19	3000-3200

Free-Range groups had free access to the field in the beginning of the third week, and were held until the end of the fifteenth week of age. A shelter was provided for the birds to keep away from the sunshine during the daytime. Free-Range groups did not receive the concentrated feed during the grazing. The compositions of the grass grazed by the birds were of plants like clover, grass, trefoil, vetch, wheat and barley. After the fifteenth day of fattening, the turkeys were fed the same ration as the indoor groups until the eighteenth weeks of age. The study was carried out between June and October 2014. The birds were wing banded at the beginning of the trail and weighted weekly.

Feeding with intensive and free-range system affected fattening performance of turkeys. Grow growth is also affected by gender. For this reason, the birds were separated by gender and feeding systems and turkeys used in this study were not evaluated all together. This has already been said in the previous sentence.

Von Bertalanffy, Logistic, Gompertz and Gauss models were applied in the weekly analyses of live weights of turkeys in the study.

Von Bertalanffy´s growth model is as shown below;

$$Y_t = A*(1-b*e^{-kt})^3$$

and it has been presented by Von Bertalanffy (1934) with three-parameters, and improved by Beverton & Holt (1957).

Logistic´s growth model is expressed as (Graybill & Iyer, 1994);

$$Y_t = A/(1+e^{-(b+kt)})$$

Gompertz´s growth model is expressed as (Winsor, 1932);

$$Y_t = A*e^{-be^{-kt}}$$

Gauss´ growth model is expressed as (Norusis, 2005);

$$Y_t = A*(1-ke^{-bt^2})$$

Here, Y_t is: the weight observed in the age; A is: the asymptotic limit of weight while the age goes to infinity; that is, the highest weight that an animal can reach. This parameter which shows the mature live weight is guessed as the same in all growth curve models; b: the rate of the first weight achieved after birth to mature weight; k is: the speed of getting mature; that is, the speed of the approach of live weight to mature age. The value of e=2.71828 is the base of logarithm. Measures such as coefficient of determination (R^2). Adjust R^2, error mean squares (MSE) and model efficiency, are used in comparing the effectiveness of models impending the observed value Y_t and expected value $Y_t = E(\hat{Y}_t | X_t)$.

Coefficient of determination (R^2) is;

$$R^2 = \frac{RKT}{GKT} = \frac{\sum_{t=1}^{n}(\hat{Y}_t - \overline{Y})^2}{\sum_{t=1}^{n}(Y_t - \overline{Y})^2}$$

It is the total of RKT: Regression mean squares and GKT: General mean squares. The values of Coefficient of determination is between 0-1. As the value approaches to 1, the consistency of the model increases.

Coefficient of determination (Adjust-R^2) is;

$$\overline{R}^2 = 1-\left(1-R^2\right)\frac{n-1}{n-k}$$

as defined (Gujarati, 2003). Here, n is: number of observation, k: number of parameter.

Error mean squares (MSE) is showed as;

$$MSE = \frac{SSE}{n}$$

SSE: Error sum of squares; n: Observation (Seber & Wild, 1989).

Model efficiency (ME) is expressed as:

$$ME = 1 - \frac{\sum_{t=1}^{n}(\hat{Y}_t - Y_t)^2}{\sum_{t=1}^{n}(Y_t - \overline{Y})^2}$$

$\hat{Y}_t$: Expected value, Y_t: observed value. The efficiency value of the model should be up to 90% for being efficient (Mohanty & Painuli, 2004).

Durbin-Watson statistics (Ünver *et al.* 2011); e_i: Residuals;

$$DW = \frac{\sum_{i=2}^{n}\left(e_i - e_{i-1}\right)^2}{\sum_{i=1}^{n} e_i^2}$$

Akaike Information Criterion (AIC),

$$AIC = n\ln(\hat{\sigma}^2) + 2M$$

Schwartz Bayesian Criterion (SBC);

$$SBC = n\ln(\hat{\sigma}^2) + M\ln(n)$$

as defined (Wei, 2006). Here, $\hat{\sigma}^2$ is the maximum likelihood of σ, M is the number of parameters in the model, and n is the effective number of observations.

A, B and k parameters, were determined as a result of Levenberg Marquardt iteration technique by using SPSS 22.0 statistical program. While iteration was done, 1.0E-8 was used as convergence criteria (Akbaş *et al.* 2001).

In comparing the models, the measures of coefficient of determination (R^2), Error mean squares (MSE) which shows the difference between the points belongs to true growth and growth curve determined to the model, and model efficiency were used.

RESULTS AND DISCUSSION

Live weight averages of male and female turkeys in the weeks of 0-18 is shown in Table 2.

Table 2 – Live weights (g) of male and female turkey´s growth in Intensive and free-range systems according to the weeks

	Intensive System		Free-Range System	
Age (Weeks)	Body Weight (g)-Male	Body Weight (g)-Female	Body Weigh (g)-Male	Body (g)- Female
0	63.10	61.87	64.75	65.14
2	234.71	224.75	262.18	249.82
4	687.14	642.40	754.64	689.06
6	1685.00	1509.25	1768.27	1517.06
8	3188.14	2854.05	3460.73	2928.24
10	5249.00	4597.30	3448.73	2933.82
12	6920.57	5945.60	4405.73	3757.94
14	8186.43	7369.30	5308.55	4491.71
16	10833.57	9080.00	7650.55	6401.24
18	12285.71	10164.20	8438.18	6985.29

Hatching weight for male and female birds were 63.10 and 61.87g in commercial groups, 64.75 and 65.14 g in Free-Range groups, respectively. While the live weights of the turkeys for male and female were 12285.71 and 10164.20 g in commercial groups, and 8438.18 g and 6985.29 g in Free-Range groups at the end of the trail, respectively.

Live weight values of turkeys were comparatively observed by Von Bertalanffy, Logistic, Gompertz and Gauss models, and the results are shown in Table 3.

As it is seen in Table 3, the turkeys raised in intensive system had the values of Error mean squares (MSE) = 67085.950, Coefficient of correlation (r) = 0.9994, and growth speed =0.166 g according to Von Bertalannffy´s model. Determination coefficients (R^2) =0.9974, Adjusted-R^2=0.9967, Model efficiency (ME) =0.9974, DW=2.335, AIC=136.596 and SBC=143.656. According to the results obtained with the Logistic´s model were MSE=178332.669, r=0.997 and growth speed 0.610 g. R^2=0.996, Adj-R^2=0.994, ME=0.990, DW=1.491, AIC=146.373 and SBC=154.410. The results obtained with Gompertz´s model were MSE=79876.142, r=0.998 and growth speed 0.279 g. R^2=0.9969, Adj-R^2=0.9960, and ME=0.9969, DW=2.416, AIC=138.341 and SBC=145.576. The results obtained with Gauss´s model were MSE=74646.109, r=0.999 and growth speed 0.011 g, R^2=0.9971, Adj-R^2=0.9962, and ME=0.9971, DW=2.587, AIC=137.664 and SBC=144.831.

In female turkeys grown in intensive system; in Von Bertalannffy´s model, the results were calculated as MSE=15477.841, r=0.99960, the growth speed=0.200 g. R^2=0.99915, Adjusted-R^2=0.99891, model efficiency (ME) =0.99940, DW=2.441, AIC=121.931 and SBC=127.524. In Logistic´s model, the results were calculated as MSE=71695.646, r=0.9983, and the growth speed= 0.648 g. R^2 =0.9961, Adj- R^2=0.9949, and ME=0.9972, DW=1.141, AIC=137.261 and SBC=144.387. In Gompertz´s model, the results were calculated as MSE=16176.236, r=0.99956, and the growth speed= 0.313 g. R^2=0.99911, Adj- R^2=0.99886, and ME=0.99937, DW=2.280, AIC=122.372 and SBC=128.009. In Gauss´s model, the results were calculated as MSE=24691.170, r=0.99932, and the growth speed=0.014 g. R^2=0.9986, Adj- R^2=0.9983, and ME=0.99904, DW=1.864, AIC=126.601 and SBC=132.661.

According to the Gompertz´s model, growth speeds in different studies were 0.2137 in male partridges and 0.2255 in female partridges (Çetin et. al., 2007); 0.010 in sheep (Tariq *et al.*, 2013), 0.218 in male calves and 0.309 in female calves (Şahin *et al.* (2014), 0.010 in female Anatolian buffalo and 0.007 in male Anatolian buffalo (Sosyal *et al.* 2015). According to the Von Bertalanffy´s model, the growth speeds were 0.0044 in sheep (Tariq *et al.*, 2013) and 0.005 in male buffalo and 0.012 in female buffalo (Soysal *et al.* 2015).

In Von Bertalannffy´s model, male turkeys reared in Free-Range system the results were found as follow; MSE= 231089.161, r=0.9897 and growth speed= 0.093, R^2=0.9794, adjusted-R^2=0.9735, model efficiency (ME) =0.9794, DW=2.089, AIC=148.965 and SBC=157.261. In the results obtained in Logistic´s model, MSE=313900.941, r=0.9897, growth speed = 0.456 g, R^2=0.972, Adj- R^2=0.964, ME=0.972, DW=1.616, AIC=152.027 and SBC=160.630. According to Gompertz´s model, the results were; MSE =254176.033, r=0.9888, and the growth speed= 0.185g, R^2=0.9773, Adj- R^2=0.9709, ME= 0.9773, DW=1.932, AIC=149.917 and SBC=158.309. In Gauss´s model, the results were; MSE=267465.980, r=0.988, and the growth speed is found as 0.010 g. R^2=0.9761, Adj-R^2=0.9693, ME= 0.9761, DW=1.846, AIC=150.427 and SBC=158.869.

In Von Bertalannffy´s model for female turkeys reared in Free-Range system, the results were; MSE is 151000.416, r= 0.9902, and the growth speed=0.102g, R^2 =0.9804, Adjusted-R^2 = 0.9748, model efficiency (ME)=0.9802, DW=2.167, AIC=144.709 and SBC=152.580. In Logistic´s model; MSE=208664.111, r= 0.9868, and growth speed=0.461, R^2 =0.9729, Adj-R^2 =0.9651, ME= 0.9727, DW=1.655, AIC=147.944 and SBC=156.138. In Gompertz´s model; MSE=166554.915, r= 0.9893, and growth speed= 0.194 g, R^2 = 0.9784, Adj-R^2 = 0.9722, ME= 0.9782, DW=1.998, AIC=145.690 and SBC=153.659. In Gauss´s model; MSE= 177604.528, r= 0.9884, growth speed= 0.012 g, R^2 = 0.977, Adj-R^2 = 0.9704, ME=0.9768, DW=1.888, AIC=146.332 and SBC=154.365. In all models, the most appropriate model, in which MSE value is the least, was selected.

Mathematical growth models of male and female turkeys reared in intensive and Free-Range systems is shown in Table 4.

Table 3 – Parameters of growth models for male and female Large White Turkeys

Intensive system-Male

Parameters	Von Bertalanffy	Logistic	Gompertz	Gauss
A	25673.654	14233.320	19131.256	21597.618
b	0.968	-3.756	5.490	0.011
k	0.166	0.610	0.279	1.003
r	0.9994	0.997	0.998	0.999
R^2	0.9974	0.9931	0.9969	0.9971
Adj R^2	0.9967	0.9911	0.9960	0.9962
MSE	67085.950	178332.669	79876.142	74646.109
ME	0.9974	0.9931	0.9969	0.9971
DW	2.355	1.491	2.416	2.587
AIC	136.596	146.373	138.341	137.664
SBC	143.656	154.410	145.576	144.831

Intensive system-Female

Parameters	Von Bertalanffy	Logistic	Gompertz	Gauss
A	17583.723	11246.675	14213.138	15308.655
b	1.003	-3.752	5.629	0.014
k	0.200	0.648	0.313	1.005
r	0.99960	0.9983	0.99956	0.99932
R^2	0.99915	0.9961	0.99911	0.9986
Adj R^2	0.99891	0.9949	0.99886	0.9983
MSE	15477.841	71695.646	16176.236	24691.170
ME	0.99940	0.9972	0.99937	0.99904
DW	2.441	1.141	2.28	1.864
AIC	121.931	137.261	122.372	126.601
SBC	127.524	144.387	128.009	132.661

Free-Range system- Male

Parameters	Von Bertalanffy	Logistic	Gompertz	Gauss
A	21771.690	11769.879	18625.261	14594.647
b	0.823	-3.171	4.194	0.010
k	0.093	0.456	0.185	0.979
r	0.9897	0.9864	0.9888	0.988
R^2	0.9794	0.972	0.9773	0.9761
Adj R^2	0.9735	0.964	0.9709	0.9693
MSE	231089.161	313900.941	254176.033	267465.980
ME	0.9794	0.972	0.9773	0.9761
DW	2.089	1.616	1.932	1.846
AIC	148.965	152.027	149.917	150.427
SBC	157.261	160.630	158.309	158.869

Free-Range system- Female

Parameters	Von Bertalanffy	Logistic	Gompertz	Gauss
A	16614.034	9435.685	14263.744	11175.027
b	0.812	-3.104	4.089	0.012
k	0.102	0.461	0.194	0.976
r	0.9902	0.9868	0.9893	0.9884
R^2	0.9804	0.9729	0.9784	0.9770
Adj R^2	0.9748	0.9651	0.9722	0.9704
MSE	151000.416	208664.111	166554.915	177604.528
ME	0.9802	0.9727	0.9782	0.9768
DW	2.167	1.655	1.998	1.888
AIC	144.709	147.944	145.690	146.332
SBC	152.580	156.138	153.659	154.365

A, b, k: Model parameters, (A: Asymptotic weight; b: Integration constant, k: Maturing index, r: Correlation coefficients, R^2: Determination coefficients, Adj R^2: Adjusted determination coefficients, MSE: Mean of Squares Error, ME: Model efficiency, DW: Durbin-Watson, AIC: Akaike Information Criterion, SBC: Schwartz Bayesian Criterion (SBC).

Table 4 – Functions belonging to growth curves of turkeys

Intensive system		
Models	Functions	
	Male	Female
Von Bertalanffy	$Y = 25673.654(1 - 0.968e^{-0.166t})^3$	$Y = 17583.723(1 - 1.003e^{-0.200t})^3$
Logistic	$Y = 14233.320/(1 + e^{-3.756+0.610t})$	$Y = 11246.675/(1 + e^{-3.752+0.648t})$
Gompertz	$Y = 19131.256(e^{-5.490e^{-0.279t}})$	$Y = 14213.138(e^{-5.629e^{-0.313t}})$
Gauss	$Y = 21597.618(1 - 1.003e^{-0.011t^2})$	$Y = 15308.655(1 - 1.005e^{-0.014t^2})$
Free-Range system		
Model	Function	
	Male	Female
Von Bertalanffy	$Y = 21771.690(1 - 823e^{-0.093t})^3$	$Y = 16614.034(1 - 812e^{-0.102t})^3$
Logistic	$Y = 11769.879/(1 + e^{-3.171+0.456t})$	$Y = 9435.685/(1 + e^{-3.104+0.461t})$
Gompertz	$Y = 18625.261(e^{-4.194e^{-0.185t}})$	$Y = 14263.744(e^{-4.089e^{-0.194t}})$
Gauss	$Y = 14594.647(1 - 0.979e^{-0.010t^2})$	$Y = 11175.027(1 - 0.976e^{-0.012t^2})$

When we compare growth models of male turkeys reared in Intensive system, the values for Von Bertalanffy´s, Logistic´s, Gompertz´s, and Gauss´s models were; MSE=67085.950, 178332.669, 79876.142, and 74646.109; coefficient of determinations (R^2)=0.9974, 0.9931, 0.9969, and 0.9971; adjusted coefficient of determinations (Adjust-R^2)= 0.9967, 0.9911, 0.9960, and 0.9962, respectively. Again for the same models and in the same order; ME were 0.9967, 0.9911, 0.9960, and 0.9962. DW were 2.355, 1.491, 2.416, and 2.587; AIC were 136.596, 146.373, 138.341, and 137.664; SBC were 143.656, 154.410, 145.576, and 144.831, respectively. Von Bertalanffy´s model had the lowest MSE AIC and SBC values, and highest R^2, Adj-R^2, and ME values; and Logistic´s model was the one which had the highest MSE, AIC and SBC values and the lowest R^2, Adj-R^2, and ME values. Thus, the most relevant model for estimation of growth curve was Von Bertalanffy´s growth model. In other words, it was determined that Von Bertalanffy´s growth model identifies the growth curve of male turkeys in intensive breeding system best, and Logistic´s model identifies the growth curve the least.

Comparing growth models for female turkeys reared in intensive system, the values for Von Bertalanffy´s, Logistic´s, Gompertz´s, and Gauss´ models were; MSE=15477.841, 71695.646, 16176.236, and 24691.170; coefficient of determinations (R^2)= 0.99915, 0.9961, 0.99911, and 0.9986; adjusted coefficient of determinations (Adjust-R^2)= 0.99891, 0.9949, 0.99886, and 0.9983, respectively. Again for the same models in same order; ME= 0.9994, 0.9972, 0.9993, and 0.99904. DW were 2.441, 1.141, 2.280 and 1.864; AIC were 121.931, 137.261, 122.372 and 126.601; SBC were 127.524, 144.387, 128.009 and 132.661, respectively. Von Bertalanffy´s model had the lowest MSE, AIC and SBC values and highest R^2, Adj-R^2, and ME values; and Logistic´s model was the one which had the highest MSE, AIC and SBC values and the lowest R^2, Adj-R^2, and ME values. Thus, the most relevant model for estimation of growth curve of female turkeys was seen in Von Bertalanffy´s growth model. In other words, the best model was Von Bertalanffy´s model and the worst one was Logistic´s model for female turkeys in intensive breeding system. The results obtained in coefficient of determinations in accordance with the results of approximate (0.99) coefficient of determinations were Gompertz´s, Logistic´s, Richard´s and Morgan-Mercer-Flodin´s models in growth curves of Large White turkeys.

When we compare growth models for male turkeys reared in Free-Range system, the calculated values for Von Bertalanffy´s, Logistic´s, Gompertz´s, and Gauss´ models were; MSE=231089.161, 313900.941, 254176.033, and 267465.980; coefficient of determinations (R^2)= 0.9794, 0.972, 0.9773, and 0.9761; adjusted coefficient of determinations

(Adjust-R^2)= 0.9735, 0.964, 0.9709, and 0.9693, respectively. Again for the same models in same order, ME were 0.9794, 0.972, 0.9773, and 0.9761. DW were 2.089, 1.616, 1.932 and 1.846; AIC were 148.965, 152.027, 149.917 and 150.427; SBC were 157.261, 160.630, 158.309 and 158.869, respectively. Von Bertalanffy´s model had the lowest MSE, AIC and SBC values and highest R^2, Adj-R^2, and ME values; however, Logistic´s model had the highest MSE, AIC and SBC values and the lowest R^2, Adj-R^2, and ME values. In other words, Von Bertalanffy´s growth model best identifies growth curve values and Logistic´s model identifies the growth curves the least for male turkeys reared in Free-Range system.

When we compare growth models for female turkeys, the calculated values for Von Bertalanffy, Logistic, Gompertz, and Gauss models were: MSE=151000.416, 208664.111, 166554.915, and 177604.528; coefficient of determinations (R^2) = 0.9804, 0.9729, 0.9784, and 0.9770; adjusted coefficient of determinations (Adjust-R^2) = 0.9748, 0.9651, 0.9722, and 0.9704, respectively. For the same models in the same order, ME= 0.9802, 0.9727, 0.9782, and 0.9768. DW were 2.167, 1.655, 1.998 and 1.888; AIC were 144.709, 147.944, 145.690 and 146.332; SBC were 152.580, 156.138, 153.659 and 154.365, respectively. Von Bertalanffy model had the lowest MSE, AIC and SBC values and highest R^2, Adj-R^2, and ME values; but Logistic model had the highest MSE, AIC and SBC values and the lowest R^2, Adj-R^2, and ME values. Thus, the most relevant model for estimation of growth curve of live weight of female turkeys was Von Bertalanffy growth model, and the least relevant was Logistic model. Similar results for Von Bertalanffy model were also reported by Akbaş *et al.* (2001) in Holstein Friesians cows, and by Soysal *et al.* (2015) in male buffalo. However, the best fitted model in Anatoilan buffalo was Richards model (Şahin *et al.* 2014).

The results obtained in coefficient of determinations were 0.99 with Gompertz, Logistic, Richards, Morgan-Mercer-Flodin models in growth curves of Large White turkeys. In both of the systems, Von Bertlanffy model had the highest mature weight, and, Logistic model had the least in both gender.

In this study, estimation curves identified with 4 different growth models were in Figure 1 and 2 for male and female turkeys reared in Intensive system, and in Figure 3 and 4 for male and female turkeys reared in Free-Range system, respectively. Even if the values observed in the models were so close to each other, Von Bertalanffy model was more relevant than the others.

Many measures such as the consistence of growth models, R^2, MSE, their biologic relevancies, and consistency of estimations can generally be used in comparison of growth curve models characterizing the growth in livestock production (Torres and Ortiz, 2005; Malhado et. al., 2008, Torres et. al., 2012).

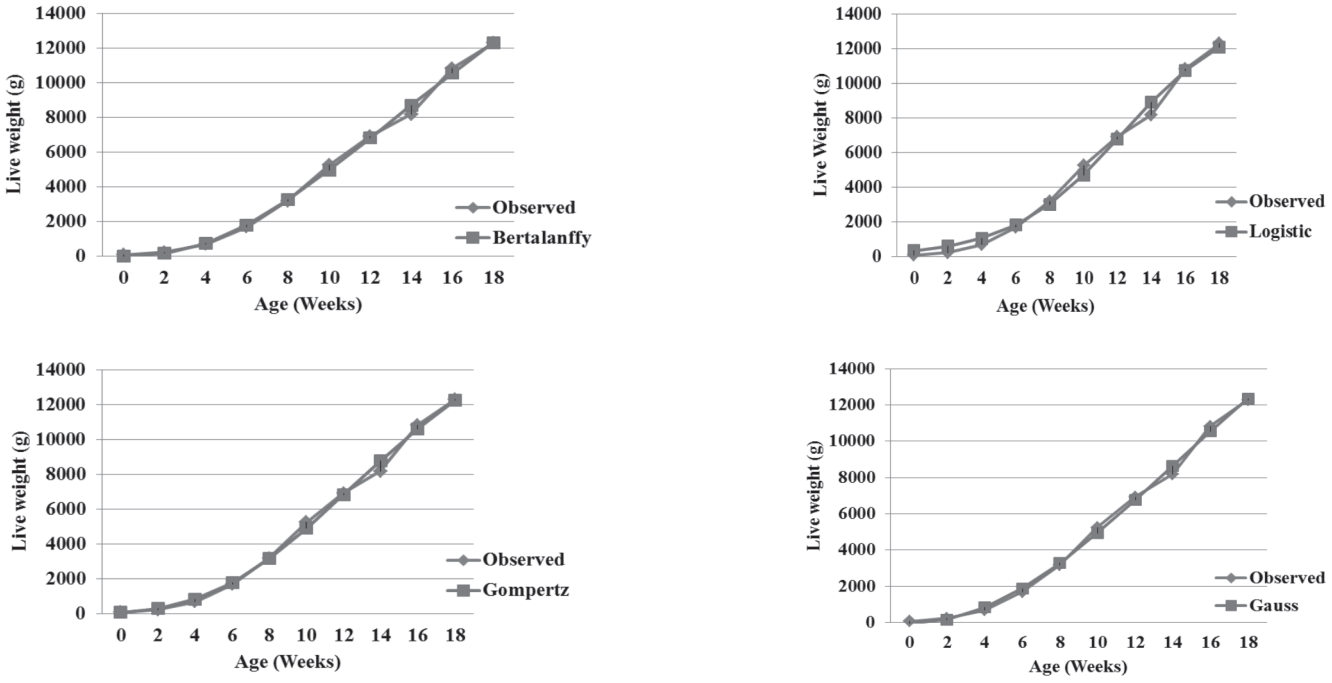

Figure 1 – Growth curves of male Large White turkeys in Intensive system

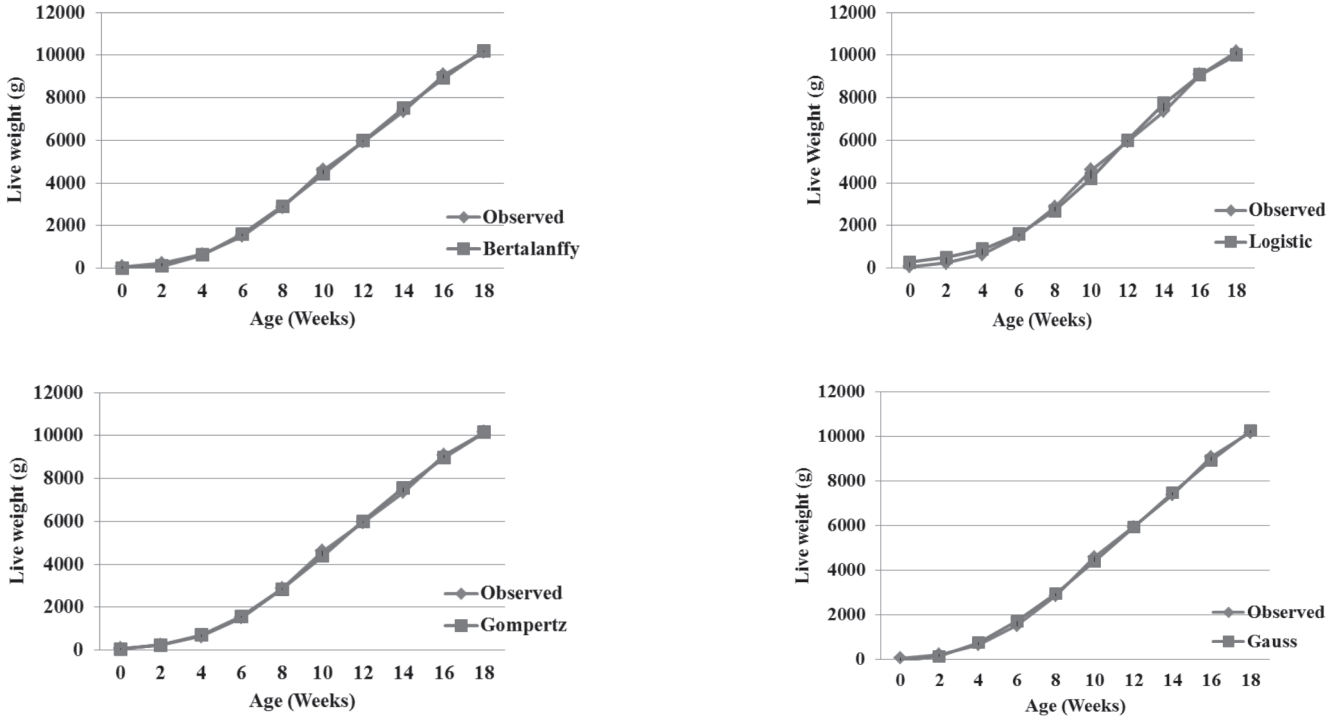

Figure 2 – Growth curves of female Large White turkeys in Intensive system

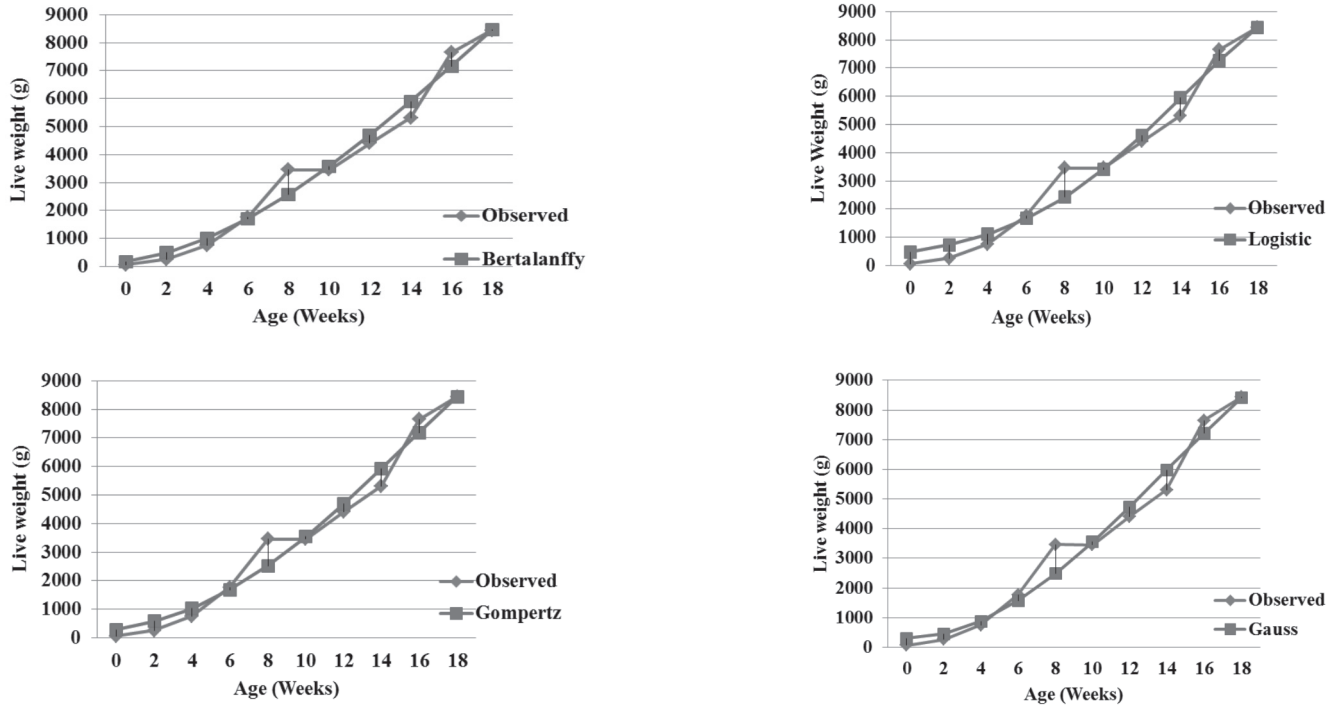

Figure 3 – Growth curves of male Large White turkeys in Free-Range system

In the comparison of growth curve models in which R^2 and MSE values were scored together, the model which had the highest R^2 value and the least MSE values, explain the live weight changes according to the age. (Quirino et. al. 1999; Bayram % Akbulut; 2009; Yıldız *et al.* 2009; Kucuk & Eyduran 2009; Mohammed, 2015).

Çetin *et al.* (2007), calculated DW values for Gompertz, Richards and Logistic as 1.9543, 1.6179, 0.4017 in male partridges; 1.1763, 1.2025 and 0.5426 in female partridges, respectively. Faridi *et al.* (2011), AIC were 5980.53, 5632.6, 5525.255, 5912.12 and 5713.70; SBC were 6002.34, 5658.82, 5555.45, 5920.85 and 5726.80 by using NT1, NT2, NT3, Gompertz

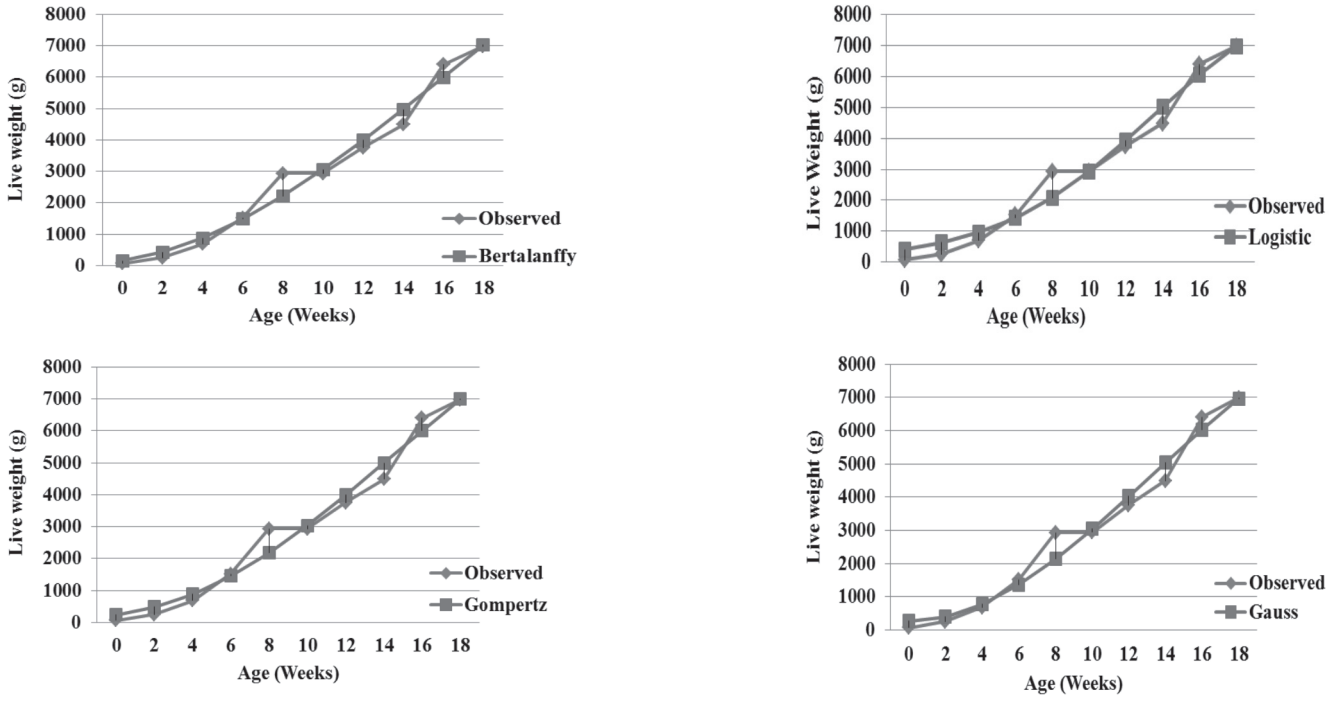

Figure 4 – Growth curves of female Large White turkeys in Free-Range system

and Richards models for growth in broiler breeder flocks, respectively. Narinc *et al.* (2013) calculated AIC as -301.43, -299.56, -282.51 and -307.47; SBC as -295.57, -291.75, -274.71 and -297.71 for Gamma, McNally, Modified compartmental and Adams-Bell models in egg production in Japanese quail, respectively. Besides AIC were found as -176.75, -195.92, -356.32 and -386.56; SBC were as-171.02, -188.27, -346.76 and -378.95, respectively by using Gamma, McNally, Modified compartmental and Adams-Bell models in egg production (Narinc *et al.* (2014) .

CONCLUSION

In this research, growth models of male and female turkeys reared in Intensive and Free-Range systems from their hatching to the 18th week of age were compared. The 4 models have been applied for live weight data of turkeys. The values of R^2 and Adj-R^2 of all the models have been found very high. The efficiency value of the model was up to 0.90 in all models and that means that models were efficient.

In conclusion, Von Bertalanffy model explained the weight-age change of male and female turkeys reared in different systems best.

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