Analysis Egg Production and Egg Weight Curves by Two Mathematical Models in Japanese Quail *(Coturnix.C. Japonica)*

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Abstract

This study was conducted at the Japanese quail farm of Animal Resource Department/College of Agriculture/University of Basra. Data of egg production and egg weight were analyzed by using two mathematical models. A total of 148 birds were used; 136 females and 12 males. Family 2 showed highest b parameter values and highest c parameter value compared to other families respecting egg production curves. R^2 values of most families obtained by either Wood or Rational functions were high respecting egg production curve description. Family 4 showed highest b and R^2 values in comparison with other families respecting using Wood function in egg weight curve description. Family 4 showed highest R^2 value compared to other families.

Key words: Egg production, Egg weight, curves, Mathematical models, Japanese quail

Introduction

Application of new approaches on the genetic level will help in possibility of finding new QTL of important effect on the shape of egg production curve. A major step toward understanding egg production and egg weight curves, the mathematical models have been used to investigate the changes in those two traits over time. Generally, it is concentrated more in chicken in such studies but very less data is available regarding Japanese quail's egg production curve (Minvielle *et al.*,2000 b, 2006; Mignon-Grasteau and Minvielle, 2003; Narine *et al.*, 2013). In chickens, Faridi *et al*. (2011) fitted non regression Adams-Bell model for egg production curve and Lokhorst model for egg weight curve. McNally (1971) noted that egg production curve for a group of hens had the same general form as the lactation curve and he described the mean egg production curve, therefore, with a modified Wood (1967) model. Despite the highly repeatable nature of a clutch, egg production curve shows an increase in the number of eggs and then a decrease with increasing age (Bahr and Palmer,1989). On the other hand, Bell and Adams (1992) studied the shape (linear, quadratic, asymptotic, and cyclic) of egg production curve and compared between chickens strains respecting the analysis of variance of the early lay cycle slope with the slope over the last 10 weeks. All linear or nonlinear mathematical models that implemented into genetic evaluation of poultry types such as Wood compartment, algebratic, McMillan and logistic models have easy to use and give good results respecting description the curve of egg production depending mainly on time of peak and the decline in egg production as well as the persistency of lay (Schaeffer *et al.*,2000).The most important stages of egg production curve is the peak and the persistency. Selection of hens for egg production was efficient for modifying the curve of egg production, thus resulting in genetic gains at the fourth week of laying and improving peak egg production and persistence of egg production in this population (Savegnago *et al*.,2011). Furthermore, mathematical models can be used to evaluate genetic worth by predicting whole record performance based on part record egg production as this prediction plays an important role in the facilities of early selection (Fairfull and Grow, 1990; Al-Samarai *et al*.,2008). So, keeping in view the above, present an experiment was planned to compare two mathematical models (Wood and Rational functions) respecting their relative efficiency to describe egg production and egg weight curves of Japanese quail and to investigate extensive knowledge of egg production and egg weight during the period of egg production.

Material and Methods

This study was carried out at the Japanese Quail Farm, Animal Resource Department., College of Agriculture. University of Basra during the period from1/10/2014 to 30/1/2015. Random bred females and males of Japanese quail birds were used in this study. All were at 42 days old. Birds were randomly divided into eight families reared in cages (70 × 70 × 50 cm), to be depended upon to produce new chicks. After eggs of those families had hatched, chicks were placed in the chicks growing boxes at the first week of age. At two weeks of age, chicks were put in the growing cages (70 × 70 × 50 cm). Birds were provided with feed containing 24% CP and 2850 kcal/kg of ME for the first 4 weeks of age. At 4 weeks of age up to the end of the study period, birds were provided with feed containing 21% CP and 2900 kcal of ME ad libitum. At 4 weeks of age, females were separated and divided into four families (34 females for each family). The eggs of each family were recorded daily between 0900 and 1200 h starting from the onset of egg production period till the 15 weeks of age. Egg weights were recorded every day by using a sensitive balance 0.1 gm sensitivity. A 16-h lighting program was applied in the egg production period. Curves of egg production and egg weight of families were described by the mathematical models. For this purpose, nonlinear Gamma Function (Wood, 1967) and the Rational Function were used table 1. Computation of the efficiency of the two models based on the percent coefficients of determination (R^2). Statistical analysis regarding non-Linear models were done by using non-Linear Regression within SPSS program (SPSS, 2006).

Table 1: Expressions of the two linear functions used in the study

Function	Expression[1]
Gamma Wood	Yt = at exp(-ct)
Rational	Yt =a+bx\1+cx+dx

[1]Yt is egg production (egg weight) at t time (week);exp is the exponential function ;a: the initial production (egg weight);b:the rate of production (egg weight) increase to the peak;c: the rate of production (egg weight) decrease from the peak; d:proportional to the square root of time.

Results and Discussion

Egg production curves

Analysis patterns of average egg production curves are illustrated in figures 1 and 2 by using each of Wood and Rational functions. After fitting the values of a, b, c and d parameters, two functions displayed similarity in average description of egg production curve. Egg production increased from more than 15 eggs at 1 week to more than 25 eggs at 3 and 4 weeks of egg production period. However, the decrease in egg number started from 4 week and it continued to the end of egg production period. The comparison among different families regarding the shape of egg production curve by using Wood function, are illustrated in figure 3. Despite of different trajectories of egg production of family 2 and family 4 at the initial stage (1week of egg production period), both of them reached to peak of egg production at the same level of egg production (less than 30 eggs) at 4 week of egg production period. Both of families 1 and 3 displayed close patterns of egg production curves. 25 eggs (for family 1) and less than 25 eggs (family 3), were laid at 4 week of egg production period when the peak of production occurred (figure 3). The decrease in egg production for all families occurred after 4 week of egg production up to 15 weeks of egg production.

Description of egg production curve by using Rational function (figure 4) illustrated clearly superiority for family 4 and family 2 in the number of egg laid 30 eggs) at 4 week of egg production period when the peak of egg production occurred. Although of the same level of egg number laid by family 1and family 3 (less than 25 eggs) at 4 week of egg production, the decrease rate in egg number of both families happened after 5 weeks of egg production period in comparison with 4 week of egg production period of families 2 and 4. In our study, it was determined that the peak of egg production occurred almost at 4 week of production stage in most of Japanese quail families. This result disagrees with the finding of Narine *et al*. (2013) study that reported 9 week of egg production stage as the peak stage of egg production with the level of 94% of hen day peak production in Japanese quail by using Wood function. Whereas Minvielle *et. al.* (2000b) observed that peak production ranged from 88 to 98% in 8 genetic groups of quail at about 3 months of age. The values of estimated parameters (a, b, c and d) in our study by using the two mathematical models are different and as a result, those differences have affected the graph of fitted curves of egg production of different families as shown in figures (3, 4). Many previous studies were conducted in chickens(Grossman and Koop, 2001; Oni *et al*., 2007; Atta *et al*., 2010), pointed out that mathematical models differ in depicting the shape of egg production curve and the goodness of fitting depending on the value of R^2 of the model .In our study, because of more higher values of R^2 obtained by using Rational function compared to those obtained by using Wood function, there were dissimilarity in the shape of egg production of different families which indicate it is possible, in general, to describe the curve of egg production by both of the two models .Furthermore, the differences in the time at transition from slow to rapid increase in egg production ,the time at transition from rapid increase to constant level, the level of constant production (persistency stage) and the rate of decline in production (slopes) from constant production, all are of high variation among individuals which may be responsible of the different slopes in the rate of decrease egg production after the peak of production of families and shapes of egg production curves of different families. The stage of persistency is very important in order to discriminate among individual's genetic ability of egg production. In this respect, Grossman *et al*. (2000) revealed that measure of persistency among individuals as production of the same numbers of eggs during 52 wk in laying chickens is important for genetic selection because it might be desirable to select for increased persistency. Heritability estimates for different measures of persistency will vary according to the measure of persistency.

Table 2. Estimates of model's parameters and goodness of fit statistics of each model of egg number of different families.

Function	Family	Parameter	Estimate	R^2
Gamma Wood	1	a	21.292	85.6
		b	0.804	
		c	0.260	
	2	a	22.809	81.5
		b	1.144	
		c	0.340	
	3	a	23.343	88.9
		b	0.774	
		c	0.257	
	4	a	24.787	64.1
		b	0.821	
		c	0.245	
Rational	1	a	13.564	91.50
		b	0.457	
		c	-0.209	
		d	0.030	
	2	a	10.978	89.10
		b	2.021	
		c	0.276	
		d	0.047	
	3	a	18.370	98.10
		b	-1.290	
		c	-0.167	
		d	0.014	
	4	a	16.561	94.70
		b	-2.398	
		c	-0.327	
		d	0.033	

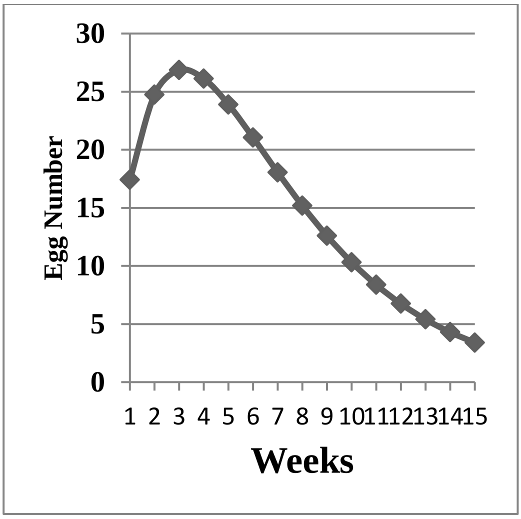

Figure 1. Egg number curve described by Wood function

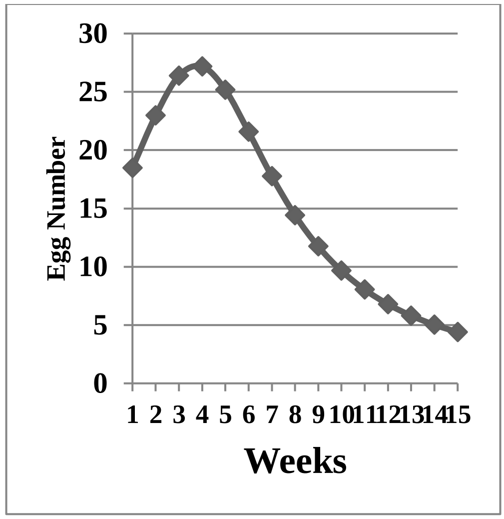

Figure 2. Egg number curve described by Rational function

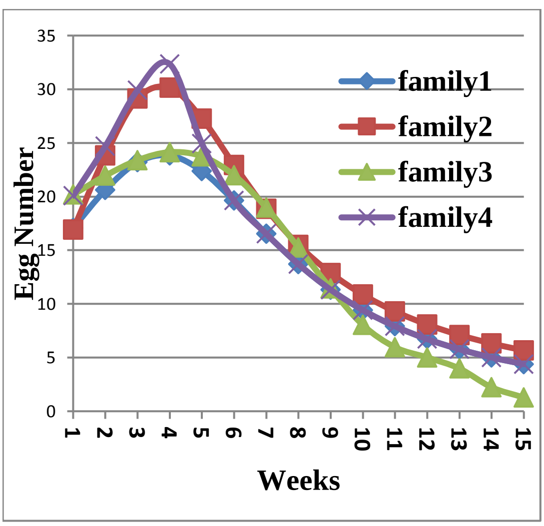

Figure 3. Egg number curves of different families described by Wood function.

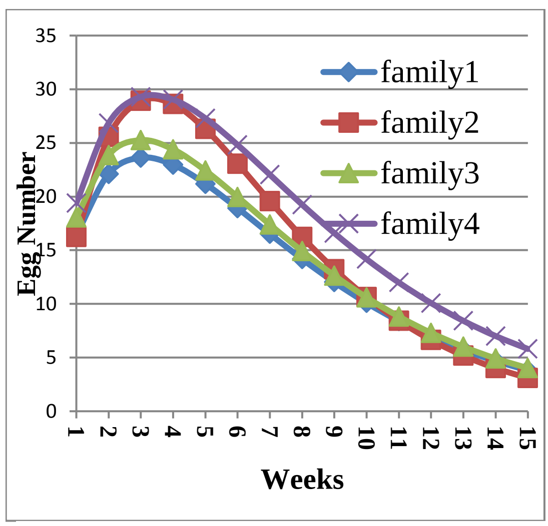

Figure 4. Egg number curves of different families described by Rational function.

Egg weight curves

Analysis patterns of average egg weight curves are illustrated in figure 5 and 6 by using Wood and Rational functions. The two Functions explain resemblance in the shape of egg weight curve. Initial egg weight increased from more than 9.8 gm at 1 week of egg production period by using Wood Function .Maximum egg weight was 11.6 gm at 5 and 6 weeks of egg production period whereas the decrease in egg weight occurred after 6 week of egg production up to 10 week of egg production when the decrease reached to less than 11.2 gm. Respecting Rational Function, egg weight increased from 9.8 gm at 1 week up to the maximum (11.4 gm) at 6 week of egg production period .The decrease in egg weight happened at 7 up to 15 weeks of egg production period when the egg weight was 11 gm.

Figure 7 shows obvious apparent increase in egg weight of all families with age advantage by using Wood function, excluding family 1. The maximum egg weight (12 gm), was recorded by family 3 at 6 week of egg production (the peak stage). However, the decrease level in egg weight was slowly up to 10 week of egg production period as it was less than 12 gm. Family 4 reached the peak of egg weight at 4 week of egg production period with more than 11.5 gm maximum egg weight, but the decrease in egg weight reached to 10 gm at 10 week of egg production period.

The curve of family 2 illustrated maximum egg weight (11 gm) at 5 week of egg production period while it decreased at more than 10 gm at 10 week of egg production period. The shape of egg weight curve of family 1 that described by Wood function was linear along the trajectory of egg weight from 1 to 10 weeks of egg production period.

Figure 8 illustrated description of egg weight curve by Rational Function. Highest egg weight value (12 gm) of 3 family at 5 week of egg production period (the peak stage), however, the decrease in egg weight started from less than 12 gm at 6 weeks to 11.5 gm at 15 week of egg production period.

Families 1,4 and 2 reached the stage of egg weight peak at 5 week of egg production with maximum values of egg weight (more than 11.5,11.5 and 11 gm, respectively).Our finding, herein reveals that families showed different trajectories respecting the initial increase in egg weight and in the age of maximum egg weight as well as the level of decrease in egg weight after reaching the stage of peak of egg weight. These differences may be attributed to the genetic variations and genetic abilities of those families in most previous studies conducted in Japanese quail (Oloyo, 2003; Brand *et. al.*, 2004; Rizzi and Chiericato, 2005; Johnston and Grous, 2007) the concentration was on the truth of increase in egg weight with age advantage without more explaining to the relation between egg weight and age during different phases of egg production period via mathematical functions in order to analyze genetic variations among individuals during those phases and possibility of genetic improvement for egg weight by searching for new underlying QTL of this trait .Furthermore, Minvielle *et al.* (2006) analyzed different phases of egg laying in quail using molecular markers and observed eight QTL of different effects on egg laying curve. Those QTL may also have effects on the shape of egg weight curve because of the genetic correlation between those traits. Morever, It is important to concentrate on another QTL which have effects on egg weight in order to study the relationship between QTL of egg production and QTL of egg weight.

Parameters of Egg Production and Egg Weight

The expression of the two linear functions used in this study are presented in table 1. Estimates of Wood function parameters of families are summarized in table 2. Values of a parameter (initial increase in egg number) were at the same level for all families. Family 2 showed highest b (the increase of egg number stage) value (1.144) compared to 0.821, 0.804 and 0.774 for families 1,4 and 3, respectively. The highest value of c parameter (0.340) was recorded by family 2 in comparison with other families.

The values of a, b, c and d parameters of different families by using Rational function are presented in table 2. Although, family 2 showed less value (10.978) of a parameter at the initial stage of increase, it obviously was of the highest b value (2.021) at the increase egg production stage in comparison with other families. The rate of decrease in egg number was higher (0.327) for family 4 comparatively with other families. The values of a parameter of different families in the present study were lower than those obtained by Narine *et. al.* (2013) whereas, the values of a parameter were close to those stated by Minvielle *et. al*. (2002) after fitting the data of egg production by using Wood function. The differences in the values of b and c parameters among families indicated obvious variation in the shape of egg production curve (figure 3). Atta *et. al*. (2010) attributed the similarity in the shape of egg production curve of two commercial egg layers hybrids to the similarity in the values of b and c constants of them.

A comparison between the two mathematical models regarding the goodness fit of the egg production data ,the values of R^2 of all families that described by either Wood or Rational functions were high and close (excluding the value of family 4) and ranged between 81.5 for family 2 to 88.9 for the family 3 by using Wood function. Whereas, R^2 values ranged between 89.10 for family 2 up to 98.10 for family 3 by using Rational function. This result is due to the fact that each of two models performed best for the data of egg production.

Table 3 illustrated the values of models parameters of families egg weight curves description. Despite of the fluctuating in the initial egg weight of different families but family 4 showed the highest b value (0.240) (increase in egg weight) in comparison with other families (0.222,0.187 and 0.092 for families 2,3 and 1, respectively). All families showed close values of egg weight decrease through the period of egg production. The value of R^2 was higher (32.6) for 4 family compared to other families.

Despite of the abnormal values of the rational function parameters of all families regarding egg weight curve, the highest value of R^2 was 32.60 for family 4 compared to 22.20,22.20 and 9.01 for families 2, 3 and 1 respectively. It is observed from present results there is variations in the values of the coefficient of determination R^2 of family's curves respecting the two functions, thus the shapes of the families curves of egg weight were different. In this respect, Minvielle *et. al.* (2006) found that the differences in the shape of egg production curves were related to the individual between-bird variations which it might be difficult to achieve more uniform goodness of fit for the within-bird curve parameters. Because of less published reports on the QTL analysis of egg production and egg weight curves, the precision on the phenotypes (the estimated parameters of the curve) used for the QTL analysis varied between birds, possibly making the detection of QTL more difficult to achieve than for traits measured directly.

Table 3. Estimates of model's parameters and goodness of fit statistics of each model of egg weight of different families.

Function	Family	parameter	Estimate	R^2
Gamma Wood	1	a	11.106	4.7
		b	0.092	
		c	0.020	
	2	a	9.608	22.0
		b	0.222	
		c	0.041	
	3	a	10.442	18.1
		b	0.187	
		c	0.031	
	4	a	10.641	32.6
		b	0.240	
		c	0.060	
Rational	1	a	-954159	9.0
		b	3576585	
		c	258580.6	
		d	5523.107	
	2	a	3.270	22.20
		b	20.851	
		c	1.609	
		d	0.025	
	3	a	-3506789	22.20
		b	13380013	
		c	990476.5	
		d	10855.6	
	4	a	-0.7110	32.60
		b	45.639	
		c	3.434	
		d	0.0568	

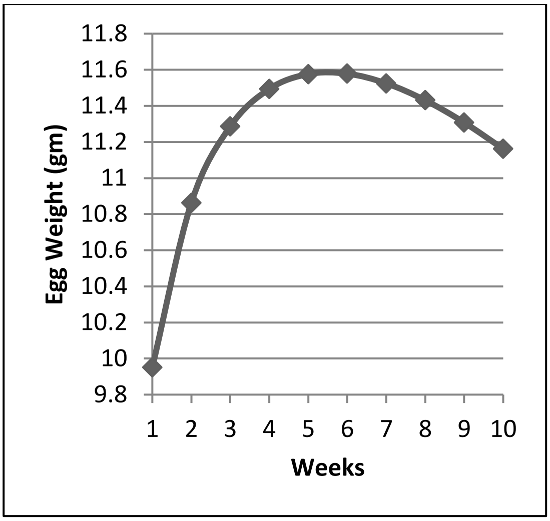

Figure 5. Egg weight curve described by Wood function

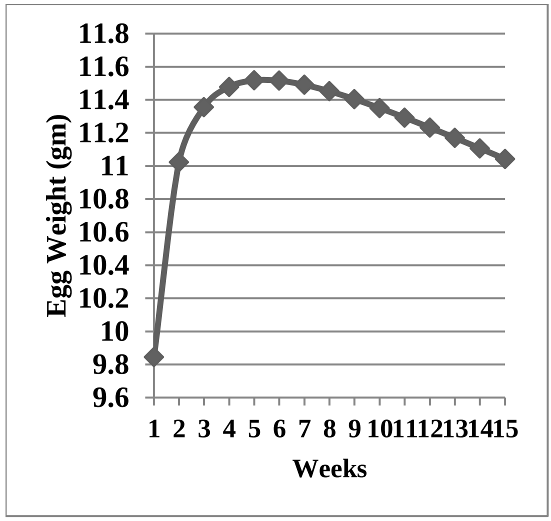

Figure 6. Egg weight curve described by Rational function

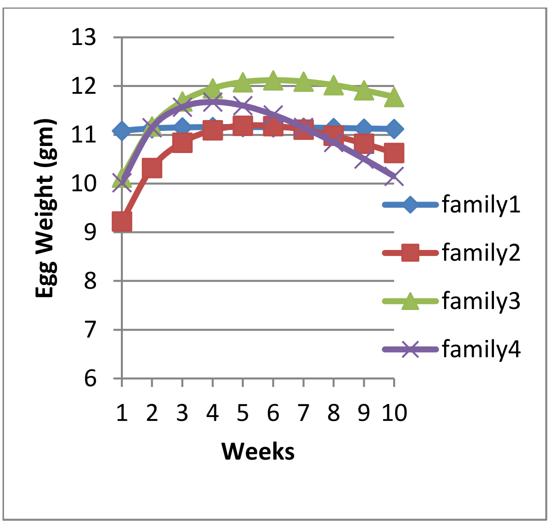

Figure 7. Egg weight curves of different families described by Wood function.

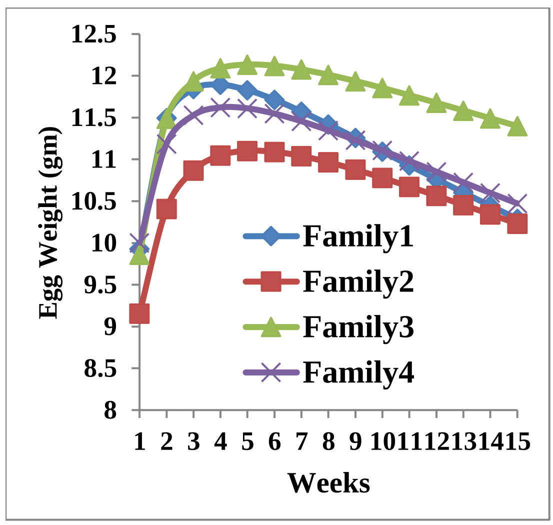

Figure 8. Egg weight curves of different families described by Rational function.

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تحليل منحنيات انتاج البيض ووزن البيض باستخدام معادلتين رياضيتين في طائر السمان الياباني (*Coturnix c.japanica*)

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المستخلص

أجريت هذه الدراسة في حقل السمان الياباني التابع لقسم الثروة الحيوانية/ كلية الزراعة/جامعة البصرة.حللت بيانات منحنيات إنتاج ووزن البيض باستخدام معادلتين رياضيتين.استخدم 148 طيرا من طيور السمان الياباني(136 انثى و12 ذكر) في الدراسة.حققت العائلة الثانية أعلى قيمة لأعلى زيادة في إنتاج البيض باستخدام كلتا المعادلتين الرياضيتين واعلى قيمة في معدل الأنخفاض في إنتاج البيض مقارنة بجميع العوائل الأخرى فيما يخص وصف منحنيات إنتاج البيض. ارتفعت قيم معاملات التحديد لأغلب العوائل التجريبية بالنسبة لمنحنيات إنتاج البيض عند استخدام كلتا المعادلتين الرياضيتين. حققت العائلة الرابعة أعلى قيمة بالنسبة لأعلى وزن بيض بالمقارنة مع العوائل الأخرى عند استخدام معادلة Wood الرياضية كما تفوقت في تحقيق أعلى قيمة لمعامل التحديد مقارنة ببقية العوائل التجريبية الأخرى.

الكلمات المفتاحية: إنتاج البيض، وزن البيض، منحنيات، معادلات رياضية، طائر السمان الياباني.