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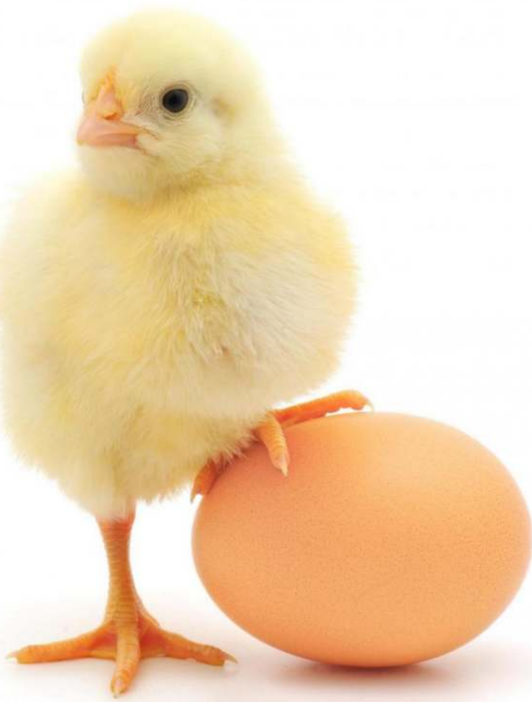

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Mathematical Models for Egg Production in an Indian Colored Broiler Dam Line

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Abstract: Six mathematical models, namely, Logistic, MMF, Polynomial Fit, Rational Function, Sinusoidal Fit and Quadratic fit were identified to fit the average weekly hen housed egg production from 19 to 52 weeks of age, of two generations of a colored broiler dam line. Out of these, on account of the high coefficient of determination, the non-significance of Chi-square values and their simple form, Rational Function (R^2: 94.08-97.22%) and Polynomial Fit (R^2: 93.26-96.67%) were identified to be the best fitting models that could be conveniently used for predictive purposes in the strain.

Key words: Mathematical models, egg production, broiler dam line

INTRODUCTION

Egg production, a genetically controlled trait with a behavioral pattern specific to a breed or a line, generally increases to a peak and then gradually decreases in the form of a curve when summarized on a monthly or weekly basis. The use of appropriate mathematical models to fit such egg production curves accurately is of great importance in practical poultry breeding for making the prediction of egg production on annual or any chosen period basis in order to facilitate the early selection of the breeder birds. The behavioral trends in production like the time of peak and decline as well as the persistency of lay can also be studied from such egg production curves thus effectively managing the housing dates, egg marketing and labor needs of the enterprise. In the above context, the present study aims at fitting of curves for egg production up to 52 weeks of age using mathematical models and the comparison of their relative efficiency to predict the egg production trend of a broiler breeder dam line. The study is virtually a new attempt in any broiler breeder population in India.

MATERIALS AND METHODS

The present investigation was undertaken on two generations of a colored broiler dam line, Punjab Broiler-II (PB2), maintained at the All India Co-ordinated Research Project on Poultry for Meat, located at Bangalore, India. The breeder females were trap-nested and the weekly egg production data spread over 19 to 52 weeks of age of the individual dams that completed 52 weeks of age (N = 1775) were utilized for the investigation. The data were corrected for significant generation effects, according to the method of Least squares by Harvey (1966). The following mathematical models were fitted to the average weekly hen housed egg production of the entire flock in each generation (S9, S10) and the generations pooled (P):

(Model-I) Logistic model:

$$Y = \frac{A}{1 + B\,e^{-Cx}}$$

(Model-II) MMF Model:

$$Y = \frac{AB + C\,x^{D}}{B + x^{D}}$$

(Model-III) Polynomial fit of nth degree:

$$Y = A + B\,x + Cx^2 + Dx^3 + Ex^4 + \ldots\ldots\ldots$$

(Model-IV) Rational function:

$$Y = \frac{A + B\,x}{1 + C\,x + D\,x^2}$$

(Model-V) Sinusoidal fit:

$$Y = A + B\cos(C\,x + D)$$

(Model-VI) Quadratic fit:

$$Y = A + B\,x + Cx^2$$

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Where, Y = Average hen housed egg production in a particular period of recording, x = The week (of production) in which egg production was recorded, A, B, C, D, E = Model parameters as defined in a particular model and e = A mathematical constant.

The Windows based software package of CurveExpert-Version-1.3 (Daniel, 1997) was utilized to identify the suitable models. The derivation of the model parameters, A, B, C, D and E as well as the computation of the efficiency or reliability of the models based on the percent coefficients of determination (R^2) was done as per the least squares curve fit method suggested by Cox (1984). Chi-square test of significance was carried out for the values estimated using the fitted models in order to test the goodness of fit of the models.

RESULTS AND DISCUSSION

The R^2 values ranged from 88.33-97.22% in S9 generation and 85.16-96.65% in S10 generation for the various models fitted for the flock (Table 1). Rational Function (Fig. 1 and 2) had the highest R^2 value (97.22% in S9 and 96.65% in S10) closely followed by Polynomial Fit (Fig. 3 and 4) with a 94.25% in S9 for the fourth degree and a 93.26% in S10 generation for the third degree. Out of the six models identified to be fitting to individual generations, only four models fitted to the average weekly egg production pooled over generations. The fitted models were Logistic Model, Polynomial Fit, Sinusoidal Fit and Quadratic Fit with R^2 values ranging from 89.19-94.20%. Out of these, Polynomial Fit of fourth degree (Fig. 5) had the highest R^2 value (94.20%) indicating the best model for the pooled data.

The range of R^2 values in the present investigation were in conformity with the findings of various research workers who adopted different models in layer type chicken viz., Gavora *et al.* (1982) who applied McMillan's model (97%) and Cason and Britton (1988) who applied Compartmental model (95.23%). The R^2 values are also comparable with the findings of Murthy (1998) for Linear and Reciprocal model (71.39-91.75%) and second order Hyperbola (83.91-96.05%) for egg production in egg type chickens. Thomas *et al.* (1994) and Lal *et al.* (2003) have identified the same models, viz., Rational Function and Quadratic Fit, to fit well to the flocks of egg type

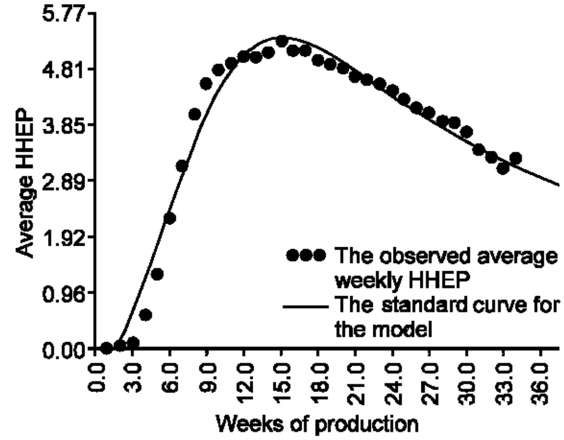

Fig. 1: Rational function (S9)

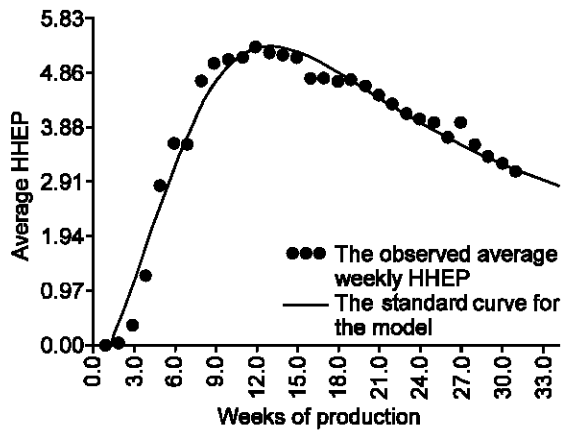

Fig. 2: Rational function (S10)

Table 1: Estimates of Model parameters, Coefficient of determination (R^2) and Standard error for average weekly HHEP in PB2 strain of broiler dam line

Models	Gen	Intercept A	Coef. B	Coef. C	Coef. D	Coef. E	SE	R^2 (%)
Logistic	S9	4.411	619.56	1.082	-	-	0.580	88.65
	S10	4.391	377.98	1.265	-	-	0.613	86.52
	(P)	4.398	1959.27	1.088	-	-	0.572	90.03
MMF	S9	0.110	490620.6	4.412	7.368	-	0.598	88.33
	S10	0.05	28783.98	4.39	6.70	-	0.626	86.44
4th deg Polynomial	S9	-0.850	0.594	0.001	-0.001	2.583	0.427	94.25
3rd deg Polynomial	S10	-1.118	1.016	-0.051	-0.0007	-	0.441	93.26
4th deg Polynomial	(P)	-0.626	0.279	0.039	-0.003	4.573	0.451	94.20
Rational	S9	-0.716	0.416	-0.072	0.005	-	0.292	97.22
	S10	-0.706	0.549	-0.071	0.007	-	0.311	96.65
Sinusoidal	S9	-63.32	68.51	0.021	-0.409	-	0.597	88.35
	S10	-70.725	75.93	0.021	-0.376	-	0.655	85.16
	(P)	-31.184	36.30	0.029	-0.581	-	0.606	89.19
Quadratic	S9	-0.474	0.572	-0.015	-	-	0.586	88.42
	S10	-0.132	0.601	-0.017	-	-	0.641	85.27
	(P)	-0.875	0.589	-0.015	-	-	0.596	89.20

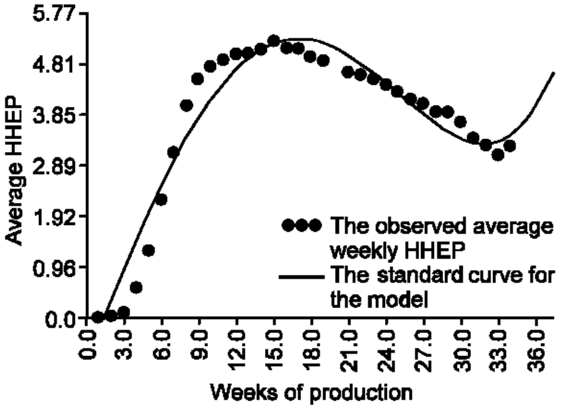

Fig. 3: Polynomial fit (4th degree)-S9

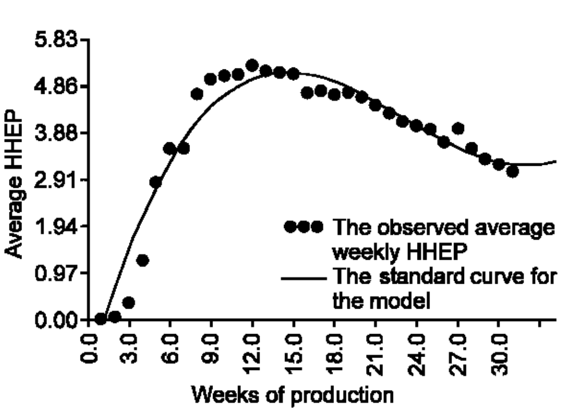

Fig. 4: Polynomial fit (3rd degree)-S10

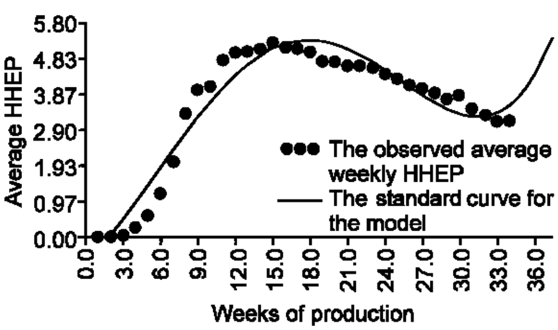

Fig. 5: Polynomial fit (4th degree)-pooled

chicken with similar very high R^2 values as obtained in the present investigation.

Rational Function which gave the best fit for predictive purposes in individual generations, failed to fit to the data when generations were pooled. MMF Model also showed the same trend. This could be attributed to the large difference in the age at sexual maturity between the generations, which caused a lot of variation in the data so as not to suit the pattern projected by this mathematical model. Hence, the Rational Function which gave the best fit with excellent R^2 values in individual generations and the Polynomial Fit identified to be the most suitable for the pooled data, are recommended for the strain.

It was found that when the generations of the genetic group were pooled, the estimated weekly egg production for almost all the models fitted was slightly deviant from the observed values for the period from 19th week to 24th week of age. This was not unexpected since it is the outcome of differences in body weights of the birds housed and also differences in age at sexual maturity due to hormonal influences besides the differences in age of the birds belonging to different hatches. From 25th week onwards, there was close proximity between the observed and expected values till the attainment of 52 weeks of age.

The deviations of the expected values (derived using the fitted models) from the observed values were tested by chi-square for testing the goodness of fit considering the entire production period from 19 to 52 weeks of age. Irrespective of the generations, the computed chi-square values were non-significant and thereby good fitness of all the models for the egg production during the entire period from 19 to 52 weeks of age. The standard errors estimated for the models remained lower wherever the coefficient of determination was higher. The criteria of R^2 values and standard errors, together with the status of non-significance of Chi-square values were used to assess the applicability and fitness of the models.

Overall results revealed Rational Function to be the best fit, very closely followed by Polynomial Fit for the PB2 strain of colored broiler dam line. The other models, Logistic Model, MMF Model, Quadratic Fit and Sinusoidal Fit also gave good fit but the ranking differed between generations. Rational Function and Polynomial Fit being simple were more useful for predictive purposes and therefore could be conveniently adopted.

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