EGG PRODUCTION CURVE OF RHODE ISLAND RED CHICKENS

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ABSTRACT

Data on the monthly egg production of a strain of Rhode Island chickens (500 breeder hens) were used to test the goodness of fit of six mathematical models, viz; Exponential, Parabolic exponential, Wood's Gamma type and modified Gamma type by McNally, Inverse polynomial and Linear regression. Egg production was summarized for each hen into 28-d periods, starting from the day of first egg. The hens were classified into different production cycle length based on the number of 28-d periods. The models were fitted to the mean results obtained for periods within groups of hens. The effect of cycle length on goodness of fit was also examined separately for the 'best' three models with highest R^2 values. The egg production cycle (i.e. number of 28-d periods) varied from 9 to 15 periods. Similarly, the coefficients of determination (R^2) varied from 0.16 to 0.95 from fitting the models to mean egg production data for groups of hens. The results suggest that the 'best' three models that were chosen fitted 52 week laying records quite well, judging from their respective R^2 values, which were higher for McNally (0.95) and Parabolic exponential (0.93) than for Wood (0.75). Based on the goodness of fit to 52-week production record, the McNally model gave the best results. However, its suitability in predicting full year production from part year record needs to be further investigated.

Keywords: Egg production, model, Rhode Island Red layers.

INTRODUCTION

Poultry egg production is believed to be a complex quantitative trait which shows a considerable variation over time within the production cycle of a hen. Several methods of expressing egg production and its component characters have been investigated (Tonkinson, *et al.*, 1969; Gavora *et al.*, 1981; John *et al.*, 1986; Caso and Briton, 1988). However, studies have shown that when egg production in chickens is summarized on a weekly, bi-weekly or monthly basis, it generally increases to a peak and subsequently gradually decreases. This trend is generally denoted as egg production curve in poultry. Therefore, a mathematical model describing such a trend would enable poultry breeders and commercial egg producers to analyse egg production process and to predict annual production from part records.

Several workers (McNally, 1971; Gavora *et al.*, 1971; Timmermans, 1973; McMillan, 1981; Gavora *et al.*, 1982; Johari *et al.*, 1986; McMillan *et al.*, 1986; Yang *et al.*, 1989; Cason and Ware, 1990) have fitted equations of varying mathematical complexity to poultry egg production curves, expressing production as a function of calendar time periods. Comparisons of the "goodness of fit" of these models based on the observed coefficient of determination (R^2), both for individual hens and group mean production have also been made (Timmermans, 1973; Gavora *et al.*, 1982; Cason and Ware, 1990).

All of these investigations appeared to have been carried out mainly in the temperate regions. Thus, there is paucity of information

on the nature of egg production curves of chickens in tropical areas, where environmental factors are known to influence egg production tremendously. Therefore, this study attempts to provide such information by evaluating the adequacy of six mathematical models in describing egg production curves in a tropical environment.

MATERIALS AND METHODS

The data used for this study were obtained from a random-bred population of breeder hens which form part of the poultry breeding flock maintained at the National Animal Production Research Institute (NAPRI), Shika. The location and climatic conditions of Shika have been described elsewhere (Oni *et al.*, 1988).

Five hundred Rhode Island Red breeder hens were used. The birds were brooded and reared to 18 weeks of age in deep-litter floor pens. Floor space allowed per bird varied from 0.15 to 0.50m² depending on age of bird. The rations, formulated at the Institute, contained a minimum of 18 and 14% crude protein for chick and grower diets, respectively. The birds were randomly placed in individual cages. During laying, birds were fed *ad-libitum* on layer ration containing about 16% crude protein and drinking water was available at all times.

Data Collection and screening

For each bird, egg production was summarized into 28-day periods, starting from the day the pullet laid the first egg. The individual hen records were grouped by record length in terms of the number of 28-d periods in the first production cycle. Within each group, mean egg production was calculated period by period. Egg production records from point of lay to the 52nd week in lay were examined.

Records of hens, whose egg production in any one 28-d period (except the first two) was less than 50% of the mean of the two immediately preceding periods, were excluded from the

analysis. After the screening, only 484 records remained and were analysed.

Models Fitted

Denoting egg production in the 28-d period starting from the day of 1st egg by Y_t , the following curves were studied;

(a) Linear regression.

$$Y_t = m + kt$$

(b) Exponential Curve (Brody *et al.*, 1923)

$$Y_t = ae^{(-bt)}$$

(c) Parabolic exponential (Sikka, 1950)

$$Y_t = ae^{(bt+ct^2)}$$

(d) Gamma type Function (Wood, 1967)

$$Y_t = at^b e^{(-ct)}$$

(e) Gamma type Function (McNally, 1971)

$$Y_t = at^b e^{(-ct+dt^{1/2})}$$

(f) Inverse polynomial (Nelder, 1966)

$$Y_t = t(at+bt+ct^2)^{-1}$$

In all the models, the constants a , b , c , d , m and k represent the model parameters as defined by the above equations and have their specific significance in each model. Where, Y_t is the number of eggs laid by an individual or the average number of eggs laid by the group over the period, t , b and c represent the rate of increase and decline of production, respectively in egg production of the group, and ' a ' is the peak production the group could achieve.

To examine the fit of each equation to the data, the functions with the exceptions of ' a ' were transformed to the linear forms by taking logarithm of both sides. These linear forms were then fitted to the 28-d mean egg production for groups of hens over 52-weeks of production on a hen-housed basis. for the estimation of the curve parameters and R^2 values.

RESULTS AND DISCUSSION

Egg Production length and Choice of Model

Egg production cycle length (i.e. number of 28-d periods) varied from 9 to 15 periods, with about 84% of the birds having cycles with not less than 13 periods (Table 1). The values of

LAYING HENS EGG PRODUCTION MODELS

TABLE 1: ESTIMATES OF COEFFICIENT OF DETERMINATION (R^2) FOR EGG PRODUCTION DATA

Egg Prod. Cycle Length (No of 28-d periods)	No. of Hens	Linear	Exponential	Parabolic Exponential	Gamma Type (Wood)	Gamma Type (McNally)	Inverse Polynomial
9	4	0.42	0.46	0.74	0.58	0.88	0.54
10	8	0.16	0.19	0.94	0.77	0.95	0.64
11	19	0.40	0.40	0.92	0.75	0.93	0.59
12	47	0.29	0.30	0.79	0.58	0.82	0.44
13	104	0.49	0.46	0.87	0.68	0.90	0.54
14	211	0.57	0.55	0.95	0.80	0.95	0.67
15	91	0.62	0.62	0.93	0.83	0.94	0.73

co-efficient of determination (R^2) range from 0.16 to 0.95, being maximum for cycle length 14 in Parabolic exponential and McNally, and minimum for cycle length 10 in linear regression.

A comparison on the basis of R^2 shows that the mean egg production of the group (for all cycle lengths) was fitted best by the McNally model followed by Parabolic exponential and Wood model, respectively. Consequently, only these three models were entertained subsequently in this study. Generally, with increasing cycle length, the models result in adequate fit to group egg production data as evidenced by a somewhat higher R^2 for longer cycles, although the values for cycle length of 12 periods were consistently lower than the preceding cycle length.

The average R^2 values from fitting the above three models to individual production records of different lengths are 0.59 ± 0.01 for the Parabolic exponential, 0.51 ± 0.01 for Wood and 0.63 ± 0.01 for McNally. The parameter estimates and $R^2(\%)$ values for each of the three models are shown in Table 2. The McNally and Parabolic exponential have significantly ($P < 0.001$) higher R^2 values (mean) for individual curves than the Wood model.

Although both the McNally and Parabolic exponential models gave a good fit to the group average egg production data (Table 1), the mean R^2 values obtained for the two models, when fitted to the individual records, differed significantly ($P < 0.05$) (Table 2). Figure 1 shows the mean egg production of the

TABLE 2: ESTIMATES OF MODEL PARAMETERS OF HEN-HOUSED EGG PRODUCTION DATA FOR GROUPS OF HENS HAVING THIRTEEN 28-D PERIODS

Model	Parameters*		Group	Individual	R^2	R2 (Mean)
	A	b	c	D		
Parabolic-Exponential	2.807	0.087	-0.008	-	0.925 ± 0.048	0.586 ± 0.011^a
Wood	2.953	0.327	0.090	-	0.753 ± 0.088	0.509 ± 0.010^b
McNally	-1.005	-1.956	0.614	4.585	0.946 ± 0.043	0.629 ± 0.010^c

*Constants determined by a least squares LIN-fitting programme.

a, b, c = within a column, means with different superscripts are significantly different ($P < 0.001$)

groups of hens with thirteen 28-d periods with the Parabolic exponential, Wood and McNally models fitting data points very closely compared to other models. On a comparative basis, the mean egg production of the group was fitted best by the McNally model followed by the Parabolic exponential and the Wood model in that order.

Fig.1 Fitted egg production Models for Strain A

Some reports dealing with mathematical models of group egg production expressed egg production on the basis of the birds' chronological age (McNally, 1971; Yang, *et al.*, 1989). Under such circumstances, the increasing slope of the egg production curve depends on the actual rate of increase in egg production of the individual hens, as well as on the variation in age at sexual maturity within the group (Gavora *et al.*, 1982). In the present study, individual egg production was expressed in 28-d periods from the day the birds laid the first egg. Consequently, summation of such records resulted in group egg production data free of the influence of sexual maturity.

The results of this study confirmed earlier observations by other authors that the McNally, Parabolic exponential and Wood

models indicate relative adequacy to fit group egg production data (McNally, 1971;

McMillian, *et al.*, 1986; Johari *et al.*, 1987). However, contrary to report of Johari *et al.* (1987), in which the Wood model gave better fits than Parabolic exponential, the latter was found to perform better than the former in this study. For production records that peaked more gradually, the difference between McNally and Parabolic exponential was negligible (Fig. 2). Similarly, Fig. 1 shows that the Three models fitted data points very closely and could generate well the two most critical periods, i.e. the initial slowly increasing slope and the abrupt change from a positive to negative slope near the peak. Although the Parabolic exponential model had high R^2 , but in the initial period of lay, it could not accurately describe the changes. However, in the middle and latter periods of lay, the model gave a good description of actual changes in egg production. This probably suggests that if data for the first 1 or 2 weeks were excluded from the model fitting, the goodness of fit of the model might probably be improved with respect to the R^2 and estimated peak values. Similar observations have been made by Cason and Britton (1988) and Yang *et al.* (1989) who reported that early egg production data are important in determining the goodness of fit of different models. So, arbitrarily starting flock production records at 5 or 10% production may influence the ability to predict future egg laying behaviour by mathematical analysis of those records.

Fig.2. Fitted models for individual number 2486

LAYING HENS EGG PRODUCTION MODELS

Both the Linear and Exponential models gave a poor fit to the data (Table 1) when compared with the other models. The main reason for the inferior fit obtained for the linear regression to mean group egg production data seems to be the fact that even the 'Synrochronized' data have a short increasing slope before reaching peak production, which cannot be expressed by the Linear regression. With increasing cycle length, this deficiency of the linear regression seems to become less important.

The average R^2 obtained from fitting the three models to the individual production records was 0.59, 0.63 and 0.51 for Parabolic, McNally and Wood models, respectively. Individual records varied from 0.02 to 0.94 for Parabolic, 0.03 to 0.95 for McNally and 0 to 0.93 for Wood, indicating the possible existence of patterns not fitted by either of these models. The patterns suggest that some birds may have undergone a partial moult and started new egg production cycles. The criteria used to distinguish between the first and subsequent egg production cycles within the hen's record as described earlier, were apparently too crude to detect multiple production cycles separated by smaller production decreases and may require refinement (Gavora *et al.*, 1982). This probably explains the sudden decrease in R^2 value observed for the production cycle length of 12 periods compared with other periods. Ibe and Hill (1988) also reported that egg production traits, particularly those based on early records, exhibit markedly non-normal distributions. They observed that age at first egg, a measure of sexual maturity, is usually positively skewed, whereas survivor, hen-housed and hen-day egg productions are negatively skewed. The outliers which cause skewness in data may be simply aberrant or may be true values inherent in the underlying distribution.

Similarly, the R^2 values for the individual curves and mean curve values were substantially different (Table 2). Detailed

examination of fitting the models to individual records revealed that, for some records, the parameters have either large negative or positive values. Also, some of the records typically reached their peak in the first 28-d period. Consequently, such records contributed to the differences between "individual curve" and "mean curve" values of the parameters (Gavora, *et al.*, 1982). Thus, records starting at the peak and then decreasing could be expected to be fitted as well (or better) by a Linear regression than by any of the other models. This is because the exponential models tend to approach a straight line over the actual time interval considered in these cases. For hens maintaining high egg production throughout the period considered, the R^2 value may be a misleading measure of goodness of fit relative to hens with different egg production patterns.

It should be noted that the observed data in this study did not follow the expected pattern of egg production at the initial stage. This was because the onset of egg production (sexual-maturity) for the population coincided with the period of high environmental temperature. Thus, rather than the expected steady increase in production from the first to the 2nd month, the production actually dropped and later rose again. Furthermore, irregular feed supply or unavailability at this period is also a likely reason for the unusual pattern.

Based on the comparisons presented in this study, it can be concluded that the McNally model has theoretical advantages over the Parabolic exponential and Wood models in respect to its goodness of fit to the data. However, one model may not necessarily be best in all circumstances or with all data. The properties of the model and the data should be examined, and the appropriate model chosen.

Application of a mathematical model to egg production records of laying hens in a tropical environment seems practicable. However, its suitability in predicting full year production

from part year record needs to be further investigated.

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