PREDICTIVE ABILITY OF EGG PRODUCTION MODELS

O. O. ONI, B. Y. ABUBAKAR, N. I. DIM[1], O. E. ASIRIBO[2] and I. A. ADEYINKA

National Animal Production Research Institute
Ahmadu Bello University, P. M. B. 1096, Shika-Zaria, Nigeria
[1]Animal Science Department, A. B. U, Zaria, Nigeria
[2]Institute of Agricultural Research, A. B. U., Zaria, Nigeria

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ABSTRACT

The monthly egg production data of a strain of Rhode Island chickens were used to compare three mathematical models (the Parabolic exponential, Wood's Gamma and modified Gamma by McNally) on their ability to predict 52 week total egg production from part-production at 16, 20, and 24 weeks, on a hen-housed basis. The results suggest that the three models fitted 52 week laying records quite well, judging from their respective R values, which were higher for McNally (0.95) and Parabolic exponential (0.93) than for Wood (0.75). However, their ability to predict 52 week egg production from part-records of 16, 20 24 wks varied. The prediction of total production based on fit to 24 week of data was more accurate for the McNally. The latter consistently predicted less than the actual 52 week (-1.13% deviation), but the other 2 models tended to over estimate production (i.e. 12.26 and 13% deviations for Parabolic exponential and Wood models, respectively). It was concluded that based on the goodness of fit to 52 week production record and accuracy to predict full record egg production from part record, the McNally model gave the best results, and could therefore be said to have theoretical advantages over the other models. It may thus be found useful in decision making concerning replacement of layer flocks.

INTRODUCTION

Egg production in poultry shows a regularity, though not a steady process over time, that is generally denoted as egg production curve, especially when summarised on a weekly, bi-weekly or monthly basis in a group of hens.

Several mathematical models describing such egg production curve have been suggested. It has been observed (McMillan *et al.*, 1986) that although the comparative goodness of fit of model to data is a necessary criterion for its acceptance, however, depending on its intended use, other considerations become involved in the final choice. Consequently, for poultry egg production curves, the ability to predict the whole record production from part-records is one of such important criteria. This is because, the use of early partial records as a selection criterion for annual egg production has been proposed by many workers, since genetic gain measured against time would be improved as the parental age is reduced (Dickerson and Hazel, 1994.) Prediction of egg production and egg size is necessary for economic projections for laying hens. Furthermore, the predictions play important roles in early selection, production planning and economical decision making (Yang *et al.*, 1980). Mathematical models provide one means of predictions, but they are sometimes inadequate due to poor extrapolative properties or abnormal deviations from expectations (Adams and Bell, 1980). Therefore, in assessing the relative merits of models describing poultry egg production records, the accuracy of predicting full record from part record production becomes highly important. Models which do not fit data accurately or which do not extrapolate reasonably, cannot contribute to a reliable economic projection.
Thus, in this paper, three mathematical models which gave good fits to the egg production data in this study were further compared on the

basis of their abilities to predict group total 52 – wk production from part records.

MATERIALS AND METHODS

The egg production data used in this study were taken from records of 500 breeder hens maintained as a random-bred population of the poultry breeding project, at the National Animal Production Research Institute (NAPRI), Shika. The details of the composition and management of the flock have been described elsewhere (Oni, 1992).

All egg production data were summarised on a monthly (28-d) basis, with production expressed as egg per hen per month on a hen-housed basis. The first week when the flock started to lay egg was counted as first week of production, without using any arbitrary production figure, such as 5%, to determine the beginning of egg production by the flock. Thus, for each hen, egg production was summarised into 28-d periods starting from the day the pullets laid its first egg.

Three mathematical models were fitted independently to the data using SYSTATLIN outline (Wilkinson, 1988).

The Parabolic exponential is expressed as; $Y_t = ae^{(bt + ct2)}$

The Wood's model is expressed as; $Y_t = at^b e^{(-ct)}$

The McNally is expressed as; $Y_t = at^b e^{(-ct + dt^{1/2})}$

In all models Y_t = egg production in time period t, t = age of flock in month, e = base of natural logarithms, and other letters represent constants (model parameters) to be determined by least squares linear curve fitting program. Generally, the **b** and **c** represent the rate of increase and decline of production respectively, and **a** is the peak production the group could achieve. Thus to examine the fit of each equation to the data, the model equations were transformed to the linear forms. Goodness of fit of the models over the entire laying period (52-wk) or over a partial laying period (16, 20 or 24-wk) was evaluated by the mean coefficient of determination (R^2) values.

For the prediction of total 52-week egg production from part-record data of 16, 20 and 24 weeks, the monthly mean egg production over the appropriate part record data was fitted separately with each of the three models chosen and extrapolations of the areas under the resulting curves to 52 weeks was made. The predictive capacity of the models was tested by comparing predicted total egg production, based on fits of the three model to part-record data, with actual total egg production using certain criteria.

TABLE 1: ESTIMATES OF MODEL PARAMETERS OF HEN-HOUSED EGG PRODUCTION DATA FOR GROUPS OF HENS HAVING THIRTEEN 28-D PERIODS

	Parameters*				Group. Production	Individual. Curves
Model	A	B	c	d	R^2	R^2 (Mean)
Paraboli-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)

RESULTS AND DISCUSSION

Comparison of goodness of fit

The parameter estimates and R^2 (%) values for each of the three models are shown in Table 1. All the three models have high R^2 values the lowest being 0.75 for Wood model. The McNally and Parabolic exponential have significantly ($P<0.001$) higher R^2 values (mean) for individual curves than the Wood model. Several criteria of goodness of fit for the different models, including R^2 and errors of estimated 52-week egg number, estimated peak of egg production are presented in Table 2. These results show that the McNally model has higher R^2, smaller errors of 52-week egg number and greater agreement of estimated peak with actual peak than the other two models.

Thus, for complete or partial egg production data and for predicted egg production, the McNally model consistently out-performed the Wood and Parabolic exponential models. Thus, judging from the several criteria of goodness of fit presented in Table 2, the Wood model was the least preferable in this study with respect to its goodness of fit, especially for the greatly delayed estimated peak, which confirms the results of Congleton, *et al* (1981).

Comparison of abilities to predict annual egg production

The three models were fitted to part-records for 16, 20 and 24 weeks of production on a hen-housed basis in both lines. Annual (or 52 week) egg numbers were predicted by the resulting egg production curves. The predicted and actual annual egg numbers and errors of prediction (i.e. absolute values of the difference and the % difference between predicted and actual) are given in Table 3.

Predicted egg production curves can be constructed by inserting the estimated parameter values into the model equations. For example, the model equations for the three chosen models for hens having thirteen 28-d periods can be expressed as follows:

i) Parabolic exponential: $Y_t = ae^{(bt+ct2)}$ $Y_t = 2.807 \; e^{(0.087t-0.008t2)}$ ($R^2 = 0.925 \pm 0.048$)

ii) Wood: $Y_t = at^b e^{(-ct)}$ $Y_t = 2.953t^{0.327} e^{(0.09t)}$ ($R^2 = 0.75 \pm 0.088$)

iii) McNally: $Y_t = at^b e^{(-ct+dt^{1/2})}$ $Y_t = 1.005 \; t^{1.95} c(0.614t+4.585t^{1/2})$ ($R^2 = 0.946 \pm 0.043$)

The McNally model consistently predicted less than the actual 52week egg production, while the Wood and Parabolic exponential models tended to overestimate production. The latter two had similar accuracy in their predictions with a slight advantage to the Parabolic exponential especially with 20week data.

TABLE 2: GOODNESS OF.FIT OF THREE MODELS FITTED TO EGG PRODUCTION DATA FOR GROUPS OF HENS HAVING THIRTEEN 28-D PERIODS

Variable	Parabolic-exponential	Wood	McNally
R^2	0.93	0.75	0.95
Error (%) in Estimation of 52-week egg No. from part record (24 week)	12.26	13.01	(-)1.13
Deviation of estimated time of peak (i.e. No. of 28-d periods)	-2	-3	-1
Deviation in estimated peak production (%)	2.27	2.76	1.85

TABLE 3: ERRORS OF PREDICTED 52-WEEK EGG PRODUCTION BASED ON FITS TO PART RECORDS

Model	Fit to wk	Abs. Errors	% Errors
Parabolic-	16	99.72	42.0
Exponential	20	1.52	0.64
	24	28.38	11.95
Wood	16	37.07	15.61
	20	23.85	10.04
	24	30.87	13.00
McNally	16	-29.40	(-)12.38
	20	-24.51	(-)9.69
	24	-2.72	(-)1.15
Actual mean 52 week prod. (±S.D)	232.12±28.69		

The results suggest that both the McNally and Parabolic exponential models have fairly good abilities to predict. They yielded relatively smaller prediction errors than did the Wood model, but the indication is that McNally may be more reliable.

The choice of model is often difficult, especially when the purposes it serves are not clearly defined. McMillian, *et al.* (1986) considered the importance of another criterion in judging different models, that is, the predictive ability. Thus, one of the objectives in establishing a mathematical model of egg production is to predict whole record production from part-record. Prediction of egg production (and egg size) is necessary for economic projections for laying hens. Mathematical models provide one means of prediction, but they are sometimes inadeaquate due to poor extrapolative properties or large deviations from expectations. Therefore, in this study, the predictive aspect of the models was to be an important consideration for ranking the utilities of the three chosen models. The predictions play important roles in early selection, production planning and economical decision making (Yang, *et al.*, 1989).

On this basis, the Wood model is less suitable than the Parabolic exponential or the McNally models. This is similar to the result obtained by McMillian *et al.* (1986) in which they examined the predictive ability of three equations and reported that the Compartmental model performed quite well in its predictive capacity compared to the Linear model, while the Wood model did not Yang, *et al.* (1989) also reported that for the two lines studied, the Wood models consistently had the greatest errors in prediction compared to the other two models namely, the modified Compartmental and the Compartmental. This probably suggests that all models do not fit all data equally well. This agrees with the results of McMillan *et al.* (1986) who found that all the models they examined predicted whole-record egg production of two selected strains better than that of an unselected control strain, and the rank of the two best predictive models changed with strain.

As the Wood model was identical to the McNally model except for an extra term in the latter, it appeared that mathematical properties of this term was important in differentiating between the two models. Congleton, *et al.* (1981) observed that there is no inflection point in the initial period for the Wood model which causes problems in this part of the curve and that leads to greater systematic errors in model fitting. Based on the comparisons presented here, the McNally model appears to be superior to the Wood model in terms of goodness of fit or predictive ability for egg production. Also, on a R^2 basis, the McNally model came slightly ahead of the Parabolic exponential.

In this study, the predictive aspect of the models was to be the main concern for ranking the utilities of the three chosen models. Consequently, 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 and its ability to predict.

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