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A Model to Estimate the Laying Curve of White Leghorn Hens in the Last Three Years in the Province of Ciego de Avila, Cuba

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ABSTRACT

A number of 15 976 egg production records from three hen batches in Ciego de Avila (2016) were used. The laying curve was characterized in similar conditions to IIA (2013), Republic of Cuba. The estimation of the laying curves made of mean productions from three stages in a year was presented. Four mathematical models were applied for curve adjustment: McNally, Wood, quadratic logarithmic, and linear hyperbolic. Different statistical criteria were used for validation: determination coefficient (R2), (R2A), residual analysis, and others. The means, standard deviation (SD), standard error (SE), and variation coefficient (VC) were made for each period. Egg production accounted for 84.35 and 60.61% of total laying, the best year was 2016. The highest values of SE and VC were observed at the end of production, as expected. Adjustment and discrimination showed a high adjustment criterion in the four models, but the best values were observed with McNally (1971), in R2 (99.60%), and adjusted R2 (99.42%). McNally reached the highest adjustment values: YM=-2233.62-18583.8*(MONTH/426)-029.0*(MONTH/426**2+780.241*log (426/MONTH)-68.1269*(log(426/MONTH))*2, and it described the best production of White Leghorn (L33) hens in Ciego de Avila.

Keywords:*aviculture, laying curves, models, prediction*

INTRODUCTION

The laying curve model for analysis and interpretation of egg production over time is very useful; it helps make behavior predictions, and know production yields. It is also used to carry out flock balances, peak analysis, laying plateau and extension with high performance hens during late laying periods, based on partial records (Agudelo *et al*., 2009).

A model is a simplified representation of the reality, and new models are often developedto better describe or predict real behavior. Budimulyati *et al*. (2012) defined models as the expression of a complex set of functional elements directly or indirectly related to one another in a causal way.

Agudelo *et al.*(2007) claimed that scientific research directed to improve egg production commonly relies on mathematical models that provide solutions to complex problems. Models help quantify the magnitude of the main variation causes, with more precise results during research.

Salvador and Guevara (2013) characterized egg laying curves, using the best models available. They can predict the expected values and help estimate coefficients for the most probable extended laying values. The authors also said that the methodology is based on a standard egg laying curve for animal groups, then it is combined with the known side, and total production can be estimated.

The egg laying curve was based on total or partial information about production during long or weekly periods, using different models, like Wood functions, Ali Schaeffer, Mc Nally, quadratic logarithmic, and linearhyperbolic. Besides the previous models, other alternatives are being explored (Bayesian statistics, artificial neuron networks), by Galeano-Vasco and Cerón-Muñoz (2013).

Non-linear regression models are widely used for egg laying data adjustment. Mathematically, the egg laying curves can be split in three phases: I. laying rise from the first egg until the hen reaches the peak; II. from the beginning of the laying plateau until production decline; III. from the beginning of laying to its end (Aggey *et al*., 2009).

The aim of this study was to analyze the last three years, using various mathematical models to characterize the egg laying curve and the main issues concerning L33 White Leghorn hen batches.

MATERIALS AND METHODS

The production records (15 976) of egg production from eight farms housing 90 000 hens each were used. The hens were arranged by three sets (three consecutive batches, between 2014 and 1016). The eggs were collected twice a day in all the farms for monthly control. The birds were managed according to the standards of the technical instructions IIA (2013), for layers and their replacements in the Republic of Cuba.

Batch and farm production was organized monthly. The average productions of three 12-month stages were used for characterization, depending on each hen´s laying duration. Four mathematical models were applied to adjust the curve: Mc Nally (1871), Wood (1967), quadratic logarithmic,and linearhyperbolic.

The estimation of non-linear parameters demanded iterative methods;the determination coefficient (R2) and adjusted determination coefficient (adjusted R2) were included for model validation, because the models had different amounts of parameters. Residual analysis was included to verify the theoretical suppositions. Regression ANOVA and significance hypothesis of parameters were used. The daily mean, standard deviation (SD), standard error (SE), variation coefficient (VC) and the Durbin-Watson (DW) statistic were calculatedmonthly. The procedure for parameter estimation (Gauss-Newton, MLIN, SAS 9.3 (2010)) suggested by Wolfinger and O´Connell (1993)was used.

The non-linear models applied for egg laying adjustments were,

Yt=a-b*(t/426- c *t/426**2+d* Mc Nally model (1971)

log (426/t) –e*(log426/t))**2

$Yt=at^{f}\ e^{(-bt)}$ Wood Model (1967)

$Yt=a+bt \quad +c(t)^{2} \quad +d(\log)t$quadraticlogarithmic function

Yt=a-b c/t linear hyperbolicfunction

WhereYt = monthly egg production, a= asymptoticpeakvalue of egg laying; b = laying decline, following the laying peak (reduction of h/a/day per month);c = egg laying increase; d = production drop after laying; f = rise proportion.

RESULTS AND DISCUSSION

Table 1 shows the monthlyaverage of egg production values corresponding to the 12 laying curve intervals in each. A span between 60.61 and 84.35 % was observed for the minimum and maximum production, respectively. The dispersion parameters (SE± and VC%) increased during the final interval of the curve, an expected behavior based on the variations of the monthly values. These values were similar to reports by CANCA (2016unpublished data), and they are higher than other values from the rest of the country. However, they are better than international reports, (Johnson, 2015), whose birds reached superior laying peaks and persistence. Better laying intensities have also been reported (88.1-90.3% in ISA birds) to 74 weeks, according to Van de Braak (2015), from Hendrix Genetic Company.

Figures 1, 2, 3, and 4show the laying curve corresponding to each model in the study, with their particular equations. The best adjustment was made by Mc Nally´s.

Table 2 shows a summary of the curve parameters estimated, with their SE± and their significances. Goodness of fit and discrimination among the models used proved high adjustment (Table 3), since the determination coefficients for Mc Nallywere above 99%, in contrast to the linearhyperbolic, the quadraticlogarithmic and Wood´s; as well as for R2Avectors, which remained the same. The Durbin-Watson statistic was not significant in all the cases (P>0.05), indicating self-correlation issues.

Mc Nally expression had significant parameters and high adjustment values. Moreover, it complied with the variance homogeneity assumptions, with the best non-biased linear estimators and minimum variance. It also corroborated the prediction validation assumptions for the model (Table 4), where 0.94% was caused by error. It means that the expression described the L33 White Leghorns laying bestin the province of Ciego de Ávila. Likewise, the integral defined for the curve was considered an alternative to estimate yields (265 e/bird).

The top value was estimated for the best model (Mc Nally), regarding the production peak, at the beginning of the second month of laying (92.3% eggs). In a light henstudy, Ahmadi and Golian (2008) found that the laying peak was between the end of the first month and beginning of the second month of production, with figures similar to this study. The authors reported an average egg production between 90.7 and 91.2% eggs in the month, similar to the 92.3% in this study. The above mentioned average production is 1.23 and 2.34 higher than the reports by the technical instructions IIA (2013).

The egg laying curves achieved in Ciego de Ávila, using new methods and mathematical modeling allowed for better predictions and decision making in terms of curve stages or complete laying period, to predict the current and future egg production based on new methods. Now the organization has a tool that only allows for 5% error in prediction.

CONCLUSIONS

Mc Nally was the best tool to characterize egg production in the province of Ciego de Ávila, Cuba, and it might be used in further studies to analyze the factors that affect the egg laying curve, and estimate a curve free from other fixed effects.

This model truly allowed for quality evaluation of the new hen, the age of sexual maturity and other factors in each adaptation stage.

The best results were observed for 2014 and 2916, with 75% laying along the production year.

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Table1. Egg production (u) in Ciego de Ávila(2014, 2015 and 2016) at different curve intervals for L33 White Leghorn hens.

Laying months	Year means 2014*	Year means 2015*	Years means 2016*	SE±	VC, %	Maximum	Minimum
1	76.13	72.40	82.79	0.16	0.24	87.18	74.40
2	80.73	75.80	83.34	0.17	0.20	88.37	76.31
3	80.27	73.63	82.76	0.17	0.21	91.74	73.70
4	81.69	74.81	84.35	0.17	0.24	90.11	74.62
5	79.28	73.93	83.07	0.17	0.21	85.99	76.15
6	81.00	72.34	81.18	0.16	0.25	83.43	74.93
7	79.11	71.12	79.48	0.16	0.29	85.21	69.75
8	77.41	67.71	76.80	0.16	0.22	81.56	68.56
9	74.74	64.55	73.16	0.15	0.21	77.48	66.94
10	72.10	62.43	71.33	0.14	0.31	72.08	64.58
11	68.27	62.12	65.59	0.16	0.34	68.21	58.97
12	63.53	60.61	62.34	0.13	0.46	63.25	57.34
Mean	75.35	69.28	75.52			81.23	69.52

* CANCA (2016, unplublished data)

Table 2. Estimated parameters, standard error and significance of the models studied

Models	Parameters of the mathematical models			
	a	b	c	d
Mc Nally	766.0±614.2	2.348±0.518	-0.231 ±0.104	-3.194 ±9.59
Wood (1967)	51.90±3.88	0.67±0.09	0.12±0.02	
Quadratic logarithmic	56.10± 3.16	-17.96±3.39	0.40±0.138	67.90±7.96
Linear hyperbolic	118.41±1.930	3.685±0.175	-78.105±2.908	
	Significance of parameters			
Mc Nally	***	***	***	***
Wood (1967)	***	***	***	
Quadratic logarithmic	***	***	***	***
Linear				

hyperbolic	***	***	***

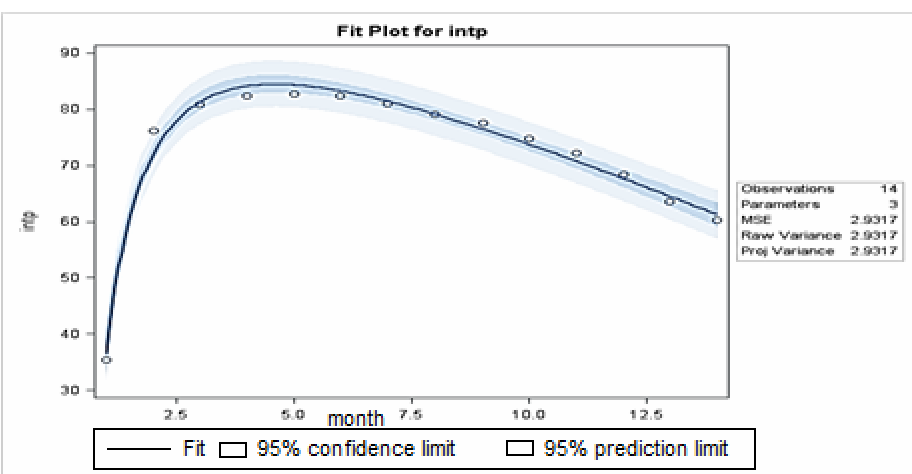
*** (P < 0.001)

Table 3. Goodness of fit and determination of the model types used

Model	Mc Nally	Wood (1967)	Quadratic logarithmic	Linear hyperbolic
Adjustment method for models	Gauss-Newton	Gauss-Newton	Gauss-Newton	Gauss-Newton
Model significance	.000	.0001	.0001	.0001
Determination coef-ficient R2	99.60	86.50	95.29	98.50
Determination coef-ficient R2A	99.42	84.05	95.88	98.20
Standard deviation of estimation error	11.26	5.136	3.180	13.71

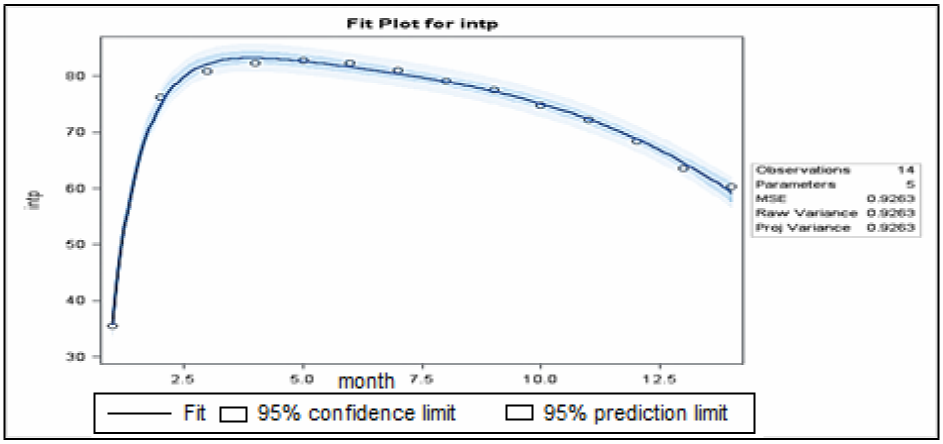
Table 4. Validation of prediction according to residualbreakdown

Residues	Mc Nally	Wood	Quadratic logarithmic	Linear hyperbolic
MSE	0.954	26.378	10.115	2.932
MAE	0.636	3.069	2.088	1.178
MAPE	0.891	5.180	3.113	1.694
ME	0.0003	-0.0586	8.131	1.903
MPE	0.024	-1.1204	-0.321	-0.118



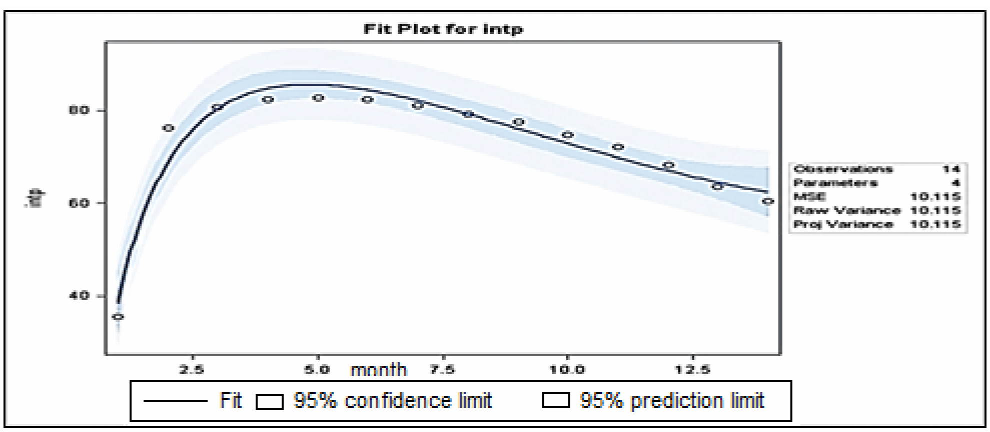
Yt=a-b*(t/426- c *t/426**2+d* log (426/t) –e*(log426/t))**2

Fig. 1. Laying curve according to Mc Nally (1971) adjusted model



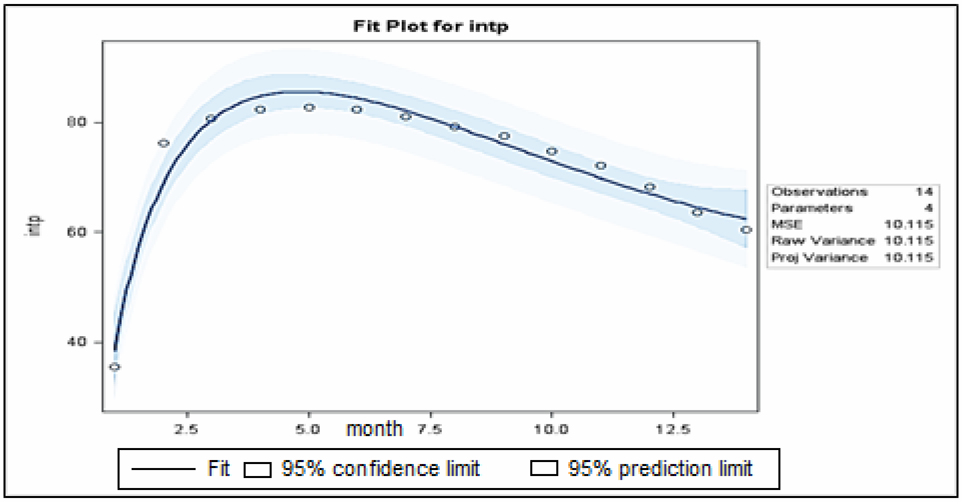
Ym = 56.1073 -17.9654*mes +0.401024*month*month + 67.9058*log(month)

Fig. 2. Laying curve according to adjusted logarithmic quadratic method



Ym= 118.408 – 3.6853*month – 78.1047/month

Fig. 3. Laying curve according to adjusted Hyperbolic linear method



Ym= 51.9082*month**(0.670349)*2,71**(-0.118063*month)

Fig. 4. Laying curve according to Wood (1967)