Journal of Animal and Veterinary Advances 8 (7): 1349-1352, 2009
ISSN: 1680-5593

Neural Network Model as a New Powerful Tool to Describe and Predict Hatchability of Broiler Breeder Eggs

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Abstract: Neural Networks offer an alternative to regression analysis for biological modeling. Very little research has been carried out to model fertility using artificial Neural Networks. The aim of this study is evaluation of a Neural Network model to describe relationship between age of broiler breeder and hatchability. Neural Network model was developed with the Matlab program. The predictive quality of the Neural Network model was tested for an external validation set of 10 weeks randomly chosen from 37 weeks. The goodness of model was determined by Mean Square Error (MSE), Mean Absolute Deviation (MAD), Mean Absolute Percentage Error (MAPE) and bias. Forecasting error measurements were based on the difference between the model and the observed values. The squared regression coefficient R^2 was 0.9934. The overall calculated statistical values MSE, MAD, MAPE, bias and R^2 have shown that Neural Network may be used to provide the accurate fit to hatchability of broiler breeder eggs.

Key words: Hatchability, age, neural network, broiler breeder, biological modeling, predictive quality

INTRODUCTION

The production of 1st-quality chicks depends on the breeding and hatching performance of the parent flocks. The fertility of eggs produced by breeder flocks is acceptable at about 90% during most of the laying period. A minor study conducted at the test unit of the Norwegian Poultry Association in 1999 showed an overall average fertility and hatchability in Ross 208 breeders of 86.6 and 72.7%, respectively (Nordvoll, 1999). Three different parent flocks at different ages were included in the study and the results suggested an association among the breeder flocks, egg storage time and hatchability. Fasenko *et al*. (1992), Roque and Soares (1994) and Lapao *et al*. (1999) have reported a relationship among hen age and hatchability. Broiler breeder age (Mather and Laughlin, 1979; O'Sullivan *et al*., 1991; Latour *et al*., 1996) influence subsequent embryogenesis and hatchability of broilers. Numerous factors influence hatchability, but in commercial flocks of similar genotype under standard management practices the major determinant of hatchability is age (Kirk *et al*., 1980; Fasenko *et al*., 1992). There is a negative correlation between body weight and reproductive success, so the effect of age may be confounded as birds become heavier with age. Mauldin (1989) by examining 18,500 hatch records from different integrated firms showed a curvilinear relationship between flock age and hatchability. Analysis of these records clearly showed that even in different commercial broiler breeder operations with variations in management procedures and diversity of quantitative feed restriction and other dietetic practices, hatchability is essentially a function of age. The model proposed by Mauldin (1989) provides a general description of the phenomenon. Its usefulness is Limited, however, because it assumes a uniform rate of decline in hatchability and does not provide a valid description of the relationship between hatchability and age or an analytical tool for breeder flock management. It portrays the hatchability-age response pattern as similar to the general egg production cycle, with an initial steep increase to a peak followed by a gradual descending age-related decline. A major concern of broiler breeder operations is the rapid decline in hatchability as the reproductive cycle progresses.

The objective of present study is evaluation of a Neural Network model to describe relationship between age of broiler breeder and hatchability.

MATERIALS AND METHODS

Animal data: The data set was used to describe the relationship between hatchability and age consisted of weekly hatchability records of 3 Ross broiler breeder

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flocks from one commercial hatchery in Simorgh Company from 28-64 weeks of age. The predictive quality of the Neural Network model was tested for an external validation set of 10 weeks randomly chosen from 37 weeks.

Artificial Neural Networks: Principles, functioning and applications of artificial Neural Networks have been adequately described elsewhere (Zupan and Gasteiger, 1999).

A 3-layer feed-forward network formed by one input layer consisting of a number of neurons equal to the number of descriptors, 1 output neuron and a number of hidden units fully connected to both input and output neurons, were adopted in this study. The most used learning procedure is based on the back propagation algorithm, in which the network reads inputs and corresponding outputs from a proper data set (training set) and iteratively adjusts weights and biases in order to minimize the error in prediction. To avoid overtraining and consequent deterioration of its generalization ability, the predictive performance of the network after each weight adjustment is checked on unseen data (validation set).

In this research, training gradient descent with momentum is applied and the performance function was the Mean Square Error (MSE), the average squared error between the network outputs and the actual output.

Model development: The Artificial Neural Network model with Back-Propagation algorithm (ANN BP) was developed with Neural Network of Matlab program for 37 weeks data set of hatchability of broiler breeder. Prior to fit the ANN BP model, data set was divided into 2 sets of training (27 weeks) and validation (10 weeks). The validation set was used to test the prediction ability of ANN BP during the training processes.

A quantitative examination of the fit of the predictive models was made using error measurement indices commonly used to evaluate forecasting models (Oberstone, 1990). The accuracy of the models was determined by: Mean Absolute Deviation (MAD), computed as:

$$MAD = \frac{\sum_{t=1}^{n} |y_t - \hat{y}_t|}{n}$$

where:

y_t = Equals the observed value at time t
$\hat{y}_t$ = Equals the estimated value and
n = Equals the number of observations

Mean Absolute Percentage Error (MAPE), computed as:

$$MAPE = \frac{\sum_{t=1}^{n} \left| \frac{y_t - \hat{y}_t}{y_t} \right|}{n} \times 100, (y_t \neq 0)$$

where:

y_t = Equals the observed value at time t
$\hat{y}_t$ = Equals the estimated value
n = Equals the number of observations

Mean Square Error (MSE), computed as:

$$MSE = \frac{\sum_{t=1}^{n} |y_t - \hat{y}_t|^2}{n}$$

where:

y_t = Equals the observed value at time t
$\hat{y}_t$ = Equals the estimated value
n = Equals the number of observations bias, computed

$$Bias = \frac{\sum_{t=1}^{n} y_t - \hat{y}_t}{n}$$

where:

y_t = Equals the observed value at time t
$\hat{y}_t$ = Equals the estimated value
n = Equals the number of observations

ANN optimization: A 3-layer Neural Network was used and starting network weights and biases were randomly generated. Weekly age was used as input of network and the signal of the output node represent the hatchability. Thus, this network has 1 neurons in input layer and 1 neuron in output layer. The network performance was optimized for the number of neurons in the hidden layer (hnn), the learning rate (lr) of back-propagation, momentum and the epoch. As weights and biased are optimized by the back-propagation iterative procedure, training error typically decreases, but validation error 1st decreases and subsequently begins to rise again, revealing a progressive worsening of generalization ability of the network. Thus, training was stopped when the validation error reaches a minimum value.

RESULTS AND DISCUSSION

Table 1 lists the resulting training and validation data and their associated weeks of collection. It appeared that

Table 1: Training and validation sets of empirical and neural network model predicted values for percentage of weekly hatchability

Age (week)	Empirical	Predicted	Residuals	Relative error
Training sets				
28	76.9	76.878	-0.02	-0.03
30	84.8	84.987	0.19	0.22
31	86.3	86.306	0.01	0.01
32	87.7	87.250	-0.45	-0.51
33	87.3	86.939	-0.36	-0.41
34	86.9	86.986	0.08	0.09
35	86.7	86.977	0.28	0.32
36	86.4	86.889	0.49	0.57
37	86.2	86.616	0.41	0.48
38	86.1	86.161	0.06	0.07
40	85.9	85.701	-0.20	-0.23
42	85.6	85.674	0.07	0.08
44	86.1	85.781	-0.32	-0.37
45	85.8	85.811	0.01	0.01
47	85.3	85.625	0.32	0.37
49	84.1	83.863	-0.24	-0.28
51	81.9	82.118	0.22	0.27
52	81.0	80.917	-0.08	-0.10
54	78.4	78.165	-0.23	-0.29
55	77.4	77.689	0.29	0.37
57	75.5	75.346	-0.15	-0.20
58	73.2	73.313	0.11	0.15
59	71.8	72.011	0.21	0.29
60	71.1	70.647	-0.45	-0.63
61	68.1	68.450	0.35	0.51
62	66.5	66.356	-0.14	-0.21
64	61.2	61.215	0.01	0.02
Validation sets				
29	83.9	83.600	-0.30	-0.36
39	86.0	85.828	-0.17	-0.12
41	85.7	85.668	-0.03	-0.03
43	86.4	85.716	-0.68	-0.77
46	85.5	85.784	0.28	0.33
48	84.9	85.049	0.15	0.18
50	83.5	82.827	-0.67	-0.80
53	80.2	79.207	-0.99	-1.23
56	76.2	76.991	0.79	1.04
63	63.4	64.015	0.61	0.96

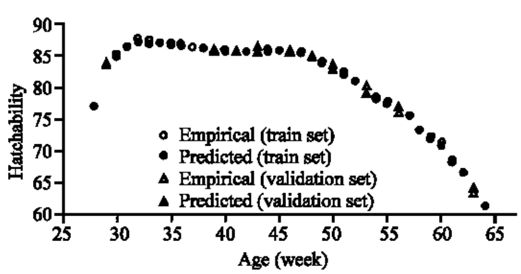

Fig. 1: Predicted hatchability values by Neural Network modeling vs. Age values for both training and validation sets

the ANN model is fitted into the hatchability of broiler breeder eggs and produced good validation values for the hatchability. We found that hatchability was increased from 28 weeks up to peak of hatchability at 32 weeks of age and decrease in post-peak hatchability is variable,

Table 2: Architecture, specification and statistic information of the neural network model

Measurments	Values
No. nodes in the input layer	1
No. nodes in the hidden layer	8
No. nodes in the output layer	1
Learning rate	0.5
Momentum	0.2
Epoch	15000
Transfer function	Sigmoid
R^2	0.9934
MSE	0.07
MAD	0.21
MAPE	0.26
Bias	0.02

MSE = Mean Square Error, R^2 = Squared regression coefficient, MAD = Mean Absolute Deviation, MAPE = Mean Absolute Percentage Error, Hidden nodes = Number of nodes are added to fit the Neural Network model

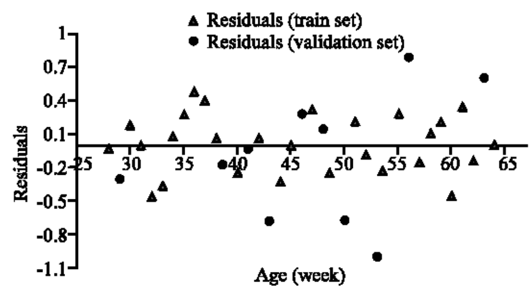

Fig. 2: Residual vs. Age values for both training and validation sets in Neural Network model

changing from gradual pace to a rapid decline at 47 weeks of age. This phenomenon, also reported by Mauldin (1989), but a rapid decline at observed at 49 weeks of age. The agreement observed between the predicted experimental values of hatchability in Fig. 1 and the random distribution of residuals about zero mean in Fig. 2 for both train and test sets confirm the good predictive ability of Neural Network modeling. Table 2 shows the statistics for the developed Neural Network. Forecasting error measurements based on the difference between the model and the observed values are shown. The advantages of Neural Networks as, there is no requirement for preselecting a model or basing the model entirely on the fit of the data, these models can efficiently and flexibly model different response surfaces with any accuracy given enough hidden nodes, Neural Networks models do not require the data meeting the assumptions that must otherwise be met in a regression model.

CONCLUSION

The results of overall calculated statistical values MSE, MAD, MAPE, bias and R^2 have shown that Neural Network may be used efficiently to provide the accurate fit to hatchability of broiler breeder eggs.

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