J I T A A
Journal of the Indonesian Tropical Animal Agriculture
Accredited by Ditjen Penguatan Risbang No. 60/E/KPT/2016

J. Indonesian Trop. Anim. Agric.
pISSN 2087-8273 eISSN 2460-6278
http://ejournal.undip.ac.id/index.php/jitaa
44(1):65-76, March 2019
DOI: 10.14710/jitaa.44.1.65-76

Modelling hatchability and mortality in muscovy ducks using automatic linear modelling and artificial neural network

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Received September 30, 2018; Accepted October 10, 2018

ABSTRAK

Penelitian ini dilakukan untuk memprediksi daya tetas dan mortalitas entok di Negara Bagian Nasarawa, Nigeria. Data diperoleh dari total 119 peternak itik. Penelitian ini menggunakan *automatic linear modelling* (ALM) dan *artificial neural network* (ANN). Rata-rata ukuran *flock* adalah 9,84 ± 0,60 per rumah tangga. Nilai rata-rata daya tetas yang diprediksi menggunakan ALM (8.66) dan JST (8.65) serupa dengan nilai yang diamati (8.66). Nilai rata-rata mortalitas yang diduga menggunakan ALM (2,95) dan ANN (3,03) sama dengan nilai yang diamati yang sebesar 2,95. Pengalaman dalam pemeliharaan itik, status pendidikan peternak, sumber stok dasar dan musim adalah variabel penting dalam pendugaan daya tetas menggunakan ALM dan ANN. Namun, pekerjaan utama, sumber stok dasar, pengalaman dalam pemeliharaan itik, pengelolaan lahan dan sistem manajemen adalah variabel penting yang secara otomatis terpilih untuk pendugaan mortalitas. Dugaan nilai sedang koefisien determinasi (R^2 = 0,422 vs 0,376) dan *adjusted* R^2 (0,417 vs 0,371) diperoleh untuk daya tetas dan mortalitas menggunakan ALM. Pola yang berbeda diperoleh pada ANN terkait dengan prediksi daya tetas (R^2 = 0,573 dan *adjusted* R^2 = 0,569) dan mortalitas (R^2 = 0,615 dan *adjusted* R2 = 0,612). Informasi ini dapat membantu keputusan manajemen dalam memperoleh daya tetas dan mortalitas yang lebih baik pada ternak entok.

Kata kunci: entok*, penampilan, neural network, regresi, Nigeria*

ABSTRACT

This study was embarked upon to predict hatchability and mortality rate of Muscovy ducks in Nasarawa State, Nigeria. Data were obtained from a total of 119 duck farmers. The automatic linear modelling (ALM) and artificial neural network (ANN) models were employed. The average flock size was 9.84±0.60 per household. The predicted hatchability mean values using ALM (8.66) and ANN (8.65) were similar to the observed value (8.66). The predicted mortality mean values using ALM (2.95) and ANN (3.03) were also similar to the observed value of 2.95. Experience in duck rearing, the educational status of farmers, source of foundation stock and season were the variables of importance in the prediction of hatchability using ALM and ANN models. However, primary occupation, source of foundation stock, experience in duck rearing, land holding and management system were the important variables automatically selected for the prediction of mortality. Moderate coefficients of determination (R^2 = 0.422 vs 0.376) and adjusted R^2 (0.417 vs 0.371) estimates were obtained for hatchability and mortality using ALM. Different patterns were obtained under the ANN models as regards the prediction of hatchability (R^2= 0.573 and adjusted R^2= 0.569) and mortality (R^2= 0.615 and adjusted R^2= 0.612). The present information may aid management decisions towards better hatchability and mortality performance in Muscovy ducks.

Kata kunci: Ducks, performance, neural network, regression, Nigeria

INTRODUCTION

In developing countries such as Nigeria, poultry production is largely managed under extensive free range or scavenging system, particular at villages and peri urban areas. Majority of the birds are reared at the rural level especially the indigenous stock, providing reservoir for the genetic conservation of the indigenous population. Poultry provide enormous opportunity to the rural poor from the generation of family income to employment opportunity (Yakubu, 2010; Yakubu *et al*., 2011; Johari *et al*., 2013). Lack of understanding of village poultry production system will normally impede design and implementation of poultry bird advancement program that will impact positively on the rural poor. It is pertinent to understand production system and constraint at this level in other to fashion policies that will enhance productivity of this system, thereby guaranteeing sustainable agriculture (Gómez *et al*., 2016).

Ducks ranked third among the various poultry species in Nigeria (Hassan and Mohammed, 2003), with population put at approximately 11 million and distribution cutting across all the agro-ecological zones of Nigeria particularly in village settings (NBS, 2012). In a section of the country, most farmers were found keeping Muscovy ducks on extensive sheds (Etuk *et al*., 2006). The advent of commercial fast-growing and egg-laying strains of chickens has relegated to the background the relevance and relative contribution of indigenous poultry species such as chicken, duck, guinea fowl and pigeon to the internal animal protein production in Nigeria. This trend has adversely impacted on duck production as exemplified in its remarkable reduced population and dearth of empirical studies directed towards management and genetic improvement of this waterfowl in Nigeria (Yakubu, 2013; Oguntunji, 2013; Oguntunji and Ayorinde, 2014). The dwindling reproductive performance and high mortality rates of Muscovy ducks is a major concern as farmers income and protein intake are drastically affected. This may in the long run negatively affect food security and livelihood of the farmers. Hence, the need to identify the factors influencing the performance of the birds at the village level with a view to mapping out appropriate strategies to boost production.

The artificial neural network (ANN) is an alternative to the traditional regression statistical technique and a potential tool in poultry production for the modelling of performance data. ANN is a non-linear parametric model that mimics the processing mechanism of the human brain. There is increasing use of this algorithm to predict hatchability (Bolzan *et al*., 2008), growth (Yakubu *et al*., 2018a) and egg production (Ahmad, 2011). It has also been used to model disease occurrence (Akil and Ahmad, 2016).

There is dearth of literature on the use of robust models to forecast reproductive and mortality performance in Muscovy ducks in Nigeria. Therefore, this study aimed at predicting the reproductive and mortality rates of Muscovy ducks from some social-economic factors of smallholder farmers and performance characteristics using different statistical algorithms.

MATERIALS AND METHODS

Description of Study Area

The study was carried out in Nasarawa State, North Central Nigeria. It is located within the guinea savannah agro-ecological zone and lies on latitudes 7° 52′ N and 8° 56′ N and longitudes 7° 25′ E and 9° 37′ E, respectively (Lyam, 2007). The three Senatorial Zones of Nasarawa South, Nasarawa North and Nasarawa West were covered.

Sampling Techniques

A total of 120 Muscovy duck farmers (40 per zone) were randomly sampled in selected villages of the study area, but data from 119 farmers were eventually used for analysis. Only farmers who were willing to participate in the exercise were interviewed.

Data Collection Techniques

Structured questionnaires were administered to the duck farmers including face-to-face interview. Information sought included the socio-economic characteristics of the respondents, livestock ownership, flock sizes and structure, productive and reproductive performance indices, mortality rate, knowledge on health and other management practices.

Statistical Analysis

The categorical (using Chi-square) and continuous variables (using Means±S.E.) were subjected to descriptive statistics. The relationship between the response variables (hatchability and mortality number; each handled singly) and predictor variables were established using Automatic Linear Modelling (ALM) and Artificial Neural Network (ANN) algorithms. The hatchability parameter fitted was number of eggs hatched while mortality was assessed in terms of number of birds that died.

Age of farmers, sex, marital status, educational background, primary occupation, experience in poultry keeping, management system, health management practices (veterinary access, veterinary category, use of herbs) season of highest hatchability, age at first lay, access to credit, personal savings in financial institution and land holding were the input predictor variables fitted into the ALM to estimate reproductive success. Similarly, mortality rate was predicted from age of farmers, sex, marital status, educational background, primary occupation, experience in poultry keeping, management system, health management practices (veterinary access, veterinary category, use of herbs) season of highest mortality, age at first lay, access to credit, personal savings in financial institution and land holding. In each case, all the variables that were nominal were assigned as factors while all variables that were continuous were treated as covariates. Every other step was as described by LaFaro *et al*. (2015) and adopted by Yakubu *et al*. (2018).

All the explanatory variables of importance under ALM were fitted into the ANN model to predict hatchability and mortality number, respectively as described by LaFaro *et al*. (2015). Multilayer Perception (MLP) with Back-Propagation network was used. The network was trained with 80% and tested (model validation) with 20% of the data set. Every other choice in the neural network was set to default (Yakubu *et al*., 2018a and b). SPSS (2015) was employed in both analyses.

RESULTS

The sex, marital status, education, primary occupation, access to credit and type of landholding varied significantly ($P \leq 0.05$; $P \leq 0.01$) among the duck farmers (Table 1). As regards the continuous variables, the average age of respondents, family size and experience in duck keeping (years) were 44.54, 8.49 and 5.02.

The mean flock size was 9.84 comprising adult males (1.85), adult females (2.63), male growers (1.48), female growers (1.36), male ducklings (1.27) and female ducklings (1.33) (Table 2). Source of foundation, management system, breeding control, access to veterinary services, veterinary services category and use of herbs were significantly influenced ($P \leq 0.01$) (Table 3).

The average age of ducks at first lay (months), clutch number per year, egg number in a clutch, brooding length (weeks), egg number hatched in a clutch and mortality rate per annum were 5.51, 2.84, 9.87, 4.68, 8.66 and 2.95, respectively (Table 4). While the highest hatchability was recorded in the wet season ($P \leq 0.01$), mortality rate was highest in the hot-dry season ($P \leq 0.01$).

The summary statistics of observed and predicted hatchability and mortality rate of Muscovy ducks are shown in Table 5. The predicted hatchability mean values using ALM (8.66) and ANN (8.65) were similar to the observed value (8.66). The Standard deviations were 1.80 (ALM), 2.12 (ANN) and 2.78 (observed), respectively. As regards mortality, the predicted mean values using ALM (2.95) and ANN (3.03) were also similar to the observed value of 2.95. The respective standard deviations were 1.72, 2.14 and 2.80.

In the ALM model, experience in duck rearing and the educational status of farmers were the two significant variables in the prediction of hatchability out of the four important parameters Table 6). In the ALM model, primary occupation, source of foundation stock, experience in duck rearing, land holding and management system were the five significant variables automatically selected for the prediction of mortality (Table 7).

In ANN model, experience in duck rearing (0.387), source of foundation stock (0.320), educational status (0.148) and season of hatchability (0.144) were the four parameters of utmost importance in the prediction of hatchability (Table 8).

Table 1. Socio Economic Characteristics of Muscovy Duck Keepers in Nasarawa State

Characteristics	No (%)	Chi-square	P-value
Categorical variables			
Sex			
Male	46 (38.7)		
Female	73 (61.3)	6.126	0.013*
Marital Status			
Single	5 (4.2)		
Married	114 (95.8)		
Widowed	0 (0.0)	99.840	0.01**
Education			
None	34 (28.6)		
Primary	29 (24.4)		
Secondary	44 (37.0)		
Tertiary	12 (10.1)	46.924	0.01**
Primary Occupation			
Livestock rearing	30 (25.2)		
Crop farming	32 (26. 9)		
Trading	44 (37.0)		
Artisan	12 (10.1)		
Civil Service	1 (0.8)	49.277	0.01**
Access to Credit			
No	18 (15.1)		
Yes	101 (84. 9)	57.891	0.01**
Personal savings			
No	59 (49.6)		
Yes	60 (50.4)	56.588	0. 927^{ns}
Type of landholding			
Individual ownership	44 (37.0)		
Communal farming system	2 (1.7)		
Rent	1 (0.8)		
Free occupation	72 (60.5)	120.496	0.01**
Continuous variables			
	Mean	Standard error	
Age of Respondent	44.54	0.94	
Household size	8. 49	0.30	
No of wives	1.36	0.09	
No of male children	3.35	0.16	
No of female children	2.50	0.18	
No of dependants	0.43	0.08	
Experience in duck keeping (years)	5.02	0.41	

** Significant at $P \leq 0.05$ and $P \leq 0.01$, respectively; ^{ns} Not significant

As regards the prediction of mortality using ANN, experience in duck rearing (0.422), primary occupation (0.315), source of foundation stock (0.125), land holding (0.082) and management system (0.057) were the five parameters of utmost importance (Table 9). The association between the observed and the predicted hatchability and mortality in form of a linear regression using ALM is shown in Figures 1 and 2. The correlation coefficients (r = 0.649 vs 0.613) were fairly high, while moderate coefficients of determination (R^2 = 0.422 vs 0.376) and Adjusted R^2 (0.417 vs 0.371) estimates were obtained for hatchability and mortality. The root mean square errors (RMSE) of 2.12150 and 2.22431 and akaike's information criterion corrected (AICC) values of

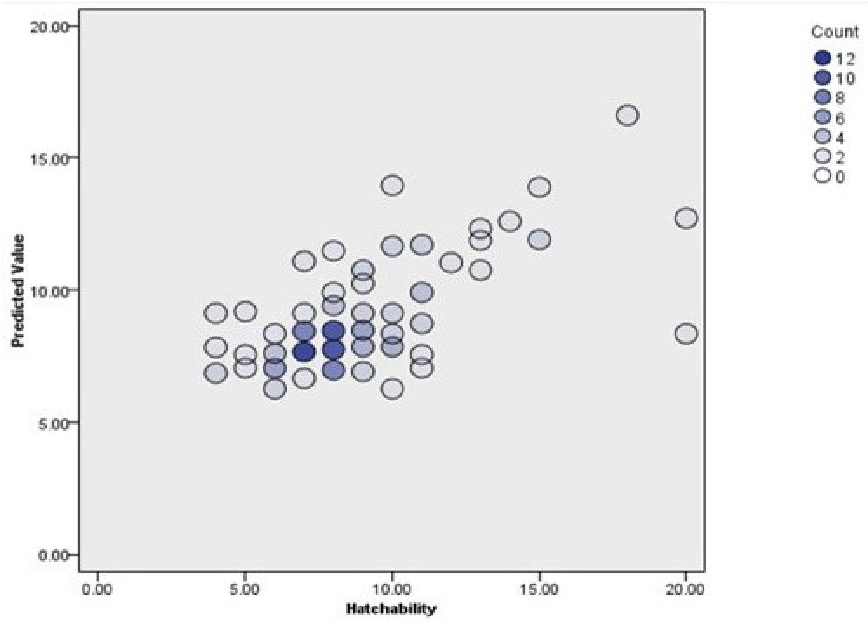

Figure 1. The Ccatter Plot of the Predicted and Observed Hatchability using ALM

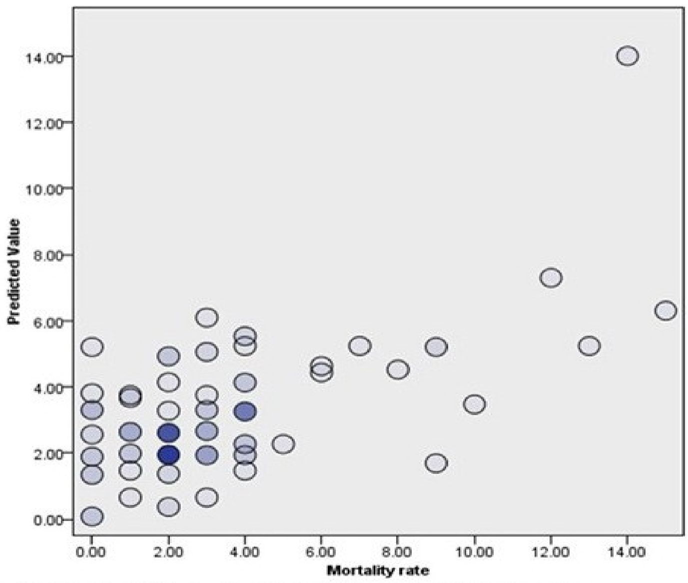

Figure 2. The Distribution Plot of the Predicted and Observed Mortality using ALM

187.519 and 203.261 for hatchability and mortality, respectively in the ALM models were very low.

Different patterns were obtained under the ANN models as regards the prediction of hatchability and mortality, where r =0.757 R^2= 0.573; Adjusted R^2= 0.569 and RMSE was 1.82357 (hatchability) (Figure 3); r =0.784 R^2= 0.615; Adjusted R^2= 0.612 and RMSE was 1.75277 (mortality) (Figure 4).

DISCUSSION

Muscovy duck is one of the meat-producing livestock (Susanti and Purba, 2017). The preponderance of women farmers agrees with the general assertion that smallholder poultry is to a large extent under the control of the women folks. The flock size obtained in the present study is

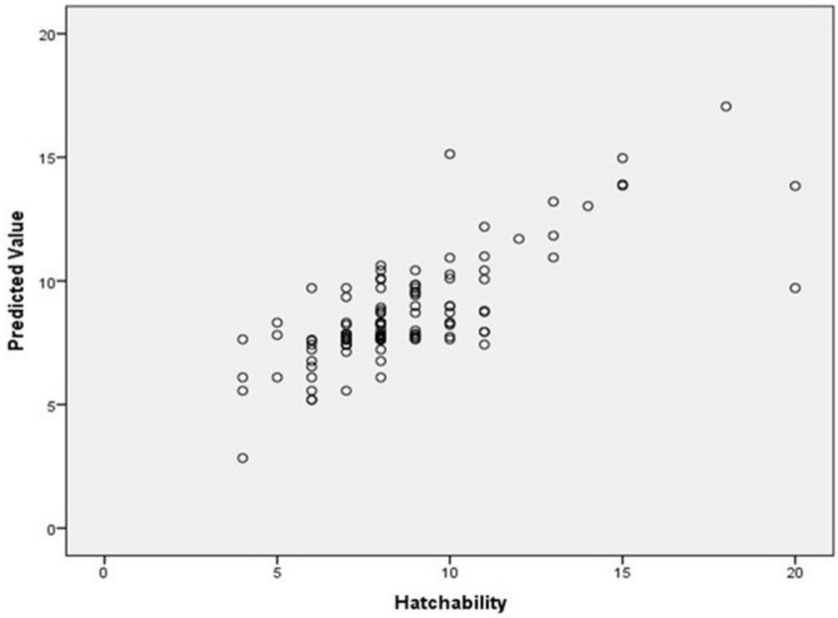

Figure 3. The Scatter Plot of Observed and Predicted Hatchability using ANN

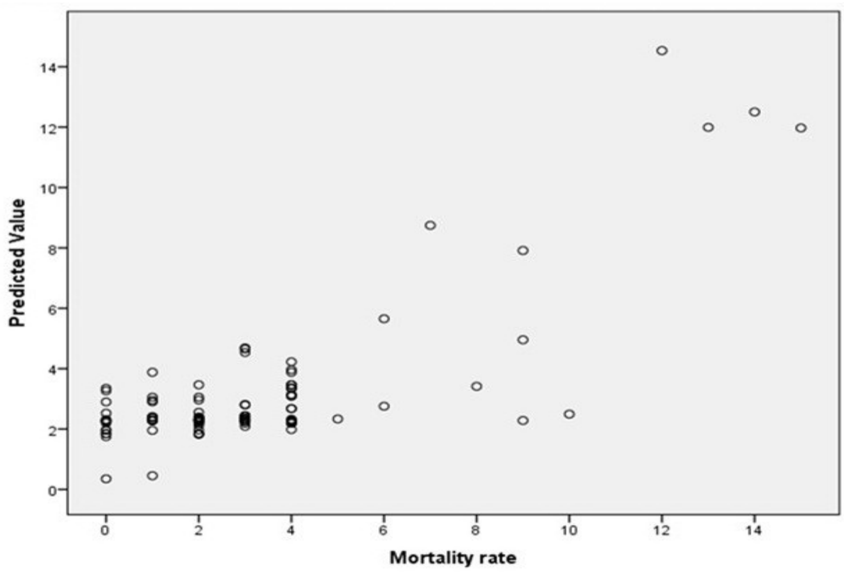

Figure 4. The Scatter Plot of Observed and Predicted Mortality Number using ANN

Table 2. Flock Structure of Muscovy Ducks Kept in Nasarawa State

Parameter	Minimum	Maximum	Mean	Standard error
Flock size	1.00	47.00	9.84	0.60
Adult males number	0.00	10.00	1.85	0.14
Adult females number	0.00	15.00	2.63	0.22
Growers male number	0.00	15.00	1.48	0.19
Growers female number	0.00	6.00	1.36	0.15
Male ducklings	0.00	7.00	1.27	0.18
Female ducklings	0.00	6.00	1.33	0.16

higher than the 7.7±3 ducks per unit reported by Banga-Mboko *et al*. (2011). The average eggs per clutch obtained in the current study appear low when compared with values reported by earlier researchers. Etuk *et al*. (2011) reported 16.23, 18.73 and 19, respectively as average eggs per clutch while values ranging from 16–20, 16.4, 16.28 and 18 were reported by Adeyemi *et al*. (2008), Nwanta *et al*. (2006), Ola (2000) and Chia and Momoh (2012), respectively. The difference between their findings and that of the current study may largely be attributed to genetic factor, varying management systems and the periods records were taken. However, there is need for improved management practices by farmers in Nasarawa State to guarantee higher egg production. The low number of farmers that use herbs to treat their ducks in the present study is an indication of poor knowledge on the use of ethnoveterinary medicine.

Muscovy duck represents a suitable model for hypothesis testing in breeding biology of waterfowl under natural incubation; reproductive consequences of eggs laid can best be assessed through the number of eggs hatched. The current findings are congruous to the findings of Oguntunji and Ayorinde where majority (44.5%) of the respondents indicated that female ducks underwent two reproductive cycles in a year. Muscovy ducks are very good setters, capable of hatching 12-15 duck eggs. The hatchability value of the present study (about 88%) appears higher than the values reported for between normal (76%) and dump nests (77%) genetically unselected variety of Muscovy duck in Mozambique (Harun *et al*., 1998), 70.7% and 69.7% reported by Widiyaningrum *et al*. (2016) and 54.21% reported by Rashid *et al.* (2009). Similar hatching rate above 80% with that of the current study has been reported (Oguntunji and Ayorinde, 2015).

The higher hatchability recorded in the wet season is an indication of the degree of environmental comfort experienced by birds. This is in consonance with the report of Widiyaningrum *et al*. (2016) that environmental factors such as temperature and humidity are important for successful hatching. Our observation, however, is contrary to the report of Boonprong (2000), where hatchability was highest in winter followed by summer and rainy season, respectively. Harsh environmental factors (e.g. temperature, humidity, turning etc.) might be causes of higher mortality in the hot-dry season as observed in the current study. Heat stress made birds to pant and could result in heat stroke and mortality. It has been reported that extremes temperatures could be experienced in the hot-dry season in North Central Nigeria (Yakubu *et al*., 2018a), thereby making the birds uncomfortable. Such heat stressed birds could experience high rate of mortality and morbidity (Nidamanuri *et al*., 2017). According to Shittu *et al*. (2014), hot-dry climatic environment is characterized by heat stress, inefficiency in the usage of feed and waning immunity, thereby leading to high mortality.

To the best of our knowledge, the present study appears as the first to predict hatchability and mortality rate of Muscovy ducks in Nigeria using robust algorithms such as ALM and ANN. Application of appropriate models to approximate the performance function warrants more precise prediction and helps to make the best decisions in the poultry industry. The better predictive ability of ANN in the present study could be as a result

Table 3. Management of Muscovy ducks Kept in Nasarawa State

Characteristics	No (%)	Chi-square	P-value
Categorical variables			
Source of Foundation Stock			
Inherited	13 (10. 9)		
Purchase from market	79 (66.4)		
Purchase from neighbor	25 (21.0)		
Borrowed	0 (0.0)		
Others	2 (1.7)	117.605	0.01**
Management system			
Semi-intensive	86 (72.3)		
Intensive	22 (18.5)		
Extensive	11 (9.2)	82.706	0.01**
Breeding Control			
No	118 (99.2)		
Yes	1 (0.8)	115.034	0.01**
Access to Vet			
No	60 (50.4)		
Yes	59 (49. 6)	0.008	0.927^{ns}
Vet Category			
Government Vet	20 (16.8)		
Private Vet	33 (27.7)	53.269	0.01**
Self medication	6 (5.0)		
Use of herbs			
Yes	7 (5. 9)		
No	112 (94.1)	92.647	0.01**
Continuous variables			
No of foundation stock	Mean 2.29	Standard error 0.11	

** Significant at P ≤ 0.01, respectively; ^{ns} Not significant

of its sensitivity to non-linear dynamics. Therefore, it could serves as a veritable means of forecasting incubation performance in Muscovy ducks. This is in consideration of its robustness in tackling noisy input data, high tolerance to faults and dimensionality problem and generalization from the input data. According to Bolzan *et al*. (2008), ANN model outperformed its multiple linear counterpart in the prediction of hatched eggs. Mehri (2013) reported ANN-based model with a better accuracy (R^2 = 0.99) than that obtained in the present study. However, the difference might be attributed to the use of egg main physical characteristics as input variables in the earlier study as against socio-economic factors in the present study. Chamsaz *et al*. (2011) reported that the ANN produced more accurate predictions of hatchability than the linear regression equation (R^2 = 0.9984 versus 0.4003). It is, therefore, possible to elucidate the performance variables of birds using ANN as it facilitates scientific and objective decision making including the simulations (Salle *et al*., 2003) of the consequences related to such decisions. When the current knowledge is applied to the present study, it could guide management decisions and strategies geared towards boosting production duck production. In a related study in

Table 4. Productivity Indices of Muscovy Ducks Kept in Nasarawa State

Parameter	Minimum	Maximum	Mean	Standard error
Continuous variables				
Age of duck at first lay (months)	4.00	9.00	5.51	0.07
Clutch number per year	2.00	3.00	2.84	0.03
Egg number in a clutch	5.00	22.00	9.87	0.26
Brooding length (weeks)	4.00	5.00	4.68	0.04
Egg number hatched in a clutch	4.00	20.00	8.66	0.25
Mortality rate per annum	0.00	15.00	2.95	0.26
Mortality male duckling	0.00	5.00	1.03	0.10
Mortality female duckling	0.00	5.00	0.79	0.10
Mortality grower male	0.00	4.00	0.37	0.07
Mortality grower female	0.00	3.00	0.31	0.06
Mortality adult male	0.00	3.00	0.26	0.05
Mortality adult female	0.00	4.00	0.34	0.06
Categorical variables				
	No (%)	Chi-square	P-value	
Season of highest hatchability				
Wet	117 (98.3)			
Hot-dry	2 (1.7)			
Harmatan	0 (0.0)	111.134	0.01**	
Season of highest mortality				
Wet	5 (4.2)			
Hot-dry	103 (86.6)			
Harmatan	11 (9.2)	152.134	0.01**	

Table 5. Descriptive Statistics of the Observed and Predicted Hatchability and Mortality Rates

Parameter	Minimum	Maximum	Mean	Standard deviation
Hatchability				
Observed	4.00	20.00	8.66	2.78
ALM Predicted	6.26	16.61	8.66	1.80
ANN Predicted	2.83	17.06	8.65	2.12
Mortality				
Observed	0.00	15.00	2.95	2.80
ALM Predicted	-0.11	14.00	2.95	1.72
ANN Predicted	0.35	14.53	3.03	2.14

Table 6. Fractional Importance of Some Variables to the Prediction of Hatchability using Automatic Linear Modelling

Model term	Coefficient	Significance (p-value)	Importance
Intercept	5.871	0.000	
Experience in duck rearing	0.392	0.000	0.724
Educational status	2.020	0.004	0.156
Source of foundation stock	0.903	0.059	0.067
Season of hatchability	2.652	0.094	0.053

Table 7. Fractional Importance of Some Variables to the Prediction of Mortality using Automatic Linear Modelling

Model term	Coefficient	Significance (p-value)	Importance
Intercept	0.898	0.273	
Primary occupation	10.336	0.000	0.395
Source of foundation stock	2.060	0.003	0.183
Experience in duck rearing	0.192	0.005	0.164
Land holding	-1.201	0.009	0.138
Management system	1.804	0.015	0.121

Table 8. The Importance of Independent Variables in the Prediction of Hatchability using Artificial Neural Network

Variables	Importance	Normalized importance (%)
Experience in duck rearing	0.387	100.0
Source of foundation stock	0.320	82.6
Educational status	0.148	38.3
Season of hatchability	0.144	37.3

humans, high accuracy was obtained in the prediction of mortality using ANN model (Shi *et al*., 2012) while ANN has also been used to detect chicken growth anomaly from mortality rate and feed conversion ratio (Purnomo *et al*., 2018).

CONCLUSION

The predicted hatchability and mortality mean values using both ALM and ANN algorithms were similar to their respective observed values. Considering the moderate to high variation explained by ANN and ALM models in the prediction of hatchability and mortality rates, they appear to be reliable. Therefore, the two models could be recommended as veritable tools for the prediction of hatchability and mortality rates in ducks. Such prediction will aid management decisions to improve flock size and the associated profitability of the farm.

Table 9. The Importance of Independent Variables in the Prediction of Hatchability using Artificial Neural Network

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