Regression model analysis of climatic effect on Mallard duck egg production in a tropical environment

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Abstract

The environmental component comprises myriads of biotic and abiotic factors exerting diverse degrees of effect on the well-being and performance of livestock. Principal among abiotic environmental factors is the meteorological indices. This study was carried out to investigate the relationship between the climatic variables {ambient temperature (AT), relative humidity (RH), rainfall (RF), and comfort index (CI)} and 12-month egg production of Mallard ducks using regression analyses. The egg production period (EPP) was divided into three (Phase 1: August-November; Phase 2: December-March and Phase 3: April-July). In addition, the production period was classified into two based on CI: EPPs 1 and 3 were classified as non-stressful production phases (NSPP) because of their higher CI while EPP 2 was classified as a stressful production phase (SPP) because of its lower CI. There was no significant (P>0.05) effect of EPP on egg production. However, egg production was highest in EPP 3, the most conducive EPP. The result of multiple regression analysis indicated that the synergistic effect (R^2) of meteorological elements (AT and RH) was high and contributed 96.71, 88.80 and 88.80%, respectively to the observed variance in egg production in EPP 1, EPP 2, and EPP 3. The beta coefficients of the two climatic variables indicated adverse relationships with egg production in EPP 2/SPP. This is suggestive of the need to monitor and artificially regulate the climatic indices for the optimum performance of Mallard ducks, most especially in stressful production periods.

Key words: Abiotic factors, Comfort index, Meteorological elements, stressful production phase

Running title: Climatic Effects on Mallard Duck Egg Production: A Regression Model Approach

Analyse du modèle de régression de l'effet climatique sur la production d'œufs de canard colvert dans un environnement tropical

Résumé

Le composant environnemental comprend une myriade de facteurs biotiques et abiotiques exerçant divers degrés d'effet sur le bien-être et la performance du bétail. Parmi les facteurs abiotiques de l'environnement, les indices météorologiques sont essentiels. Cette étude a été menée pour analyser la relation entre les variables climatiques {température ambiante (TA), humidité relative (HR), précipitations (PR) et indice de confort (IC)} et la production d'œufs de canards colverts sur une période de 12 mois en utilisant des analyses de régression. La période de production d'œufs (PPE) a été divisée en trois phases (Phase 1 : août-novembre ; Phase 2 : décembre-mars et Phase 3 : avril-juillet). De plus, la période de production a été classée en deux groupes selon l'IC : les PPE 1 et 3 ont été classées comme des phases de production non stressantes (PPNS) en raison de leur IC plus élevé, tandis que la PPE 2 a été classée comme une phase de production stressante (PPS) en raison de son IC plus faible. Il n'y a pas eu d'effet significatif (P>0,05) de la PPE sur la production d'œufs. Cependant, la production d'œufs était la plus élevée pendant la PPE 3, la phase de production la plus favorable. Le résultat de l'analyse de régression multiple a indiqué que l'effet synergique (R^2) des éléments météorologiques (TA et HR) était élevé et a contribué respectivement à 96,71 %, 88,80 % et 88,80 % de la variance observée dans la production d'œufs pour la PPE 1, la PPE 2 et la PPE 3. Les coefficients bêta des deux variables climatiques ont montré des relations négatives avec la production d'œufs lors de la PPE 2/PPS. Cela suggère la nécessité de surveiller et de réguler artificiellement les indices climatiques pour optimiser la performance des canards colverts, en particulier pendant les périodes de production stressantes.

Mots-clés : Facteurs abiotiques, Indice de confort, Éléments météorologiques, Phase de production stressante

Introduction

Poultry remains the most populous and most domesticated class of livestock in Nigeria, and are reared both at commercial and subsistence levels. It is worth mentioning that their high demand, ease of management, and low capital input compared to pigs and ruminants make them the choice of many livestock farmers. The general performance of livestock is a function of its inherent genetic and non-genetic (environmental) components. The environmental component comprises myriads of biotic and abiotic factors exerting diverse degrees of effect on the well-being and performance of livestock. Principal among abiotic environmental factors is the meteorological indices.

In a tropical environment, meteorological factors exert significant influence on domestic birds and the climatic factors mostly affecting poultry directly are high ambient temperature and high relative humidity (Ayo *et al*., 2011). These researchers stated further that meteorological elements constitute a complex system, which acts upon the body of domestic chickens and is jointly expressed as climate, that is, long-term average conditions, or weather. A recent report by Omede *et al*. (2018) corroborated this submission that climate may affect birds outside or inside the poultry houses, and their impact on birds may be beneficial or detrimental, depending on the extent of their variations. Among these meteorological indices, ambient temperature has been widely studied and its effects on poultry performance have been demonstrated in various studies (Fouad *et al*., *2016*; Varasteh *et al.*, 2016; Hirakawa *et al*., 2020; Gicheha, 2021).

Empirical studies have shown that reproductive factors such as sperm and ovary qualities, development of reproductive organs, quality of hatching, and laying performance were adversely affected by climatic conditions (Omede *et al*., 2018). For instance, in domestic laying ducks, Zhao *et al.* (2002) observed that the physiological function of laying ducks was altered by heat stress conditions as reflected in reduced feed intake and accelerated respiratory rate resulting in fewer eggs of inferior quality, higher mortality, and culling rates. Similarly, in a tropical environment, seasonal rise in ambient temperature (AT) has been shown to exert adverse effects on egg production of heat-stressed laying local Muscovy in Nigeria (Oguntunji *et al*., 2015).

Duck is one of the rarely exploited livestock in Nigeria despite the presence of a congenial environment for its husbandry across all agro-ecological zones and a readily available large market (Oguntunji and Ayorinde, 2015a). Information on breeds of duck kept in Nigeria revealed that the Muscovy duck popularly called the local duck was predominant (Oguntunji and Ayorinde, 2015b; Kadurumba *et al*., 2019; Kadurumba *et al.*, 2021). Nevertheless, the utility of this waterfowl has been limited by the throngs of taboos, myths, and superstitions despite its innate potential for egg and meat production (Oguntunji, 2014).

The advent of commercial fast-growing and egg-laying strains of chickens has relegated 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 (Oguntunji *et al*., 2015b). The Mallard duck (*Anas platyrhynchos*) is one of the breeds of common ducks in Nigeria and is endemic to Northern Nigeria where they are reared extensively alongside other livestock (Oguntunji et al., 2020). Though the breed is commonly referred to as an exotic breed; however, documented pieces of evidence on its introduction to Nigeria are lacking and there is a possibility that they were introduced to Nigeria before or during colonization by the Europeans (Oguntunji *et al*., 2020).

Though exotic ducks are found in Nigeria, their husbandry and utilization for nutritional and economic purposes are limited compared to the local Muscovy ducks (Oguntunji *et al*., 2021). It is worth emphasizing that efficient utilization of non-conventional animal genetic resources among which is the duck in addition to conventional ones is critical to filling the gap created by an inadequate supply of animal products. Empirical studies on relationships between meteorological indices and Mallard duck growth, breeding, adaptability, and reproduction in a tropical environment, and most especially in Nigeria are scanty. Given the foregoing, the present study was conducted to investigate the relationship of some climatic variables with the egg production of Mallard ducks in a humid tropical environment using regression analysis models.

Materials and Methods

Experimental Animals and Location of the Experiment

Ninety nine adult female Mallard ducks sourced from a reputable poultry market in Ibadan, Oyo State, Nigeria. The experimental stock originated in Northwest Nigeria and was brought for sale in southwest Nigeria. Besides, the experiment was conducted at a private farm in Iwo town, Osun State, Nigeria. The study area lies within the derived Savanna agro-ecological zone and the coordinate of the study area is Latitude 7° 38’ 6.97” N and Longitude 4° 10’ 53.62” E (Oguntunji et al., 2019).

Flock Management

The birds were managed intensively in deep litter on wood shavings and reared under natural daylight. They were fed commercial layers’ mash and provided clean water *ad libitum*. Furthermore, routine medications were administered against infection of pathogens and infestation of parasites.

Data Collection

The records of meteorological parameters: ambient temperature {AT (°C)}, relative humidity {RH(%)} and rainfall {RF(mm)} for the experimental period (August 2016 to July 2017) were collected from the Forest Research Institute of Nigeria (FRIN), Ibadan, Oyo State, Nigeria. Also, the egg production record of Mallard ducks was taken throughout the 12-month experimental period.

Besides, the egg production period was divided into three production phases on a 4-month basis as follows:

Egg production phase (EPP) 1: August 2016 to November 2016

Egg production phase (EPP) 2: December 2016 to March 2017

Egg production phase (EPP) 3: April 2017 to June 2017

In addition, the comfort index (CI), a parameter indicating how comfortable or stressful rearing environment is, was estimated as the ratio of RH to AT. The higher the CI value, the less stressful the rearing environment and vice versa. Based on the value of CI for the three egg production phases, the production phases were classified as the stressful production phase (SPP) and the non-stressful production phase (NSPP). Then, data of EPPs with higher CI (EPPs 1 and 3) were merged and designated as NSPP while EPP 2 with lower CI was classified as SPP.

Statistical analyses

Data collected were analysed with descriptive (mean and bar chart) and inferential (Student’s t-test and one-way analysis of variance) statistics. One way analysis of variance (Anova) was applied to test effect of egg production phase (EPP) on egg production, incidence of mortality and climatic variables with the following model:

$$Y_{ij} = U + A_i + e_{ij}$$

Where:

Y_{ij}= Individual observation

U= General mean

A_i= Fixed effect of egg production phase (i=1--------3) on egg production, meteorological variables (AT, RH, RF, CI) and mortality.

e_{ij}= experimental error assumed to be independently, identically and normally distributed, with zero mean and constant variance i.e. íínd (0, σ^2).

Duncan’s multiple range test (DMRT) was applied to separate the means at 5% probabilty level. In addition, effect of EPP on egg production, incidence of mortality, climatic elements (AT, RH and RF) and CI between NSPP and SPP was presented in bar chart and means compared using student’s t-test at 5% probability level.

Furthermore, linear and multiple regression analyses were applied to investigate the magnitude and direction of relationship between egg production and meteorological indices (AT and RH).The linear regression equation used was of the form:

$$Y = a + b_1X_1 + e$$

Where:

Y = Dependent variable (egg production)

a = Constant/intercept

b_1 = Regression coefficient of meteorological parameters (AT or RH)

X_1 = Independent variables (Ambient temperature or Relative humidity)

e = Error term

While the multiple regression analysis (MRA) model used was of the form:

$$Y = a + b_1X_1 + b_2X_2 + e$$

Where:

Y = Dependent variable (egg production)

a = Constant/intercept

b_1 = Regression coefficient of ambient temperature

b_2 = Regression coefficient of relative humidity
X_1 = Ambient temperature
X_2 = Relative humidity
e = Error term
All statistical analyses were carried out with SPSS (2001).

Results

Throughout the experimental period, there was no significant (P>0.05) effect of EPP on egg production (Table 1). However, highest number of egg was produced in EPP 3 (33.47%), intermediate in EPP 1 (29.28%) but least in EPP 2 (19.55%). In contrast, significant (P<0.05) effect of EPP was recorded for AT, RH, RF and CI (Table 1).

Table 1: Egg production and mortality records of Mallard ducks and meteorological indices

		Month	Egg Prod. (%)	Ambient Temp. (ºC)	Rel. Hum. (%)	Rainfall (mm)	CI	Mortality (%)
Egg Production Phase (EPP)	I	August	11.34	28.40	86.50	59.55	3.04	0.00
		September	22.03	30.10	92.00	209.50	3.06	0.00
		October	39.70	31.60	85.50	309.90	2.71	0.00
		November	44.04	32.90	75.50	75.60	2.29	0.00
		Mean	29.28	30.75	84.88	163.64	2.78	0.00
		(±SD)	$\pm15.29^{a}$	$\pm0.36^{b}$	$\pm6.87^{b}$	$\pm35.01^{ab}$	$\pm0.14^{b}$	$\pm0.00^{a}$
	II	December	35.00	34.20	59.00	0.00	1.73	0.00
		January	20.00	34.90	60.40	39.40	1.73	0.00
		February	15.01	34.90	58.50	9.40	1.68	0.00
		March	8.20	34.40	68.40	77.70	1.99	0.00
		Mean	19.55	34.60	61.58	31.63	1.78	0.00
		(±SD)	$\pm6.49^{a}$	$\pm2.69^{a}$	$\pm4.62^{a}$	$\pm35.01^{a}$	$\pm0.14^{a}$	$\pm0.00^{a}$
	III	April	40.22	32.00	75.30	70.60	2.35	0.00
		May	37.80	30.70	74.50	250.10	2.43	0.00
		June	28.50	28.70	80.30	250.10	2.80	0.00
		July	27.36	26.00	84.30	293.10	3.24	0.00
		Mean	33.47	29.65	78.60	215.98	2.71	0.00
		(±SD)	$\pm6.49^{a}$	$\pm2.61^{b}$	$\pm4.59^{b}$	$\pm99.01^{b}$	$\pm0.41^{b}$	$\pm0.00^{a}$

[ab] Means with different superscripts along the column are significantly (P<0.05) different;
Egg Prod.: Egg Production;
Ambient Temp: Ambient Temperature;
Rel. Hum.: Relative Humidity,
CI: Comfort Index

Furthermore, the results of regression analyses of dependent (egg production) and independent (AT and RH) variables in the three production phases were also presented in Table 2. Besides, the results of regression analyses of dependent (egg production) and independent (AT and RH) variables in the three production phases were also presented in Table 2.

Table 2. Regression models for egg production and meteorological indices.

	Model	Equation	R^2
EPP 1	1	$Y= -220.095 + 1.005X_1 + 0.031X_2$	96.71 NS
	2	$Y= -209.022 + 0.983X_1$	95.00 S
	3	$Y= 156.669 – 0.674X_2$	45.50 NS
EPP 2	4	$Y= 944.109 – 0.714X_1 - 0.891X_2$	88.80 NS
	5	$Y= 487.290 – 0.423X_1$	17.90 NS
	6	$Y= 119.361 – 0.658X_2$	43.30 NS

EPP 3	7	$Y = 53.758 + 0.465X_1 - 0.487X_2$	88.00 NS	no
	8	$Y = -34.472 + 0.932X_1$	86.90 NS	
	9	$Y = 137.270 - 0.933X_2$	87.10 S	

X_1=Ambient Temperature,
X_2 = Relative Humidity,
NS: Not Significant,
S: Significant,
R^2: Coefficient of determination
EPP: Egg production period

Generally, the values obtained for meteorological indices and CI in EPPs 1 and 3 were significantly ($P<0.05$) different from the values obtained in EPP 2. It is noteworthy that RH, RF and CI recorded least values in EPP 2 while AT had highest value in the same period compared to other EPPs. In addition, there was mortality throughout the laying period (Table 1) and no marked ($P>0.05$) effect of egg production phase was observed on mortality of laying Mallard ducks. The effect of EPP on the investigated parameters between SPP and NSPP was presented in Figure 1.

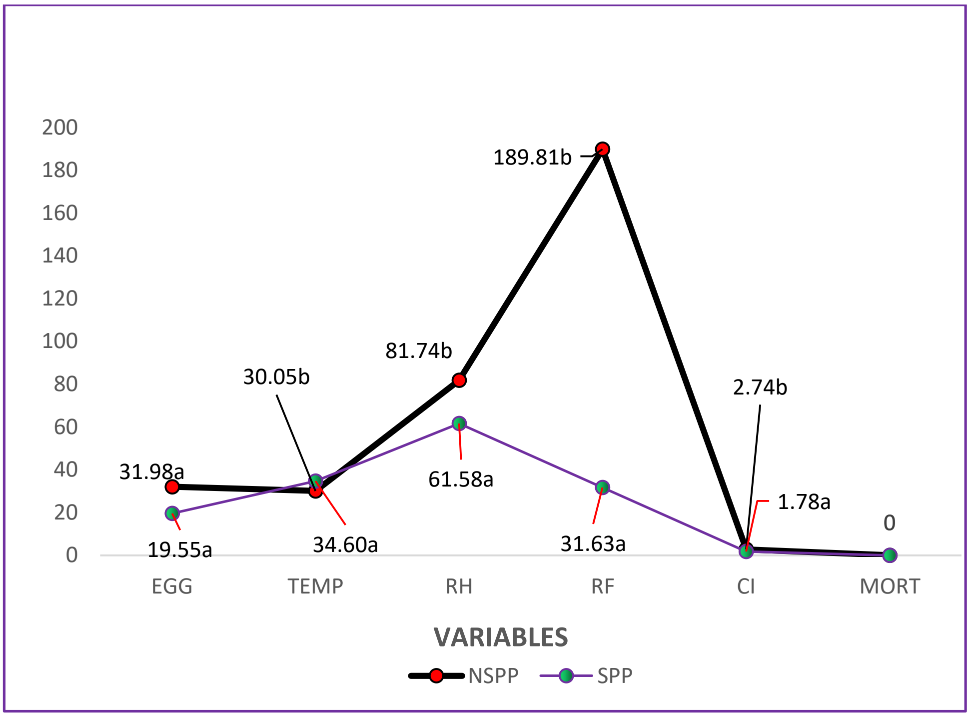

Figure 1: Production phase effect on performance and climatic variables
NSPP: Non-stressful production phases
SPP: Stressful production phases
TEMP: Temperature
RH: Relative humidity
RF: Rainfall
CI: Comfort index
MORT: Mortality

Discussion

To the best of knowledge of the authors, this is the first empirical study on modelling of egg production of Mallard ducks and meteorological parameters in Nigeria using regression analysis; hence, paucity of literature for critical comparison and validation of the results presented herein.

It is noteworthy that the average 12-month egg production of Mallard ducks (27.43%) in the present study was over 300% higher than the average 12-month egg production of local

Muscovy ducks (8.75%) in the same environment (Oguntunji et al., 2015) and in Guinea Savanna and Rain Forest ecotypes of Muscovy ducks in Nigeria (Ogah et al., 2011). The disparity in egg production of the Mallard duck and the related reports on Muscovy ducks might be attributed to genetic differences in the egg production potential of the two duck *genera*. This assertion was premised on the fact that though, Mallards were alien to the tropical environment and have not undergone either mild or intense selection for egg production; however, their superior egg production compared to Muscovy ducks in the same environment is a clear indication that they were genetically superior and more physiologically-equipped for egg production than local Muscovy ducks. This assertion was buttressed by the significantly bigger ovarian weight and higher follicle number reported or Mallard ducks compared to Muscovy ducks in a recent study in Nigeria (Oguntunji et al., 2021). These researchers indicated further that the bigger ovary and higher number of follicles are suggestive of superior reproductive performance in respect of egg production.

Another possible underlying factor could be linked to the absence of brooding instinct in Mallard ducks. It is a well-established fact that physiological mechanisms controlling oviposition are disrupted and ceased during incubation and brooding in avian species. It is instructive that while egg-laying mechanisms are impaired through incubation of eggs and brooding/rearing of ducklings by Muscovy ducks, the non-brooding Mallard ducks continue to lay eggs; hence, lower annual egg production by Muscovy ducks but higher egg production by Mallard ducks in the same period.

There was an increase in egg production throughout EPP 1 (Table 1). It was observed that egg production increased geometrically in the first three months. This could be as a result of conducive environmental conditions as exemplified in lower AT and higher RH, RF and CI compared to the stressful EPP 2.

The regression of egg production on climatic factors (AT and RH) in EPP 1 revealed that both meteorological indices impacted positively and had no adverse effect on egg production. However, a comparison of the relative contributions of the two climatic variables to egg production via their beta coefficients demonstrated that AT (1.005) contributed more than RH (0.031). This implies that the recorded AT range (28.40 - 32.90^{o}C) in EPP 1 exerted no adverse effect on egg production and was conducive for the optimum functioning of physiological mechanisms connected with egg production. Though RH had a positive relationship with egg production; however, its standardized coefficient was marginal and was about 32 times (1.005 vs 0.031) lower than the relative contribution of AT; hence, negligible effect on egg production in the period under investigation.

The higher relative contribution of AT to egg production in EPP 1 was corroborated by its significant ($P<0.05$) positive ($r = 0.983$) relationship with egg production and higher R^2 (95.00%) when egg production was regressed against AT. Conversely, the negligible contribution of RH could be adduced to its inverse (-0.674) relationship and lower R^2 (45.50%) when modelled as the only predicting variable of egg production.

It could be inferred that the relative contribution of the individual variable through simple linear and multiple regressions are indicative that AT was the principal climatic factor influencing egg production in this period. AT was so critical to egg production at this period possibly because RH was highest and the environment was too humid and detrimental to the well-being of ducks and egg production; hence, the positive mitigation role of AT via solar radiation.

Furthermore, the synergistic contribution of the two climatic factors to egg production was further demonstrated in the coefficient of determination (R^2). The higher R^2 value (96.71%) is indicative that the two independent predictors accounted for 96.71% of the variance in egg production while the remaining 3.29% was contributed by other biotic and abiotic factors not considered in the present study. The higher contribution (R^2) of the independent variables is suggestive that the two explanatory variables wield influence on egg production and indicative that adequate attention must be given to them to enhance higher egg production in EPP1.

Contrary to the trend of egg production in EPP 1, the monthly egg production was declining in each successful month in EPP 2. In fact, least monthly egg production was recorded in this period (March, 8.20%) (Table 1).The trend of egg production and meteorological indices records unequivocally demonstrated adverse influence of AT and RH on egg production. It is noteworthy that the least egg production in EPP 2 coincided with the most stressful production phase characterized with highest AT, least RH, RF and CI. It is noteworthy that despite adverse effects of climatic elements on egg production in this period, the average egg production in EPP 2 was higher than reported mean annual egg production of different populations of local Muscovy ducks in Nigeria (Ogah et al., 2011; Oguntunji et al., 2015). Besides, the least egg production recorded in this period was contrary to reproductive quiescence reported for local Muscovy ducks in the same environment in Nigeria (Oguntunji et al., 2015). This trend corroborates earlier assertion in this study that Mallard ducks are genetically-superior and more physiologically-equipped for egg production than local Nigerian Muscovy ducks.

Furthermore, it is evident from multiple regression analysis that the two climatic parameters had inverse relationships with egg production; thus, adversely affecting egg production in EPP 2. Though the regression equation showed that both predictors had inverse relationship with egg production; nevertheless, their regressions coefficients revealed that adverse effect of RH (0.891) was more pronounced than that of AT (0.714). The higher regression coefficient of RH shows that RH was the principal meteorological variable adversely affecting egg production in EPP 2.Moreover, separate investigations of relationship of independent variables with egg production through linear regression analyses reinforced result of multiple regression analyses that adverse effect of RH (r = -0.658; R^2= 43.30%) was more than that of AT (r = -0.423; R^2 = 17.90%). In addition, the synergistic effect (R^2) of the duo on egg production was higher (R^2=88.80%). This implies that both AT and RH were responsible for 88.80% of variation in egg production and jointly responsible for higher declined egg production during the period while the remaining percentage could be attributed to other variables not included in the study.

Egg production was highest in this period (EPP 3) and it is noteworthy that despite the ageing effect, the peak egg production coincided with the period characterized with least AT, intermediate RH and CI, and highest RF. This trend reveals an interplay effect of climatic elements on the egg production regulatory mechanisms of Mallard ducks. In addition, the spontaneous approximately 500% spike in egg production between the last month (March, 8.20%) in EPP 2 and the first month (April, 40.22%) in EPP 3 (Table 1) reflects the importance of prevailing conducive environmental conditions to egg production in Mallard ducks.

The result of multiple regression analysis indicated that AT and RH had a direct and inverse relationship with egg production, respectively. Nevertheless, the regression coefficients of the two independent variables showed that the relative contribution of AT (0.465) was lower than that of RH (-0.487). The direction of the relationship between independent and dependent variables as represented in multiple regression analysis was buttressed further through simple regression analyses where AT had a non-significant (P>0.05) positive relationship (r=0.932) and explained 86.90% of the variation in egg production in contrast to RH with significant (P<0.05) inverse (-0.933) relationship and accounted for 87.10% variation in egg production.

The positive impact of AT demonstrated that the range of AT (26.00 - 32.00°C) in this period was favourable and not detrimental to oviposition processes in Mallard ducks. However, its lower relative contribution compared to RH is suggestive that the range of AT at this period was lower and incapable of leveraging adverse effect of wet humid environment predicated by high RH and RF; hence, its lower positive contribution to egg production. In contrast, though the regression coefficient of RH was higher; however, its significant inverse relationship with egg production is suggestive that prevailing RH was sub-optimal and detrimental to the optimal egg production of Mallard ducks during the period under investigation.

In addition, the value of R^2 indicated that the two independent variables exerted influence on the egg production of Mallard ducks and were collectively responsible for 88.80% of the variation in egg production in the period under investigation while the remaining 11.20% was accounted for by the error terms and extraneous variables.

The superior numerical (P>0.05) egg production in NSPP characterized with significant (P<0.05) higher RH, CI, and RF but lower AT compared with SPP (Figure 1) is consistent with the highest egg production in wet and late rainy season reported by Oguntunji et al., (2015) on Nigerian Muscovy ducks. It is noteworthy that egg production in NSPP was about 38% higher than egg production in SPP (31.37 vs. 19.55%). The trend of egg production in NSPP result demonstrated that a conducive rearing environment is beneficial and enhances egg production; thus, underscoring the importance of a conducive rearing environment on egg production of Mallard duck. Conversely, the least egg production in SPP cum EPP 2 characterized with the highest AT and least RH, CI and RF were not unexpected. Livestock is confronted daily with a barrage of biotic and abiotic stressors with attendant immediate and long-term effects on their biological functions. Due to inherent diversity in their genetic makeup; differential responses to stimuli (ranging from mild to severe) have been observed among members of the same and different species, breeds, ecotypes, lines, and families.

Synthesis of genetic studies indicated that reproductive traits including egg production are lowly heritable in poultry (Bokat et al., 2014; Bal et al., 2019; Begli et al., 2019). This is indicative that the genetic component of its phenotypic variance was minimal while environmental contribution was ubiquitous and played a critical role in egg production. This is suggestive further that prevailing environmental condition is central to the optimum egg production of female poultry. Egg production in poultry involves a complex physiological mechanism modulated by the synergistic action of various reproductive hormones such as progesterone, follicle stimulating hormone, luteinizing hormone, and oestrogens. The complex physiological mechanism associated with egg production is a biological clock responsive not only to hormonal stimuli but also to changes in environmental conditions most especially climatic variables. Among meteorological indices, high ambient temperature has been shown as one of the major stressors affecting poultry production in a tropical environment, and abundant evidence shows that an adverse relationship exists between high ambient temperatures, plasma reproductive hormonal levels, and potency of reproductive hormones regulating egg production in female poultry (Oguntunji and Alabi, 2010).

Given the foregoing, it can be concluded that the attendant effect of high ambient temperature results in the poor physiological functioning of organs and mechanisms connected with the entire egg production process, via follicular recruitment and growth, ovulation, egg formation, shell formation, egg development, oviposition, and oviposition interval (Oguntunji and Alabi, 2010) contributed immensely to low egg production in heat-stressed female Mallard ducks; hence, lower egg production in stressful SPP (EPP 2) in contrast to higher egg production in NSPP (EPPs 1 and 3).

The absence of mortality throughout the laying period was similar to the report of Oguntunji et al., (2015) on Muscovy ducks reared in a similar environment but at variance with reports of similar studies in northern Nigeria where 20.00 and 24.14% mortality was reported respectively, for Guinea Savanna and Rain Forest ecotypes of laying Muscovy ducks (Ogah et al., 2011). Similarly, the reported absence of mortality throughout the laying period was contrary to the documented reports on commercial layers of chicken where the highest incidences of mortality were reported in wet (Olanrewaju et al., 2015; Akagha and Nwagbara, 2021) and dry (Shittu et al., 2014) season months in Nigeria.

Oguntunji et al. (2015) posited that absence of mortality throughout the laying period in Muscovy duck was a pointer to the fact that different physiological mechanisms were responsible for egg production and livability. This assertion may be an underlying factor responsible for no mortality throughout the laying period in Mallard ducks in the present study. Another possible reason for no mortality throughout the laying period could be attributed to the fact that Mallard ducks like Muscovy ducks have neither being selected nor improved for egg production in Nigeria in contrast to commercial egg layers which have undergone intense selection for egg production with attendant compromised immunocompetence; hence, lower mortality rate in non-selected laying Mallard and Muscovy ducks but higher incidence of mortality in commercial layers. Mallard ducks are exotic ducks and were expected to be more susceptible to the adverse environmental factors most especially stressful climatic conditions of tropical environments. However, absence of mortality most especially during the hot late dry season months in EPP 2 is indicative of their adaptability to the hot humid tropical environment and resilience to the prevailing climatic stressors during the laying period.

Conclusion

The trend of egg production record in the present study is suggestive of the innate potential of Mallard ducks for egg production. It is evident that prevailing meteorological elements exerted influence on the egg production of Mallard ducks; hence, adequate measures must be put in place to regulate climatic elements to enhance the optimal physiological functioning of the egg production regulatory mechanism of Mallard. In view of this, the adverse effect of environmental factors, most especially AT needed to be controlled for optimum egg production of this waterfowl in a hot tropical environment.

Conflict of interest

There is no conflict of interest.

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