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***Research Paper***

# Effect of changes in climatic variables on poultry egg production in Nigeria

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## ABSTRACT

This study examined the effect of changes in climatic variables on poultry egg production in Nigeria using past data from 1963 to 2022. The study employed multiple regression analysis and descriptive statistics to meet its objectives. The study found a marginal increase in the trends of relative humidity, rainfall, temperature, and poultry egg production over the years. The regression analysis showed that the $R^2$ value indicated that 72% of the variation in poultry egg production could be explained by changes in relative humidity, rainfall, and temperature. Specifically, relative humidity (-2.91; $p < 5\%$) and temperature (-27.9; $p < 1\%$) had significant negative effects on egg production, while rainfall (1.31; $p < 1\%$) had a significant positive effect. The study recommended that poultry farmers should adopt temperature management strategies, especially during periods of extreme heat, to reduce the adverse impact of high temperatures on egg production.

***Keywords**:* Rainfall, Temperature, Relative humidity, Egg production, Poultry, Nigeria

Nigeria like many other emerging nations is facing serious food shortages and more so with protein content, and thus the necessity to enhance the output of protein sources of which poultry is part of them. Poultry include chickens, turkeys, ducks, geese, guinea fowls, quail birds kept for meat and eggs (Istiak and Khaliduzzaman, 2022). *Gallus gallus* chicken is the most commonly reared of the birds because about 70% of those keeping poultry in Nigeria are reported to keep chicken (Kokoszyński, 2017). Broilers are chicken bred and kept primarily for meat while layers are kept primarily for eggs production and by implication a source of protein. Poultry egg production in large scale capacity began in Nigeria in the early 1960s. Ever since then it has assumed comparatively a crucial position in the livestock industry of the country (Wasti *et al.,* 2020).

Birds require more energy (feed) when the ambient temperature is high compared to when they are in thermo-neutral surroundings. A less effective feed to meat conversion causes significant losses and negatively affects the production and health of poultry (Olanrewaju *et al.,* 2010; Livingston *et al*., 2022). Poultry birds require feed with more energy when the environment is warm compared to when it is cold (Olanrewaju *et al.,* 2010). This is because there is a range of thermal parameters in which animals are able to maintain a generally steady body temperature in their physiological and behavioural activities, poultry flocks are susceptible to variations in climate. Birds can only maintain their peak levels of production for human consumption in a small temperature range of 11° to 26°C, therefore any unpredicted climatic changes will cause a sequence of changes in livestock and poultry birds in their struggle for survival (Nyoni *et al.,* 2022). Various thermal discomfort and bioclimatic indices have been used to characterise the comfort and discomfort level in India (Pandey, 2018; Saha *et al.,* 2016)

Several studies have examined the broader implications of climate change on agriculture in Nigeria. For instance, research by Ayanlade *et al.,* (2017) highlighted the vulnerability of Nigerian agriculture to climate variability and identified temperature changes and rainfall variability as key factors affecting agricultural productivity. Similarly, Idumah *et al.,* (2016) explored the impact of climate change on food production and food security in Nigeria, emphasizing the need for adaptive strategies to mitigate adverse effects. Despite these contributions, there exists a notable gap in the literature regarding the specific relationship between changes in climatic variables and poultry egg production in Nigeria. While

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studies such as Getabalew and Negash (2020) have investigated the effect of high temperature on body weight gain, egg production and egg shell formation process in laying hen, comprehensive research focusing on the combined impact of temperature, humidity, rainfall patterns, and extreme weather events on egg production remains limited.

Moreover, existing studies often provide conflicting or inconclusive findings regarding the precise nature and magnitude of climatic influences on poultry egg production. For example, research by Ghoname *et al.,* (2022) suggested that increased temperatures could lead to decreased egg production due to heat stress, while other studies, such as Oguntunji and Alabi (2010) indicated a more complex interplay of climatic factors affecting egg yield. This gap in knowledge hinders the development of targeted adaptation and mitigation strategies for the Nigerian poultry industry. Without a comprehensive understanding of how specific climatic variables impact egg production, stakeholders face challenges in implementing effective measures to enhance resilience and sustainability. Therefore, this study aims to address the gap in the literature by conducting a systematic analysis of the effect of changes in climatic variables on poultry egg production in Nigeria.

### *Hypothesis of the study*

**$HO_1$:** There is no significant effect of climate change variables on poultry egg production in Nigeria.

## MATERIALS AND METHODS

### *Study area and data analysis*

The study was carried out in the Federal Republic of Nigeria, which lies between latitudes 4°N and 14°N of the equator and longitudes 3°E and 15°E of the Greenwich meridian. The study's time series data, which spanned 60 years (1963–2022), were gathered from World Bank statistical data, FAOSTAT (FAO, 2023) and yearly reports from the Central Bank of Nigeria (CBN). Data on Nigeria's yearly temperature, relative humidity and rainfall were gathered. The mean annual temperature, mean annual relative humidity, and mean annual rainfall changes in Nigeria from 1963 to 2022 were all described using descriptive statistics. The effect of changing climate factors on the production of chicken eggs was ascertained by the application of multiple regression analysis.

### *Unit root test*

The analysis started with a stationarity test to check if the variables were stationary and if the model specification was appropriate. The regression equation for testing stationarity, as outlined by Oyita and Otuisi (2023), is as follows:

$$\Delta \ln Egg = \alpha_0 + \sum_{t-1}^{p} \alpha_1 \Delta \ln RFL_{t-1} + \sum_{t-1}^{p} \alpha_2 \Delta \ln TEMP_{t-1} + \sum_{t-1}^{p} \alpha_3 \Delta \ln RH_{t-1} + \beta_1 \ln RFL_{t-1} + \beta_2 \ln TEMP_{t-1} + \beta_3 \ln RH_{t-1} + U_t \quad \ldots 1$$

The presence of unit root problem or non-stationarity was accessed through hypothesis as follows:

H0: $\alpha_1 = \alpha_2 = \alpha_3 = 0$ (the time series Egg is non-stationary or has a unit root)

Ha: $\alpha_1<0$, $\alpha_2<0$, $\alpha_3<0$ (the time series Egg is stationary or has no unit root)

Where:

$\alpha_0$= constant term, $U_t$ =white noise, $\alpha_1$- $\alpha_3$ = coefficients of the first difference variables, $\beta_1$- $\beta_3$ = coefficients of the explanatory variables, p = lag length, Egg = Egg production (metric tonnes), RFL = Mean annual rainfall (millimetres), TEMP = Mean annual temperature (°C), and RH = Mean annual relative humidity (percentage %).

### *Test for co-integration*

To determine the long-run relationship between the variables, the Johansen maximum likelihood co-integration test was performed. As explained by Oyita and Otuisi (2023), co-integration identifies long-run equilibrium between variables, this is shown below:

$$\Delta lnEgg_t = \alpha_0 + \beta_1 lnRFL_{t-1} + \beta_2 lnTEMP_{t-1} + \beta_3 lnRH_{t-1} + u_t \quad \ldots\ldots\ldots 2$$

### *Multiple regression model*

The multiple regression model is as specified below:

$$Egg_t = f(RFL_t, TEMP_t, RH_t) \ldots\ldots\ldots\ldots 3$$

Where:

f = functional form, Egg = Egg output (metric tonnes) in time t, RFL = Rainfall (millimetres) in time t, TEMP = Temperature (°C) in time t, and RH = Relative humidity (percentage %) in time t

The regression model can further be specified in linear form as follows:

$$Egg_t = \beta_0 + \beta_1 RFL_t + \beta_2 TEMP_t + \beta_3 RH_t + U \ldots\ldots\ldots\ldots 4$$

Where:

t = lagged variable, $\beta_0$ = constant, $\beta_1$, $\beta_2$, $\beta_3$ = coefficients, and U = error term

Note: Linear regression model was used for the analysis due to some of the negative values of the time series data after taking their first differences.

## RESULTS AND DISCUSSIONS

### *Descriptive statistics*

The result in Table 1 shows the summary of the descriptive statistics of the dependent and independent variables. The mean, which shows the average value for each data series for dependent variable (egg production) was 340,873 tonnes for the period under review. The independent variables which are the climate variables (mean annual rainfall, mean annual temperature and mean annual relative humidity) had mean values of 1151.3mm, 27.1°C and 57.6% respectively. The minimum value of egg production was 75,000 tonnes while the maximum value was 660000 tonnes. The minimum and maximum values of number of mean annual rainfall

**Table 1:** Descriptive statistics

| Statistics | Egg production (tonnes) | Temperature (°C) | Relative humidity (%) | Rainfall (mm) |
|---|---|---|---|---|
| Mean | 340873 | 27.1 | 57.6 | 1151.3 |
| Median | 302500 | 27.1 | 57.4 | 1157.9 |
| Max | 660000 | 27.9 | 61.8 | 1335.3 |
| Min | 75000 | 26.3 | 54.0 | 872.0 |
| Std. Dev. | 201660 | 0.393 | 1.51 | 89.1 |
| Jarque-Bera | 5.22 | 1.44 | 0.883 | 2.15 |
| Prob. | 0.074 | 0.484 | 0.643 | 0.341 |
| Observations | 60 | 60 | 60 | 60 |

**Table 2:** Unit root test

| Variable | Level difference | Prob | First diff | prob | Order of integration |
|---|---|---|---|---|---|
| Egg production | -0.246 | 0.926 | -7.38 | 0.000 | I(1) |
| Rainfall | -5.64 | 0.000 | -12.8 | 0.000 | I(1) |
| Temperature | -1.37 | 0.589 | -11.5 | 0.000 | I(1) |
| Relative humidity | -7.08 | 0.000 | -14.0 | 0.000 | I(1) |

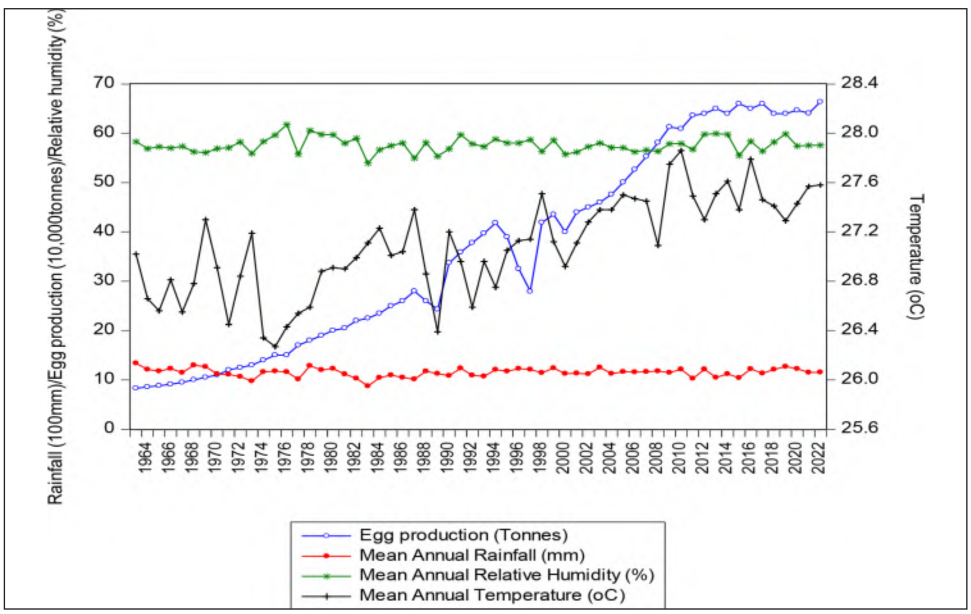


**Fig 1:** Trend of climatic variables and egg production in Nigeria.

were 1335.3mm and 872.0mm respectively. The minimum value of mean annual temperature was 26.3°C while the maximum was 27.9°C. Mean annual relative humidity had a minimum value of 54.0% while the maximum value was 61.8%.

### *Trend of climatic variables and egg production*

The result in Fig. 1 shows a clear increasing trend in average annual temperatures in Nigeria over the past six decades. Temperatures have risen from around 27°C in the 1960s to nearly 27.6°C in recent years like 2021 and 2022. This aligns with global warming patterns observed worldwide due to rising greenhouse gas emissions and climate change (IPCC, 2021). In contrast to temperature, there is no obvious long-term trend in annual rainfall levels or relative humidity for Nigeria during this period. Rainfall fluctuates between 800-1300 mm, while relative humidity varies within the 55-60% range for most years. While excessive rainfall and humidity can increase disease risks and degrade poultry house conditions, moderate levels are generally beneficial for maintaining ambient temperatures suitable for egg production (Oguntunji and Alabi, 2010; Cheng *et al.,* 2022).

Despite the rising temperatures, egg production in Nigeria has increased tremendously, growing nearly 8-fold from 83,000

**Table 3:** Lag order selection criteria

| Lag | LogL | LR test | Final prediction error | Akaike information criterion | Schwarz information criterion | Hannan-Quinn information criterion |
|---|---|---|---|---|---|---|
| 0 | 511.5 | NA | 1.58e-13 | -18.1 | -18.0 | -18.1 |
| 1 | 644.6 | 242.5* | 2.42e-15* | -22.3* | -21.6* | -22.0* |
| 2 | 653.0 | 14.1 | 3.20e-15 | -22.0 | -20.7 | -21.5 |
| 3 | 667.4 | 22.2 | 3.46e-15 | -22.0 | -20.1 | -21.3 |
| 4 | 677.7 | 14.4 | 4.44e-15 | -21.8 | -19.3 | -20.8 |

* Indicates lag order selected by the criterion; Number of observations: 56

**Table 4:** Cointegration test

| No. of CE(s) | Eigenvalue | Statistic | Critical Value | Prob. |
|---|---|---|---|---|
| None * | 0.409 | 61.1 | 47.9 | 0.002 |
| At most 1 * | 0.261 | 31.1 | 29.8 | 0.035 |
| At most 2 | 0.183 | 13.9 | 15.5 | 0.086 |
| At most 3 | 0.041 | 2.40 | 3.84 | 0.121 |

Trace test indicates 2 cointegrating eqn (s) at the 0.05 level

**Table 5:** Regression analysis between egg production and climatic variables

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| Relative humidity (%) | -2.91** | 1.13 | -2.56 | 0.039 |
| Rainfall (mm) | 1.31*** | 0.38 | 3.46 | 0.003 |
| Temperature (°C) | -27.9*** | 3.73 | -7.46 | 0.000 |
| Error correction model | -0.673*** | 0.119 | -5.65 | 0.000 |
| Constant | -35.6 | 6.93 | -5.13 | 0.000 |
| R-squared | 0.724 | F-statistic | | 35.4 |
| Adjusted R-squared | 0.703 | Durbin-Watson stat | | 1.84 |

Where *** and ** are significant at 1% and 5% respectively

tonnes in 1963 to 663,609 tonnes in 2022. This rise in poultry egg production may be as a result of the quest to meet the protein demand of the ever-growing global population. This suggests that the government's numerous initiatives and programmes to increase chicken production had a major and favourable influence. This result is in line with the report of Akpan and Nkanta (2022) who stated that in Nigeria, egg production has a favourable relationship with time. This implies that when the time factor increases, egg production also rises.

***Unit root test***

The variables in this study were subjected to Unit Root Tests, the Augmented Dickey-Fuller (ADF) Test was performed in order to ascertain their stationarity and order of integration properties for the annual data on the variables for the period of 1963-2022. The result presented in Table 2 shows that all the variables are integrated of order 1 (first difference).

***Lag order selection criteria***

The result of the selected lag order by the criterion is shown in Table 3. In this model, the lag order selected was Lag 1, due to all selection criteria showing significant 5% levels of probability at Lag 1.

***Cointegration test***

The results in Table 4 indicate that the null hypothesis (H0) of no co-integrating equation is rejected, with at least one co-integrating equation found at the 5% significance level.

***Regression analysis***

The effect of rainfall, relative humidity and temperature on poultry egg production in Nigeria is presented in Table 5. The $R^2$ which is the coefficient of determination and the goodness of fit test suggest that 72% of the total variation on changes in the poultry egg production has been explained by the relative humidity, rainfall and temperature all combined together. The coefficient for relative humidity in the regression analysis is -2.91, indicating a negative relationship with egg production. This negative coefficient suggests that an increase in relative humidity by one unit (holding other variables constant) is associated with a decrease of approximately 2.91 units in egg production. According to Kim *et al.,* (2020), high levels of relative humidity can contribute to elevated heat stress conditions for laying hens, especially when combined with high temperatures. Excessive humidity reduces the effectiveness of evaporative cooling mechanisms in birds, leading to thermal discomfort and decreased feed intake, both of which can adversely affect egg production. Poultry exposed to prolonged periods of high humidity may exhibit physiological responses such as panting and reduced activity, further impacting their productivity. The statistical significance of the relative humidity coefficient, as indicated by the t-statistic of -2.56 with a probability value of 0.038 at the 5% level, highlights the importance of considering humidity levels in poultry management practices. Strategies to mitigate the negative effects of high humidity on egg production may include improved ventilation systems, humidity control measures, and optimizing housing conditions to maintain comfortable microenvironments for laying hens (Lawniczek-Walczyk *et al.,* 2013). Studies by Cheng *et al.,* (2022) support these findings, demonstrating that elevated humidity levels, particularly in humid tropical environments, can worsen heat stress in poultry, leading to reduced egg production and compromised bird welfare.

The coefficient for rainfall in the regression analysis is 1.31, indicating a statistically significant positive relationship with egg production in Nigeria. This coefficient suggests that for every one-unit increase in rainfall (holding other variables constant), there is an associated increase of approximately 1.31 units in egg production. The t-statistic of 3.46 with a probability value of 0.003 further confirms the statistical significance of this relationship at the

1% level. This result is in line with that of Abioja *et al.,* (2020) who reported that rainfall patterns can influence environmental conditions within poultry housing facilities. Proper drainage and moisture management are essential to prevent waterlogging, dampness, and bacterial growth, all of which can negatively impact poultry health and egg production. Balanced moisture levels in the environment contribute to a comfortable and hygienic setting for laying hens, fostering optimal egg-laying behaviour (Abioja *et al.,* 2020). The observed positive relationship between rainfall and egg production emphasises the importance of climate-sensitive poultry management practices. The findings of this study is also in agreement with the findings of Alade and Ademola (2013) who stated that rainfall has a positive effect on the level of poultry egg output. Poultry farmers in Nigeria can leverage weather forecasting tools and seasonal rainfall predictions to optimize feeding schedules, manage water resources efficiently, and implement appropriate housing and environmental control measures. These strategies enhance resilience to climatic variability and contribute to sustained egg production levels, thereby supporting the long-term viability and profitability of the poultry industry.

The coefficient for temperature in the regression analysis is -27.9 (p-value<1%), indicating a significant negative relationship between temperature and egg production in Nigeria. This implies that 1% increase in temperature will lead to a corresponding 27.9% decrease in poultry egg production due to heat lower feed consumption. This result supports the findings of Abidin and Khatoon (2013) who stated that feed intake of a laying hen decreased by 1.5g a day for every degree centigrade rise in temperature above 30$^{o}$C, decreased egg output by about one egg per bird a year for every degree rise in temperature above 25-30$^{o}$C. Abidin and Khatoon (2013) further reported that the depressive effect of environmental temperature by heat stress significantly increases water consumption, reduces egg output, egg weight, shell weight, shell thickness causing a significantly higher production of shellers or very thin-shelled eggs. Biswal *et al.,* (2022) reported that the elevated temperature over the years has been affecting poultry production systems through reduced growth and egg production all over the world. El-Hack *et al.,* (2018) also opined that high temperature also results to a reduction in poultry live weight, growth speed and high mortality in addition to a decrease on productivity and quality of the eggs. This finding also aligns with existing research that highlights the significant impact of temperature on poultry performance, particularly egg-laying hens.

The error correction model (ECM) produced a positive estimate (coefficient = -0.673; p<0.01) and was statistically significant at 1 percent level of probability. This suggests the validity of long run equilibrium relationship among the variables of the estimated model. The implication of the coefficient of the ECM is that short run disequilibrium in egg production behaviour is corrected at a speed of approximately 67.3% per annum.

***Test of hypothesis***

Relative humidity, rainfall and temperature were statistically significant in the model. Therefore, the null hypothesis which stated that there is no significant effect of climate change variables on poultry egg production in Nigeria is hereby rejected.

The Breusch-Godfrey Serial Correlation LM Test showed an F-statistic of 0.267 and an observed R-squared value of 0.601, and p-values greater than 5% significance level at p > 0.5. The Breusch-Godfrey test results show that there is no serial correlation in the model, which means that the regression estimates are robust and efficient with respect to analytical and predictive goals. The Breusch-Pagan-Godfrey test of heteroskedasticity revealed an F-statistic of 0.658 and an observed R-squared value of 2.74, where the p-values were greater than the 5% significance level, p > 0.5. Thereby, it implies that the null hypothesis of homoscedasticity cannot be rejected. This further indicated the general validity of the regression estimates and following predictions.

## CONCLUSION

The study showed a nuanced relationship between climatic factors and egg production, with higher relative humidity levels correlating with decreased egg output while increased rainfall positively affects egg production. Conversely, elevated temperatures have a detrimental effect on egg production, emphasizing the importance of effective heat stress management strategies in poultry farming. These findings emphasise the complex interaction between environmental conditions and poultry productivity, highlighting the importance of climate-resilient strategies and tailored interventions to enhance the sustainability and efficiency of egg production in poultry industry in Nigeria amidst changing climatic conditions. The study recommended that;

i. Poultry farmers should implement robust temperature management strategies, especially during periods of extreme heat, to mitigate the negative impact of high temperatures on egg production.

ii. Farm managers should monitor and control humidity levels within poultry facilities to prevent excessive moisture and humidity-related stress on birds.

iii. Government authorities should develop and enforce policies that support climate-resilient agriculture, providing incentives for poultry farmers to adopt sustainable practices and climate-smart technologies.

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***Authors contribution:*** **L.B.E. Otuisi**: Conceptualization, Methodology; **G.E Oyita**: Formal analysis, Writing original draft; **V.U. Ikenga**: Data curation, supervision.

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