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Research Article
Optimum Broiler Breeders' Age for Production Performance, Internal Egg Characteristics and 7 Day Mortality of Chicks

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Abstract

Background and Objective: Breeder age strongly influences egg weight, as well as egg quality and composition, however, literature on the optimal age that influences such are scarce. This study was therefore carried out to understand the optimum age of breeder broilers (Ross 308 strains) for enhanced production, internal egg performance and 7 day mortality of chicks using regression models. **Materials and Methods:** A total of 1188 sexed breeder broiler chicks comprising of 117 males and 1071 females (1:10 ratio) were randomly assigned to pens of 3 treatment groups for this experiment, all reared to maturity. The production, internal egg performance and 7 day mortality parameters measurements were taken at ages 29, 42 and 55 weeks. **Results:** The production parameters showed that the breeder age affected the average egg weight, percentage fertility, hatch percentage and chick hatch weight significantly (p<0.05). The breeder age also had a significant effect on fertile egg protein, fat, carbohydrate, dry matter, ash and 7 day mortality. A significant linear relationship was established (p<0.05) between the breeder age and the production performance, internal egg and 7 day mortality of the broiler chickens. Optimal ages were established for hatch percentage, number hatched, protein, fat, dry matter and ash at ages of 37.8, 37.6, 40.0, 52.8, 49.3 and 47.5 weeks with a very high coefficient of determinations but only significant for protein content. **Conclusion:** This implies that between the ages of 37-53 weeks, most production and internal egg performance were at the optimal output for the Ross 308 broiler breeder strains.

Key words: Breeder, broiler, non-linear regression, egg nutrients, fertility, hatchability, optimum

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Chicken (*Gallus gallus domesticus*) is the most consumed meat globally with the meat strain (broiler) production, growing very fast, to meet the ever-rising demands for it. This increased production of broilers is mainly through genetic selection and improvement of the fast-growing and heavy breeds of chicken, which currently yields an average slaughter weight of 2.2 kg in 35 days based on 3.3 kg of feed[1]. Meanwhile, the production parameters such as average egg weight, fertility, hatch rate and chick hatch weight are critical parameters that determine the rate these meat production demands could be met faster and efficiently. King'ori[2] reported that production parameters such as hatchability, chick hatch weight and fertility which are heritable traits, are also interrelated and vary significantly amongst different breeds of chicken. Therefore, it becomes important to understand the effects of age on these parameters in Ross 308 breeder broiler chickens. Many studies[3-5] have shown that these production parameters in broiler breeders decrease with age because their reproduction efficiency is related to the quality of the hatching eggs, which comprises internal egg nutrient composition of the fertile eggs, lower quality of the shell, larger egg weight etc. However, there is a dearth of information on the internal egg nutrient composition of fertile eggs from Ross 308 breeder chickens, although[6] reported more infertility and early embryonic mortality in eggs from differently treated fertile eggs from the same boiler breeder in a comparative study. Also, Yassin *et al*.,[7] reported that the first week of a broiler's life is the most critical time in the broiler production as it has the most influence on the overall broiler performance. Mortality within 7 days of a chick's life is an important tool used to measure the level of wellbeing of a chick after hatch. Lourens *et al*.[8] reported a strong relationship between breeder age and egg weight showing that older breeders produce larger eggs, hence chick hatch weight increases with the advancing age of broiler breeders[9,10]. However, there is no information on whether this translates to lesser or higher mortality within 7 days of a broiler breeder chick's life.

Therefore, this study is carried out to understand the effects of age on average egg weight, percentage fertility, hatch percentage and chick hatch weight, as well as on internal egg nutrient composition and 7 day mortality of Ross 308 broiler breeders. Also, the study is aimed at finding the relationships and optimum age for average egg weight, percentage fertility, hatch percentage, hatch weight, fertile egg protein, fat, carbohydrate, dry matter, ash and 7 day mortality amongst Ross 308 broiler breeder chickens.

MATERIALS AND METHODS

Study area: This study was conducted at the Agricultural Research Council (ARC), Irene, Pretoria in South Africa from March, 2018-June, 2019. Irene has an average annual rainfall of 705 mm and a temperature of 16.8°C.

Broiler breeder farm production: A total of 1188 sexed breeder broiler chicks comprising of 117 males and 1071 females were randomly picked from over 3500 sexed breeder broiler chicks reared in the breeder house of the Agricultural Research station and assigned pens of 3 treatment groups. They were reared in a wire meshed house with each treatment having 39 males and 357 females, further divided into 3 replicates of 13 males and 119 females per treatment, all reared from day old to fertile egg production age.

Fertile egg collection: Fertile eggs were gently collected from nest boxes from 08:00-10:00 am from each treatment group, labelled, fumigated with potassium permanganate (2.83 per cubic meter for 20 min) before taking them to the farm egg room. The average egg weight from each treatment was measured randomly and recorded, as the eggs were kept appropriately with the broader end facing upwards while the sharp end faces downwards before setting them into the incubators.

Incubation: Before the eggs were set in the incubator for hatching, they were pre-heated for 5-6 hrs at a temperature of 30-32 to prepare the embryo for a warmer temperature on setters in the incubator. At the end of the pre-heating process, eggs were finally set for hatching in the incubator, where the temperature was set to 37.7 and humidity at 62% for 18 days, with automatic turners and heat regulators working, to maximise hatchability. On the 18th day, labelled egg groups were all candled and only the ones with the evident living embryos were transferred back to the machine to complete the hatching process. The fertility and fertility percentage was estimated from the number of fertile eggs present and the number of fertile eggs with living embryos after candling.

Post-hatch: Chicks hatched from eggs of the same treatment were kept together, with hatchability and hatchability percentage parameters are taken, before all abnormal, not sound and immobile, unhealed/damaged navels, poorly feathered and the ones with reddish hocks were removed for destruction. Also, cloaca temperature was taken, as well as chick weight was recorded as average chick weight. Chicks were later vaccinated using a 4 mm×4 nozzle spray for: Bursa disease, Infectious Bronchitis and Newcastle disease appropriately.

Broiler chick performance: The hatched chicks were placed in one poultry house but in different treatment groups for up to 7 days to measure the 7 day mortality parameter. The room temperature was maintained at 35 within the house, is well ventilated and insulated with cellophane plastics on the sides of the wall to conserve heat. Chicks were given 24 hrs of light and a floor space of 18 birds per square meter until day seven when the measurements of 7 day mortality of the chicks were taken. Feed and water were provided *ad-libitum*.

Data collection: Data on production performance such as average egg weight, percentage fertility, hatch percentage and chick hatch weight were measured and recorded within each replicate per age group. The internal parameters, such as fertile egg protein, fat, carbohydrate, dry matter and ash were generated from a certified laboratory, from 9 eggs per replicate per breeder age group, making a total of 27 eggs per treatment group. The 7 day mortality data was generated from all deaths recorded daily from the hatched chicks until the end of the 7th day. The mortality rate was calculated per replicate and a total number of deaths by the end of 7th day were converted to a percentage.

Statistical analysis: The influence of broiler breeder parent's age on their production indices, internal egg parameters and 7 day mortality of broilers was analyzed using the general linear model (GLM) procedures of the statistical analyses system according to Okoro *et al.*[11]. The model for statistical analysis was:

$$Y_{ijk} = \mu + T_i + \Sigma_{ijk}$$

Where:

- Y_{ijk} = Total effects due to production indices, internal egg parameters (protein, lipids and carbohydrates volume etc.) and 7 day mortality of hatched chicks
- μ = Population means
- T_i = Effect of different broiler breeder ages (29, 42 and 55 weeks)
- Σ_{ijk} = Residual effect

Where, there were significant differences ($p<0.05$) between treatment means, Duncan's New Multiple Range Test was used to separate the means according to Okoro *et al.*[11].

The direct relationships between response variables (production parameters, egg chemical content and 7 day chick mortality) and breeder age in weeks were deployed using linear regression model, as well as the evaluation of the optimum response of breeder age to attain best production indices, internal egg parameters and 7 day mortality of broilers was achieved using the curve estimation procedure in the Regression model of SPSS according to Okoro *et al.*[11], The production performance, egg chemical contents and 7 day mortality significantly affected by breeder age were modelled using the linear and quadratic models below:

$$Y = a+bX+e \quad (1)$$

$$Y = a+b_1X_1+b_2X_2+e \quad (2)$$

where, Y is production performance, egg chemical contents and 7 day mortality indices of broilers, a is intercept on Y-axis, b is coefficients of the independent variable X, i.e. the different age levels of breeders estimated, as -b1/2b2 is for the quadratic model, that gives the optimum age. The quadratic model was fitted to the experimental data utilizing the non-linear model (NLIN) procedure of SPSS according to Okoro *et al.*[11]. The linear and curve functions were deployed because they gave the best fit for such models.

RESULTS

The broiler breeder age affected the average egg weight, percentage fertility, hatch percentage and chick weight significantly ($p<0.05$) at different age groups (Table 1). At age 55 weeks, average egg weight and chick weight were significantly higher ($p<0.05$) than other weeks, while hatch percentage and percentage fertility of the breeders were better at 42 weeks of age than at 55 weeks of age, there was no significant difference ($p>0.05$) in percentage fertility between 29 and 42 weeks of age. However, chick hatch weight was significantly higher ($p<0.05$) at 55 weeks of age than for 29 and 42 weeks old breeders, respectively.

Breeder age has a significant effect on egg nutrient contents and 7 day mortality of breeder chickens (Table 2). Protein content was higher and similar for breeders at ages 29 and 42 weeks old with breeder hen of 55 weeks of age having the least ($p<0.05$) protein content. Fat, carbohydrates, dry matter and ash contents were significantly higher ($p<0.05$) at 55-week-old breeders, relative to other ages. However, chick mortality was significantly higher ($p<0.05$) at 29 weeks of age followed by breeders of 42 weeks of age but lower for breeders of 55 weeks of age ($p<0.05$).

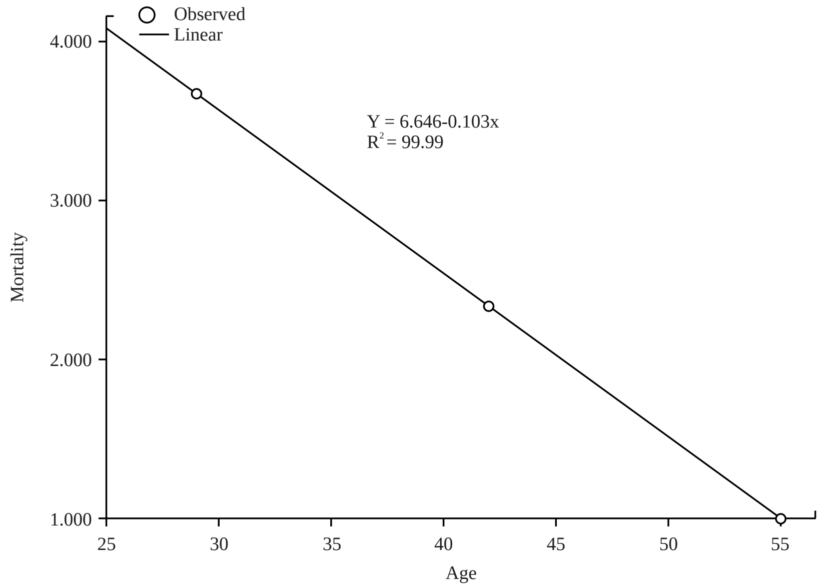

Fig. 1: Relationship between breeder age and 7 day chick mortality of broiler breeder chickens

Table 1: Effects of breeder age on external egg and hatching parameters

	Age (weeks)				
Parameters	29	42	55	SEM	p-value
Number of eggs trayed	264	264	264	-	-
Average egg weight (g)	54.27[c]	64.27[b]	68.76[a]	2.10	0.0001
Fertility (%)	97.86[a]	97.48[a]	92.42[b]	0.88	0.0001
Hatch percentage (%)	86.363[b]	89.14[a]	74.24[c]	2.29	0,0001
Chick hatch weight (g)	38.600[c]	43.27[b]	45.70[a]	1.04	0,0001

[abc]Means on the same row with different superscripts are significantly different ($p<0.05$)

Table 2: Effects of breeder age on egg chemical content and 7-day mortality of broiler breeder chickens

	Age (weeks)				
Parameters	29	42	55	SEM	p-value
Protein (kDa)	11.910[a]	11.93[a]	11.87[b]	0.009	0.008
Fat (mmol L^{-1})	8.91[c]	9.38[b]	9.43[a]	0.083	0.0001
Carbohydrate (Kj)	2.71[c]	2.90[b]	2.970[a]	0.038	0.0001
Dry matter	24.36[b]	25.12[a]	25.09[a]	0.126	0.0001
Ash	0.84[b]	0.91[a]	0.91[a]	0.014	0.055
7 day mortality	3.67[a]	2.33[ab]	1.00[b]	0.441	0.013

[abc]means on the same row with different superscripts are significantly different ($p<0.05$)

The relationship between breeder age, response variables and egg chemical content of broiler chickens are shown in Table 3. Generally, a strong and positive relationship was observed between breeder age, response variables and egg chemical content of broiler chickens. Average egg weight and chick hatch weight showed high coefficients of determination values (r^2) of 95% and 96%, respectively, for both variables while 7 day mortality was inversely correlated with breeder age ($r^2 = 99.9$), however, not significantly (Fig. 1). Egg protein content also expressed an inverse correlation with a low r^2 value of 44% (Fig. 2), compared with egg fat content, egg carbohydrate content, egg dry matter content and egg ash content which showed a positive and high coefficient of determination values (r^2) of 81, 94, 71 and 75%, respectively (Table 3).

Age of breeder birds had a quadratic regression effect on some performance variables and most egg nutrient content values of Ross 308 broiler chickens (Table 4). For the number of chicks hatched, the optimal breeder age with an optimal number of chicks hatched showed a quadratic value of

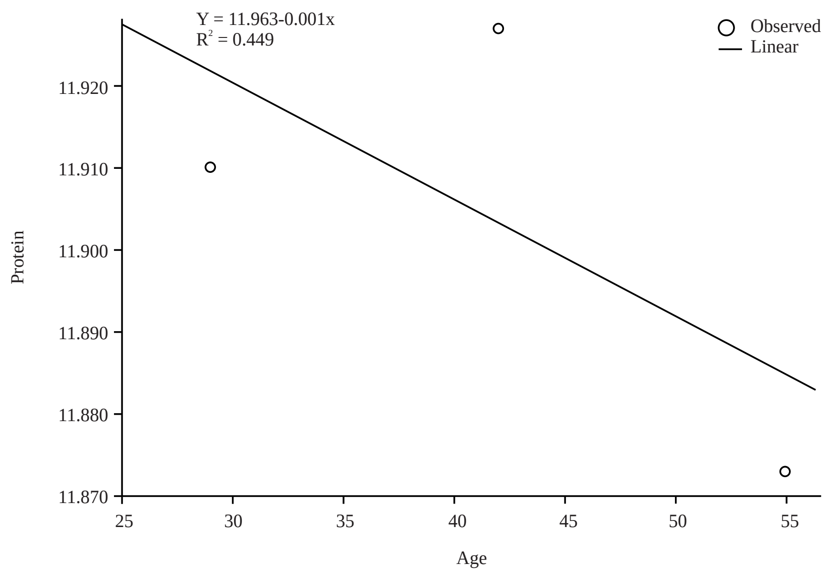

Fig. 2: Relationship between breeder age and egg protein content of broiler breeder chickens

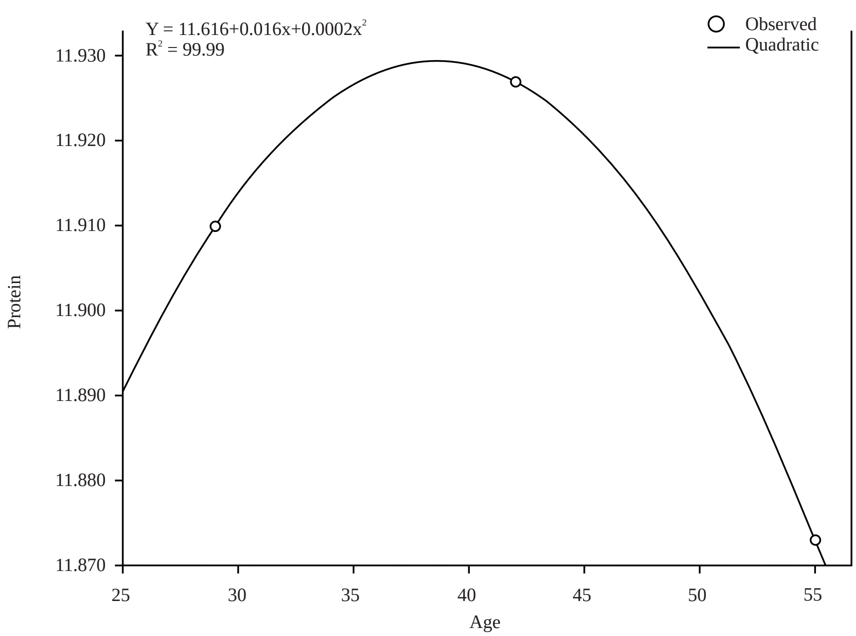

Fig. 3: Effect of breeder age for optimal egg protein content of broiler breeder chickens

Table 3: Relationship between breeder age and response variables (production performance and egg chemical content of breeder broiler chickens

Variables	Formula	r^2	Probability
Average egg weight	Y = 39.524+0.548x	0.957	0.034
Chick hatch weight	Y = 31.053+0.273x	0.968	0.048
7 day mortality	Y = 6.646-0.103x	0.999	0.098
Protein	Y = 11.963-0.001x	0.449	0.016
Fat	Y = 8.407+0.020x	0.818	0.008
Carbohydrate	Y = 2.445+0.010x	0.941	0.026
Dry matter	Y = 23.682+0.028x	0.713	0.009
Ash	Y = 0.779+0.003x	0.750	0.052

Breeder age (weeks) and r^2 = Coefficient of determination

Table 4: Effect of breeder age for the optimal response of different variables and egg chemical content of Ross 308 broiler chickens

Variables	Formula	x-value	y-value	r^2	Probability
No. hatched	$Y = 43.507+10.365x-0.138x^2$	37.60	238.10	99.99	0.877
Hatch percentage	$Y = 16.440+3.928x-0.052x^2$	37.80	90.60	99.98	0.761
Protein	$Y = 11.616+0.016x+0.0002x^2$	40.00	11.60	99.99	0.049
Fat	$Y = 6.340+0.125x-0.0012x^2$	52.80	10.20	99.96	0.909
Dry matt	$Y = 19.779+0.227x-0.0023x^2$	49.30	26.20	99.97	0.233
Ash	$Y = 0.452+0.019x+.0002x^2$	47.50	1000	99.99	0.391

Optimal breeder age (weeks), x-value: Optimal, y-value and r^2: Coefficient of determination

37.6 weeks and 238.1 chicks, respectively, with, an r^2 value of 99.99%, but not a significant difference. However, fertile egg protein had a significant optimal breeder age of 40 weeks and a protein response of 11.6 g dL^{-1}, respectively, with a high r^2 value of 99.99% (Fig. 3).

DISCUSSION

Values generated from the results of this study show a trend that is similar to other studies elsewhere, such as[11-13]. The Ross 308 broiler breeder age affecting the average fertile egg weight, chick weight, percentage fertility and hatch percentage significantly ($p<0.05$) is in line with findings of Alquati *et al.*[14] and Iqbal *et al.*[15], who reported, that young broiler breeder starts by laying small eggs, progresses with age, to as heavy as 75 g around 64 weeks affecting positively the performance parameters. The average egg weight of 68.76 g obtained in the present study is moderately high in comparison with the average egg weight of 52.81g reported by Mbajiorgu[12] and 52.2 g by Grobbelaar *et al.*[16], respectively for indigenous Venda chickens at the same age. However, this slight variation in the egg weights obtained could be attributed to genetic differences among the different chicken breeds used in those studies. The higher average chick hatch weight obtained as the parent's age, could be attributed to the heavier eggs laid by the older broiler breeder birds. You *et al.*[17] reported that heavier eggs contain more nutrients than small or medium-sized eggs and hence, chicks from heavier eggs tend to have a more yolk attachment at hatching and higher chick weight. Machado *et al.*[18] further reported that the yolk attachment is subsequently utilized by the chicks after hatching and therefore, the potential performance and weight of the day-old chicks could depend on the quality and quantity of this yolk. Similar results have also been observed elsewhere by Abanikannda *et al.*[19].

Although fertility percentage and hatch percentage of the breeders were better at 42 weeks of age than at 55 weeks of age, there was no difference in fertility percentage between breeders of 29 and 42 weeks of age ($p>0.05$) as reported in this study, the non-significant differences in fertility percentage between breeders of 29 and 42 weeks of age may indicate that the effect of breeder age on those parameters was similar. Mesquita *et al.*[20] reported very high fertility percentages similar to the ranges of 92.42-97.8% obtained in the study for different incubation systems of chickens at 40 weeks of age. However, these fertility percentage values are higher and different from 88.57% reported in Fayoumi chickens, 80.77% reported in dual-purpose Rhode Island Red chickens (RIR) and 60% observed in desi chicken[21]. These variations could be attributed to the genetic differences amongst the chicken breeds. Tona *et al.*[5] reported a decline of 9% in hatchability on the egg with a mass of 70 g as well as a drop of 11% on fertility from parents of 60 weeks old, hence suggesting that eggs from younger parent stock weighing an average of 60 g could have a higher hatchability. This is similar to the findings in this study, where the fertility of the broiler breeder's age (55 weeks) declined by 5.06% and hatch percentage declined by 14.90% from 42-55 weeks of age. Nevertheless, these drop-in fertility and hatchability values with increasing breeder age might suggest that the heavier eggs laid by the older breeder birds of 55 weeks of age and above harms fertility and hatchability. Leeson and Summers[22] also reported similar findings, suggesting that heavier eggs laid by older parent stocks drop in hatchability, as the rooster and hens might have advanced in age, hence a reduction in fertility and hatchability. Thus, as suggested by Brillard[23], egg fertility highly depends on the hen, her ability to mate correctly, keep the semen, ovulating without complications and provide the most comfortable environment for the growing embryo, as well as the quality of the rooster semen.

The significant effect of broiler breeder age on egg chemical content and 7 day mortality indicates that the internal egg parameters are influenced by age. As the protein content was higher and similar for breeders at ages 29 and 42 weeks old, breeder hens of 55 weeks of age laid fertile eggs of lesser protein ($p<0.05$) content, while fat, carbohydrates, dry matter and ash contents were significantly higher ($p<0.05$) in 55-week-old breeders fertile eggs than to other ages. This could be as a result of the variations in the chemical composition of the dietary feed given to the birds, as it could vary during mixing of the feed and processing and transportation. Meanwhile, Machado *et al.*[18] reported higher mortality at an earlier stage of the layers, where he observed high mortality in the 1st week of chicks hatched from broiler breeders at the age of 29 weeks followed by the ones from broiler breeders at the age of 40 weeks and the best of chicks with minimum mortality was from eggs laid by broiler breeders at the age of 60 weeks.

The significant linear relationship between broiler breeder age and egg weight, hatch weight, egg chemical contents and 7 day mortality shows that while protein and 7 day mortality expressed an inverse relationship, the average egg weight, hatch weight, fat, carbohydrates, dry matter and ash contents expressed a direct relationship. This implies that as the broiler age increased, the protein content and 7 day mortality rate decreased and vice-versa, while for those expressing direct relationship, as the breeder age increases, so do those parameters and vice versa. Most of the parameters showed a high coefficient of determination (r^2) values with significant effects ($p<0.05$). Traldi *et al.*[13] reported that high correlation coefficients obtained for egg parameters were as a result of the higher average egg weight obtained for the older breeder birds of 55 weeks of age in the present study, while Sugano and Matsuoka[24] found a negative correlation between mortality and breeder age in their study on the effect of age of parent and egg mass on Ross-308 chick mortality. Okoro *et al.*[25] reported a significant linear relationship between age and egg-laying parameters in 4 strains of table egg laying birds compared amongst themselves. Keum *et al.*[26] reported that the fat content of 51 and 64 weeks old Arbor Acres broiler breeders were higher than in breeders with 36 weeks. In contrast to our findings, Cherian and Quezada[27], observed no significant influence of the breeder age (21-57 weeks) on fat content.

Meanwhile, the optimum and minimum ages, of breeder birds had a quadratic effect on the response variables, egg nutrient content values and 7 day mortality of the chicks, with the number of chicks, hatched having the minimal age, while the fat content of the fertile eggs having the optimal age of 52.8 weeks. This is similar to the findings of Okoro *et al.*[28] where quadratic regression models were used to estimate the optimal effects of age on egg production parameters of Boschveld indigenous chicken. However, this study has shown that protein was significantly affected quadratically amongst all the variables measured, implying that at age 40 weeks of age, broiler breeders had the highest level of protein in their fertile eggs. Mbajiorgu[12] observed that medium-sized eggs produced chicks with better livability in seven days than large and small-sized eggs.

CONCLUSION

In conclusion, rearing Ross 308 broiler breeder parent stock for broiler production gives the optimal performance of chicks when they reproduce within the ages of 40 weeks of age and above, with the protein content of the fertile eggs laid having a significantly optimal content of 11.7 g dL^{-1} at 40 weeks of age.

SIGNIFICANCE STATEMENT

This study discovers that there is no significant optimum age that explains any of the production parameters of breeder broilers in terms of regression models, except egg protein. This discovery further buttresses the findings in several quarters that the age of breeders does not affect the egg quality characteristics of breeder chickens, rather the egg size and quality. This study which discovered a possible optimum age upon which the quality of protein in a fertile egg is at its best will help researchers in the field of broiler breeding to understand the critical area of age that affects fertile egg protein quality most and could uncover more critical points of egg quality that many researchers were not able to explore.

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