Age–related optimal performance of Isa Brown layers in the tropics

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ABSTRACT

The identification of appropriate models to optimize the performance of layers will help boost poultry production. This study aimed at evaluating the production characteristics of Isa Brown layers in cages and to estimate the age of optimal production using two different regression models. A total of two hundred and forty hens on cage were utilized in the study. There were three replicates of sixteen cells each containing five birds. The parameters measured were weekly body weight (BW), feed intake (FI), water intake (WI), number of birds that died (mortality, MTLY), cumulative egg number (CEN) per week, hen-day egg production (HDEP), hen–housed egg production (HHEP) and egg weight (EW). Data were collected from 25 to 70 weeks of age. The effect of age (25, 30, 35, 40, 45, 50, 55, 60, 65 and 70 weeks) on weekly BW, FI, WI, MTLY, CEN, HDEP, HHEP and EW was determined using one-way analysis of variance (ANOVA). Where there were significant differences in the means of the seven production parameters based on age, they were separated using Duncan's Multiple Range Test procedure. Linear and quadratic functions were fitted to predict the performance parameters from age. With the exception of MTLY ($P > 0.05$) which was not affected by age, other parameters increased significantly ($P < 0.05$) with age. The quadratic model appeared to be better in forecasting performance parameters [coefficient of determination (R^2) of: 0.863 versus 0.761 (BW), 0.797 versus 0.793 (FI), 0.745 versus 0.531 (WI), 0.853 versus 0.414 (CEN), 0.843 versus 0.380 (HDEP), 0.870 versus 0.483 (HHEP) and 0.876 versus 0.838 (EW)]. This prediction model revealed that BW, FI, CEN, HDEP, HHEP and EW would attain optimal limits at ages 64.93, 66.67, 53.49, 53.30, 54.23 and 81.28 weeks of laying, respectively. The implication is that at appropriate ages based on the quadratic models, the production characteristics of Isa Brown layers can be targeted for maximal production.

Keywords: Birds, period, egg, regression, optimization

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INTRODUCTION

Poultry farming is fast becoming an attractive business and a sub–sector which generates employment opportunities for both skilled and unskilled labor. This is due to its short gestation period and generation interval, prolificacy and lack of taboos to its production coupled with an increasing demand for its production by a large segment of the populace especially during religious and other local and national festivals (Akinwumi *et al*., 2010). In order to meet this increasing demand, however, there is an urgent task of developing or procuring the fastest growing strain for new entrant and long-time poultry farmers considering the environmental sensitivity of every genotype (Jesuyon and Oseni, 2015).

There is strong evidence that there are genetic differences in growth rate between strains or breeds of chicken (Deeb and Lamount, 2002; Yakubu *et al*., 2009). Certain studies have shown that there are significant differences between body weight, weight gain and egg production characteristics at different ages of chicken (Leeson *et al*., 1997; Taha *et al*., 2010). There is no doubt about the fact that the bird's live weight at times of commencement of egg laying determines its age at first egg production and its peak production as well as the overall performance of the hen (Balogun *et al*., 1997). A hen that reaches sexual maturity earlier will produce more eggs than the one that reaches its sexual maturity later.

The primary concerns of poultry farmers are to have birds that not only lay more eggs, but that lay eggs with optimum size and grow to optimum body weight. Therefore, there is a need to evaluate the production characteristics of egg laying chicken strains to ascertain their level of performance. This will give the necessary information on the suitability to the production environment and hence, the profitability of such strains. There is a dearth of information on the production characteristics of Isa Brown layers in Nasarawa, State, north central, Nigeria. The objective of the study was to establish the relationship between age (weeks of rearing) and production characteristics of Isa Brown hens in conventional cages and hence, predict optimal performance from age.

MATERIALS AND METHODS

Study Location

The current study was carried out in the hot-dry season at Greater Light Agricultural Farm, Masaka, Nasarawa State, north central Nigeria. Masaka in Karu is located on the coordinates of 9°0'N 7°40'E/9.000°N 7.667°E, with an elevation of 448 m. The area has two separate seasonal periods namely raining season (April-October) and dry season (November–March). The dry season temperature is from 27.5°C to 37°C while in the raining season, it could range from 23.5°C to 36°C. The relative humidity ranges from 20 to 30% in the dry season and an average of 70% in the raining season. The total annual rainfall is between 1,145.6 mm and 1,631.7 mm (Kanayochukwu and Dogo, 2019).

Experimental Birds

A total of two hundred and forty Isa Brown hens on the cage system were utilized in the study. The birds were randomly arranged in a completely randomized design. There were three replicates each comprising eighty (80) birds. In each replicate, there were sixteen cells each containing five birds. They were fed conventional commercial feeds [Animal Care Feeds (Laymore Mash), containing crude protein 16.5%, energy 2,500 kcal/kg, fat 5%, fibre 6%, calcium 3.5% and available phosphorus 0.41%] and water provided *ad libitum* from week 25 to week 70 of the study period. There were appropriate vaccination [oral administration of Newcastle Disease Virus (NDV) booster vaccine at 28 weeks of age] and medication of the birds in line with established standards and procedures. Other routine management practices were strictly carried out. These included regular cleaning of the cages and removal of dead birds. The feeders and water drinkers were also cleaned daily. The foot bath was changed regularly to maintain good hygiene. Feeds were turned periodically to ensure feeding to appetite. There were regular egg collection and separation of broken or cracked eggs. The movement of visitors was also highly restricted as part of disease prevention measures.

Data Collection

The performance parameters were weekly body weight (BW, g, determined weekly), feed intake (FI, kg, measured daily), water intake (WI, litre, measured daily) and number (n) of birds that died (MTLY, n, determined daily). Cumulative egg number (CEN, n) per week was also calculated. The hen-day egg production (HDEP, %) was calculated by dividing the number of produced eggs by the number of hens surviving, then multiplied by 100 (Okoro *et al*., 2017). The hen–housed egg production

(HHEP, %) was calculated by dividing the number of produced eggs by the number of birds housed at the start of lay and then multiplied by 100. Egg weight (EW, g, weighed daily) was also determined using a sensitive scale.

Statistical Analysis

The effect of age (25, 30, 35, 40, 45, 50, 55, 60, 65 and 70 weeks old) on weekly BW, FI, WI, MTLY, CEN, HDEP, HHEP and EW was determined using one–way analysis of variance (ANOVA). Significant means were separated at 95% confidence interval using Duncan's Multiple Range Test (DMRT) procedure (SPSS, 2015). The following statistical model was used:

$$y_{ij} = \mu + A_i + e_{ij}$$

where, y_{ij} is an individual observation for each production characteristic, μ is general mean, A_i is an effect of i^{th} age (25, 30, 35, 40, 45, 50, 55, 60, 65 and 70 weeks old) and e_{ij} is random error associated with each error.

The relationship between each production characteristic and age was also established using linear and quadratic regression models. The linear and quadratic functions fitted were:

Linear model: $y = b_0 + b_1X + e$

Quadratic model: $y = b_0 + b_1X + b_2X^2 + e$

where, y is production characteristic, b_0 is the intercept, X is the age of birds (weeks), b_1 and b_2 are regression coefficients and e is an error term. The slope of the quadratic regression plots ($y' = dy/dx = 0$) was used to determine the optimum age in weeks for each production characteristic as described by Dağdemir *et al*. (2007).

RESULTS

Effect of Age on Production Characteristics

There was a significant difference ($P < 0.05$) in FI of birds, which implies that FI increased from age 25 to 30 weeks. However, from age 30 to 45 weeks, the FI appeared to be the same, after which there was an increase from age 50 to 60 weeks (Table 1). There was no clear pattern for WI per bird, although there was a significant difference ($P < 0.05$) from age 25 to 35 weeks. For BW per bird from week 25 to 70, there was a significant difference ($P < 0.05$). The highest BW was recorded at week 70, although not significantly ($P > 0.05$) different from that of age 65 weeks.

Table 1 Effect of age (week) on production characteristics of Isa Brown hens

Age (week)	BW (g/bird)	FI (kg/bird)	WI (litre/bird)	MTLY (n)	CEN (n)	HDEP (%)	HHEP (%)	EW (g/bird)
25	1,691.0^{h}	0.866^{f}	1.250^{e}	0.20^{ns}	22.60^{f}	18.95^{g}	18.76^{g}	48.77^{f}
30	1,783.0^{g}	0.871^{e}	1.382^{d}	0.30^{ns}	49.70^{e}	42.10^{f}	41.41^{f}	52.06^{e}
35	1,826.9^{f}	0.880^{d}	1.466^{c}	0.10^{ns}	60.10^{d}	51.32^{e}	50.33^{e}	52.89^{e}
40	1,869.1^{e}	0.878^{de}	1.464^{c}	0.10^{ns}	74.10^{c}	63.55^{cd}	61.75^{d}	55.95^{d}
45	1,889.7^{de}	0.877^{de}	1.478^{abc}	0.10^{ns}	84.90^{a}	72.64^{ab}	70.99^{ab}	62.59^{c}
50	1,901.0^{cd}	0.897^{c}	1.476^{bc}	0.10^{ns}	88.10^{a}	74.38^{a}	75.30^{a}	68.27^{b}
55	1,915.9^{bcd}	0.907^{b}	1.480^{abc}	0.20^{ns}	82.20^{ab}	68.50^{bc}	71.27^{ab}	70.35^{ab}
60	1,927.7^{bc}	0.917^{a}	1.487^{abc}	0.20^{ns}	77.30^{bc}	64.41^{cd}	67.71^{bc}	70.56^{ab}

Table 1 Continue.

Age (week)	BW (g/bird)	FI (kg/bird)	WI (litre/bird)	MTLY (n)	CEN (n)	HDEP (%)	HHEP (%)	EW (g/bird)
65	1,937.5[ab]	0.920[a]	1.504[a]	0.00[ns]	75.10[c]	62.58[d]	66.08[bcd]	70.76[a]
70	1,955.5[a]	0.920[a]	1.502[ab]	0.00[ns]	72.10[c]	60.08[d]	63.54[cd]	70.87[a]
SEM	8.26	0.002	0.008	0.04	2.00	1.69	1.75	0.89

Note: BW = body weight, FI = feed intake, WI = water intake, MTLY = number of birds that died, CEN = cumulative egg number per week, HDEP = hen–day egg production, HHEP = hen–housed egg production and EW = egg weight, SEM = standard error of means, means in the columns with different superscripts are different significantly (P < 0.05), ns = not significant

CEN was also significantly (P < 0.05) influenced based on the age of the birds. The highest average number of eggs was obtained at week 50, with a gradual decline observed at week 55, which significantly extended to week 60 to 70. A similar pattern of egg production with that of CEN was observed for HDEP and HHEP. However, the highest HDEP was recorded at week 50 while that of HHEP was observed at week 55. The lowest egg production was recorded at week 25. There were significant differences (P < 0.05) in the EW, with the highest value recorded at week 70, although not significantly (P > 0.05) different from those of ages 55, 60 and 65 weeks, respectively. MTLY was not significantly (P > 0.05) influenced by age.

Prediction of Performance Characteristics from Age of Birds

From the age of the birds, the quadratic function appeared to predict better for weekly BW, FI, WI, CEN, HHEP, HDEP and EW compared to the linear model. This is based on the higher coefficient of determination (R^2) and adjusted R^2, and a lower RMSE (root mean square error) values (Table 2). At ages 64.93, 66.67, 53.49, 53.30, 54.23 and 81.28 weeks of laying, BW (Figure 1A), FI (Figure 1B), CEN (Figure 1C), HDEP (Figure 1D), HHEP (Figure 1E) and EW (Figure 1F) were optimized. The slope of each graph appeared more parabolic than linear.

Table 2 Regression models for the prediction of production parameters from the age of Isa Brown hens

Equation	Optimal age (week)	R^2	Adjusted R^2	RMSE	P–value
Body weight (BW)					
BW = 1,632.650 + 4.991(Age)		0.761	0.758	40.587	0.01
BW = 1,336.829 + 18.700(Age) – 0.144(Age^2)	64.93	0.863	0.860	30.916	0.01
Feed intake (FI)					
FI = 0.829 + 0.001(Age)		0.793	0.791	0.010	0.01
FI = 0.844 + 0.001(Age) + 0.0000076(Age^2)	66.67	0.797	0.793	0.010	0.01

Equation	Optimal age (week)	R^2	Adjusted R^2	RMSE	P–value
Water intake (WI)					
WI = 1.260 + 0.004(Age)		0.531	0.526	0.054	0.01
WI = 0.851 + 0.023(Age) + 0.000(Age^2)	NA	0.745	0.740	0.040	0.01
Cumulative egg number (CEN)					
CEN = 26.198 + 0.893(Age)		0.414	0.408	15.426	0.01
CEN = –123.048 + 7.809(Age) – 0.073(Age^2)	53.49	0.853	0.853	7.753	0.01
Hen–day egg production (HDEP)					
HDEP = 23.556 + 0.722(Age)		0.380	0.373	13.392	0.01
HDEP = –105.793 + 6.716(Age) – 0.063(Age^2)	53.30	0.843	0.840	6.763	0.01
Hen–housed egg production (HHEP)					
HHEP = 18.677 + 0.843(Age)		0.483	0.478	12.650	0.01
HHEP = –103.534 + 6.506(Age) – 0.060(Age^2)	54.23	0.870	0.867	6.384	0.01
Egg weight (EW)					
EW = 35.417 + 0.566(Age)		0.838	0.837	3.608	0.01
EW = 16.064 + 1.463(Age) – 0.009(Age^2)	81.28	0.876	0.873	3.181	0.01

Note: NA= not available due to zero level of age^2, R^2 = coefficient of determination, RMSE = root mean square error

DISCUSSION

Egg production was highly influenced by age in the current study. This is consistent with the findings of Tůmová and Gous (2012) and Şekeroğlu *et al*. (2014). The pattern of feed intake indicates that it promotes the production of more eggs until the peak period when the further increase in feed intake may not necessarily correspond to increase egg production. The impact of continuous feeding was also stressed by Gibson *et al*. (2008). The lowest egg production and small egg size recorded at week 25 could be due to the birds had just got into laying.

There appeared to be a negative association between egg number and egg size in the present study. This is because as egg production reduced, the egg size became larger. According to Johnston and Guos (2007), the age of hens is a very vital factor that influences egg production and egg size. They further stated that the rate of egg production increased as the age of the bird increased, and at a particular age of about 70 weeks, egg production began to decline gradually. It has been reported that older birds of about 70 weeks and above have a larger preovulatory follicle and oviduct compared to younger birds. This allows them to lay large egg sizes, though fewer eggs compared to when at their peak of production. In their own study, Ledvinka *et al*. (2012) reported that age significantly affected egg size with values of 53.4 g (20 to 24 weeks old), 61.6 g (38 to 42 weeks old) and 63.7 g (56 to 60 weeks old). Similarly, Samiullah *et al*. (2014) reported values of 60.35, 63.90, 63.27, 62.97, 64.47 and 68.60 g as the age of the flock increased (25, 35, 45, 55, 65 and 75 weeks old, respectively) while Shafey *et al*. (2015) reported values of 58.37, 61.12 and 65.93 g for 32, 45 and 59 weeks old birds, respectively. In a related study, Campbell *et al*. (2017) observed that hen age affected the majority of egg measurements. The low mortality rate obtained in the present study might be attributed to genetic factor and good management practices.

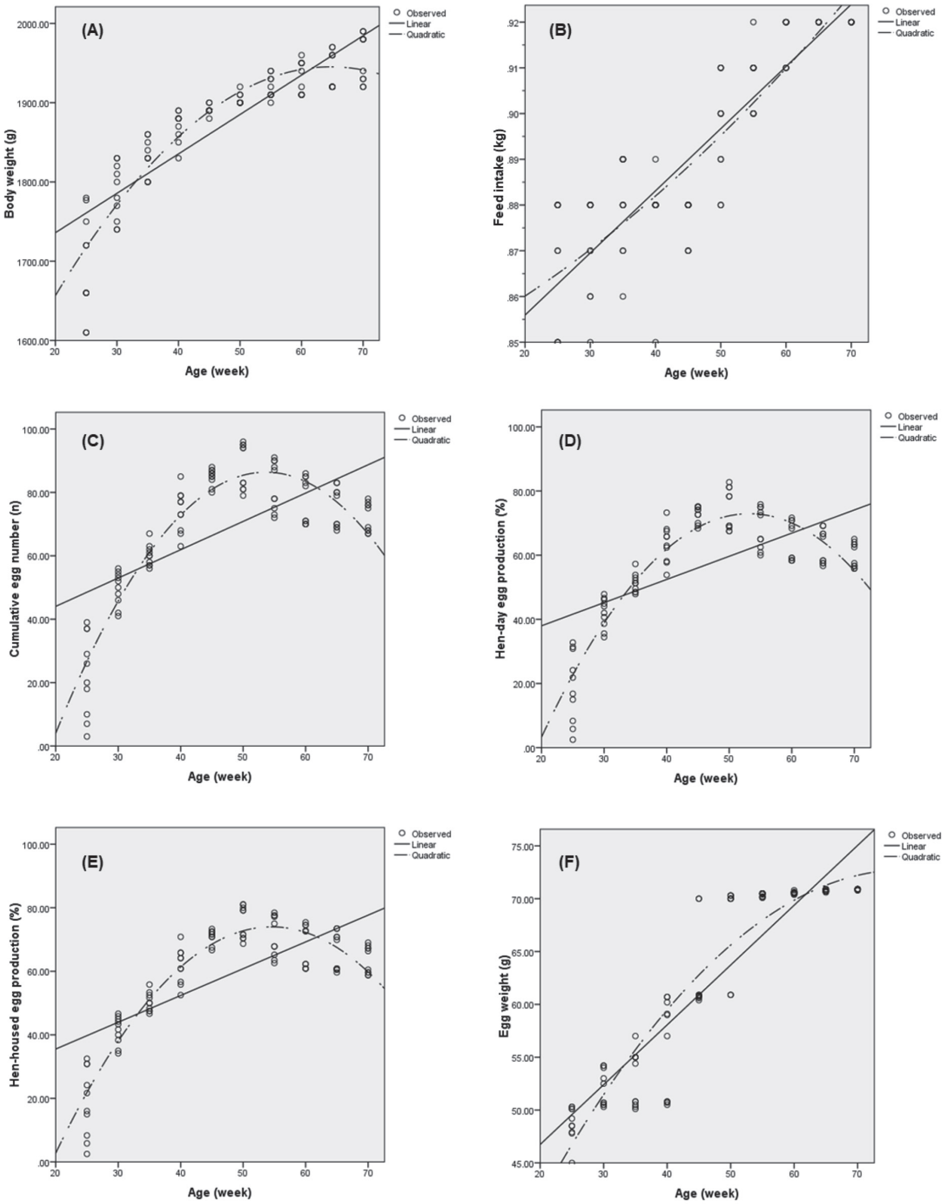

Figure 1 Relationship between age of the layers and their body weight (A), feed intake (B), cumulative egg number (C), hen–day egg production (D), hen–housed egg production (E) and egg weight (F)

Modelling production parameters of laying hens permits a good understanding of the production cycle. This might be exploited in decision making especially where there is an unexpected decline in production at a particular phase. To validate a regression function or estimate, the R^2 is taken often (Olaniyan *et al.*, 2017). It is a reflection of the amount of variation in the y–values that are explained by the regression line. In this wise, R^2, as depicted in the quadratic model of the present study, indicated that 86.3, 79.7, 74.5, 85.3, 84.3, 87.0 and 87.6% of the variability between BW, FI, WI, CEN, HDEP, HHEP and EW, and age have been accounted for. The current values appear high enough and reliable in predicting the various body parameters from age. The current observation is consistent with the submission of Yakubu and Madaki (2017) where the prediction of body weight from age (weeks) using the quadratic model gave R^2 and adjusted R^2 values of 0.852 and 0.852, respectively. However, the current optimal BW is greater than the 47.5 weeks of age reported by Yakubu and Madaki (2017).

Several authors have adopted different models in the layer–type birds to predict performance characteristics (Narinc *et al.*, 2014; Selvaggi *et al.*, 2015; Okoro *et al.*, 2017; Safari−Aliqiarloo *et al*., 2018). In poultry farms, optimum production time estimation is very important as regards economic production. The determination of the best performance of birds at appropriate ages may be exploited in the improvement of farm output. The set of optimal values obtained in the present study could guide management decisions on the use of resources to reduce wastage and losses while maximizing economic gains in the poultry farms. In a related study, Nwogu and Acha (2014) observed that birds were at their best at approximately 44.36 weeks of age while Yakubu *et al*. (2018) submitted that optimal egg production performance is beyond 48 weeks of age.

CONCLUSION

Age significantly affected the production characteristics of Isa Brown layers such as weekly BW, FI, WI, CEN, HDEP, HHEP and EW. The MTLY did not significantly vary with age. The quadratic model appeared to be better in forecasting performance parameters compared with the linear model. This quadratic prediction model revealed that at ages 64.93, 66.67, 53.49, 53.30, 54.23 and 81.28 weeks of laying, the BW, FI, CEN, HDEP, HHEP and EW would be optimized. For maximal production, therefore, poultry farmers can target layers' production characteristics at appropriate ages.

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