



INFLUENCE OF DURATION-IN-LAY ON HEN-DAY PRODUCTION AND INTERNAL EGG QUALITY INDICES OF ISA BROWN LAYER STRAIN UNDER NIGERIAN TROPICAL CLIMATE

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ABSTRACT

The study examined how duration-in-lay affects hen-day production and internal egg quality in Isa Brown layers. Forty-eight pullets were sourced from the Federal College of Agriculture, Moor Plantation Ibadan, and raised in a deep litter system. The birds were divided into six groups based on duration-in-lay; 0-6 weeks, 7-12 weeks, 13-18 weeks, 19-24 weeks, 25-30 weeks, and 31-36 weeks. Parameters measured included percent hen-day production (%HDP), total egg weight (TEW), average egg weight (AEW), total feed intake (TFI), daily feed intake (DFI), Haugh unit (HU), albumen index (AI), yolk index (YI), percent shell weight (%SW), and shell thickness (ST). A completely randomized design (CRD) was used. Results showed that duration-in-lay significantly influenced production performance, with percent hen-day production peaking at 87.10% and total egg weight reaching its maximum (17,658.13 kg) during weeks 19-24. Daily feed intake (121.47 g/bird/day) and total feed intake (244.86 kg) peaked at weeks 25-30, indicating reduced feed efficiency as production declined. Average egg weight increased steadily from 47.26g to 58.35g by week 13, then stabilized through week 36 (59.38g). Internal egg quality declined progressively with laying duration, as evidenced by the highest Haugh unit (86.28) recorded at 0-6 weeks. Duration-in-lay showed strong negative correlations with Haugh unit ($r = -0.809$), albumen index ($r = -0.763$), and yolk index ($r = -0.854$), confirming significant deterioration in egg freshness and internal quality over time. Shell thickness remained unaffected by duration-in-lay ($r = 0.007$), while percent shell weight declined moderately ($r = -0.449$). These findings demonstrate that early laying phases produce superior egg quality, while the 19–24 weeks period represents the optimal window for peak production, after which feed efficiency declines despite continued egg output.

Keywords: Laying performance, Haugh unit, Yolk index, Albumen index, Shell thickness

INTRODUCTION

Nigeria, a sovereign country in West Africa with a tropical to equatorial climate, has a significant poultry industry where egg production accounts for approximately 30% of total poultry output (Esiobu *et al.*, 2014). Eggs, valued for their affordability and nutritional richness, and are a key dietary protein source in Nigeria and globally (Amao and Olugbemiga, 2016). They provide essential nutrients like amino acids, omega-3s, vitamins, and minerals (Lesnierowski and Stangierski, 2018). Hen-day egg production measures the average daily productivity of a flock, while duration-in-lay (phase) indicates the age or period over which hens are actively producing eggs, both serving as key indicators of flock performance and efficiency (Cronin *et al.*, 2018).

Egg quality is influenced by both intrinsic factors (species, strain, age, and laying stage) and extrinsic factors (feeding, management, environment, storage, and transport) (Tougan & Thewis, 2024). The quality of an egg, affected by genetic influences, hen age, laying cycle stage, nutritional level, microclimate parameters, and management system, is economically important. Bird age affects internal and external egg traits, with older hens producing lower-quality eggs (Sam & Meme, 2023). Internal parameters like albumen and yolk weights are key for nutritional assessment (Okon *et al.*, 2022), while overall quality impacts consumer preference and reproductive success (Duman *et al.*, 2016). The amount of thick albumen and Haugh units serve as indicators of egg quality and freshness, depending on the origin, age, nutrition, laying date, and storage time (Huang *et al.*, 2012). According to Oluyemi and Roberts (2000), the albumen index and Haugh unit are vital indicators of internal egg quality.



However, internal egg qualities diminish as the egg ages due to the weakening of egg membranes (Quan *et al.*, 2021). Likewise, the Haugh unit reflects the average quality of the albumen and it declines with the age of the laying bird (Quan *et al.*, 2021). Duration-in-lay plays a pivotal role in shaping both the productivity and internal quality of eggs produced by laying hens. Dalhatu and Makwashi (2023) reported that Isa-Brown hens showed higher egg weight at first lay, 24th week, 28th week, and 32nd week, and had higher mean hen-day and hen-housed production than Noiler chickens. They recommend Isa-Brown layers to farmers for better egg productivity and maximum production of high-quality eggs in terms of egg number and egg weight.

Jimoh and Namakka (2024) backed this up by pointing out that Isa Brown chickens consistently produce larger, heavier eggs with tougher shells. This makes the Isa Brown strain particularly useful for studying egg production dynamics, given their well-known laying abilities. Their research showed that Isa Brown eggs stand out when it comes to internal quality, specifically having better albumen index and Haugh unit scores. For poultry farmers, understanding how duration-in-lay influences hen-day production and various internal egg quality parameters are essential for optimizing performance and reducing production costs. Nevertheless, there is limited literature relating duration-in-lay, hen-day egg production, internal egg quality analysis, correlations, and prediction equations of Isa Brown egg traits in tropical environments like Nigeria. To ensure the longevity of this strain in the industry and maximize farmers' productivity, it is imperative to study and predict its optimum production capabilities in tropical environments. Keeping in mind the above gaps, this study was undertaken to investigate the influence of duration-in-lay and its correlations with hen-day production and internal egg quality parameters of the Isa Brown layer strain in Nigeria.

MATERIALS AND METHODS

The Study Area

The study was conducted at the Animal Science Teaching and Research Farm, University of Calabar. Calabar is situated in the tropical, rainforest belt of Nigeria within longitude 8°9'E and latitude 4°57'N of the equator. It is located at an elevation of 98 meters above sea level with an annual temperature and rainfall range of 25°C and 30°C and 1260mm to 1280mm, respectively. The relative humidity is between 70% and 90%, and its land mass is about 2332 sq.m (604m²) (NMA, 2020).

Experimental Animals and Management

The research was carried out using Isa brown strain obtained from the Federal College of Agriculture, Animal Health and Production Farm, Moore Plantation, Ibadan, Oyo State, Nigeria, and reared under a deep litter system. A total of forty-eight (48) pullets, fed a conventional diet containing 16.5% crude protein and 2650kcal/kg metabolic energy diet and provided with fresh water *ad libitum* during the laying period were used. There were appropriate vaccination (oral administration of Newcastle Disease Virus (NDV) and medication of the birds in line with established standards and procedures. Other daily routine management practices were strictly adhered to.

Experimental design

The experimental birds were subjected to a completely randomized design (CRD) with six treatments: 0-6 weeks, 7-12 weeks, 13-18 weeks, 19-24 weeks, 25-30 weeks, and 31-36 weeks.

Data collection

Data was collected according to treatments. Egg production parameters recorded were total egg weight (TEW, g.), average egg weight (AEW, g.), total feed intake (TFI, kg/bird/day.), daily feed intake (DFI, g/bird/day.) and shell thickness (ST/mm). Eggs were weighed using a sensitive digital scale, (Mettler Toledo, PL203CE) with an accuracy of 0.001g.

Statistical analysis

Data collected were subjected to a one-way analysis of variance (ANOVA) in a completely randomized design (CRD) using SAS (2010). Simple linear regression and correlation analyses were performed to examine the relationships between: (i) percent hen-day production and duration-in-lay, (ii)

egg quality indices (yolk index, albumen index, and Haugh unit) and duration-in-lay, and (iii) total and average egg weight and percent hen-day production. The regression model used was: $Y = a + bX$, where Y is the dependent variable (percent hen-day production, total egg weight, or average egg weight), X is the independent variable (duration-in-lay in weeks), a is the intercept (predicted value of Y when $X=0$), and b is the slope, representing the rate of change in the egg production trait per week of laying.

Percent hen-day production

Percent hen-day production (%HDP) was calculated by dividing the number of eggs produced by the number of surviving hens and multiplying the result by 100 (Yakubu & Aguda, 2020).

$$\text{Percent hen-day production (\%)} = \frac{\text{Total number of eggs produced in a day} \times 100}{\text{Total number of hens present on that day}} \quad \dots(1)$$

Feed intake

The birds were offered a weighed quantity of conventional feed daily and leftover feed was collected, weighed, and subtracted from the initial feed provided to determine feed intake (Dalhatu & Makwashi, 2023).

Shell thickness

Shell thickness was measured using a micrometer screw gauge with an anvil jaw calibrated in millimeters. Measurements were taken after cleaning the internal part of the shell. Three readings were obtained at the broad end, middle, and tapering end of each egg, and the average value was recorded as the eggshell thickness, following the procedures of Anene *et al.* (2020).

Percent shell weight (% SW)

Egg shell weight was determined after removing the egg contents. The inner surface of the shell was cleaned with tissue paper and allowed to dry, after which the percentage shell weight was calculated using the equation below, following the procedures of Adegbenro (2023).

$$\text{Percent shell weight} = \frac{\text{Shell weight} \times 100}{\text{Egg weight}} \quad \dots(2)$$

Yolk index (YI)

The yolk index was used to assess the quality and firmness of the egg yolk. The yolk of each egg was carefully placed on a flat glass surface to avoid rupture or spreading. Yolk height and yolk diameter were measured using a vernier caliper respectively. The yolk index was then calculated as the ratio of yolk height to yolk diameter following the procedures of Ukwu *et al.* (2017) and Jimoh and Namakka (2024).

$$\text{Yolk index} = \frac{\text{Yolk height (mm)}}{\text{Yolk diameter (mm)}} \quad \dots(4)$$

Albumen index

The albumen index was used to evaluate the freshness and internal quality of the albumen. After breaking the egg onto a glass plate, albumen height and albumen diameter were measured using a vernier caliper for diameter. The albumen index was computed as the ratio of albumen height to albumen diameter, following the methods described by Ukwu *et al.* (2017) and Jimoh and Namakka (2024).

$$\text{Albumen index} = \frac{\text{Albumen height (mm)}}{\text{Albumen diameter (mm)}} \quad \dots(5)$$

Haugh unit

The Haugh unit was used to estimate egg freshness based on albumen height and egg weight. Freshly broken eggs were measured for albumen height using a vernier caliper, while egg weight was recorded using a sensitive electronic balance. The Haugh unit was calculated using the standard logarithmic formula as outlined by Ukwu *et al.* (2017) and Jimoh and Namakka (2024).

$$\text{Haugh unit} = 100 \log (H - 1.7W^{0.37} + 7.6) \quad \dots(6)$$

Where,

H = albumen height (in mm) and W = egg weight (in g).

RESULTS AND DISCUSSION

Egg production parameters of Isa Brown Layers in 6-Weekly Phases

Table 1 presents the egg production performance of Isa Brown layers across six laying phases. The results show that hen-day production and total egg weight increased steadily up to 24 weeks in lay before declining at later phases. This indicates that peak laying and feed utilization efficiency occurred between 13-24 weeks, while performance declined as the birds aged.

Table 1: Egg production parameters of Isa brown layers in 6-weekly phases

Parameters	0-6weeks	7-12 weeks	13-18weeks	19-24weeks	25-30weeks	31-36weeks
Percent Hen-Day Production (%HDP)	34.96 ^c ±12.065	82.04 ^a ±1.145	86.50 ^a ±1.596	87.10 ^a ±1.425	84.37 ^a ±1.532	62.84 ^b ±2.671
Total Egg Weight (kg)	5931.57 ^c ±2144.616	15102.63 ^{ab} ±313.245	16958.96 ^a ±442.078	17658.13 ^a ±174.7	16851.83 ^a ±336.39	12573.66 ^b ±570.019
Average Egg Weight (g)	47.26 ^c ±1.878	54.72 ^b ± 1.550	58.35 ^a ± 1.540	60.24 ^a ±1.416	59.47 ^a ±1.276	59.38 ^a ±1.284
Daily Feed Intake (g/bird/day)	93.40 ^c ±4.479	106.25 ^c ± 1.648	118.87 ^a ± 2.430	116.39 ^a ±2.771	121.47 ^a ± 1.689	119.05 ^a ± 2.003
Total Feed Intake (kg)	188.3 ^c ± 2.055	214.20 ^c ± 2.553	242.22 ^a ± 2.59	234.66 ^a ± 2.259	244.86 ^a ± 2.568	239.94 ^a ± 2.673

Means with different superscripts in the same row are significantly (p<0.05) different.

Influence of Duration-In-Lay on Egg Production Parameters

Percent hen-day production (% HDP)

The study showed that percent hen-day production rose steadily from 34.96% at the start of lay, reaching its peak of 87.10% during weeks 19-24, before declining to 84.37% at weeks 25-30 and dropping more noticeably to 62.84% by weeks 31-36. This pattern reflects the natural progression of the laying cycle, where hens gradually build up to peak production, maintain high output for several weeks, and then experience a gradual decline as they age and their reproductive capacity diminishes. The %HDP values recorded in this study compare favourably with those reported by Ebeid *et al.* (2012), Adegbenro *et al.* (2018), Fajemilehin and Alamuoye (2019), and Yakubu and Aguda (2020), who observed 85.84-86.26%, 64.29-76.11%, 81.43%, and 18.95-74% respectively. This improved performance may be attributed to better genetics, refined management practices, or more favorable environmental conditions in the present study. The production trend observed aligns with established reproductive physiology in commercial layers, where ovulation rates and oviduct functions peak during mid-lay and gradually decline with advancing age. These findings affirm the practical importance of implementing phase-specific strategies such as adjusting nutrient density in feed formulations and considering selective culling of persistently low egg producers after peak production to maintain flock efficiency and optimize returns throughout the laying cycle.

Total egg weight (TEW)

Total egg weight mirrored the trend of percent hen-day production, peaking at 17,658.13 kg during the 19-24 weeks' phase, which coincided with the flock's highest productivity at 87.10% hen-day production. This phase represents the optimal convergence of high laying frequency and adequate egg size, establishing it as the critical period for maximizing cumulative egg output and production efficiency. Notably, total egg weight remained significantly elevated and statistically similar across the 7-12 weeks (15,102.63 kg), 13-18 weeks (16,958.96 kg), 19-24 weeks (17,658.13 kg), and 25-30 weeks (16,851.83 kg) phases, indicating sustained high productivity throughout the peak production cycle. The subsequent decline to 12,573.66 kg at 31-36 weeks reflects the expected reduction in laying performance as the flock aged beyond peak production. Şekeroğlu *et al.*, (2024) observed a similar pattern of increasing egg weight with advancing hen age, reporting the lowest (61.96 g) and highest (67.08 g) egg weights at weeks 26 and 58 respectively (p<0.01). These findings are consistent with studies by Şekeroğlu *et al.* (2014); Samiullah *et al.* (2017); Dikmen *et al.* (2017) and Hammershøj *et al.* (2021), whose documented significant increases in egg weight with flock age. Strategically, these results demonstrate the importance of aligning management interventions including feed optimization, health monitoring, and resource allocation with the 19-24 weeks' peak production window to maximize egg mass output, enhance production efficiency, and improve overall profitability in commercial layer operations.

Average egg weight (AEW)

The results showed that average egg weight increased progressively from 47.26g during the initial laying phase (0-6 weeks) to 58.35g by 13-18 weeks, after which it stabilized and remained consistent through 36 weeks, with no significant ($p < 0.05$) differences observed between weeks 13-18 (58.35g), 19-24 (60.24g), 25-30 (59.47g), and 31-36 (59.38g). This stabilization pattern indicates that the birds reached physiological maturity in egg size by week 13, maintaining uniform egg weight characteristics throughout the remainder of the production cycle. Although the AEW values in this study were slightly lower than 69.50g, 64.33-65.15g, 61g, 70.87g and 58.57g reported by Garba *et al.* (2016), Adegbenro *et al.* (2018), Anene *et al.* (2020), Yakubu and Aguda (2020) and Udo *et al.* (2025) respectively. The variations observed across studies can be attributed to differences in genetic strain, nutritional programs, environmental conditions, and flock management practices. These findings emphasize the importance of phase-specific nutritional strategies, particularly during the early laying period, to support optimal egg size development and maintain consistency throughout the production cycle.

Total and Daily feed intake (TFI and DFI)

The results of this study revealed that feed intake, both total (244.86 kg) and daily (121.47 g/bird/day) peaked significantly during the 25-30 weeks' phase, despite hen-day production declining from its peak of 87.10% (at 19-24 weeks) to 84.37%. This pattern suggests increased maintenance energy requirements as the birds aged, coupled with reduced feed conversion efficiency, as more feed was consumed to produce proportionally fewer eggs compared to the previous phase. While the feed consumption values align with 111.28, 119, 115, 114.12 and 124.9 g/bird/day reported by Ebeid *et al.* (2012); Adegbenro *et al.* (2018); Fajemilehin and Alamuoye (2019) and Anene *et al.* (2020) respectively, the elevated intake coinciding with declining production efficiency indicates a critical transition point where production costs per egg increase substantially. This highlights the importance of phase-specific feeding strategies to optimize nutrition, minimize waste, and sustain profitability throughout the laying cycle. Early identification of declining production efficiency enables timely adjustments in feeding programs, ensuring that nutritional inputs remain aligned with productive output. Such precision management is critical for maintaining economic viability in commercial layer operations, particularly during transition phases where feed efficiency begins to deteriorate.

Egg Quality Indices of Isa Brown Layers in 6-Weekly Phases

Table 2 summarizes the internal and shell quality characteristics of Isa Brown eggs across different laying phases. Egg quality indices, including Haugh unit, albumen index, and yolk index, gradually declined with increasing duration in lay, indicating reduced freshness and structural quality in older layers, while percentage shell weight showed only slight variation across the phases.

Table 2: Egg quality indices of Isa brown layers in 6-weekly phases

Parameters	0-6 weeks	7-12 weeks	13-18 weeks	13-18 weeks	25-30 weeks
Haugh Unit	86.28 ^a ±1.862	86.05 ^{ab} ±1.868	80.11 ^b ±1.781	79.45 ^{b+} ±1.728	74.58 ^c ±1.853
Albumen Index	0.13 ^a ±0.011	0.12 ^{ab} ±0.002	0.10 ^{bc} ±0.002	0.10 ^{bc} ±0.004	0.09 ^c ±0.004
Yolk Index	0.48 ^a ±0.007	0.45 ^{ab} ±0.007	0.44 ^b ±0.003	0.43 ^b ±0.005	0.41 ^c ±0.005
Shell Weight (%)	13.42 ^a ±0.380	12.87 ^{ab} ±0.092	12.76 ^b ±0.090	12.71 ^b ±0.130	12.83 ^b ±0.067

Means with different superscripts in the same row are significantly ($p < 0.05$) different.

Influence of Duration-In-Lay on Internal Egg Quality Parameters

Haugh unit (HU)

Internal egg quality, measured by Haugh unit, was highest at the start of production (86.28 during weeks 0-6) and declined steadily through weeks 7-12 (86.05), 13-18 (80.11), 19-24 (79.45), and 25-30 (74.58). This progressive decline is a natural consequence of aging, as older hens experience reduced albumen synthesis and changes in oviduct function that affect thick albumen formation. The values obtained compare favourably with findings from Menezes *et al.* (2012), Tadesse *et al.* (2015), Onbaşlılar *et al.* (2018), Fajemilehin and Alamuoye (2019), Adegbenro (2023), and Jimoh and Namakka (2024), who reported



ranges between 73.53 and 88.22 across different housing systems. However, they were lower than the exceptionally high values of 90.7-100 reported by Duman *et al.* (2016) and Anene *et al.* (2020), suggesting room for improvement. The results demonstrate that early-phase eggs from Isa Brown layers maintain excellent internal quality, but strategic improvements including amino acid supplementation, optimal environmental control, and selective breeding for sustained albumen quality could also help preserve freshness characteristics for longer periods and reduce the rate of quality decline as flock age.

Albumen index (AI)

Albumen quality was at its best during the initial laying phase of 0-6 weeks (0.13), showing firmer and fresher egg whites when production first began. As the hens aged, albumen index declined progressively to 0.12, 0.10, 0.10, and 0.09 for weeks 7-12, 13-18, 19-24, and 25-30 respectively, reflecting the natural weakening of egg white structure that occurs with advancing hen age. This age-related decline affects both the visual appeal and functional properties of eggs, with potential implications for shelf life and consumer acceptance. The albumen index values recorded in this study were consistent with 0.093-0.106 reported by Padhi *et al.* (2013) and 0.12 by Jimoh and Namakka (2024), confirming that the performance observed falls within expected ranges for commercial layers. These findings show that eggs laid during the early production phase have noticeably better thick albumen quality, more cohesive whites that hold their shape better when cracked. For farmers, this means that eggs from younger flocks are likely to command better prices and higher consumer satisfaction, particularly for uses requiring firm egg whites such as poaching or frying. The steady decline in albumen quality as hen's age highlights the importance of strategic flock management, including timely replacement of older birds and prioritizing early-phase eggs for premium markets to maximize both quality and profitability.

Yolk index (YI)

Yolk quality, measured by the yolk index, was at its peak during the 0-6 week's phase (0.48), indicating well-rounded, firm yolks at the start of production. As the laying cycle progressed, yolk index declined gradually to 0.45, 0.44, 0.43, and 0.41 for weeks 7-12, 13-18, 19-24, and 25-30 respectively, reflecting the natural flattening and softening of yolks that occurs as hen's age. Despite this decline, the yolk index values recorded in this study (0.41-0.48) were notably higher than those reported by Padhi *et al.* (2013) at 0.37-0.43, Garba *et al.* (2016) at 0.36-0.46, and Jimoh and Namakka (2024) at 0.36, suggesting that the Isa Brown layers in this study maintained superior yolk quality throughout the production period. From a practical perspective, eggs produced during the early laying phase exhibited the best yolk characteristics; firm, well-shaped yolks that stand up nicely when cracked, which are highly valued by consumers for both visual appeal and culinary performance. While yolk quality naturally diminishes with hen age, the consistently higher yolk index values observed across all phases in this study demonstrate that Isa Brown layers are capable of producing premium-quality yolks well beyond the early production period. This sustained yolk quality makes these birds particularly valuable for producers targeting quality-conscious markets and suggests that proper nutrition and management can help maintain desirable yolk characteristics even as flocks mature.

Percentage shell weight (% SW)

Shell quality, measured as percentage shell weight, was highest during the early laying phase at 13.42% (0-6 weeks), indicating stronger shell formation when production began. Although values declined slightly in later phases to 12.76%, 12.71%, and 12.83% for weeks 13-18, 19-24, and 25-30 respectively, these differences were not statistically significant, showing that shell weight remained fairly stable throughout the production cycle. The range of 12.71-13.42% recorded in this study was notably higher than values reported by Essien (1992), Ebeid *et al.* (2012), Menezes *et al.* (2012), Padhi *et al.* (2013), and Anene *et al.* (2020), suggesting improved shell formation in the Isa Brown layers used. According to Ledvinka (2003), the genetic makeup of modern hybrid breeds primarily determines eggshell weight and strength, though interestingly,



white-egg-laying hybrids generally demonstrate better shell quality than brown egg hybrids (Halaj *et al.*, 1998; Leyendecker *et al.*, 2001a, 2001b). These findings show that the layers consistently produced eggs with strong, well-formed shells across all production phases, with the best quality appearing early on. The superior shell weight percentages compared to earlier studies likely reflect genetic improvements in this modern Isa Brown strain, which translates to better egg protection during handling, reduced breakage losses during transportation, and extended shelf life, all important factors for both producers and consumers.

Shell thickness (ST)

Shell thickness remained relatively stable across all production phases, with no significant differences observed despite minor numerical variations. The highest value was recorded at 13-18 weeks (0.37mm), while other phases measured 0.36mm, 0.35mm, 0.35mm, and 0.36mm for weeks 0-6, 7-12, 19-24, and 25-30 respectively. This consistency contrasts with findings from several studies reporting shell thickness decline with hen age (Roberts *et al.*, 2013; Şekeroğlu *et al.*, 2014; Dikmen *et al.*, 2017; Samiullah *et al.*, 2017; Hammershøj *et al.*, 2021; Şekeroğlu *et al.*, 2024), though it aligns with Chung and Lee (2014) who observed similar stability in Hyline hens. The shell thickness range of 0.35-0.38mm recorded in this study is consistent with values reported by Essien (1992); Ebeid *et al.* (2012); Padhi *et al.* (2013); Ukwu *et al.* (2017); Mosobaleje *et al.* (2020) and Benavides-Reyes *et al.* (2021) confirming acceptable shell quality throughout the laying cycle. Interestingly, research findings on how age affects shell thickness have been mixed with some studies showing deterioration with age (Silversides and Scott, 2001), others reporting increased thickness (Yannakopoulos and Tserveni-Gousi, 1987), and some found no significant effect (Yannakopoulos *et al.*, 1994; Vanden Brand *et al.*, 2004). Campo *et al.* (2007) suggest these varying results may stem from interactions between hen age and genetic breed characteristics, which could explain why the Isa Brown layers in this study maintained consistent shell thickness regardless of production phase.

Relationship among egg production traits

Table 3 shows the correlation matrix among key egg production traits in Isa brown layers. All traits exhibited strong positive correlations, indicating that increases in hen-day production were strongly associated with higher egg weight and greater feed utilization efficiency, with the most pronounced relationship observed between total feed intake and average egg weight.

Table 3: Relationship among egg production traits

Egg Production Traits	% Hen-day Production	Total Egg Weight	Average Egg Weight	Daily Feed Intake	Total Feed Intake
%Hen-day Production	1.000				
Total Egg Weight	0.989**	1.000			
Average Egg Weight	0.813**	0.871**	1.000		
Daily Feed Intake	0.744**	0.798**	0.915**	1.000	
Total Feed Intake	0.806**	0.847**	0.941**	0.976**	1.000

** = correlation is significant at $p < 0.01$; * = correlation is significant at $p < 0.05$; % Hen-day Production (%HDP), Total Egg Weight (TEW), Average Egg Weight (AEW), Daily Feed Intake (DFI), Total Feed Intake (TFI).

Positive Correlations with Hen-Day Production (%HDP)

All relationships among egg production traits were strongly positive and highly significant ($p < 0.01$). Hen-day production showed very strong correlations with Total Egg Weight ($r = 0.989$), Average Egg Weight ($r = 0.813$), Daily Feed Intake ($r = 0.744$), and Total Feed Intake ($r = 0.806$). These correlations reveal a clear pattern: as laying rate increases, hens naturally produce more and heavier eggs while consuming greater amounts of feed to meet the energy demands of higher production. This demonstrates the direct link between production efficiency and nutritional requirements, adequate feeding that productive layers need to sustain their output. The findings align well with Dalhatu and Makwashi (2023), who found that Isa-Brown chickens exhibited superior egg weight at critical production stages (1st lay, 24th, 28th, and



32nd weeks) along with higher hen-day and hen-housed production compared to Noiler chickens. The strong correlations observed in this study suggest that the genetic advantages of Isa-Brown layers particularly their capacity for sustained egg production and larger egg size are inherently tied to their elevated quality feed consumption and efficient reproductive performance. These results are further supported by Anene *et al.* (2020), who reported similar positive correlations ($r=0.32$, $p<0.01$), reinforcing the principle that genetic selection for improved productivity naturally leads to corresponding increases in both feed intake and egg output as birds strive to meet the metabolic demands of enhanced laying performance.

Strong Internal Relationships among Egg Traits

The strong positive correlations observed among egg traits ($p<0.01$) reveal that larger total egg weights are closely associated with heavier individual eggs and increased feed consumption. Specifically, Total Egg Weight showed strong relationships with Average Egg Weight ($r = 0.871$), Daily Feed Intake ($r = 0.798$), and Total Feed Intake ($r = 0.847$), indicating that as hens produce heavier eggs, their nutritional demands rise proportionally. This pattern aligns with findings from Alig *et al.* (2023a, 2023b) and Akyol *et al.* (2024), who reported that egg weight naturally increases with hen age, a biological progression that necessitates greater feed intake to support the production of larger eggs. Practically, these relationships highlight the importance of adjusting feeding strategies as flocks mature and egg size increases. Producers aiming to maximize egg mass must carefully balance this goal against feed efficiency, since heavier eggs inherently require more nutrients to produce. This means that while selecting for larger egg size can improve market value, it must be accompanied by intentional strategic nutritional planning to ensure that the increased feed costs don't outweigh the benefits of higher egg weights. The findings reinforce the principle that successful layer management requires a dynamic approach where feeding programs evolve alongside the changing nutritional demands of maturing hens.

AEW's Relationship with Feed Intake

Average egg weight showed very strong positive correlations with both Daily Feed Intake ($r = 0.915$) and Total Feed Intake ($r = 0.941$), revealing a clear and consistent pattern, affirming that hens that consume more feed produce heavier eggs. This relationship biologically aligns, as the nutrients required to form larger eggs must come from the hen's diet, meaning that adequate feed intake is essential for achieving desirable egg weights. These findings are well supported by Anene *et al.* (2020), who documented a significant increase in egg weight from 60g to 63g alongside a concurrent rise in average daily feed intake from 126g to 128g between 25 and 30 weeks of age. The close alignment between their observations and the strong correlations found in this study reinforces an important principle in layer management affirming that egg size is directly tied to nutritional intake. For farmers, this basically means that achieving target egg weights particularly the larger sizes that often command better market prices requires ensuring that hens have access to sufficient, high-quality feed. However, it also highlights the need for efficiency, as simply increasing feed without considering the cost-benefit ratio can erode profitability. The key is finding the optimal feeding level that maximizes egg weight while maintaining reasonable feed costs per dozen eggs produced.

DFI vs. TFI Correlation

The extremely high correlation ($r = 0.976$) between Daily Feed Intake and Total Feed Intake is expected, as total intake is essentially the cumulative sum of daily consumption over time. This near-perfect relationship confirms that consistent daily feeding patterns reliably predict overall feed usage throughout the production cycle. The finding aligns with Anene *et al.* (2020), who documented a modest but steady increase in average daily feed intake from 126g at 25 weeks to 128g at 30 weeks, demonstrating how even small daily increases accumulate into substantially higher total feed consumption over time. Practically,

this strong correlation highlights an important management principle that, small daily changes in feed intake, while seemingly minor, compound significantly across weeks and months of production. For egg farmers, this means that monitoring daily feed consumption provides an accurate early indicator of long-term feed costs and allows for timely adjustments before expenses spiral. It also has implications for genetic selection programs, where traits like egg weight and hen-day production must be evaluated alongside feed efficient birds that produce more or heavier eggs but consume disproportionately more feed may not be economically viable. Ultimately, the tight relationship between daily and total feed intake reinforces the need for precise feed management, where every gram of daily consumption must be justified by corresponding improvements in egg output to maintain profitability across the entire laying cycle.

Relationship Among Internal Egg Quality Indices

Table 4 presents the correlation relationships among internal egg quality parameters across different duration's in lay. Increasing duration in lay showed strong negative correlations with Haugh unit, albumen index, and yolk index, indicating a decline in internal egg freshness and structural quality over time, while shell thickness remained unaffected and percent shell weight showed only a weak negative association.

Table 4: Relationship among internal egg quality indices

	Duration -In-Lay	Haugh Unit	Albumen Index	Yolk Index	Shell Thickness	% Shell Weight
Duration-In-Lay	1.000					
Haugh Unit	-0.809**	1.000				
Albumen Index	-0.763**	0.906**	1.000			
Yolk Index	-0.854**	0.830**	0.834**	1.000		
Shell Thickness	0.007	0.010	-0.090	-0.049	1.000	
% Shell Weight	-0.449*	0.456*	0.708**	0.540**	0.007	1.000

**=correlation is significant at $p < 0.01$; *=correlation is significant at $P < 0.05$; Haugh Unit (HU), Albumen Index (AI), Yolk Index (YI), Shell Thickness (ST), % Shell Weight (%SW)

Relationships among Internal Egg Quality Indices

Internal egg quality declined significantly as hens aged, with duration-in-lay showing strong negative correlations with Haugh Unit ($r = -0.809$), Albumen Index ($r = -0.763$), Yolk Index ($r = -0.854$), and Shell Weight Percentage ($r = -0.449$, $p < 0.05$). The particularly strong negative correlation with Yolk Index ($r = -0.854$) indicates that yolk quality deteriorates most noticeably as laying duration increases, reflecting progressive loss of structural integrity and freshness. These findings align with Freitas *et al.*, (2017), who reported a similar negative correlation between age-in-lay and Haugh unit ($r = -0.256$). In contrast, Lee *et al.* (2016) focused on storage period and storage temperature, showing that albumen height and Haugh unit declined significantly under longer storage and higher temperatures, while yolk color and albumen viscosity increased with storage time but decreased with higher temperature. Shell thickness, however, was not significantly affected. Their results highlight that egg quality deterioration is strongly influenced by storage conditions rather than hen age. Among the quality indices themselves, Haugh Unit proved to be a reliable overall quality indicator, showing strong positive correlations with Albumen Index ($r = 0.906$), Yolk Index ($r = 0.830$), and Shell Weight Percentage ($r = 0.456$). This suggests that monitoring Haugh Unit alone could effectively reflect changes in multiple other quality parameters, making it a practical tool for quality assessment. Ukwu *et al.*, (2017) reported similar positive correlations between HU and AI ($r = 0.897$, $p < 0.01$) and HU and YI ($r = 0.357$, $p < 0.01$), supporting these observations.

Additionally, strong positive correlations were found between Albumen Index and Yolk Index ($r = 0.834$) and between Albumen Index and Shell Weight Percentage ($r = 0.708$), consistent with Ukwu *et al.*, (2017) who observed a positive correlation between AI and YI ($r = 0.369$, $p < 0.01$). These interconnected relationships indicate that quality traits do not decline independently but rather deteriorate together as a systemic response to aging, confirming age-related changes documented by numerous researchers (Şekeroğlu *et al.*, 2014; Samiullah *et al.*, 2017; Dikmen *et al.*, 2017; Eleroğlu and Taşdemir, 2020;

Hammershøj *et al.*, 2021; Şekeroğlu *et al.*, 2024). For commercial egg producers, these findings provide practical guidance for balancing production duration against quality maintenance. Understanding that internal quality declines predictably with age allows for strategic decisions about optimal marketing periods and timely culling of older birds, and ensuring that eggs reaching consumers meet quality expectations while maintaining farm profitability.

Relationship Between Egg Production Traits (Y) and Duration-In-Lay (X)

Table 5 shows the relationship between egg production traits and duration-in-lay using regression analysis. Percent hen-day production, total egg weight, and average egg weight generally increased with duration in the early laying phases but declined in later phases, with high correlation coefficients indicating strong predictive relationships between laying phase and production performance.

Table 5: Relationship between egg production traits (Y) and duration-in-lay (X)

Egg Production Traits Independent Variable (Y)	Duration (phase- in-lay (weeks) Dependent Variable (X)	Prediction Equation	Correlation Coefficient (r)	Coefficient of Determination (r ²)
Percent Hen-day Production	1-12	7.009 + 7.921X	0.901	0.811
	1-18	25.269 + 4.480X	0.826	0.682
	1-24	37.703 + 2.795X	0.751	0.564
	19-36	130.586– 1.909X	-0.856	0.732
	25-36	168.066– 3.097X	-0.905	0.819
	1-12	561.855+ 1531.576X	0.924	0.853
Total Egg Weight (kg)	1-18	3641.489+ 949.779X	0.879	0.772
	1-36	-722.573+ 204.234X	0.989	0.978
	19-36	26665.103- 398.929X	-0.862	0.743
	25-36	33825.756- 626.656X	-0.908	0.824
	1-12	42.393 + 1.323X	0.942	0.887
Average Egg Weight (g)	1-18	44.324 + 0.960X	0.938	0.879
	1-36	43.371 + 0.181X	0.813	0.660
	19-36	61.229 – 0.056X	-0.343	0.117
	25-36	60.056 – 0.021X	-0.113	0.012

The relationships between percent hen-day production, egg production traits, and duration-in-lay Percent Hen-Day Production (HDP)

Hen-day production was most predictable during the early laying phase (weeks 1-12), showing a very strong positive correlation ($r = 0.901$) and high predictability ($r^2 = 0.811$), indicating consistent and responsive egg production when hens first began lay. This strong performance continued through week 18, though with gradually decreasing correlation strength ($r = 0.826$ at 1-18 weeks; $r = 0.751$ at 1-24 weeks). However, production trends shifted dramatically after week 18, with negative correlations emerging from weeks 19-36 ($r = -0.856$) and becoming even stronger from weeks 25-36 ($r = -0.905$, $r^2 = 0.819$), confirming the natural decline in laying rate as hens aged beyond their peak production period. These findings align closely with Williams *et al.* (2009), who reported similarly high prediction values during the early laying phase across multiple farms (Farm A: $r = 0.924$, $r^2 = 0.853$; Farm B: $r = 0.894$, $r^2 = 0.799$; Farm C: $r = 0.992$, $r^2 = 0.937$; all at $p < 0.001$). The production pattern observed rapid increase, peak attainment around weeks 19-24, followed by gradual decline mirroring the classical egg production curve described by



Oluyemi and Roberts (2000) and corresponds with similar models reported by Wilson and Ogasawara (1998) for Leghorn birds and Essien (1989) for Shaver laying strains. These results highlight the critical importance of maximizing efficiency during the high-production phase (weeks 7-24) and implementing timely interventions such as phase-specific feeding or strategic culling to maintain profitability as production naturally declines in older hens.

Total Egg Weight (TEW)

Total egg weight showed the strongest predictive relationship across the entire production cycle (weeks 1-36), with an exceptionally high correlation ($r = 0.989$) and predictive power ($r^2 = 0.978$), indicating that cumulative egg output increased steadily over time despite declining hen-day production in later phases. This reveals an important insight that although hens lay fewer eggs per day as they age; total egg weight continues to accumulate because individual egg size increases with hen age, compensating partially for reduced laying frequency. Early phases showed strong positive trends (weeks 1-12: $r = 0.924$, $r^2 = 0.853$; weeks 1-18: $r = 0.879$, $r^2 = 0.772$), while later phases exhibited declining trajectories (weeks 19-36: $r = -0.862$; weeks 25-36: $r = -0.908$), consistent with the natural production curve. The relationship between hen age and egg weight has been well documented, with numerous researchers including Silversides and Scott (2001) and Zita *et al.* (2009) confirming that egg weight increases as hens age. However, Zemková *et al.* (2007) found no significant age effect, suggesting that this relationship may vary depending on genetics and management conditions. This study has practical implications educating that while daily egg production naturally declines with flock age, the cumulative egg mass output remains substantial due to larger individual eggs, making extended laying cycles economically viable when feed efficiency and egg quality remain acceptable.

Average Egg Weight (AEW)

Average egg weight showed the strongest predictability during the early laying period, with very high correlations at weeks 1-12 ($r = 0.942$, $r^2 = 0.887$) and weeks 1-18 ($r = 0.938$, $r^2 = 0.879$), indicating rapid and consistent increases in egg size as hens matured. Beyond week 18, the relationship weakened considerably (weeks 1-36: $r = 0.813$; weeks 19-36: $r = -0.343$; weeks 25-36: $r = -0.113$), suggesting that egg weight stabilized after the mid-lay phase with minimal further increase. This pattern reflects the biological reality that hens initially produce smaller eggs which grow steadily heavier until around 18 weeks of age, after which size plateaus and remains relatively stable. The increase in egg weight during early lay is partly attributed to concurrent increases in hen body weight, with research showing moderate to strong correlations ($r = 0.4-0.7$) between the two (Holoubek and Jankovský, 2002).

Genetic factors also play a substantial role, with Zhang *et al.* (2005) reporting a heritability coefficient of 0.63 for egg weight and Máchal (1999) noting that both egg and body weights exhibit medium to high heritability in modern laying hybrids. As hens gain body mass through proper nutrition during early lay, their eggs naturally increase in size. Akjol *et al.* (2024) confirmed that average egg weight increases significantly ($p < 0.01$) with hen age, supporting these observations. Also, the relationship between egg weight and laying intensity appears inversely implying that higher production rates tend to be associated with lighter eggs (Ledvinka and Klesalová, 2002). This may explain why egg weight stabilizes once peak production is reached around weeks 34-35 (Halaj, 1983), as the metabolic demands of high laying frequency limit further increases in individual egg size. These findings establish that egg weight results from a balanced interplay between genetics, body weight development, and production intensity, with optimal size achieved when hens reach physiological maturity but before the stress of peak production limits further growth.

CONCLUSION AND RECOMMENDATIONS

The study showed that the age and laying duration of Isa Brown hens have significant effects on both their productivity and the quality of eggs they produce. Production performance followed a predictable pattern where the hens reached their peak laying rate at 19-24 weeks (87.10% hen-day production), which also coincided with the highest total egg output (17,658.13 kg), making this the most productive phase of the laying cycle. Looking at the entire production phases from start to finish (weeks 1-36), total egg weight



was remarkably predictable ($r = 0.989$, $r^2 = 0.978$), showing consistent cumulative productivity despite natural declines in daily laying rates as hens aged. Individual egg size increased steadily during early lay, reaching 58.35g by week 13, and then remained stable through week 36 (59.38g), indicating that eggs reach their mature size relatively early and maintain consistent weight thereafter.

Economic implications were that feed consumption peaked at 121.47 g/bird/day during weeks 25-30, even as egg production was declining from its peak. This means the layers were eating more but laying proportionally fewer eggs, resulting in poorer feed efficiency and higher costs per egg produced during this later phase. The strong positive relationships observed between productivity and feed intake particularly between egg weight and both daily ($r = 0.915$) and total feed intake ($r = 0.941$) confirm that producing heavier eggs naturally requires more feed, highlighting the needs of balancing egg size goals with feed costs. Egg quality declined steadily as hens aged, with notable decreases in freshness indicators like Haugh unit ($r = -0.809$), albumen index ($r = -0.763$), and yolk index ($r = -0.854$), as well as shell weight percentage ($r = -0.449$). These quality traits were closely linked to each other, declining together as part of the natural aging process rather than independently. Remarkably, shell thickness was not affected by hen age ($r = 0.007$), suggesting that some aspects of egg structure are more resilient to aging than others. For layer farmers, these findings offer practical guidance and focus management efforts on maximizing output during the peak 19-24 weeks window, adjusting feeding strategies after peak production to avoid wasting feed on declining layers, prioritize eggs from younger hens for quality-focused markets, and use the predictive relationships identified here to make informed decisions about when to replace aging flocks. Ultimately, successful layer management means finding the right balance between keeping hens in production long enough to maximize returns while recognizing when declining efficiency and quality make replacement more profitable.

Poultry farmers should focus management efforts on the early to mid-laying phases (weeks 1-24) when production and quality are highest, using optimal feeding and lighting programs to maximize output during this critical period. Flocks can be maintained through week 36 to capture cumulative egg yield, but feed programs should transition from performance-focused diets during peak production to maintenance rations post-peak (after week 24) to control costs as efficiency declines. Producers should monitor egg weight trends to ensure market standards are met by week 18 and consider strategic flock replacement decisions around weeks 24-36 based on individual farm economics, balancing the trade-off between continued productions and declining feed efficiency. Eggs from younger hens (weeks 1-18) should be prioritized for quality-sensitive markets, while adjusting feeding strategies in later phases can help maintain profitability throughout the extended laying cycle.

CONFLICT OF INTEREST

The authors declare no conflict of interest

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