

Influence of cage tiers height on cloaca temperature, performance, and egg quality of Isa-Brown laying hens reared in a humid tropical climate

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ABSTRACT

This research was carried out to evaluate the influence of cage tiers height on cloaca temperature, performance and egg quality of Isa-Brown laying birds. A total of One hundred and eight (108) Isa-Brown laying birds were selected from a healthy stock. The poultry house contained conventional battery cages arranged in a three-tier design. One unit of the battery cage made up of three (3) tiers with three (3) cells per tier was setup to accommodate three (3) birds per cell and a total of 27 birds per unit cage. This setup was replicated for three additional cage units. The performance of the birds was evaluated in terms of the egg weight, egg mass, feed conversion ratio, hen day production, and total feed consumed. The results revealed no significant ($P > 0.05$) difference among cage tiers in terms of egg weight and feed conversion ratio but egg mass, hen day production and total feed consumed were significantly influenced. Highest egg mass (38.96g), highest Hen Day production (78.66%) and highest daily feed intake (99.01g) were recorded in birds raised in the upper tier of the cage. For the period of the study, cloaca temperature ranged between 36 °C and 41 °C. Cloaca temperature was not significantly ($P > 0.05$) affected by cage tiers height. In comparison to layers raised in low-tier cages, those raised in high-tier cages had higher egg production and better feed efficiency. These findings suggest that cage tier heights play an important role in the production performance of laying hens but cloaca temperature was not affected. However, further researches on the effect of cage tiers height on cloaca temperature should be carried out in a controlled setting

Keywords: cage tiers; cloaca; temperature; performance; egg quality

INTRODUCTION

The basic objective of a laying hen establishment is to achieve sufficient productivity and quality at a low cost of production. According to (Sekeroglu et al., 2014), egg quality and animal welfare can be severely affected by production systems. However, the prevalent perception that increasing animal wellbeing has a detrimental effect on farm profitability makes animal welfare problematic (Jongbo and Falayi, 2020). The majority of commercial laying hens worldwide are raised in cage systems rather than non-cage systems such as aviaries, barns or free-range (Nura et al., 2021). Cage tier levels are important factors in layer production as they can affect bird health, welfare, and egg production. Although cage systems can accommodate more hens per unit area than other systems and produce higher yields while consuming less feed and requiring less labor, studies have indicated that the height of the cage tiers can influence eggshell quality, egg weight, and the number of cracked eggs produced. It has also been established that climate environments have a significant impact on the growth, reproduction, and other biological processes of both plants and animals. The climatic condition to which the poultry is subjected could also adversely affect the feed intake, egg production most especially during hot weather periods (Jongbo et al., 2020). In addition, extreme weather conditions in tropical regions of the world have been shown to be detrimental to livestock production in general and are of particular concern to chickens as they are very sensitive to temperature changes (Oloyo and Ojerinde, 2019). Cloaca temperature refers to the temperature of the bird's reproductive tract and it can be influenced by factors such as environmental temperature, lighting conditions, and bird behaviour. The laying performance of the bird and the quality of the eggs it produces may suffer if the cloaca temperature is either too high or too low (Liu et al., 2019). A higher cloaca temperature in laying birds can lead to improved egg quality, including larger egg size, thicker eggshells, and improved yolk color (Leksriaompong et al., 2010; Chen et al., 2017). This may be due to increased nutrient absorption and utilization by the reproductive system at higher temperatures (Brito et al., 2014). Research have indicated that for optimum egg production and quality, the cloaca temperature must be maintained consistently within a particular range. This can be accomplished by carefully controlling the temperature, ventilation, and nutrition of the surroundings, as well as by keeping an eye on the bird's wellbeing and hormonal balance.

Hot weather in poultry production causes malnutrition, stunting, reduced egg production and size, premature laying and even death (Oloyo and Ojerinde, 2019). This environmental research in poultry houses is focused on the impact of environmental factors on animal performance and performance, as well as developing new understandings of environmental physiology. Since environmental conditions are not the same in all parts of the poultry house

and micro-environmental differences such as ventilation, lighting and temperature can occur between cage floors, optimal environmental conditions should be provided to ensure appropriate development, growth, maintenance and production (Muchaka et al., 2010; Karaman et al., 2013). Although there are many publications on the effect of density and cage type on egg quality and performance parameters of laying birds, the effect of cage tiers height and cloaca temperature on the performance and egg quality of Isa-Brown laying birds is rarely considered.

MATERIALS AND METHODS

Experimental site

The experiment was carried out at the Layers Unit of the Teaching and Research Farm. A total of One hundred and eight (108) Isa Brown laying birds were selected from a healthy flock for the study.

Experimental birds and their management

The poultry house contained conventional battery cages arranged in a three-tier design. One unit of the 3-tier battery cage made up of three (3) cells per tier was set up to contain three (3) birds; per cell making a total of 27 birds per unit cage. The set up was repeated for 3 other cage units. The experiment was carried out using Completely Randomized Design. Feed was supplied to the birds two (2) times daily with each bird consuming (110g) per day. This is to prevent feed wastage. Water was supplied ad libitum throughout the experimental period of twelve (12) weeks. All required managerial practices such as strict bio-security measures were ensured and as at when due, appropriate vaccines and prophylactic treatments was administered. The birds were housed in an open-sided building in a thoroughly cleaned, washed and disinfected three tier battery cage of 32 x 38 x 42 cm dimension. The experiment commenced in March and ended in June.

Upper tier	Upper tier	Passage	Upper tier	Upper tier
Middle tier	Middle tier		Middle tier	Middle tier
Lower tier	Lower tier		Lower tier	Lower tier
Side C	Side A		Side B	Side D

Figure 1. Floor plan view of battery cage tiers positions in the experimental building
Note: Sides A, B, C and D represent different cage units of the battery cages.

Data collection

Data collected and analyzed include feed intake, percentage hen-day production (HDP), egg mass, shell weight, yolk weight, albumen weight, shell thickness and feed conversion ratio of the birds; and economy of production. On a daily basis, the feed supplied to the laying birds was weighed and the left over was weighed weekly to determine the quantity of feed consumed by the birds and average quantity consumed by each bird was calculated.

Eggs from each replicate was collected in the afternoon (2pm – 3.00 pm). On the last day of every four (4) weeks, twelve (12) eggs were randomly selected from each replicate to assess the egg quality. The measurements were collected in triplicates, totalling 108 eggs that was used. Egg weight, yolk weight and shell weight were measured with sensitive scale calibrated in grams (model: AX 1000). The albumen weight was calculated by subtracting the sum of the weights of the shell and the yolk from the total egg weight. After the eggs has been carefully broken and the contents removed, the shells were air-dried for two days before weighing. Shell thickness was measured with digital vernier caliper (Yuansen) as an average of three measurements taken at the equator, the blunt edge and pointed edge of the egg without membrane.

- Average egg mass = % Hen-day production (HDP) × Average egg weight (gram).
- Feed conversion ratio = Feed intake (kg) / Egg production (kg)

$$\frac{\text{Shell weight} \times 100}{\text{Egg weight}}$$

- Eggshell ratio = $\frac{\text{Shell weight} \times 100}{\text{Egg weight}}$
- Shell surface area will be calculated by the formula:

$$\text{SSA} = W^{0.667} \times 4.67 \quad (\text{Mueller and Scott, 1940})$$
 Where SSA = Shell Surface Area
 W= Average Egg Weight
 0.667 and 4.67 are constants.
- Hen Day production (HDP) in percentage will be calculated by adding all the eggs per replicate on weekly basis using the formula below:

$$\frac{Ne}{Nb \times 7} \times \frac{100}{1}$$

Where Ne= Number of eggs laid per replicate per week

Nb= Number of birds per replicate

7= Number of days per week (North, 1984)

- Yolk index will be calculated as the ratio of the yolk height to the yolk width. Yolk height and width will be measured with a ruler calibrated in centimeter with the aid of optical pins and mathematical compass. Yolk index and Haugh Unit (HU) will be determined as follows.

Yolk height

Yolk Index= $\frac{\text{Yolk height}}{\text{Yolk width}}$

HU= $100 \log (H + 7.57 - 1.7W^{0.37})$

Where H= observed albumen height in mm

W= observed weight of eggs in grams.

- The yolk weight was determined after the albumin has been separated from it and placed in a pet dish and weighed in a sensitive scale (model: AX 1000).
- The width and the length of the eggs was measured with the aid of vernier caliper (Yuansen) calibrated in centimeters. Egg width (maximum) was divided by the maximum egg length to get the egg shape index. Albumen heights in millimeter was taken with the aid of optical pin which was used for the calculation of Haugh Units.
- Yolk Color: Egg yolk color was measured visually by using Roche colorimetric fan (RCF) scale, also named as DSM® yolk color fan (DSM, 2016), which is an industrial color scale varying from 1 (pale yellow) to 16 (dark orange). Egg colour was determined for individual yolk by comparing the yolk with color chips of the yolk color fan.
- Using a digital pHmeter (TEXT0), the pH measurement was taken individually in albumen, yolk and whole egg by emerging the probe inside the sample solution. Four (4) eggs were selected per replicate and used for the pH assessments. The assessment was done in triplicates. The albumen was separated from the yolk, and both components were distributed into three identical glass beakers. In a beaker, 2.0 grams of the sample were homogenized in 20.0 milliliters of deionized water. The pH meter was first calibrated with buffer solutions of pH 4.01 and 9.20. After rinsing the electrode with deionized water, it was plunged into the homogenate and given sufficient time to stabilize before readings were taken. The albumen and yolk were then thoroughly combined for each egg sample, and the pH was measured as a whole egg.

Instrumentation

Cloaca temperature was measured using a non-contact infrared thermometer (Pegasus IR-988). Four (4) birds were selected randomly from each tier and the cloaca temperature of the birds were taken and recorded. Data was collected three (3) times in a week between the hours of 12 noon to 1pm. The data was processed using Microsoft Excel 2019 and subjected to one way analysis of variance (ANOVA) using SPSS version 25 package. However, data for the egg storage was subjected to two-way ANOVA. The differences among

means were separated using New Duncan's multiple range test of the same package.

RESULTS

Effect of cage tiers on performance of laying birds

Table 1 shows the result for performance and yield of birds. Highest egg mass, highest hen day production and highest daily feed intake were recorded in birds reared under upper cage tier, while lowest egg mass, lowest hen day production, and lowest daily feed intake were recorded in birds reared under lower cage tier. Best feed conversion ratio was recorded in birds reared under upper cage tier, while worst feed conversion ratio was recorded in birds reared under lower cage tier. Numerically, highest egg weight and lowest egg weight were recorded in birds reared under lower cage tier and upper cage tier, respectively.

Table 1. Effect of cage tiers on performance of laying birds

Parameters	Upper tier	Middle Tier	Lower tier	P-value
Egg weight (g)	49.53 ± 0.46	49.97 ± 0.86	50.75 ± 0.40	0.37
Egg Mass (g)	38.96 ± 99.57 ^a	37.10 ± 107.25 ^{ab}	34.50 ± 139.69 ^b	0.03
Hen Day Production (%)	78.66 ± 1.85 ^a	74.24 ± 1.68 ^a	67.98 ± 2.84 ^b	0.01
Daily Feed Intake (g)	99.01 ± 10.99 ^a	94.40 ± 15.60 ^{ab}	92.12 ± 17.88 ^b	0.04
Feed Conversion Ratio	2.54 ± 0.05	2.54 ± 0.05	2.67 ± 0.10	0.36

*a,b, = means within the same column with different superscripts are significantly different (P<0.05)

Effect of cage tier on egg quality characteristics of laying birds

The findings obtained on egg quality characteristics from different tier levels are presented in Table 2. The results of this study indicated that cage tier position had no effect on egg quality characteristics. Both internal and external egg quality characteristics were independent of cage tier level. Numerically, highest egg weight, highest shell weight/unit surface area and highest shell surface area were observed in birds reared under lower cage tier, while lowest egg weight, lowest shell thickness, lowest shell weight/unit surface area and lowest shell surface area were observed in birds reared under upper cage tier. Highest yolk weight, highest yolk width and highest yolk color were observed in birds reared under lower cage tier, while lowest yolk weight, lowest yolk width and lowest yolk color were observed in birds reared under middle cage tier. Highest yolk length and highest albumen width were observed in birds reared under lower cage tier, while lowest yolk length and albumen width were observed in birds reared under upper cage tier.

Table 2. Effect of cage tier on egg quality characteristics of laying birds

Parameters	Upper tier	Middle Tier	Lower tier	p-value
Egg Weight (g)	49.53 ± 1.22	49.97 ± 1.32	50.75 ± 0.78	0.75
Egg Width(cm)	3.88 ± 0.08	3.76 ± 0.03	3.83 ± 0.04	0.38
Egg Length (cm)	5.16 ± 0.06	5.13 ± 0.05	5.14 ± 0.04	0.93
Shell Weight (g)	5.03 ± 0.17	4.90 ± 0.18	4.82 ± 0.18	0.68
Shell Thickness (In)	0.01 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.41
Shell Weight/Unit Surface Area	53.48 ± 0.89	53.78 ± 0.94	54.37 ± 0.56	0.73
Shell Without Membrane (g)	4.66 ± 0.15	4.39 ± 0.18	4.51 ± 0.16	0.52
Shell Surface Area	63.02 ± 1.05	63.38 ± 1.11	64.08 ± 0.66	0.73
Yolk Weight (g)	12.80 ± 0.37	12.73 ± 0.36	12.99 ± 0.23	0.84
Yolk Width(cm)	3.68 ± 0.05	3.63 ± 0.05	3.72 ± 0.05	0.47
Yolk Length (cm)	3.88 ± 0.05	3.88 ± 0.07	4.06 ± 0.05	0.07
Yolk Height (cm)	1.09 ± 0.07	1.28 ± 0.09	1.24 ± 0.09	0.25
Yolk Index	0.30 ± 0.02	0.36 ± 0.03	0.33 ± 0.02	0.23
Yolk Colour	7.83 ± 0.21	7.75 ± 0.30	8.08 ± 0.34	0.69
Albumen Weight (g)	27.30 ± 0.81	28.26 ± 0.97	26.59 ± 0.98	0.45
Albumen Length (cm)	7.88 ± 0.23	7.61 ± 0.24	7.70 ± 0.17	0.65
Albumen Width (cm)	6.01 ± 0.13	6.14 ± 0.13	6.53 ± 0.28	0.16
Albumen Height (cm)	0.58 ± 0.04	0.58 ± 0.07	0.53 ± 0.05	0.70
Haugh Unit	78.21 ± 2.86	76.56 ± 4.25	72.40 ± 4.03	0.54
Albumen pH	8.28 ± 0.16	8.53 ± 0.19	8.30 ± 0.09	0.47
Yolk pH	6.68 ± 0.06	6.53 ± 0.09	6.60 ± 0.08	0.43
Whole pH	7.30 ± 0.12	7.60 ± 0.18	7.58 ± 0.13	0.32

Highest yolk height, highest yolk index, highest albumen pH and highest whole pH were recorded in birds reared under middle cage tier, while lowest yolk height lowest yolk index, lowest albumen pH and lowest whole pH were recorded in birds reared under upper cage tier. Numerically, highest albumen length and highest yolk pH were recorded in birds reared under upper cage tier, while lowest albumen length and lowest yolk pH were recorded in birds reared under middle cage tier. Highest Haugh unit was recorded in birds reared under upper cage tier, while lowest Haugh unit was recorded in birds reared under lower cage tier.

Storage effect on external egg quality of Isa-Brown laying birds reared under different cage tier

Table 3 shows the result for effect of tiers and storage duration on external egg quality. Among all the parameters measured, only the final egg weight was significantly ($p < 0.05$) influenced by the storage period. Highest final egg weight was recorded in eggs stored for 1day, while final egg weight for 21days was lowest. Numerically, highest egg width was recorded in eggs stored for 21days, while lowest egg width was recorded in eggs stored for 1

day. Numerically, highest egg length, highest shell weight, highest shell weight/unit surface area and highest shell without membrane were recorded in eggs stored for 14days, while, lowest egg length, lowest shell weight, lowest shell weight/unit surface area and lowest shell without membrane were recorded in eggs stored for 21days. For the cage tiers, all the parameters measured (except shell thickness) were significantly influenced. Highest initial egg weight, highest final egg weight, highest egg width, highest egg length, highest shell weight, highest shell weight/unit surface area and highest shell without membrane was recorded in birds reared under lower cage tier, while lowest initial egg weight, lowest final egg weight, lowest egg width, lowest egg length, lowest shell weight, lowest shell weight/unit surface area and lowest shell without membrane were recorded in birds reared under upper cage tier. In term of interaction, all the parameters measured were not significantly influenced. However, the highest initial egg weight was recorded in eggs stored for 14days and gotten from birds reared under lower cage tier, while lowest initial egg weight was recorded in eggs stored for 7days and from birds reared under upper cage tier. Highest final egg weight was recorded in eggs stored for 14days and from birds reared under lower cage tier, while lowest final egg weight was recorded in eggs stored for 14days and from birds reared under middle cage tier.

Table 3. Storage effect on external egg quality of Isa-Brown laying birds reared under different cage tier

	Storage Period	Cage Tier	Initial Egg weight	Final Egg weight	Egg Width (cm)	Egg Length (cm)	Shell Weight (g)	Shell Thickness (Inches)	Shell weight/unit surface area	Shell weight without membrane (g)
Storage Period (Days)	1		50.82	50.82 ^a	3.64	5.20	5.03	0.01	54.21	4.77
	7		50.56	50.19 ^a	3.65	5.20	5.06	0.01	54.39	4.80
	14		50.50	48.43 ^{ab}	3.71	5.23	5.09	0.01	54.18	4.85
	21		49.11	47.68 ^b	3.66	5.14	4.90	0.01	53.17	4.67
	±SEM		0.84	0.82	0.05	0.04	0.09	0.00	0.59	0.09
	P-value		0.475	0.042	0.751	0.378	0.525	0.0898	0.469	0.508
Cage Tiers		Upper	49.23 ^b	48.20 ^b	3.59 ^b	5.15 ^b	4.87 ^b	0.01	53.26 ^b	4.63 ^b
		Middle	49.42 ^b	48.39 ^b	3.63 ^b	5.17 ^{ab}	4.97 ^b	0.01	53.40 ^b	4.73 ^b
		Lower	52.09 ^a	51.06 ^a	3.76 ^a	5.26 ^a	5.22 ^a	0.01	55.30 ^a	4.95 ^a
		±SEM	0.73	0.71	0.05	0.03	0.08	0.00	0.52	0.08
		P-value	0.010	0.008	0.022	0.056	0.012	0.651	0.010	0.014
Storage Period * Tiers	1	Upper	48.93	48.93	3.59	5.14	4.68	0.01	53.01	4.45
		Middle	49.96	49.9 6	3.55	5.14	5.09	0.01	53.79	4.83
		Lower	52.80	52.80	3.79	5.32	5.31	0.10	55.83	5.04
	7	Upper	48.10	47.54	3.60	5.08	4.74	0.01	52.47	4.51
		Middle	49.98	49.34	3.54	5.16	4.99	0.01	53.78	4.74
		Lower	54.38	53.70	3.77	5.36	5.45	0.01	56.91	5.16
	14	Upper	49.51	48.08	3.55	5.21	4.96	0.01	53.46	4.70
		Middle	48.20	46.76	3.65	5.09	4.83	0.01	52.53	4.63
		Lower	49.63	48.20	3.76	5.11	4.93	0.01	53.52	4.68
	21	Upper	50.39	48.25	3.62	5.24	5.11	0.01	54.09	4.88
		Middle	49.54	47.50	3.77	5.21	4.99	0.01	53.49	4.74
		Lower	51.58	49.54	3.74	5.25	5.18	0.01	54.95	4.94
		±SEM	1.45	1.42	0.09	0.07	0.16	0.00	1.04	0.15
		P-value	0.485	0.489	0.758	0.11	0.172	0.428	0.486	0.199

*a,b, = means within the same column with different superscripts are significantly different (P<0.05), SEM= standard error of mean.

Storage effect on internal egg quality of Isa-Brown laying birds reared under different cage tier

Table 4 shows the storage effect on internal egg quality of Isa-brown laying birds reared under different cage tiers. All the parameters measured were significantly ($p < 0.05$) influenced by the storage period. Highest yolk width, highest yolk length and highest yolk color were recorded in eggs stored for 21 days, while lowest yolk width and lowest yolk length were recorded in eggs stored for 1 day. Lowest yolk colour was recorded in eggs stored for 7 days. Highest albumen length and albumen width were recorded in eggs stored for 21 days, while lowest yolk height, lowest yolk index, lowest albumen height and lowest haugh unit were recorded in eggs stored for 21 days. Highest yolk length was recorded in storage duration of 14 days. For the cage tiers, among all the parameters measured, only yolk weight, yolk height and albumen weight were significantly ($p < 0.05$) influenced. Highest yolk weight, highest yolk height and highest albumen weight were recorded in birds reared under lower cage tier. The lowest yolk height and lowest albumen weight were recorded in birds reared under middle cage tiers. Lowest yolk weight was recorded in birds reared under upper cage tier. In term of interaction, all the parameters measured were not significantly ($p > 0.05$) influenced. Numerically, highest yolk weight, highest yolk width, highest yolk length, highest yolk color, highest albumen length and highest albumen width were recorded in eggs stored for 21 days and from birds reared under lower cage tier, while lowest yolk weight, lowest yolk width, lowest yolk length, lowest yolk color, highest albumen length and lowest albumen width were recorded in eggs stored for 1 day and from birds reared under upper cage tier. Highest yolk height, highest yolk index, highest albumen weight, highest albumen height and highest haugh unit were recorded in eggs stored for 1 day and from birds reared under lower cage tier, while lowest yolk height, lowest yolk index, lowest albumen weight, lowest albumen height and lowest haugh unit were recorded in eggs stored for 21 days and from birds reared under upper cage tier.

Table 4. Storage effect on external egg quality of Isa-Brown laying birds reared under different cage tier

	Storage	Tiers	Yolk Weight (g)	Yolk Width (cm)	Yolk length (cm)	Yolk Height (cm)	Yolk Index	Yolk Colour	Albumen Weight (g)	Albumen Length (cm)	Albumen Width (cm)	Albumen Height (mm)	Haugh Unit
Storage Days Effects	1 Day		13.31 ^c	3.85 ^c	4.14 ^b	1.16 ^a	0.30 ^a	8.08 ^{ab}	29.93 ^a	7.69 ^d	6.24 ^c	5.08 ^a	71.83 ^a
	7 Days		13.87 ^c	3.92 ^c	4.16 ^b	1.10 ^a	0.28 ^a	7.79 ^b	28.84 ^a	9.07 ^c	7.02 ^b	4.17 ^b	64.27 ^b
	14 Days		14.73 ^b	4.29 ^b	4.80 ^a	0.81 ^b	0.19 ^b	7.83 ^b	25.70 ^b	9.81 ^b	7.12 ^b	3.83 ^{ab}	60.60 ^{ab}
	21 Days		15.52 ^a	4.43 ^a	4.76 ^a	0.67 ^c	0.15 ^c	8.58 ^a	26.30 ^b	10.66 ^a	8.41 ^a	3.21 ^c	54.21 ^c
	±SEM		0.28	0.05	0.15	0.03	0.01	0.23	0.63	0.21	0.15	0.25	2.03
	P-value		<0.001	<0.001	0.002	<0.001	<0.001	0.070	<0.001	<0.001	<0.001	<0.001	<0.001
Tiers Effects		Upper	13.92 ^b	4.09	4.38	0.93 ^{ab}	0.23	8.22	27.20 ^b	9.29	7.11	3.84	61.34
		Middle	14.17 ^b	4.09	4.54	0.90 ^b	0.23	7.75	27.13 ^b	9.41	7.20	4.28	64.49
		Lower	14.99 ^a	4.18	4.47	0.98 ^a	0.24	8.25	28.75 ^a	9.23	7.28	4.09	62.36
		±SEM	0.24	0.04	0.13	0.04	0.01	0.20	0.55	0.18	0.13	0.22	1.76
		P-value	0.005	0.240	0.672	0.073	0.316	0.152	0.065	0.762	0.623	0.360	0.438
Storage Days* Tiers Effects	1 Day	Upper	12.93	3.88	4.03	1.18	0.31	8.00	28.91	7.66	6.15	4.75	70.02
		Middle	13.10	3.81	4.14	1.11	0.29	7.50	29.75	7.63	5.96	5.63	76.16
		Lower	13.91	3.85	4.25	1.19	0.31	8.75	31.14	7.78	6.60	4.88	69.32
	7 Days	Upper	13.19	3.88	4.03	1.09	0.28	7.88	27.21	8.90	6.84	4.00	64.29
		Middle	13.90	3.95	4.14	1.10	0.28	7.75	27.84	9.44	7.11	3.75	60.28
		Lower	14.51	3.93	4.31	1.13	0.29	7.75	31.48	8.88	7.10	4.75	68.24
	14 Days	Upper	14.41	4.13	4.58	0.84	0.20	7.88	25.96	10.05	7.16	3.50	57.36
		Middle	14.14	4.35	5.30	0.73	0.17	8.00	25.59	9.50	7.00	4.50	66.29
		Lower	15.65	4.39	4.51	0.88	0.20	7.63	25.54	9.89	7.19	3.50	58.16
	21 Days	Upper	15.14	4.49	4.88	0.59	0.13	9.13	26.71	10.55	8.28	3.13	53.69
		Middle	15.53	4.25	4.60	0.68	0.16	7.75	25.33	11.08	8.71	3.25	55.23
		Lower	15.89	4.56	4.80	0.75	0.17	8.88	26.85	10.36	8.24	3.25	53.72
		±SEM	0.48	0.009	0.27	0.05	0.01	0.40	1.09	0.36	0.25	0.43	3.52
		P-value	0.906	0.133	0.424	0.430	0.522	0.244	0.365	0.612	0.473	0.343	0.312

*a,b,c = means within the same column with different superscripts are significantly different (P<0.05), SEM= standard error of mean

Effect of tiers and storage duration on egg pH of laying birds

Table 5 shows the result for effect of tiers and storage duration on egg pH. All parameters measured were ($p < 0.001$) significantly influenced by storage duration. Highest albumen pH, highest yolk pH and highest whole pH were recorded in storage duration 14days, while lowest albumen pH, lowest yolk pH and lowest whole pH were recorded in storage duration of 1day. For the cage tiers, all parameters measured were not significantly influenced by cage tiers. Numerically, highest albumen pH, highest yolk pH and highest whole pH were recorded in birds reared under upper cage tier, while lowest albumen pH, lowest yolk pH and lowest whole pH were recorded in birds reared under middle cage tier. In term of interaction, all the parameters measured were not significantly influenced. Numerically, highest albumen pH, highest yolk pH and highest whole pH were recorded in eggs stored for 14days and from birds reared under lower cage tier, while lowest albumen pH, lowest yolk pH and lowest whole pH were recorded in eggs stored for 1day and from birds reared under upper cage tier.

Table 5. Effect of tiers and storage duration on egg pH of laying birds

	Storage Days	Tiers	Albumen pH	Yolk pH	Whole pH
Storage Days Effects	1 Day		7.88 ^b	5.80 ^c	6.79 ^b
	7 Days		8.62 ^a	6.29 ^a	7.01 ^a
	14 Days		8.55 ^a	6.30 ^a	7.12 ^a
	21 Days		8.52 ^a	6.12 ^b	7.11 ^a
	±SEM		0.07	0.05	0.07
	P-value		<0.001	<0.001	<0.001
Tiers Effects		Upper	8.43	6.09	7.00
		Middle	8.36	6.19	6.98
		Lower	8.39	6.11	7.04
		±SEM	0.06	0.04	0.06
		P-value	0.639	0.231	0.805
Storage Days * Tiers Effects	1 Day	Upper	7.90	5.78	6.78
		Middle	7.88	5.88	6.83
		Lower	7.88	5.75	6.78
	7 Days	Upper	8.50	6.28	7.10
		Middle	8.65	6.38	6.93
		Lower	8.70	6.23	7.00
	14 Days	Upper	8.58	6.13	6.98
		Middle	8.55	6.43	7.15
		Lower	8.53	6.35	7.23
	21 Days	Upper	8.75	6.18	7.15
		Middle	8.35	6.08	7.03
		Lower	8.45	6.10	7.15
		±SEM	0.11	0.09	0.12
		P-value	0.276	0.345	0.730

*a,b,c = means within the same column with different superscripts are significantly different ($P < 0.05$), SEM= standard error of mean

Effect of cage tiers height on cloaca temperature

The results of the effect of cage tiers height on the cloaca temperature of Isa-Brown laying birds reared on Sides A, B, C and D of the experimental building over a period of days are shown in Table 6. There was no significant effect of cage tiers height on cloaca temperature of birds across all sides (Side A, B, C and D) within the poultry building.

Table 6. Effect of cage tiers height on cloaca temperature of laying birds

Cage Tiers	Cloaca Temperature (°C)
Upper	38.58 ± 0.09
Middle	38.53 ± 0.08
Lower	38.55 ± 0.09
P-value	0.941

For the period of the study, cloaca temperature ranged between 36 °C and 41 °C (Figure 2). There was a consistent drop in cloaca temperature of the birds on all sides (Side A, B, C and D) on day 10 of the study. The drop in the cloaca temperature can be explained by the effects of low environmental temperature recorded on that day (This was reported in a different study).

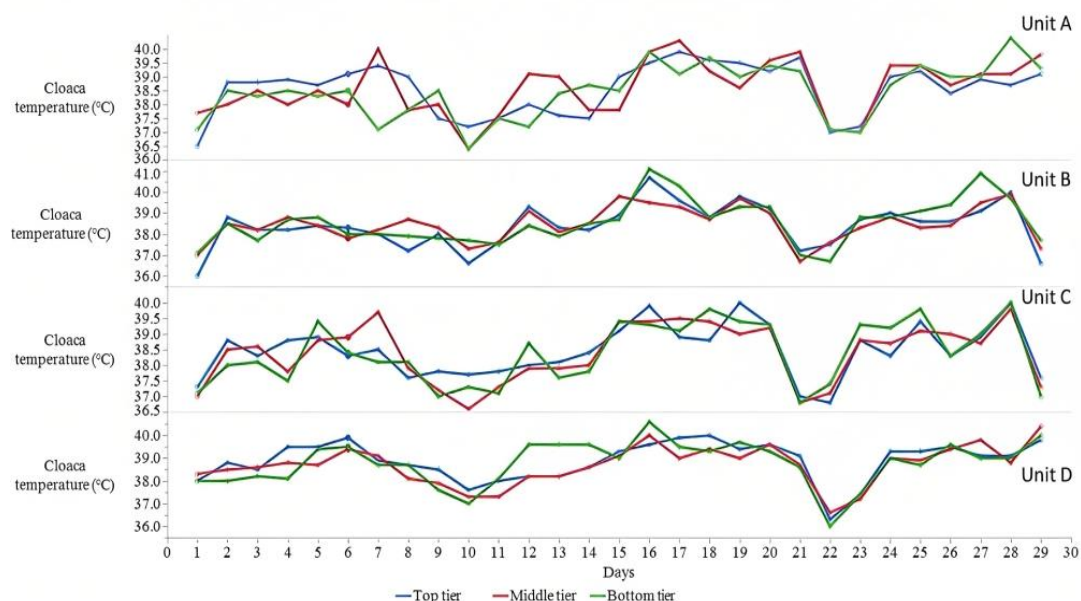


Figure 2. Cloaca temperature of birds housed in different units of the experimental house against days

DISCUSSION

The performance of Isa-Brown is greatly influenced by the environmental conditions and comfort. In conventional cage systems, hens are usually housed in tiers, with three or more levels of cages stacked on top of each other. The upper tier cages are often associated with the best housing conditions, such as more ventilation and light. On the other hand, the lower tier cages may have reduced air quality and poor lighting conditions, which may negatively impact the health and productivity of the hens. This research found that cage tier had a significant effect on the performance of laying birds. Cage tiers played a major role in affecting Henday production, egg weight, egg mass, total feed consumed and feed conversion ratio. In this current study, it was observed that hen day production was highest in birds raised in the upper tier, which is in line with the observation (Yildiz et al., 2006; Tai et al., 2013) that hens in the higher tier of the cage produced more eggs per day due to greater lighting than hens in the lower tier. Thereby, supporting the idea that cage tiers affect hen day production. This contradicted earlier report by (Akinmoladun and Oni 2010) who found that hens kept in higher tiers (i.e., third and fourth tiers) had significantly lower egg production, feed intake, and body weight compared to hens kept in lower tiers (i.e., first and second tiers). According to this study, until the peak phase, when subsequent increases in feed intake may not always be associated with increases in egg production, an increase in a layer's feed intake predicts a higher egg output. In this study, cage tier influenced feed intake significantly thereby contradicting earlier report by (Fidan and Nazligul 2012) that feed intake was not significantly different with respect to cage tiers in the denizli genotype.

Egg quality refers to various criteria that define both external and internal quality. Internal quality focuses on yolk height, yolk color, albumen viscosity, and Haugh units. External quality, on the other hand, is related to shell thickness, egg width and height, and cleanliness (Dilawar et al., 2021). Egg quality can be evaluated by several parameters, such as Haugh unit (HU) value, yolk color, albumen quality, shell integrity, and microbial safety. In this research, egg quality was not significantly influenced by cage tiers. However, egg weight increased numerically from upper tier to lower tier. Hence, corroborating the observation (Giroux et al., 2019) on White Leghorn laying hens, which reported that higher-tier cages (i.e., those with more tiers) were associated with a decrease in egg weight, shell thickness, and shell strength, as well as an increase in the incidence of cracked and misshapen eggs. Furthermore, storage, environmental conditions and cage tier levels can affect the quality of eggs produced by Isa Brown laying hens, which can impact the shelf-life, safety, and nutritional value of eggs. In this research, for all parameters measured for external egg quality only final egg weight was significantly influenced by storage duration. Cage tiers significantly influenced

all parameters measured for external egg quality (except shell thickness). However, there was no significant influence of the interaction between cage tiers and storage duration on external egg quality. All parameters measured for internal egg quality were significantly influenced by storage duration. For all parameters measured for internal egg quality only yolk weight, yolk height and albumen weight were significantly influenced by cage tiers effect. However, there was no significant influence of the interaction between cage tiers and storage duration on internal egg quality. According to this study, the weight loss, yolk weight, yolk height, yolk length, yolk width, yolk color, albumen weight, albumen width, albumen length, albumen height and the pH of albumen and yolk exhibited significant alterations between the storage groups. pH is a useful means of describing changes in albumen quality over time during storage (Sekeroglu et al., 2014). The weight loss of the eggs and pH values were observed to have tendency to increase as the storage duration increases. Albumen weight decreased with storage duration, whereas yolk weight increased with storage time. This corroborated the report of (Sekeroglu et al., 2014). It was observed that the pH in both albumen and yolk increased significantly with storage which is similar to other studies (Bayklair et al., 2021; Kumbar et al., 2016). In this study, significant changes in yolk color occurred. There was reduction in HU value, albumen quality and yolk color which is similar to a report by (Singh et al., 2016). According to (Jin et al., 2011), the yolk membrane degenerates during storage, water enters the yolk, diluting the pigment, and after an extended period of storage, albumen proteins may enter the yolk, reducing its color. Haugh Units (HU) are calculated from the height of the inner thick albumen and the weight of the egg and are considered a typical measure of protein quality. Haugh units are a measure of egg freshness and are related to shelf life. Hence, it is generally accepted that the higher the Haugh unit score, the better the egg quality (Guni et al., 2021; Abd El-Hack et al., 2020). The result from this study showed that eggs stored for 1 day have the highest HU value, which means the eggs are of high quality. Also, the eggs kept for 21 days has the lowest his HU score and the poorest egg quality. There was no significant difference of cage tiers height or location on the cloaca temperature of Isa-Brown laying birds, thereby corroborating the report of (Ajakaiye et al., 2019). A sharp drop in cloaca temperature across all sides was also observed on days 10, 11 and 22. This could be due to a drop in air temperature on these days (10,11 and 22) which could be due to rainfall on those days (day 10, 11 and 22). This result is found in another part of this research paper.

CONCLUSION

The results of the current study indicated that cage tier significantly influenced the performance of Isa-Brown laying birds. Birds raised in the

upper tiers had better performances than birds in the middle and lower tier in terms of Hen day production, egg mass, daily feed intake and feed conversion ratio. According to the findings of this study, the internal quality of eggs from laying birds deteriorated significantly as storage days increased and eggs stored for 1day had the best quality in terms of internal and external characteristics. Cloaca temperature was not significantly affected by cage tiers. However, further researches on the effect of cage tiers height and location on cloaca temperature should be carried out in a controlled setting.

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