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A comparative study of performance and profitability measures for broilers raised in open and closed systems: Investigating the histopathological effects of heat stress during summer in Egypt

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ABSTRACT

Background: Proper animal welfare and economic benefits are essential for the broiler industry.

Aim: This study assessed the productivity and profitability of open and closed broiler production systems in Egypt, with a particular focus on the histopathological effects of heat stress on broiler health.

Methods: Data were collected from 18 broiler cycles, involving 186,300 broiler chicks (9 cycles for each system for about 6 months). The independent *t*-test was used to analyze data and assess outcomes.

Results: According to the findings of the broiler performance study, the study was analyzed using an independent *t*-test to test the average body weight and performance index that significantly increased in the closed system (2.31 kg and 377.1, $t \leq 0.05$, respectively) compared to the open system (2.07 kg and 224.48, $t \leq 0.05$, respectively) with better feed conversion ratio and lower mortality rate in the closed system (1.65% and 5.46%, $t \leq 0.05$, respectively) than in the open one (1.93% and 15.96%, $t \leq 0.05$, respectively). Additionally, the profitability index for open and closed broiler houses in Egypt, as reported in our study, was 0.04 and 0.14, $t \leq 0.05$, respectively. This indicates that for every 100 EGP earned as revenue, 4 EGP are returned to the farmer as net income in the open system, whereas 14 EGP are returned in the closed system. Moreover, heat-stressed birds in an open system induced several pathological alterations in different organs, such as blood vessel congestion, degeneration, and vacuolation of breast muscle and parenchymatous organs (liver and kidney).

Conclusion: Productive and economic performance favors fully automated climate-controlled broiler housing; thus, a closed system is recommended for broiler farm owners. These improvements are crucial because they can directly contribute to increased profitability and sustainability in poultry farming, especially in regions experiencing extreme heat stress.

Keywords: Broilers welfare, Open and closed systems, heat stress pathology, Closed housing profitability.

Introduction

Effective business development begins with entrepreneurs who encounter numerous challenges in the business landscape. The broiler business is one of the most important agricultural sectors in Egypt, which attracts investment, primarily due to the enormous internal market for poultry meat consumption, coupled with the growing population and increased per capita consumption (Fotouh *et al.*, 2024). Poultry industries, particularly broiler production, serve as a significant economic foundation with great potential for boosting economic growth and creating numerous job opportunities (Hamiyanti *et al.*, 2023). According to Atapattu *et al.* (2017), greater scientific knowledge

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about the economic, social, environmental, and production performance of chicken production systems is necessary before undertaking such an undertaking. According to the Food and Agriculture Organization, global chicken meat production is steadily increasing. For instance, global broiler production reached approximately 133 million metric tons in 2022, and it is expected to continue growing due to the increasing demand for affordable protein sources, particularly in developing nations (Aggrey and Rekaya, 2024).

The house, where all poultry activities take place, is a key component of a successful broiler farm. To ensure that the chickens are healthy and productive, the house must be comfortable. Open- and closed-house systems are the two main types of housing systems; the climate of an open house is definitely uncontrolled. In contrast, a closed house allows the climate to be adjusted as needed, minimizing temperature and humidity changes and reducing the density of the house (12–14 chickens/m^2) compared to an open house (8–10 chickens/m^2) (Purnomo and Santosa, 2007). Broiler farming is a capital-intensive business, and a closed-house system provides high revenue and profitability during each raising period. The income generated is a key indicator of a farm's economic health, serving as a foundation for potential business expansion (Sarjana and Setiadi, 2018). Subkhie and Saleh (2012) reported that the causes affecting the high value of feed conversion rate (FCR) include overfeeding and improperly positioned feed, which result in feed waste.

Additionally, high temperatures and chickens suffering from diseases, especially respiratory diseases, lead to decreased appetite. Body weight (BW), FCR, and mortality percentage all have an impact on the performance index, which is a number that displays the success rate of broiler chicken production reared for a certain period (Farida *et al.*, 2022). Unang and Sumarsih (2014) reported that the performance index in broiler chickens in open houses ranged from 340 to 360, whereas in closed houses, it could reach 400. The failure of the body to cope with increased temperatures may result in adverse pathological changes at both the macroscopic and histological levels of vital organs. The housing system has a significant impact on broiler health and performance of boilers. Systems that provide optimal air quality, space, temperature, and disease control while promoting natural behaviors tend to lead to better overall welfare, health, and performance. Conversely, poor management or restrictive systems can lead to stress, disease, and reduced growth rates. A balance between welfare considerations and production efficiency is key to optimizing both the health and performance of broilers (Mesa *et al.*, 2017).

The gross changes in heat-stressed birds were dehydration (sunken eyes, dry skin), Pale comb and wattles, edema (swelling of the neck, eyes, abdomen), congested organs (liver, lungs, kidneys), and postmortem changes such as rapid rigor mortis. Thus, such establishment of cellular changes can lead to an understanding of the mechanisms associated with the adaptation of livestock to heat stress (Rebez *et al.*, 2023).

In regions with extreme temperatures or highly variable weather, such as the hot summer months in Egypt, heat stress can significantly affect broiler health, performance, and profitability. A closed-house system offers more consistent climate control, reducing heat stress and improving broiler health and growth (Ranjan *et al.*, 2019). It ensures a more stable environment in which factors such as temperature, humidity, and air circulation can be managed to optimize production. With improved temperature regulation, closed houses help mitigate the negative effects of heat stress, resulting in better growth rates, FCRs, and lower mortality rates (Farida *et al.*, 2022).

Heat stress in poultry is a critical factor in animal welfare and the economic health of the poultry industry. Welfare concerns include reduced productivity, health issues, and compromised reproductive performance. The economic consequences are wide-ranging and include increased operational costs, reduced efficiency, and potential losses due to mortality. As climate change continues to affect global temperatures, addressing heat stress will become even more important for ensuring poultry welfare and maintaining the economic viability of the industry (Nawab *et al.*, 2018).

In addition, heat-stressed birds become immunodeficient and may be susceptible to viral infections Elmeligy *et al.* (2024) and bacterial infections such as *Escherichia coli* (Abu El Hammed *et al.*, 2022) and *Salmonella* (Soufy *et al.*, 2016). Broiler production development was slowed down by heat stress, and exposure to environmental stress throughout the broiler's growth stage has been associated with unfavorable meat quality (Ranjan *et al.*, 2019). The pectoralis muscle of chickens exposed to heat stress exhibited smaller myofibers with large fat deposition areas, resulting in altered meat quality with increased fat and decreased protein content (Patael *et al.*, 2019).

Research on the impact of heat stress on broiler performance and profitability is limited, especially in hot climates like Egypt, where open systems are preferred over closed systems. Although heat stress is known to negatively impact poultry health, histopathological effects and their direct correlation with performance indicators [such as weight gain (WG), FCR, and mortality] and economic outcomes (such as profitability) have not been extensively studied. Additionally, comparisons of the economic feasibility of heat stress management in open versus closed systems are scarce. This study aimed to investigate and compare the performance and profitability of broilers raised in open and closed systems during the summer in Egypt, with a particular focus on the histopathological effects of heat stress on broiler health.

Materials and Methods

Study area and sampling

This research (cross-sectional study) was conducted in both open and closed broiler farms in Egypt from April 1, 2024, to September 1, 2024. Data were collected from 18 broiler cycles across 3 open farms (83,000 broiler chicks) and 3 closed farms (103,300 broiler chicks). Information about three consecutive production cycles for each farm was recorded. Data related to growth and economic performance were gathered from farm records and informal discussions with farmers. All broilers were fed commercial broiler feeds: starter diet from days 1 to 14 (23% protein), grower diet from days 14 to 28 (21% protein), and finisher diet from day 28 until sales (19% protein). The house floors were bedded with clean and fresh wood shavings from all farms.

Determination of growth performance parameters

BW, feed intake (FI), FCR, performance index, and mortality rate (%) are all components of broiler performance.

1. Every week, the broiler's BW (g) is recorded. The sample was selected randomly from 2% of the entire population.
2. The difference between the remaining ration and the total amount of ration given is the FI (g/chicken). Every week, the leftover feed is weighed.
3. WG divided by ration consumption yields the FCR, as described by Hamiyanti *et al.* (2023):

$$\mathrm{FCR} = \frac{\mathrm{FI(g)}}{\mathrm{WG(g)}}$$

4. The following formula was used to calculate the performance index according to Hamiyanti *et al.* (2023):

$$\text{Index of performance} = \frac{[100\text{-mortality\%}] \times \text{average weight(kg)}}{\text{Harvest time (day)} \times \mathrm{FCR}} \times 100$$

5. The number of dead chickens is known as the mortality rate, which is calculated daily and then expressed as a percentage after each cycle.

Determination of economic indices

1. Fixed costs (depreciation of buildings and equipment) were included in the production costs. Additionally, variable costs (drugs, vaccines, disinfectants, veterinary supervision, feed, chicks, litter, labor, and electrical costs during the entire production cycle/chick) are also incurred (Atallah, 2000). The total cost is equal to the sum of all fixed and variable expenses (Abd-El Hamed and Kamel, 2021).
2. Total return: The market pricing at the time of the study was used to compute the returns from the sales of both live BW and litter (Ibrahim, 2017).
3. Net profit (NP) = total return total cost (Kato *et al.*, 2022).
4. The profitability index was calculated according to Atapattu *et al.* (2017)

$$\text{Profitability index} = \frac{\mathrm{NP}}{\text{Total revenue}}$$

Histopathological examination

Tissue specimens from the brain, pectoral muscle, liver, and kidney were collected from three freshly dead chickens (30–40 days old). Each sample was 1–2 cm thick, fixated, processed, and treated with 10% neutral buffered formalin. After proper fixation (24–48 hours), the samples were dehydrated in ascending grades of ethyl alcohol, cleared in xylol, embedded in paraffin, and finely blocked. The samples were sectioned at 5 µm in thickness and stained with hematoxylin and eosin (H&E). Dehydrate again in ascending ethanol concentrations (95%, 100% ethanol) and then clear in xylene, as described earlier. Mount the stained slides with a mounting medium (e.g., DPX or Permount) and cover them with a glass coverslip for microscopical examination (Elbarbary *et al.*, 2024).

Statistical analysis

The statistical procedures were performed using the computer programs SPSS/PC+ "version 23" (SPSS, 2015). The study was analyzed using an independent *t*-test after checking the normality of the distribution and homogeneity using Levene's test to test the effect of housing systems on the productivity and profitability of broiler farms. In this study, using a confidence level of 95%, the *t*-test hypothesis was as follows: if a significant value $t \leq 0.05$, then H_o is rejected (H_a accepted), and if a significant value $t > 0.05$, then H_o is accepted (H_a rejected).

Ethical approval

This study protocol was established by ensuring ethics and rules for experimental animals and was approved by the Scientific Research Ethics Committee of the Faculty of Veterinary Medicine, Aswan University, Protocol number 10-2-2024.

Results

Table 1 and Figure 1 show a significant variation in temperatures among all weeks from the first to the fifth weeks. The open system showed a highly increase temperature than the closed system. This was due to the temperature conditions in the closed system being controlled with automatic tools for maintenance and the comfort of broiler chickens. BW was also shown in Table 1 and Figure 2, with a highly significant increase in the closed system to the open one from the second week until the final weight. This was due to the effect of temperature on the environment of broiler chickens affecting their FI, which in turn affected their production performance.

Table 2 shows the difference between the open and closed systems in the space of birds/m^2 (10.5 and 11.67 birds/m^2, respectively). In addition, there was a highly

Table 1. Effect of housing systems in the summer season on broiler growth rate.

Item	Open system	Closed system	
	Mean ± SEM	Mean ± SEM	*t* Test *p* values
Temperature (°C)			
First week	33.33 ± 1.54	29.89 ± 0.31	0.060
Second week	34 ± 1.72	28.89 ± 0.35	0.020
Third week	34.67 ± 1.6	27.44 ± 0.29	0.002
Fourth week	35.78 ± 0.95	27.89 ± 0.82	0.000
Fifth week	38.11 ± 0.89	27.11 ± 0.59	0.000
BW (gm)			
First week	166.44 ± 1.83	169.44 ± 1.83	0.300
Second week	407.22 ± 6.24	479.44 ± 13.81	0.000
Third week	830 ± 13.28	948.89 ± 10.43	0.000
Fourth week	1,273.33 ± 29.91	1,457.78 ± 21.65	0.000
Fifth week	1650 ± 55.05	2207.78 ± 34.95	0.000
Final weight	2,071.56 ± 36.84	2,310.56 ± 52.6	0.000

SEM: Standard error of the mean.

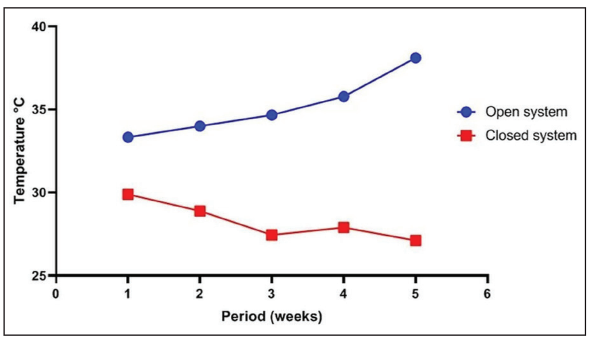

Fig. 1. Weekly temperature degrees in open and closed systems during the summer.

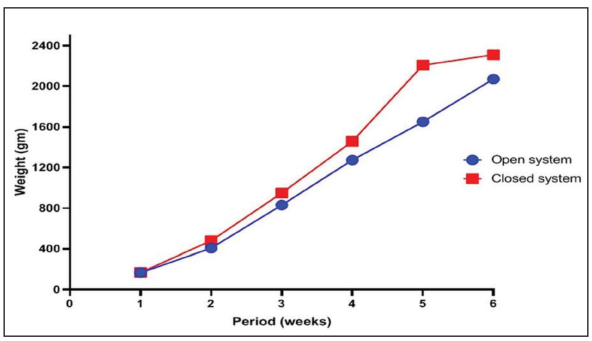

Fig. 2. Broiler growth rate in the summer in open and closed houses.

significant variation between the open (7.02) and closed systems (7.82) in terms of the number of cycles/year. From our results, we revealed no significant difference in total FI between the open (3.91 kg) and the closed system (3.74 kg). This little FI decreases in closed systems due to the use of automatic feeders, better feeding system management, and less feed wastage. Our results showed a significant increase in average body weight (ABW) and WG in the closed system (2.31 and 2.27 kg, respectively) than in the open system (2.07 and 2.03 kg, respectively). FCR is a measure of efficiency for the feed that broiler chickens consume to maximize their growth, as the lower the FCR value, the more efficient it is. Our results revealed that the average FCR was 1.93 and 1.65 for the open and closed systems, respectively. This demonstrates that the feed consumption value significantly differs between the open and closed systems. High temperatures are one of the factors that influence the mortality percentage, according to our data. Our results found a highly significant difference between the open (4.4%) and closed systems (0.23%) in heat mortality% and 15.96% and 5.46% in mortality%, respectively. Higher production performance was associated with a lower harvest age for high-weighted crops and a better performance index. The performance index values show a highly significant difference between the open (224.48) and closed systems (377.1). This means that a closed system is better than an open one for the maintenance and production of broiler chickens. Regarding the economic indices, the feed cost and total cost showed nonsignificant differences between the two systems; the feed cost was higher for the open system (91.04 EGP/bird) than for the closed one (88.79 EGP/bird), while the total costs were slightly higher for the closed system (139.23 EGP/bird) compared to the open one (138.79 EGP/bird). However, total return

Table 2. A comparison of the production and economic performances of broilers in open and closed systems.

Items	Open system	Closed system	
	Mean ± SEM	Mean ± SEM	*t* Test *p* values
Birds per house	9311.11 ± 1408.55	11,477.78 ± 1644.92	0.33
Birds/m2	10.5 ± 0.29	11.67 ± 0.17	0.003
Cycles/year	7.02 ± 0.07	7.82 ± 0.03	0.00
Total FI (kg)	3.91 ± 0.1	3.74 ± 0.09	0.2
ABW (kg)	2.07 ± 0.04	2.31 ± 0.05	0.002
WG (kg)	2.03 ± 0.04	2.27 ± 0.05	0.002
FCR	1.93 ± 0.04	1.65 ± 0.02	0.000
Heat mortality%	4.4 ± 0.53	0.23 ± 0.12	0.00
Mortality%	15.96 ± 1.03	5.46 ± 0.36	0.000
Performance index	224.48 ± 9.55	377.1 ± 10.03	0.000
Feed cost (EGP)	91.04 ± 2.18	88.79 ± 1.99	0.46
TC (EGP	138.79 ± 3.19	139.23 ± 1.76	0.9
TR (EGP)	145.1 ± 4.46	162.1 ± 3.75	0.010
NP (EGP)	6.3 ± 3.75	22.88 ± 2.62	0.002
Profitability index	0.04 ± 0.03	0.14 ± 0.01	0.004

SEM: Standard error of mean; ABW: Average body weight; WG: Weight gain; FCR: Feed conversion rate; TC: Total cost; TR: Total return; NP: net profit.

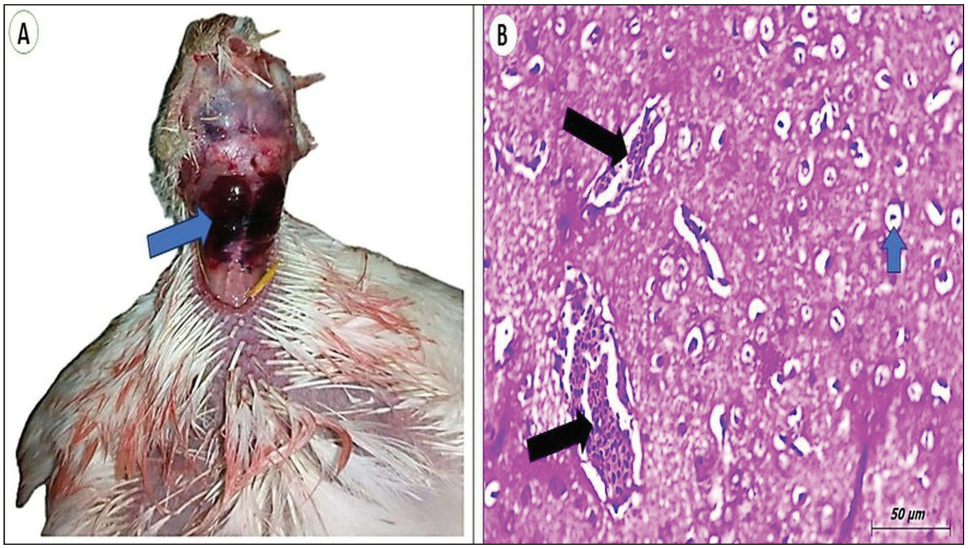

Fig. 3. Brain of examined morbid chicken (open system) A) severely hemorrhagic head and neck muscle (arrow). B) Brain sections showing congestion of most blood vessels (black arrow) with Wallerian degeneration of the brain tissue (blue arrow) (H&E stain, scale bar, 50 um).

and NP differ significantly between the two systems. They were 162.1 and 22.88 EGP, respectively, for the closed system and 145.1 and 6.3 EGP, respectively, for the open one. The profitability index for open and closed broiler houses in Egypt, as reported in our study, was 0.04 and 0.14, respectively.

Pathological alterations

Broilers reared in a closed system did not exhibit pathological changes. Several pathological alterations were noticed with the examination of the dead chickens exposed to heat stress in an open system. Grossly, the muscles of the head and neck showed severe hemorrhage (Fig. 3A).

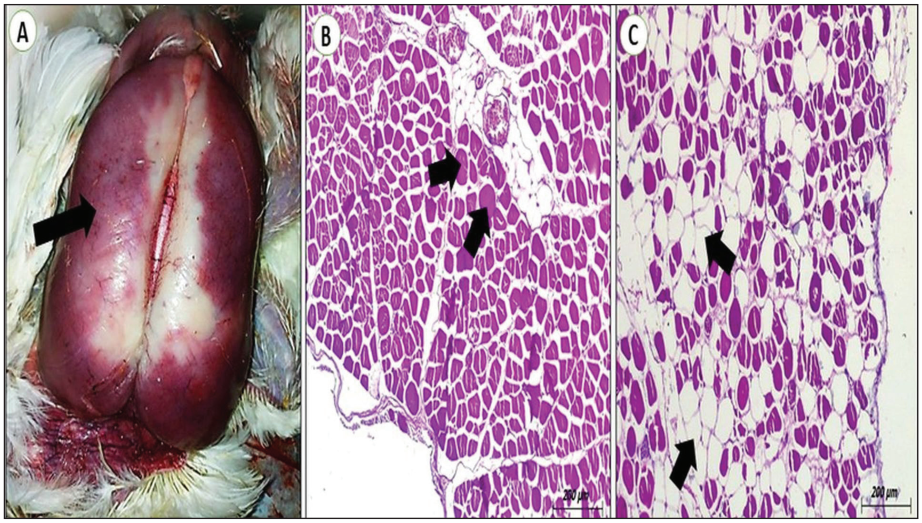

Fig. 4. Breast muscle of the examined chicken (open system). A) Grossly showing dark red coloration (arrow) with whitish spots. B) The breast muscle section suffered from Zenker necrosis (arrows) with fat vacuoles between muscle fibers (H&E stain, scale bar, 50 um). C) Complete replacement of the muscle with fat vacuoles (arrows) (H&E stain, scale bar, 200 um).

In addition, the pectoral muscle showed dark congested areas with pale white color in other parts (Fig. 4A). Microscopical examination of most organs showed pathological changes that varied from degenerative changes such as vacuolar degeneration and fatty changes or extended to necrosis and fibrosis.

The examined brain sections showed congestion of most blood vessels with degenerative and vacuolation in the brain tissue (Fig. 3B). Meanwhile, the pectoral muscle suffered from coagulative necrosis with fat vacuoles between muscle fibers, and some cases showed complete replacement of the muscle with fat vacuoles in the absence of the muscle fiber (Fig. 4B and C). Liver sections show congestion of the portal vein and hepatic sinusoid (Fig. 5A), with fibrosis around the portal vein and bile duct. Bile duct showing mild hyperplasia with newly formed bile ductules (Fig. 5B). Kidney sections showing congestion of sub-capsular blood vessels (Fig. 6A), as well as congestion of inter-tubular blood capillaries. Additionally, glomeruli show congestion of glomerular blood vessels with necrosis of the glomerular tuft epithelium, whereas renal tubules show vacuolation and sloughing of renal tubular epithelium (Fig. 6B and C).

Discussion

Poultry production is essential on a global scale because of its contributions to food security, economic development, job creation, and nutrition (Shosha *et al.*, 2024). In general, poultry are exposed to a broad and diverse array of stressors, including environmental, biological, nutritional, and production factors (Abdel-Kareem *et al.*, 2025). Closed-system farms are important for disease control, biosecurity, animal health, and risk management (Fotouh *et al.*, 2020). There was a highly significant variation between the open (7.02) and closed systems (7.82) in a number of cycles/year. This might be due to broiler chickens in the closed system reaching marketing age in less time of period with controlled feeding and temperature than in the open system. The results were in the same line as those obtained by Atapattu *et al.* (2017), who stated that the open house system reported a significantly lower number of growing cycles/year (4.4) than the closed house (6.9). This is due to the number of growing cycles per year being impacted by numerous factors, including the number and availability of chicks and market conditions. Our results revealed that there was a significant increase in ABW and WG in the closed system (2.31 and 2.27 kg, respectively) compared to the open system (2.07 and 2.03 kg, respectively). Similar results were obtained by Atapattu *et al.* (2017), who reported that broilers in the open system showed significantly lower final live weight (1,922 g) compared to those under the closed one (1,974 g). FCR is the quantity of feed that broilers need to generate 1 kg of live weight. According to Marom *et al.* (2020), who noted that the ratio of FI to WG over a period is known as FCR. Patterson (2001) found that the value of FCR could be more efficient if it reaches the number < 2 for the maintenance of broiler chickens. In our results, FCR showed a very significant difference between the open system (1.93) and the closed one (1.65). Our findings were in agreement with Atapattu *et al.* (2017), who said that FCR in an open system (1.94) was higher than closed one (1.56). In contrast, Farida *et al.* (2022) noted no significant difference in FCR between open (1.554) and closed systems (1.516)

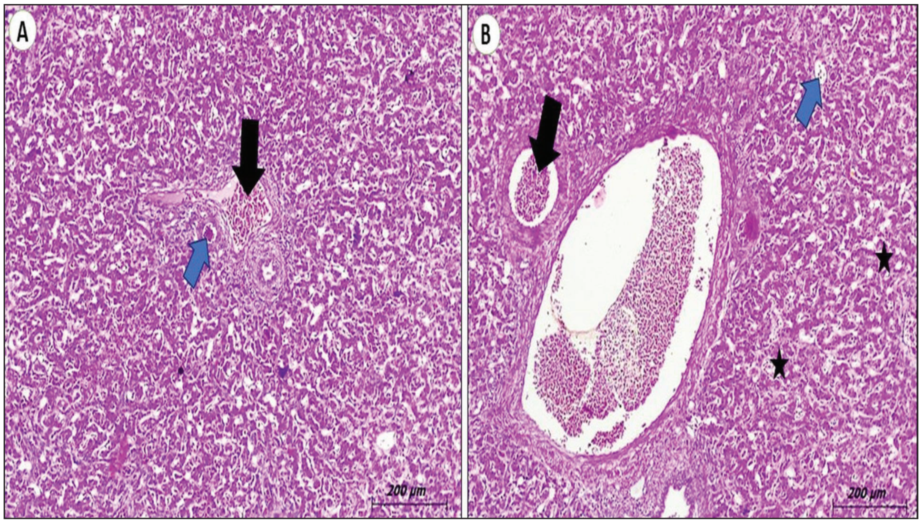

Fig. 5. Liver section picture of the examined chicken (open system) showing A) congestion of the portal vein and hepatic sinusoid (black arrow) with fibrosis around the portal vein and bile duct with mild hyperplasia of the bile duct and newly formed bile ductules (blue arrow) (H&E stain, scale bar, 200 um). B) Hydropic degeneration of hepatocytes (black stars) with severely dilated central veins (black arrow) and newly formed bile ductules (blue arrow) (H&E stain, scale bar, 200 um).

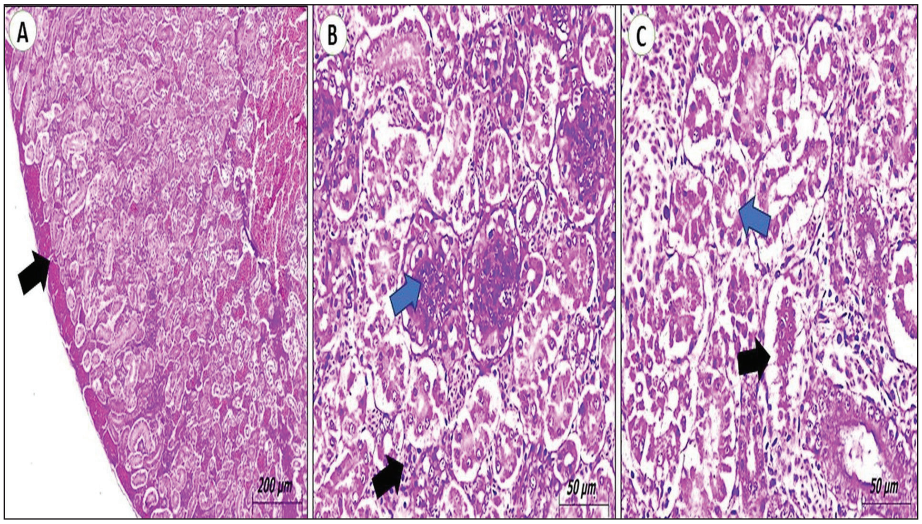

Fig. 6. Brain of examined morbid chicken (open system) A) severely hemorrhagic head and neck muscle (arrow). B) Brain sections showing congestion of most blood vessels (black arrow) with Wallerian degeneration of the brain tissue (blue arrow) (H&E stain, scale bar, 50 um).

in broiler chickens. The percentage of mortality was significantly ($p < 0.01$) higher in the open system compared to the closed one. This is owing to that broiler chickens have homoeothermic (warm-blooded) characteristics of body temperature of 40°C–41°C because they do not have sweat glands and all body covered with feathers (Farida *et al.*, 2022). Therefore, high mortality % in open systems may be due to uncontrolled climatic conditions especially in summer with high temperatures in contrast to the closed one that supported with ventilation and cooling system. Our results agreed with Farida *et al.* (2022), who noted mortality percentage in the closed system was 3% and the open one was 4.14%. In addition, Nuryati (2019) reported a 7.70% mortality % in open systems in broiler chickens. Susanti *et al.* (2016) revealed that the mortality % was 13.07% in the open system of broiler. The performance index is used to find out the success of poultry rearing, counting the index of performance. From our results, performance index values revealed a highly significant difference between the open (224.48) and closed system (377.1). On the same trend, Farida *et al.* (2022) reported that the performance index in the closed system (389) was higher than in the open one (358). In addition, Zaki *et al.* (2025) found a decrease in the performance index in the open system that ranged from 260 to 370 and an increase in value in the closed one that ranged from 400 to 420. This means that the performance and production of broilers in the closed system were better than in the open one. As Levy (2017) reported that the closed system showed a better growth performance than the open one. Concerning the economic indices, profit efficiency refers to a company's capacity to maximize profits based on its pricing and fixed elements, while profit inefficiency is the lack of profit resulting from the failure to operate at the highest level of efficiency. In this study, the total costs were slightly higher for the closed system (139.23 EGP/bird) compared to the open one (138.79 EGP/bird), but the closed system demonstrated greater temporal utilization efficiency of resources (utilized the available housing spaces more effectively) to achieve better returns for profit maximization. In our results, between the two systems, there were notable differences in NP and total return; they were 162.1 and 22.88 EGP, respectively, for the closed system, while they were 145.1 and 6.3 EGP, respectively, for the open one. Our results align with Atapattu *et al.* (2017), who concluded that the NP for the raising of broilers in the closed system was significantly higher than that of the open one. Additionally, our findings are consistent with Trentin *et al.* (2025) who demonstrated that fully automated climate-controlled housing yields better economic results. According to our research, the comfort system maximizes chicken productivity, which suggests that the rearing system is essential to this achievement. Our results ran counter to those of Respati *et al.* (2020), who discovered that broiler farms using open-house systems in partnership patterns are more profitable than those using closed-house systems. The profitability index for open and closed broiler houses in Egypt, as reported in our study, was 0.04 and 0.14, respectively. This indicates that for every 100 EGP earned as revenue, 4 EGP are returned to the farmer as net income in the open system, compared to 14 EGP in the closed system. Compared to the open system, the closed system is more profitable. Our findings concurred with Farhadi *et al.* (2016), who concluded that the closed system is financially more profitable than the open one because it results in a higher initial investment while improving the production efficiency under a larger scale of operations.

Increased heart rate and blood vessel congestion in the brain, liver, kidneys, and heart are the primary manifestations of stress's impact on the body's homeostatic condition (Ewing, 1999). In our study, the brain, liver, and kidneys showed blood vessel congestion in response to homeostasis. When a chicken is subjected to heat stress, its oxygen intake will ultimately decrease, leading to hypoxia of cells (Xing *et al.*, 2019). Additionally, contaminants in the environment, such as copper (Cu), hydrogen sulfide (H2S), and ammonia (NH3), induced oxidative stress, resulting in a reduction of antioxidant activity, which causes an inflammatory response damage and inflammatory cell infiltration (Chen *et al.*, 2019). Additionally, in our results, most degenerative changes in the form of vacuolation of cells as these cells are exposed to hypoxia leading to failure of them to maintain proper homeostasis and cellular membrane damage and vacuolation of these cells (Akinyemi and Adewole, 2021).

Conclusion

Growth performance parameters and economic indices of broilers in closed systems were significantly better than those in open systems. Growth performance revealed a significant increase in ABW and performance index along with a decrease in FCR and mortality percentage in the closed system to an open one. The NP increased significantly in closed systems (22.88 EGP/bird) compared to open systems (6.3 EGP/bird), so an environmentally controlled housing system is recommended for broiler farm owners. These improvements are crucial because they can directly contribute to increased profitability and sustainability in poultry farming, especially in regions experiencing extreme heat stress. By reducing the negative impacts of heat stress, closed systems offer a viable solution for enhancing broiler welfare and productivity, making them an important tool in modern poultry management. Future studies should investigate whether short-term performance improvements in closed systems lead to long-term health benefits. Tracking broiler health beyond the immediate production period, including assessing organ function, immune response, and disease resistance, will provide critical insights into the sustainability of these systems.

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Conflict of interest

The authors declare that they have no relevant conflicts of interest.

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None.

Author contribution

Data collection, Methodology, Analysis, and Writing original draft were done by Amira M. Abd-El Hamed, Zienab H. Abo-Gamil, Nady Khairy, and Ali Ghania.

The pathological sections were studied by Ahmed Fotouh and Marwa Darwish. All authors contributed equally and have revised and edited the final version of the manuscript.

Data availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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