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Adapting to Change: Investigating Climate-Induced Microclimate Shifts in the Closed House of Laying Hens

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CLIMATE CHANGE poses considerable challenges to poultry farming, as it affects the microclimate and air quality in enclosed poultry houses. This study investigated the influence of seasonal climate variations on the indoor microclimate of a commercial laying hen house. Over seven months, outdoor and indoor temperatures, relative humidity (RH%), air velocity (AV), and temperature-humidity index (THI) were systematically measured. The indoor temperatures closely mirrored the outdoor trends and significantly differed from the outdoor temperatures, except for April and May. The outdoor temperature significantly influenced the indoor front (Beta = 0.732) and back (Beta = 0.685) temperatures. Positive correlations were observed between the outdoor and indoor front (R^2 = 0.536) and back (R^2 = 0.470) temperatures. The indoor RH% was notably affected by the outdoor RH%, especially in warmer months. The outdoor RH% significantly predicted the indoor front (Beta = 0.463) and back (Beta = 0.427) RH%. Weak positive correlations existed between the outdoor and indoor front (R^2 = 0.214) and back (R^2 = 0.182) RH%. Indoor AV consistently lagged outdoor values, with no impact as a predictor of indoor front (P = 0.130) or back (P = 0.361) AV. The outdoor THI significantly influenced the indoor front (Beta = 0.774) and back (Beta = 0.751) THI. The indoor microbiological analysis revealed significant differences in the total colony count and the back-side total fungal count. In conclusion, these findings underscore the challenges posed by temperature and humidity fluctuations, highlighting the need for climate-responsive strategies to optimize indoor conditions for poultry production.

Keywords: Climate change, Environmental factors, Laying hens, Macroclimate, Poultry farming.

Introduction

Climate change refers to alterations in long-term weather conditions, including temperature, relative humidity, wind, and precipitation [1]. Over the past century, the Earth's average temperature has surged by 0.7°C [2]. Nevertheless, the 21st century is witnessing a more pronounced increase in global temperatures, with estimates ranging from 1.8 to 4°C [3]. The main factors driving this temperature increase are greenhouse gases (GHGs), with a focus on carbon dioxide (CO_2) and methane (CH_4), as highlighted by the Intergovernmental Panel on Climate Change in 2023 [4].

Egypt has four distinct climatic regions: the Delta, Eastern Desert, Western Desert, and Sinai. The climate ranges from Mediterranean along the coast to hot in the Upper region. Winter typically extends from December to February, while summer spans from June to August [5].

Egypt faces climate change challenges driven by three critical factors: rising sea levels, a water crisis, and heightened temperatures. These factors compel a shift in agricultural approaches [6]. A pivotal aspect of Egypt's agricultural strategy in response to climate change involves mitigating the impact of rising temperatures and increasingly extreme weather events on animal production [4]. Climate change exerts a multifaceted influence on poultry farming, impacting both egg production and management techniques. Climate variations can lead to higher indoor temperatures and reduced humidity levels, creating favourable conditions for the proliferation of fungi and bacteria [7].

Achieving peak performance in laying hen houses hinges on effective air quality management, a goal

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that necessitates well-designed heating and ventilation systems capable of maintaining a harmonious indoor environment [8]. The humidity levels within these housing facilities are of particular importance because they are influenced by both the respiration of the chickens and the exchange of surface moisture [9].

The design and management of poultry housing systems are pivotal in addressing the challenges posed by shifting climatic conditions. For example, two-tier cage systems are highly recommended due to their ability to facilitate efficient air exchange within buildings. In contrast, three- and four-tier cage systems can present difficulties in maintaining optimal air quality [10].

Closed-house systems equipped with exhaust fans and cooling pads are commonly employed in poultry farming to regulate indoor climatic conditions. However, it is important to note that the distributions of airflow, temperature, and humidity within a house can vary from the inlet to the exhaust fan [11]. In areas with elevated humidity, water-pad ventilation systems might not adequately mitigate thermal stress in animals. Furthermore, the humidity in the inlet air can significantly affect the temperature distribution throughout the house, resulting in higher temperatures in the rear areas than in the front sections. Addressing these challenges requires careful design considerations, including controlling the length of the layer house and managing temperature differentials between the front and rear sections [12].

Thermoregulation in birds refers to their ability to maintain body temperature through careful equilibrium between heat acquisition and dissipation. When temperatures surpass the upper threshold (27-29°C) or drop below the lower limit (16°C), laying hens need to control their metabolic heat production to maintain their core body temperature [13–14]. Within this temperature range, a thermoneutral zone exists, which represents the physiological range in which biological functions exhibit minimal variation and heat is lost through non-evaporative mechanisms such as conduction, convection, and radiation [15]. The thermoneutral zone is affected by various internal and external factors. Internal factors encompass genotype, species, and physiological state, while external factors encompass relative humidity, airflow, and solar radiation levels in the environment [16]. The severity of heat stress is predominantly determined by the combination of dry bulb temperature and humidity, which can be combined to form a THI [13]. The categorization of stress levels depends on various methods used for THI calculations.

This research aimed to explore the impact of seasonal climate change on the indoor microclimate and air quality within closed-laying hen houses. We will focus on various microclimate elements, ammonia levels, and microbial loads on both the front and rear sides of houses, aiming to provide insights into the impact of changing climate conditions on poultry production and welfare.

Material and Methods

Ethical approval for the study was obtained from the following number: VET CU 09092023767, the Cairo University Institutional Animal Care and Use Committee (Vet. CU. IACUC). The study was executed following all the guidelines of the Bioethics Committee, Cairo University, Egypt.

Laying Hens' Housing and Equipment:

Location:

The study was conducted between November 2022 and May 2023 within a privately owned commercial laying hen facility. The facility is situated in the eastern region of Cairo (Eastern Desert), Egypt, with an orientation in the north–south direction. The geographical coordinates are approximately 30.17°N in latitude and 31.61°E in longitude, and the average altitude above sea level is approximately 132 m.

The structural specifications of each building are as follows:

The farm has a height of 2.76 m and a ridge height of 2.9 m. It spans a length of 85 m and has a width of 14 m, resulting in a floor surface area of 1190 square meters and a total volume of 3368 cubic meters. Additionally, there is a 19 square meter service area. The foundations are constructed from reinforced concrete, and the floor of the house is covered with a 15 cm thick layer of concrete. The plastered walls and the ceiling of the poultry house are made of double sandwich panels with thermal insulation foam. Proper equipment arrangement is crucial for facilitating management tasks such as feeding, drinking, and egg collection. Laying hens are commonly provided with feed through a mechanical automatic feeder system. All of the laying hens had unrestricted access to water, facilitated by adjustable nipple drinkers, an automatic feeding bunker, and a microclimate controller for environmental control.

Ventilation and cooling system:

To manage the indoor climate, outdoor air was forcibly directed through a 20.4 m^2 surface area of 10 cm thick cellulose cooling pads positioned in the middle of the northern vertical wall and the front 2 sides of the house facing the prevailing winds. Thirty corrugated cellulose pads, each measuring 60 cm in width and 200 cm in height, were utilized to facilitate airflow at a rate of 75 m/min. A 12.5 mm diameter polyvinyl chloride (PVC) pipe was suspended just above the pads. Holes spaced approximately 5 cm apart along the upper side were drilled, and the end of the pipe was sealed. A baffle was installed above the water pipe to prevent any water leakage. A gutter system was positioned beneath the pads to collect and return water to a 500-liter capacity water tank. This water could be recycled back to the pads using a water pump.

After passing through the pads, the air traveled a distance of 85 m before being expelled by thirteen extraction fans, as shown in Figure 1, on the back side of the facility. Each extraction fan produced an airflow rate of approximately 39500 m^3/h under a 2.5 mm Hg static pressure. The evaporative cooling system was in continuous operation when the indoor air temperature reached 27°C. The indoor air temperature at a height of approximately 1.8 m above the floor (monitored level) was regulated by an on-off controller (differential thermostat) to initiate ventilation at 29°C and suspend it at 27°C. In practice, Egyptian growers believe that the positive impact of reducing the indoor air relative humidity could outweigh the negative effects of increasing the indoor air temperature above 25°C.

Laying hens:

Within a single, enclosed commercial house dedicated to laying hens, there were a total of 25,600 Hy-line W-80 white chickens. These chickens were primarily used for egg production, with an initial daily egg production rate of 23,550 eggs in November, marking the start of the study. At the outset of the study, the birds were 280 days old and had an average weight of 1.760 kilograms.

Cage systems:

Cage systems are widely employed in poultry layer farming for commercial egg production due to their efficiency and effective egg management. These cages are typically constructed from metal and are designed to provide a controlled environment for each bird. In this particular study, the cages were organized in a configuration of 6 rows and 3 tiers, optimizing the use of available space. The east and west aisles of the chicken house measured 0.9 m in width, while the central 5 aisles were 1.2 m wide. Fig. 1, illustrates the structural layout of the chick brooder house. This cage system is a three-tier setup, meaning that there are three levels of cages stacked on top of one another. Multi-tiered systems are advantageous for utilizing the vertical space within poultry houses efficiently. The cage dimensions were 60 cm in length, 50 cm in width, and 45 cm in height, resulting in a volume of 135,000 cubic centimetres or 0.135 cubic meters. Each cage accommodated 8 birds. Each tier was equipped with an egg collection belt and a feeding chain row located in front of the cages, with a dropping belt beneath them.

Microclimatic measurements:

Air temperature (°C), RH (%), and AV (m/s) were systematically monitored and recorded at fourteen distinct locations within the laying hen facility. Seven measurements were taken from the seven aisles 14 m from the cooling pads on the front side of the farm, while the other seven readings were obtained from the seven aisles 14 m before the extracting fans on the back side of the farm, as depicted in Fig. (1). The temperature, RH%, and AV (m/s) were measured using a Lurton LM8100 instrument manufactured by Lurton Electronic in Taiwan. The Lurton LM8100 microclimate measurement device provides precise readings, measuring temperature (°C) within a range of 0 to 50°C with an accuracy of ±0.1°C, RH% within a range of 10 to 95% with an accuracy of ±0.1%, and AV within a range of 0.4 to 30.0 m/s with an accuracy of ±0.1 m/s [17]. Concurrently, data on microclimatic (interior) and macroclimatic (exterior) variables were gathered daily at 11:00 AM over 7 months.

Indoor air ammonia gas levels were assessed using a Bargain KXL-804 LCD Display Ammonia Gas Detector NH3 Meter, which is capable of detecting ammonia gas concentrations in the range of 0 to 100 ppm with an accuracy of ±1 ppm. This detector continuously monitors the levels of ammonia gas within the farm environment, triggering sound, light, and vibration alarms when the concentration exceeds the upper permissible limit, as specified by Huda et al. [18].

The THI was computed using a modified equation proposed by Marai et al. as follows: THI = db °C - [(0.31 - 0.31 * RH) * (db °C - 14.4)], where THI represents the temperature humidity index, db °C represents the dry bulb temperature in degrees Celsius, and RH represents the relative humidity as a percentage divided by 100 [19]. The THI scores were categorized into the following classes: THI < 27.8 = no heat stress, 27.8 < THI < 28.9 = moderate heat stress, 28.9 < THI < 30.0 = severe heat stress, and THI ≥ 30.0 = very severe heat stress.

Indoor air microbiological examination:

Air sampling through the settle plate method was carried out using six nutrient agar plates, six MacConkey plates, and six Sabouraud dextrose plates for total colony count (TCC), total *Enterobacteriaceae* count (TEC), and total fungal count (TFC), respectively. Three plates were distributed in the front aisles, and three were distributed in the back aisles of the farmhouse. The culture plates were exposed by removing the plates' cover and left open for 5 minutes at a height of 1.20 m. The plates were subsequently covered, collected, neatly stacked, secured in a plastic bag, and subsequently transported in an ice box to the microbiology laboratory at the Faculty of Veterinary Medicine, Cairo University [20].

Statistical analysis:

The data collected and the subsequent results were managed and computed using Microsoft Excel 2016. For the data analysis, Statistical Package for Social Sciences software, version 25.0 (SPSS, Inc., Chicago, IL), was used. Initially, all the collected information was encoded into variables for systematic analysis. The normality of the data was assessed through the Kolmogorov–Smirnov test. Both descriptive and inferential statistics, including ANOVA, Spearman's correlation coefficient, and linear regression, were used to present and interpret the results. Additionally, a post hoc least significant difference (LSD) test was performed on the obtained results. For each statistical test, a significance level of less than 0.05 was used to indicate statistical significance [21].

Results

Table 1, summarizes the climatic parameters recorded during the seven-month study period for the layer farm, both outdoors and indoors on the front and back sides. The results revealed significant variations in temperature, RH%, AV, and THI among the three sites over most of the months.

Temperature (T°C):

In November and December, the outdoor temperatures were significantly lower (22.93 ± 0.44°C and 18.21 ± 0.43°C, respectively) than the indoor front (24.03 ± 0.14°C and 21.75 ± 0.21°C) and indoor back (25.71 ± 0.25°C and 23.67 ± 0.20°C) temperatures ($p < 0.05$). Similar trends were observed in January and February, when the outdoor temperatures (15.21 ± 0.33°C and 14.64 ± 0.57°C) were lower than the indoor front (19.38 ± 0.15°C and 20.53 ± 0.42°C) and indoor back (21.38 ± 0.30°C and 22.04 ± 0.63°C) temperatures ($p < 0.05$). In March and April, the outdoor temperatures were comparable to the indoor temperatures, with no significant differences ($p > 0.05$). May had slightly higher outdoor temperatures than did the indoor areas, but the difference was not significant ($p > 0.05$).

Relative humidity (RH%):

In November and December, the indoor front and back sides exhibited significantly greater RH% values than did the outdoor environment ($p < 0.05$). This trend continued in January and February when the indoor areas had significantly greater RH% than the outdoor areas ($p < 0.05$). In March and April, the RH% showed variations, but the indoor areas generally had higher RH% values. In May, the measurement spots in the indoor front and back quadrants had significantly greater RH% than did those in the outdoor environment ($p < 0.05$).

Air velocity (AV):

In all months, the outdoor AV was notably greater than the indoor AV on the front and back sides ($p < 0.05$).

Temperature-humidity index (THI):

Throughout the study period, the THI values in the outdoor environment were generally significantly lower than those in the indoor front and back regions ($p < 0.05$).

Table 2, presents the standardized coefficient (Beta) values for outdoor climatic parameters as predictors of the indoor farm front and back ambient temperature, RH%, AV, and THI. The outdoor temperature had a strong positive influence on the indoor temperature (Beta > 0.6, $p < 0.001$) and THI (Beta > 0.7, $p < 0.001$), especially on the front side. RH% had a positive influence on the indoor RH% (Beta > 0.4, $p < 0.001$), while AV had a relatively weak influence.

Table 3, shows the differences in the TCC, TEC, and TFC between the indoor front and back sides of the layer farms during the seven-month study period.

The indoor air ammonia level:

The indoor air ammonia level was zero throughout the study's seven months.

Air microbiology:

The TCC on the front and back sides exhibited significant ($P < 0.05$) variation across months, but the TCC on the front side was generally lower than that on the back side. However, the TEC and the front-side TFC exhibited variation, but there was no significant difference between the seven-month follow-up measurements on the front and back sides ($p > 0.05$). With higher counts than on the front side, the TFC on the back side varied significantly ($p < 0.05$) during the study months.

The figures presented in the study illustrate the relationships between outdoor and indoor climatic parameters, demonstrating the significant impact of the outdoor climate on indoor conditions. Fig. 2, displays the maximum and minimum values of temperature, RH%, AV, and THI, highlighting the fluctuations observed both in the indoor front and on the back sides in response to outdoor conditions. Figure 3 shows the linear regression analysis outputs (standardized coefficients) (Beta) of the outdoor climate predictors for the indoor ambient temperature, RH%, AV, and THI, emphasizing the strong influence of the outdoor temperature and RH% on the indoor conditions. Figs. 4, 5, 6, and 7, illustrate correlations and regression analyses between outdoor climate parameters and indoor conditions, highlighting the significant relationships observed between outdoor and indoor temperature, RH%, AV, and THI.

Discussion

Climate change poses a significant challenge to poultry farming because it impacts various aspects of production, including the microclimate within closed poultry houses. This study investigated the influence of seasonal climate change on the indoor microclimate and air quality in a commercial laying hen closed house in Egypt. The results shed light on the dynamic interactions between outdoor climate conditions and indoor poultry house environments.

The study's findings revealed significant variations in temperature, RH%, AV, and THI across different months. These variations are consistent with the seasonal climate changes observed in Egypt, where temperatures vary considerably between the winter and summer months. As expected, outdoor temperatures were generally lower during the winter months (November to February) and higher during the warm months (May), with transitional temperatures occurring in March and April.

One of the key observations from this study was the strong influence of outdoor climate conditions on the indoor microclimate of the laying hen house (Table 1). For instance, the outdoor temperature was significantly ($P < 0.05$) different from the indoor front and back temperatures during the study months, except during the April and May spring months (Fig. 2). However, the indoor temperatures closely followed the trends observed outdoors, with the indoor temperatures increasing during the hotter months and decreasing during the cooler months. This is indicative of the passive thermal exchange that occurs through the building envelope and ventilation systems, highlighting the challenges of maintaining stable indoor conditions in the face of external temperature fluctuations. These results were previously reported by Chen et al. who evaluated the relationship between the temperature of the indoor front and the temperature of the rear of poultry farms [12]. It is common for the temperature on the rear side to be higher than that on the front, which is often an inherent challenge in the design of tunnel-type water pad systems within layer houses. Linear regression analysis revealed that outdoor temperature was a significant ($P < 0.001$) predictor of the indoor front (Beta = 0.732) and back (Beta = 0.685) temperatures (Table 2 and Fig. 3). A positive correlation was detected between the outdoor and indoor front ($R^2 = 0.536$) and back ($R^2 = 0.470$) temperatures (Fig. 4).

The indoor RH% (Table 1) was also significantly influenced by the outdoor RH%, particularly during the summer months. A higher outdoor RH% in May (36.93 ± 3.50) corresponded to an elevated indoor RH% (60.44 ± 0.70) (56.70 ± 2.05), suggesting that the building's design and ventilation systems may need to be further optimized to address humidity control (Fig. 2). Proper humidity management is crucial for maintaining poultry health and preventing conditions conducive to fungal and bacterial growth. However, when the relative humidity falls below the recommended level, mortality can increase, and in certain instances, respiratory diseases may develop [22]. According to the findings of Chen et al., the humidity of the incoming air has a direct impact on the temperature that hens experience [12]. Additionally, various sources contribute to the increase in indoor RH%, including water vapor emissions from drinking water devices, cooling pads, and the ground within the chicken house, as indicated by Manonmani et al. [23]. Our results follow those of Babadi et al. and Chen et al., who reported that a house length greater than 30 m might induce more heat and humidity accumulation, affecting indoor air quality, hen health, and performance indices [12–24]. Linear regression analysis revealed that the outdoor RH% was a significant ($P < 0.001$) predictor of the indoor front (Beta = 0.463) and back (Beta = 0.427) RH% (Table 2 and Fig. 3). A weak positive correlation was detected between the outdoor and indoor front ($R^2 = 0.214$) and back ($R^2 = 0.182$) RH% (Fig. 5).

The indoor AV consistently lagged behind the outdoor AV, underscoring the limitations of ventilation systems in achieving uniform airflow distribution within poultry houses. The indoor air velocity plays a crucial role in the temperature distribution and results in the transfer of temperature from the front to the rear side of the farm, as highlighted by Chen et al. [12]. Our study revealed significant differences ($P < 0.001$) between outdoor and indoor AV over the seven months (Table 1) (Fig. 2). AV is responsible for the chilling effect and can be maintained at minimum levels if the indoor temperature is within 25-30°C [25]. The control of AVs can be achieved through the strategic placement of fans within a fixed area of the tunnel ventilation system. This arrangement takes into consideration the geometric effects of the fixed area and is one of the contributing factors to temperature accumulation [12].

Efficient ventilation is essential for maintaining air quality and preventing heat stress in laying hens. The study's results highlight the need for improvements in the ventilation system to ensure adequate air exchange and distribution, especially in the rear sections of the house. However, linear regression analysis showed that outdoor AV had no effect and was not a predictor of indoor front ($P = 0.130$) or back ($P = 0.361$) AV (Table 2 and Fig. 3). A very weak positive correlation was detected between the outdoor and indoor fronts ($R^2 = 0.024$) and back ($R^2 = 0.009$) AV (Fig. 6).

The THI values indicated that indoor conditions tended to be more stressful for laying hens than outdoor conditions, particularly during hotter months. The THI is a critical parameter for assessing thermal comfort and heat stress in poultry. Our findings revealed significant differences ($P < 0.001$) between the outdoor and indoor THI during the study months, except in April, due to a highly non-significant difference in temperature during that month (Table 1) (Fig. 2). The humidity level in the air inlet significantly impacts the temperature distribution within the house. In regions with a subtropical climate, regulating the humidity of the incoming air becomes essential. This control enables comprehensive management of the temperature and humidity of the house, ultimately influencing the THI. The THI falls within the alert range when the humidity level is less than 70% [12].

These findings emphasize the importance of developing strategies to mitigate heat stress, such as enhanced cooling and ventilation systems, especially during hot months in Egypt. Linear regression analysis revealed that the outdoor THI score was a significant ($P < 0.001$) predictor of the indoor front (Beta = 0.774) and back (Beta = 0.751) THI scores (Table 2 and Fig. 3). A positive correlation was detected between the outdoor THI and the indoor front ($R^2 = 0.559$) and back ($R^2 = 0.564$) THIs (Fig. 7). Modifying housing systems can serve as an effective approach to mitigate the severity of thermal stress. This, in turn, can help minimize the economic losses linked to elevated THI [26].

The indoor air ammonia level was zero throughout the study's seven months. The birds' droppings are automatically removed once daily through the dropping belt scraper. Battery cages provide the benefits of cost-efficient production and high hygiene standards [27]. Prior research has demonstrated that ammonia emissions from laying hen facilities are influenced by various factors, including manure management practices, ventilation rates, and building design [28]. Ammonia losses are also influenced by atmospheric temperature, relative humidity, and the dry matter content of the manure [29].

Microbiological analysis of the indoor air quality revealed a significant difference ($P < 0.05$) in the TCC and the back-side TFC between the seven months of the study. The back side of the house consistently had higher TCC and TFC values, highlighting potential challenges associated with air quality management in different parts of the house. While the TEC did not significantly differ among the seven months of the study, its overall level was relatively low, suggesting effective hygiene practices. Our findings follow those of Chen et al., who reported increased TCC and TFC on the rear side of laying hen farms due to the accumulation of stall air and humidity affecting air quality, hen health, and performance indices [12].

Humidity is a vital environmental factor for the air quality of chicken houses, as emphasized by Goma and Phillips [13]. Damp indoor environments harbor microorganisms, which are significant contributors to the deterioration of indoor air quality, as noted by Verdier et al. [30]. The decline in indoor air quality attributed to microorganisms, including molds, bacteria, and fungi, is a subject of increasing concern for international health organizations, as highlighted by Hänninen [31].

Climate variation manifests as a rise in temperature, causing a change in humidity and providing a medium for fungal and bacterial growth [7]. Controlled laboratory experiments have demonstrated that temperature (Ta°C) and RH% exert significant effects on the survival of various bacterial strains, as indicated by Tang [32].

Conclusions

This study has provided valuable insights into the impact of seasonal climate change on the indoor microclimate and air quality within laying hen closed houses in Egypt. The results highlighted the challenges posed by temperature and humidity variations and underscored the need for climate-responsive management strategies to optimize the indoor environment for poultry production. Further research and investments in ventilation, cooling, and insulation systems are essential for enhancing the resilience of poultry farming to climate change and ensuring the welfare and productivity of laying hens.

Conflicts of interest

There are no conflicting interests that the authors claim to hold.

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Author contribution

The researcher created the research topic, organized the practical portion of the study, performed statistical analysis, wrote the study, and completed a final review.

TABLE 1. Ambient temperature (T°C), RH%, air velocity (AV, m/s), and THI during the study 7 months in the layer farm outdoor, indoor front, and indoor back with their statistical significances

	Outdoor	Indoor Front	Indoor Back	Sig.	Outdoor	Indoor Front	Indoor Back	Sig.
		November				December		
T°C	22.93±0.44[a]	24.03±0.14[b]	25.71±0.25[c]	0.000	18.21±0.43[a]	21.75±0.21[b]	23.67±0.20[c]	0.000
RH%	70.43±3.22	72.46±0.48	68.34±0.37	0.316	56.71±2.99[b]	50.71±1.93[ab]	49.14±1.44[a]	0.049
AV	4.46±0.69[c]	0.57±0.01[a]	2.39±0.05[b]	0.000	3.49±0.67[c]	0.59±0.02[a]	2.13±0.07[b]	0.000
THI	22.11±0.34[a]	23.21±0.13[b]	24.60±0.22[c]	0.000	17.73±0.38[a]	20.63±0.19[b]	22.22±0.20[c]	0.000
		January				February		
T°C	15.21±0.33[a]	19.38±0.15[b]	21.38±0.30[c]	0.000	14.64±0.57[a]	20.53±0.42[bc]	22.04±0.63[c]	0.000
RH%	59.57±5.23	54.79±1.50	51.08±1.54	0.196	57.14±3.61[c]	47.04±2.01[ab]	46.47±2.09[a]	0.011
AV	3.07±0.57[c]	0.42±0.01[a]	1.52±0.05[b]	0.000	4.19±0.64[c]	0.42±0.01[ab]	1.02±0.05[b]	0.000
THI	15.09±0.28[a]	18.68±0.12[b]	20.32±0.26[c]	0.000	14.54±0.48[a]	19.49±0.32[bc]	20.73±0.49[c]	0.000
		March				April		
T°C	17.07±1.04[a]	22.23±0.96[bc]	23.77±0.90[c]	0.000	23.71±1.34	23.76±0.77	25.49±0.54	0.325
RH%	44.29±4.39	40.34±2.38	39.44±1.96	0.506	36.50±4.88[a]	53.31±1.47[bc]	48.35±1.84[b]	0.002
AV	4.56±0.80[c]	0.43±0.01[ab]	1.50±0.17[b]	0.000	3.87±0.65[c]	0.63±0.02[a]	2.53±0.11[b]	0.000
THI	16.52±0.78[a]	20.73±0.74[bc]	21.96±0.69[c]	0.000	21.65±0.92	22.39±0.64	23.70±0.44	0.119
		May						
T°C	24.71±0.79	25.42±0.29	26.28±0.35	0.126				
RH%	36.93±3.50[a]	60.44±0.70[bc]	56.70±2.05[b]	0.000				
AV	4.70±0.56[c]	0.66±0.02[a]	3.06±0.16[b]	0.000				
THI	22.61±0.54[a]	24.07±0.26[bc]	24.66±0.25[c]	0.001				

[a,b,c] In the rows, the mean values marked with different superscript letters are significantly different (P < 0.05). The values are presented as the means±SEs.

TABLE 2. Standardized coefficient (Beta) values of the outdoor climatic parameters as predictors of the indoor farm front and back ambient temperature, RH%, air velocity (AV), and THI

		Indoor Front	Sig.	Indoor Back	Sig.
T°C	Outdoor	0.732	0.000	0.685	0.000
RH%		0.463	0.000	0.427	0.000
AV		0.154	0.130	0.093	0.361
THI		0.774	0.000	0.751	0.000

TABLE 3. Differences in the total colony count (TCC), total *Enterobacteriaceae* count (TEC), and total fungal count (TFC) at the indoor front and back sides of the layer farm over the study 7 months with their statistical significances

	November	December	January	February	March	April	May	Sig.
TCC_ Front	433±46.7[a]	220±30.6[bc]	173±6.7[c]	206.7±24[bc]	166.7±13[c]	240±11.5[bc]	253±17.6[b]	0.000
TCC_ Back	573±35.3[a]	260±30.6[b]	193±6.7[c]	240±11.5[bc]	186.7±6.7[c]	230±17.3[bc]	220±11.5[bc]	0.000
TEC_ Front	12.7±4.5	1.7±0.9	14.7±14.2	2.0±0.6	0.3±0.3	0.0	1.3±0.9	0.356
TEC_ Back	2.7±0.7	3.3±1.9	12.0±11.5	1.3±0.3	0.7±0.3	0.0	0.7±0.3	0.529
TFC_ Front	1.7±0.7	3.0±1.0	1.0±1.0	1.0±1.0	0.3±0.3	0.3±0.3	0.3±0.3	0.179
TFC_ Back	3.7±1.5[a]	4.3±0.3[a]	0.7±0.7[b]	0.7±0.7[b]	0.3±0.3[b]	0.3±0.3[b]	0.0[b]	0.002

[a,b,c] In the rows, the mean values marked with different superscript letters are significantly different (P < 0.05). The values are presented as the means±SEs.

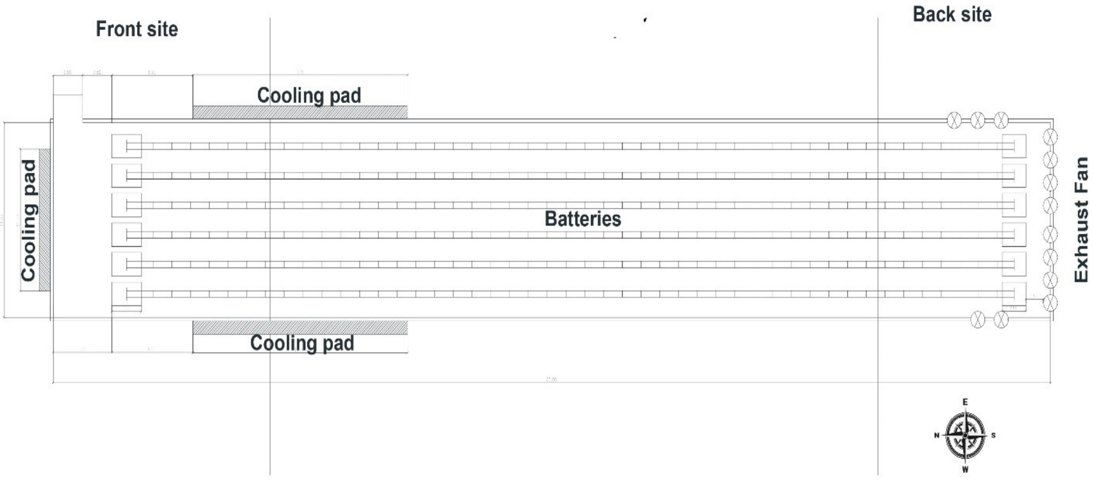

Fig. 1. Diagrammatic representation of the structure of the chicken house

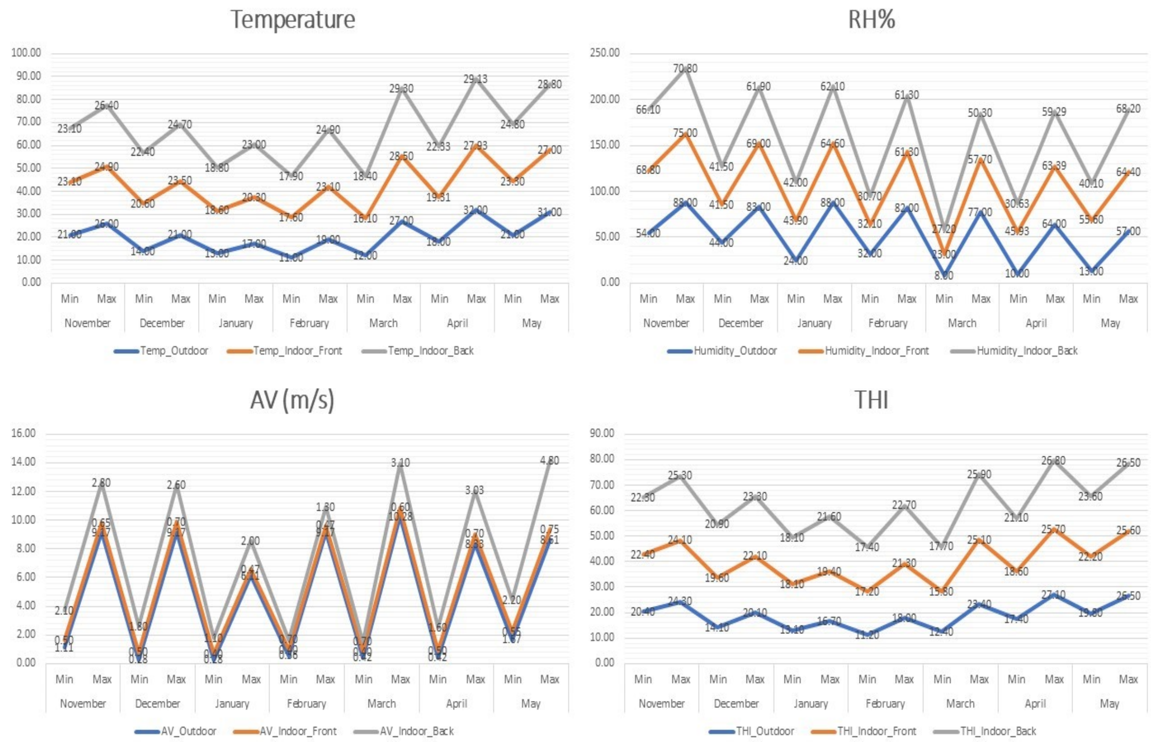

Fig. 2. Maximum and minimum values of temperature (T°C), RH%, air velocity (AV), and THI during the study 7 months in the farm outdoor climate, indoor front, and indoor back

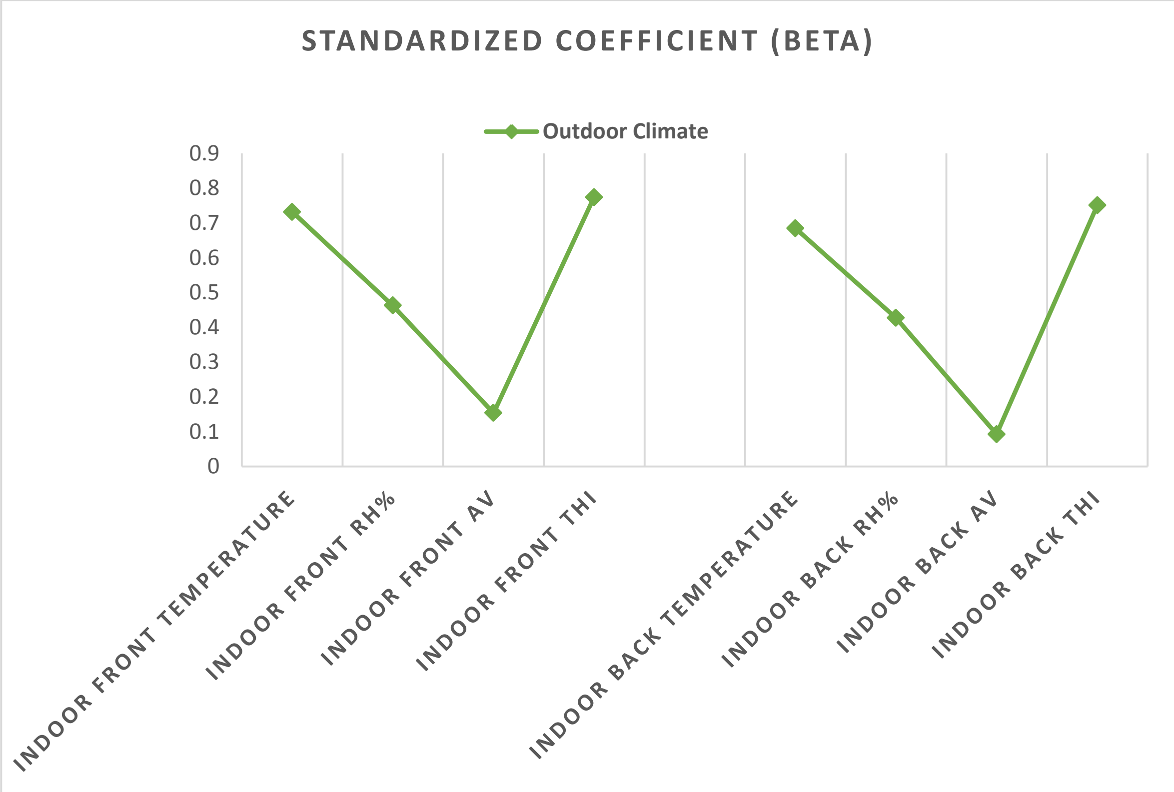

Fig. 3. Standardized Coefficient (Beta) of the outdoor climate predictors for indoor farm front and back ambient temperature, RH%, air velocity (AV), and THI

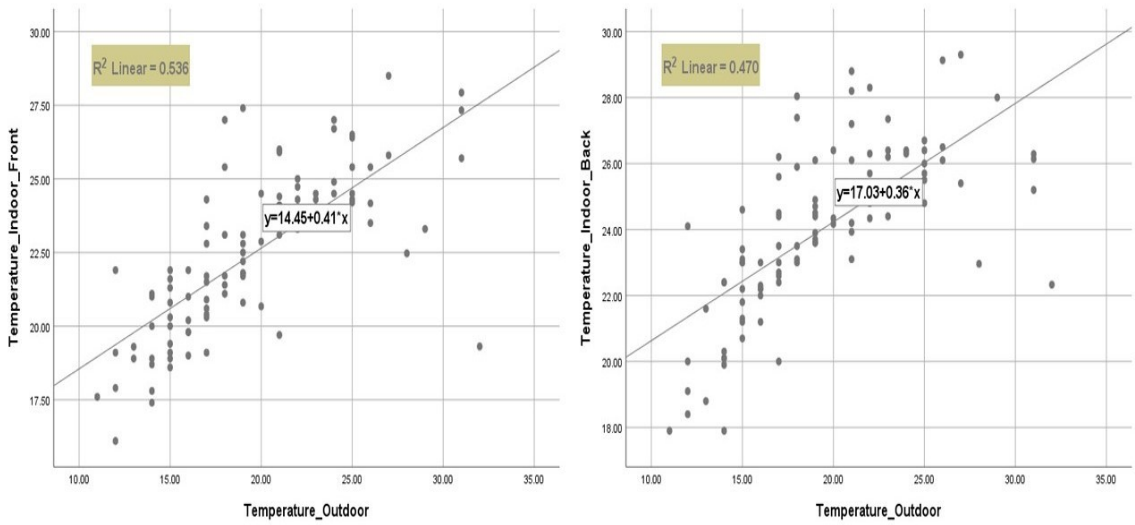

Fig. 4. Correlation, regression line equation, and R square between the outdoor climate temperature and indoor temperature in the front and back sides of the farm

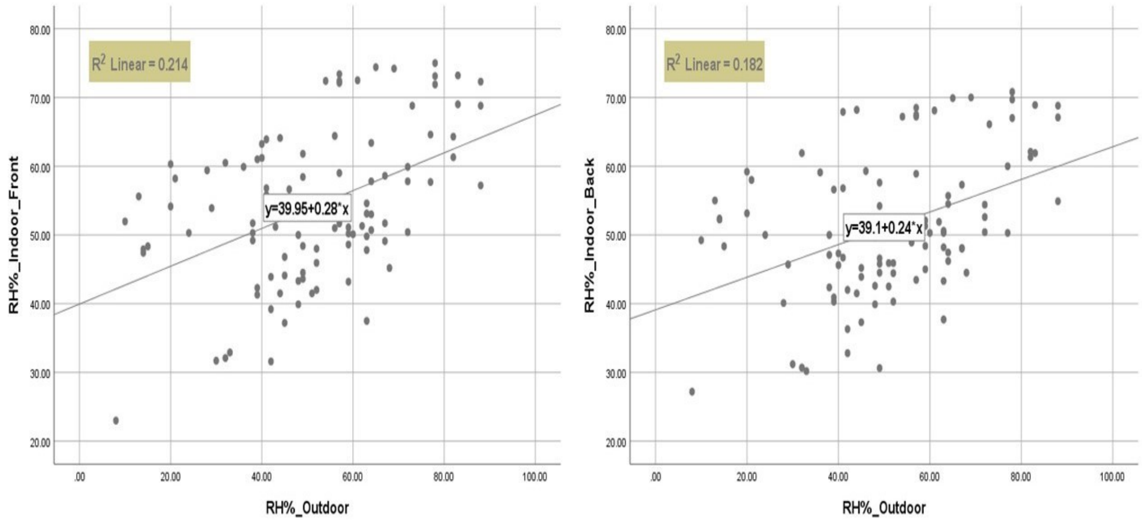

Fig. 5. Correlation, regression line equation, and R square between the outdoor climate RH% and indoor RH% in the front and back sides of the farm

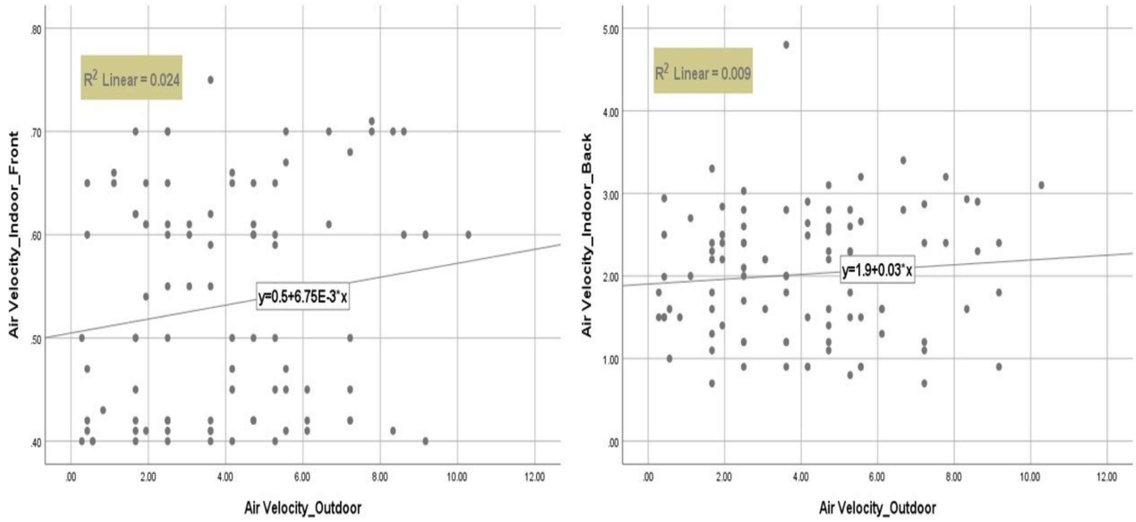

Fig. 6. Correlation, regression line equation, and R square between the outdoor and indoor air velocity in the front and back sides of the farm

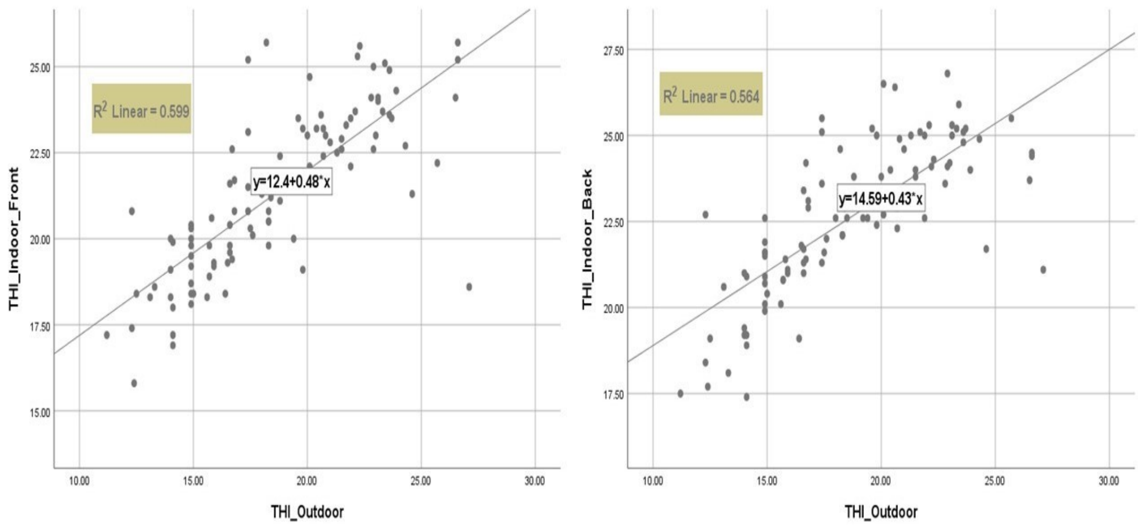

Fig. 7. Correlation, regression line equation, and R square between the outdoor THI and indoor THI in the front and back sides of the farm

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التكيف للتغيير: دراسة تحولات الميكرومناخ الداخلي في مزارع الدجاج البياض المغلقة والناتجة عن التغير المناخي

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المستخلص

توجه التغيرات المناخية تحديات كبيرة إلى مجال تربية الدواجن، حيث تؤثر على الميكرومناخ الداخلي وجودة الهواء في مزارع الدواجن المغلقة. قامت هذه الدراسة بدراسة تأثير التغيرات الموسمية في الميكرومناخ على المناخ الداخلي في مزرعة لتربية الدجاج البياض التجارية. خلال سبعة أشهر، تم قياس درجات الحرارة الخارجية والداخلية، الرطوبة النسبية (RH%)، سرعة الهواء (AV)، ومؤشر درجة الحرارة والرطوبة (THI) بشكل منتظم. أظهرت درجات الحرارة الداخلية تقديرًا وثيقًا للاتجاهات الخارجية واختلفت بشكل كبير عن درجات الحرارة الخارجية، باستثناء أبريل ومايو. كانت درجات الحرارة الخارجية لها تأثير كبير على درجات الحرارة الداخلية الأمامية (بيتا = 0.732) والخلفية (بيتا = 0.685). لوحظت علاقات إيجابية بين درجات الحرارة الخارجية والداخلية الأمامية (R2 = 0.536) والخلفية (R2 = 0.470). كانت الرطوبة النسبية الداخلية تأثرت بشكل ملحوظ بالرطوبة النسبية الخارجية، خاصة في الأشهر الأكثر دفئًا. تنبأت الرطوبة النسبية الخارجية بشكل كبير بالرطوبة النسبية الداخلية الأمامية (بيتا = 0.463) والخلفية (بيتا = 0.427). كانت هناك علاقات إيجابية ضعيفة بين الرطوبة النسبية الخارجية والداخلية الأمامية (R2 = 0.214) والخلفية (R2 = 0.182). كانت سرعة الهواء الداخلية تتأخر بشكل مستمر عن القيم الخارجية، دون أي تأثير كمتنبئ لسرعة الهواء الداخلية الأمامية (P = 0.130) أو الخلفية (P = 0.361). أثر مؤشر درجة الحرارة والرطوبة الخارجية بشكل كبير على مؤشر درجة الحرارة والرطوبة الداخلية الأمامية (بيتا = 0.774) والخلفية (بيتا = 0.751). أظهر التحليل الميكروبيولوجي الداخلي اختلافات كبيرة في العد الكلي للبكتريا وعد الفطريات الكلية في الجزء الخلفي. في الختام، تؤكد هذه النتائج التحديات الناجمة عن التقلبات في درجات الحرارة والرطوبة، مما يبرز الحاجة إلى استراتيجيات استجابة للمناخ لتحسين الظروف الداخلية لإنتاج الدواجن.

الكلمات الدالة: تغير المناخ ، العوامل البيئية ، الدجاج البياض ، الميكرومناخ ، تربية الدواجن.