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Research Article/Araştırma Makalesi

Evaluation of heat stress using temperature-humidity index in laying hens in battery cages under Bursa conditions

Bursa Koşullarında Batarya Kafeste Yumurtacı Tavuklarda Sıcaklık Stresinin Sıcaklık-Nem İndeksiyle Değerlendirilmesi

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ABSTRACT

Heat stress has become a more severe threat to the poultry industry with increasing global warming. Poultry is a sensitive animal affected more quickly by environmental conditions than other farm animals. Therefore, they are more easily exposed to heat stress. High temperature and relative humidity are significant environmental factors affecting animal growth, productivity, and welfare by causing heat stress. In laying hens under heat stress, egg production decreases, feed consumption increases, feed efficiency decreases, and deterioration in egg quality occurs. This study aims to determine the heat stress of laying hens using the temperature-humidity index (THI) in a farm where commercial egg production is conducted in battery cages in the Bursa region. According to the study results, the highest THI values occurred in the summer months and were at a critical level for chickens in July (26.0) and August (24.8). There is no statistically significant relationship between egg yields obtained in spring, summer, and autumn and the calculated temperature humidity index values. There is an inverse relationship between indoor temperature and egg production.

Key Words: Bursa, Heat stress, Relative humidity, Outdoor temperature, Laying hen

ÖZ

Artan küresel ısınmayla birlikte ısı stresi kanatlı endüstrisi için daha ciddi bir tehdit haline gelmiştir. Kümes hayvanları diğer çiftlik hayvanlarına kıyasla çevresel koşullardan daha çabuk etkilenen hassas hayvanlardır. Bundan dolayı daha kolay ısı stresine girmektedirler. Yüksek sıcaklık ve bağıl nem, ısı stresine neden olarak hayvanın büyümesini, verimliliğini ve refahını etkileyen başlıca çevresel faktörlerdir. Isı stresine giren yumurta tavuklarında yumurta verimi düşer, yem tüketimi azalır, yemden yararlanma oranı azalır ve yumurta iç dış kalitesinde bozulmalar meydana gelmektedir. Bu çalışmada, Bursa bölgesinde batarya tipi kafeste ticari yumurta üretimi yapılan bir işletmede, yumurta tavuklarında görülen ısı stresinin sıcaklık-nem (THI) indeksiyle belirlenmesi amaçlanmaktadır. Çalışma sonucuna göre, en yüksek THI değerleri yaz aylarında meydana gelmiştir ve Temmuz (26.0) ve Ağustos (24.8) ayında tavuklar için kritik seviyededir. İlkbahar, yaz ve sonbahar aylarında elde edilen yumurta verimleri ile hesaplanan sıcaklık-nem indeksi değerleri arasında istatistiksel olarak anlamlı bir ilişki bulunmamaktadır. Kümes iç ortam sıcaklığı ile yumurta üretimi arasında ters bir ilişki vardır.

Anahtar Kelimeler: Bursa, Çevresel sıcaklık, Isı stresi, Bağıl nem, Yumurta tavuğu

Introduction

Just as humans are affected by environmental factors, animals are also affected by environmental factors. In order to increase the productivity expected from animals, it is necessary to keep the environmental conditions in which they are raised at an optimum level, as well as their genetic capacity. Excessive heat and humidity are the most critical environmental factors in animal production houses. Protecting animal health and ensuring their welfare undoubtedly contributes to animal-derived foods' safety and productivity preservation. Therefore, it is essential to provide conditions that meet the demands of animals in order to achieve the highest efficiency by using resources at an optimum level.

With egg producers focusing so much on house temperatures, relative humidity is often overlooked. However, whether the hens are comfortable in the poultry house is the result of the house's interaction between temperature and relative humidity. As the house's temperature and relative humidity increase, the animal's body temperature begins to increase. When they cannot release heat through sweating or respiration, body temperature increase cannot be prevented, and heat stress begins. In other words, heat stress is the sum of external forces acting on an animal, causing an increase in body temperature and evoking a physiological response (Herbut et al., 2018). Environmental factors such as temperature, relative humidity, air movement, radiation, and precipitation affect heat stress (Narmilan et al., 2021). Animal species and humans may show different sensitivity to these environmental conditions.

The average body temperature of hens is around 41-42°C, and the thermoneutral temperature is between 18-21°C to maximize the growth rate in breeding. Studies have shown that heat stress occurs in poultry at ambient temperatures higher than 25°C (Donkoh, 1989; Kumari and Nath, 2018; Wasti et al., 2020). Physiological changes in hens under heat stress can cause a decrease in feed utilization, changes in body weight, low feed consumption, a decrease in the quality and quantity of egg production, and an increase in the mortality rate (Şentürk et al., 2020).

Heat stress is an essential problem in the poultry industry that affects the health and performance of birds. Heat stress negatively affects the comfort and convenience of hens in the house and suppresses their productivity. In poultry farming, high ambient temperatures and high humidity can devastate hens. Combining these factors produces even more harmful results (Akyuz and Boyacı, 2010). The higher the humidity in the air, the more difficult it is for animals to balance their body temperature. Various indices can be used to estimate the degree of heat stress in farm animals (Akyuz et al., 2010). The temperature-humidity index is widely used to determine the effect of heat stress on animals. The Temperature-Humidity Index (THI) is an indicator to evaluate the stress level caused by high ambient temperature and humidity. By looking at THI values, it is determined whether the animals are in the comfort or stress zone (Bohmanova et al., 2007).

Many studies about the temperature-humidity index in cattle, especially in dairy cattle houses, are in the literature. However, the number of studies on poultry needs to be increased. This study aims to determine the heat stress of laying hens in egg production in battery-type cages in the Bursa region with the temperature-humidity index. In addition, the relationship between heat stress and egg production was tried to be revealed by regression analysis with SPPS statistical software.

Materials and Methods

This study determined the temperature-humidity index for a year in a battery-type laying hen house operating in the Bursa region. There were 3349 hens in the hen house at the beginning of the study period, and when dead hens were taken into account throughout the study, it was seen that there were 2516 hens. The values of temperature, air velocity and relative humidity were measured in the poultry house with a Testo 435-2 instrument for a period of one year (Figure 1). Measurements were taken continuously for 24 hours throughout the year from December 2020 and data was recorded every 5 minutes. In the study, the dry-bulb temperatures measured indoors and entered into the web-based programme were converted into wet-bulb temperatures (Anonymous, 2023).

Figure 1. Testo 435-2

Temperature humidity index values for laying hens are calculated based on dry and wet bulb temperatures (Gates et al., 1995). Temperature-humidity index values were calculated from the data obtained using the equation (I) given below (Zulovich and DeShazer, 1990; Purswell et al., 2012).

$$THI = 0.6\ T_{db} + 0.4\ T_{wb} \qquad (I)$$

THI= Temperature-humidity index

T_{db}= Dry bulb temperature (˚C)

T_{wb}= Wet bulb temperature (˚C)

Figure 2 shows the index card created by combining the effects of temperature and relative humidity for livestock. According to this graph, the white area is the comfort zone, meaning that animals in this region do not experience heat stress (Normal<23). In the yellow area, animals show signs of heat stress, indicating an alarm condition (Alert 24-25.5). The orange zone indicates a dangerous situation for the animals. Serious precautions should be taken, and the animals should be closely monitored (Danger 26-28). Ventilation rates can be increased to increase air movement over the birds to protect flock health in the danger zone. If the humidity in the house is suitable, cooling can be provided through evaporative cooling pads. In addition, feed intake should be carefully monitored. The red zone indicates the most dangerous emergency (emergency >29). Bird transport during daylight hours should be avoided in this area. Animal activity can be reduced by reducing the lighting level, and it is recommended not to feed during hot hours of the day (NFACC, 2013; Yayli and Kilic, 2023)

Temperature		**Relative Humidity (%)**					
˚F	**˚C**	**20**	**30**	**40**	**50**	**60**	**70**
100	**37.8**	26	29	30	31	33	34
98	**36.7**	26	28	29	31	32	33
96	**35.6**	26	27	28	30	31	32
94	**34.4**	26	27	28	29	31	32
92	**33.3**	25	26	27	28	29	30
90	**32.2**	25	26	26	27	28	29
88	**31.1**	24	24	26	27	27	28
86	**30**	23	24	25	26	27	27
84	**28.9**	22	23	24	25	26	27
82	**27.8**	22	23	23	24	25	26
80	**26.7**	21	22	23	23	24	24
78	**25.6**	20	21	22	23	23	24
76	**24.4**	19	21	21	22	22	23

Figure 2. Temperature-humidity index (THI) chart for livestock at spesific temperatures and relative humidity levels (NFACC, 2013)

Results and Discussions

Indoor Climate Conditions

The values of indoor climate parameters obtained from one-year measurements in the examined hen house are given in Table 1. Indoor environmental conditions are mainly within the optimum limits for hens. However, average temperatures remained high in the summer, especially in July and August. Relative humidity and air velocity values were at high values in June.

Table 1. Climatic indoor conditions of the study period in the henhouse

Parameter / Month	Mean Temp (°C)	Min. Temp (°C)	Max. Temp (°C)	Wet Bulp Temp (°C)	Mean RH (%)	Min. RH (%)	Max. RH (%)	Air Velocity (m s^{-1})
Jan	14.65	10.13	21.57	10.28	55.31	41.56	73.14	0.04
Feb	11.99	5.50	21.30	8.16	58.67	27.75	73.30	0.04
March	12.52	6.30	19.70	8.71	60.00	30.60	75.23	0.04
April	16.67	10.35	25.55	12.31	58.30	31.02	78.47	0.05
May	23.22	16.40	30.00	17.42	53.25	30.10	79.70	0.07
June	22.64	16.30	32.50	18.38	65.12	38.20	86.20	0.10
July	27.10	20.40	35.30	21.34	57.35	20.30	81.80	0.07
August	27.13	20.60	33.90	20.75	53.49	28.80	78.60	0.08
Sep	21.93	13.50	36.10	16.84	57.29	31.20	81.10	0.08
Oct	17.49	10.00	25.90	13.18	59.89	34.10	79.30	0.07
Nov	16.03	9.50	26.50	12.37	66.95	42.90	83.30	0.05
Dec	15.68	8.90	21.95	11.49	59.14	38.05	80.55	0.06

Figure 3 shows the relationship between temperature and relative humidity values. Accordingly, there are decreases in relative humidity values in periods when the temperature is rising. The highest relative humidity value was obtained in June.

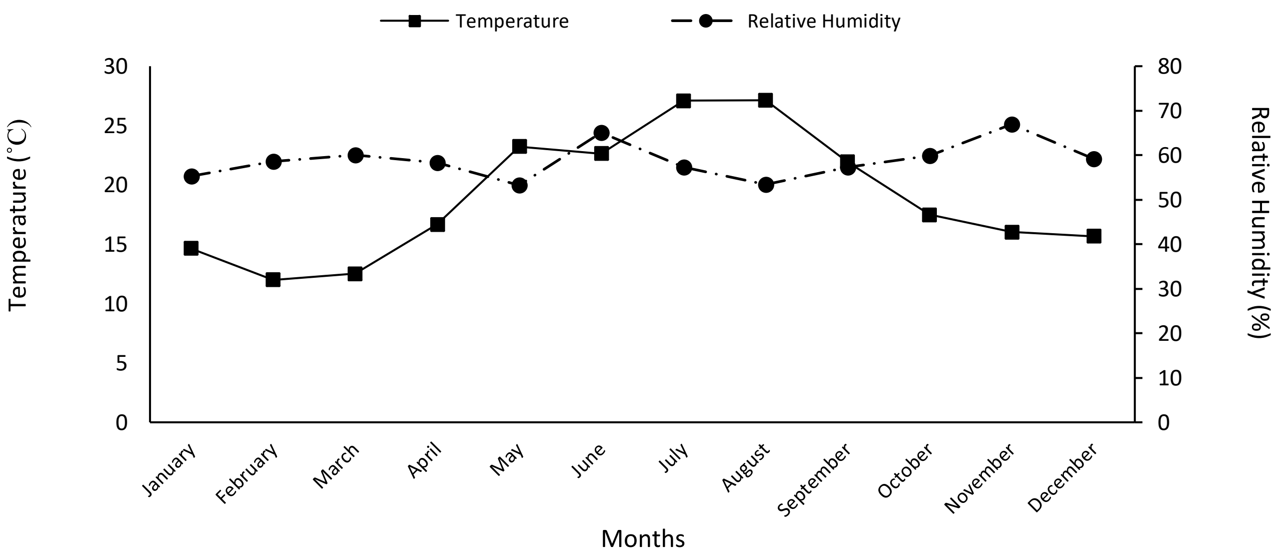

Figure 3. Interaction of between temperature and relative humidity

Temperature-Humidity Index Values

The temperature-humidity index values calculated according to the temperature, humidity, and air velocity measurements in the hen house examined within the scope of the study are given in Table 2. The temperature-humidity index values in the table show the hourly and monthly average values of the temperature-humidity index values obtained during the study period. When the average values are examined, it is seen that the hourly and monthly values are below the danger limit values given for hens. Therefore, the hens in the hen house examined according to hourly and monthly average temperature-humidity index values are far from the danger zone regarding heat stress.

Table 2. Hourly and monthly averages of temperature-humidity index values

	Parameter	THI
Hourly Basis	Mean	19.4
	Std. Dev.	2.6
	Std. Error	0.1
	Minimum	13.7
	Maximum	25.0
Monthly Basis	Mean	20.0
	Std. Dev.	2.3
	Std. Error	0.0
	Minimum	14.4
	Maximum	26.0

Hourly and Monthly Changes in Temperature-Humidity Index Values

The hourly change in temperature-humidity index values in the hen house examined in the study is given in Table 3. For the temperature-humidity index values, the most critical time for heat stress in the henhouse is 16.00-17.00, when the index values are highest. At these hours, the internal environment of the hen house is in the warning zone in terms of heat stress according to the temperature humidity index graph. However, the calculated maximum values show that the hens are in the danger zone where they can experience heat stress in the temperature humidity index graph of the hen house's internal environment.

Table 3. Hourly change of temperature-humidity index

	Hours	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00
THI	Mean	19.40	19.96	20.49	20.83	21.12	21.30	21.31	21.15	20.79
	Std. Deviation	2.66	2.84	3.02	3.11	3.12	3.10	3.03	2.91	2.72
	Std. Error	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.11
	Minimum	13.67	14.00	13.05	13.69	14.94	14.99	15.38	15.35	15.33
	Maximum	25.30	25.86	26.48	28.40	28.43	28.49	28.37	27.91	27.35

Table 4 shows the monthly temperature humidity index values change in the examined henhouse. When the table is examined, it is seen that the highest index values occur in the summer months, as expected. High outdoor temperatures can cause indoor temperatures that can cause heat stress in the hen house. Maximum THI values sometimes indicate that urgent precautions must be taken against heat stress. The obtained THI values indicate that July and August are especially critical for the examined poultry house. During these months, precautions must be taken to reduce the indoor temperature.

Table 4. Monthly change of Temperature-humidity Index

	MONTHS	March	April	May	June	July	August	Sept	Oct	Nov
THI	Mean	14.4	16.5	19.5	22.3	26.0	24.8	20.4	18.4	17.3
	Std. Deviation	1.630	1.822	2.508	2.756	2.861	2.947	2.203	2.025	2.217
	Std. Error	0.024	0.026	0.045	0.040	0.045	0.047	0.034	0.032	0.034
	Minimum	10.38	11.52	13.12	16.22	19.83	18.61	14.88	12.97	11.77
	Maximum	19.56	20.27	25.20	30.69	32.45	31.91	28.55	22.58	22.92

Hourly THI changes for the summer months, which is the critical season for hens in terms of heat stress, are given in Figure 4. When the figure is examined, it is determined that the most critical hours for THI are between 16.00-18.00 for June and between 15.00-18.00 for July and August. For this reason, growers should take precautions to reduce the indoor temperature, primarily by increasing the ventilation rate and cooling between 15.00 and 18.00, which are critical hours in terms of heat stress in the summer, especially in July and August.

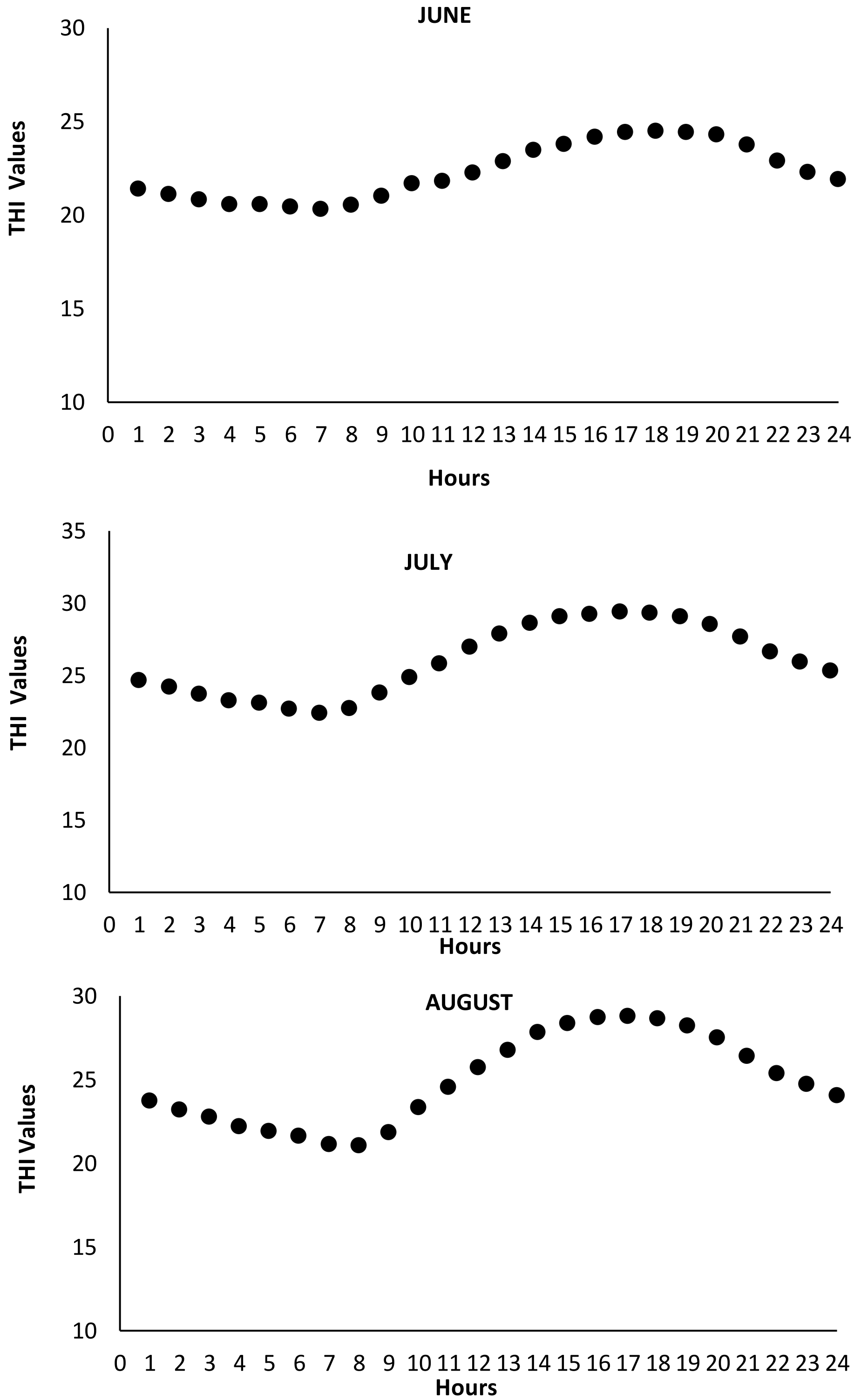

Figure 4. Hourly change of THI in the summer season in the examined hen house

Effect of Temperature-Humidity Index on Egg Production

The temperature-humidity index values calculated using the temperature and relative humidity values measured during the study and the number of eggs produced during the production period are given in Table 5. As can be seen from the table, egg production decreased in the summer season when the temperature-humidity index values are highest. The correlation between egg production and THI is negative in summer. Egg productivity improved with the decrease in indoor temperature values in spring and autumn. With an increase of approximately 7 points in the temperature humidity index, egg production decreased by 24885 units. This situation emerged as a result of the combined effect of high temperature and relative humidity, causing the hen to undergo heat stress and reduce egg production. After the summer season, towards the end of the production process, poultry began to age and die as production began to be completed. Therefore, the decrease in egg production continued in the autumn season.

Table 5. Relationship between temperature-humidity index and egg production

		Spring	Summer	Autumn
Mean	Temperature-humidity index	16.8	24.4	18.7
	Egg Production (viol)	3349	3232	2516
Standard Deviation	Temperature-humidity index	2.0	2.9	2.1
	Egg Production (viol)	18	15	11
Correlations	Pearson Corelation Coefficients	0.64	-0.953	0.99

Figure 4 shows the relationship between temperature humidity index and egg production. There is no statistically significant relationship between egg yields obtained in spring, summer, and autumn and the calculated temperature humidity index values. Although the study had a positive relationship between temperature humidity index values and egg production, a negative relationship was expected between temperature humidity index and egg production. Because the hens are young, they are less affected by increasing temperature values. In this case, the relationship between egg production and indoor temperature in Figure 5 should be examined. As seen in the figure, there is an inverse relationship between indoor temperature and egg production. Egg production will decrease at high temperatures, which causes hens to undergo heat stress.

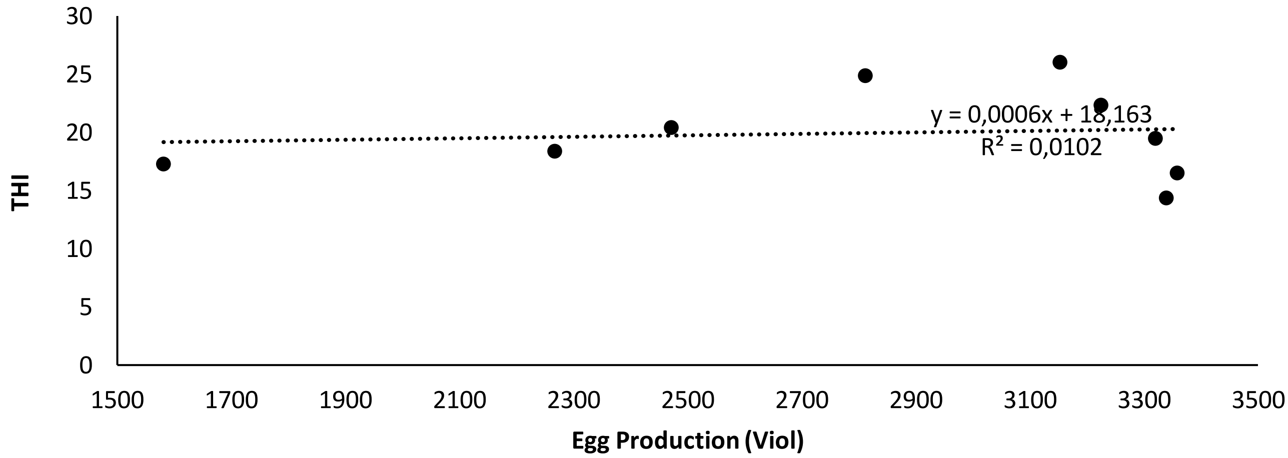

Figure 4. Interaction between THI and Egg Production in Spring, Summer and Autumn

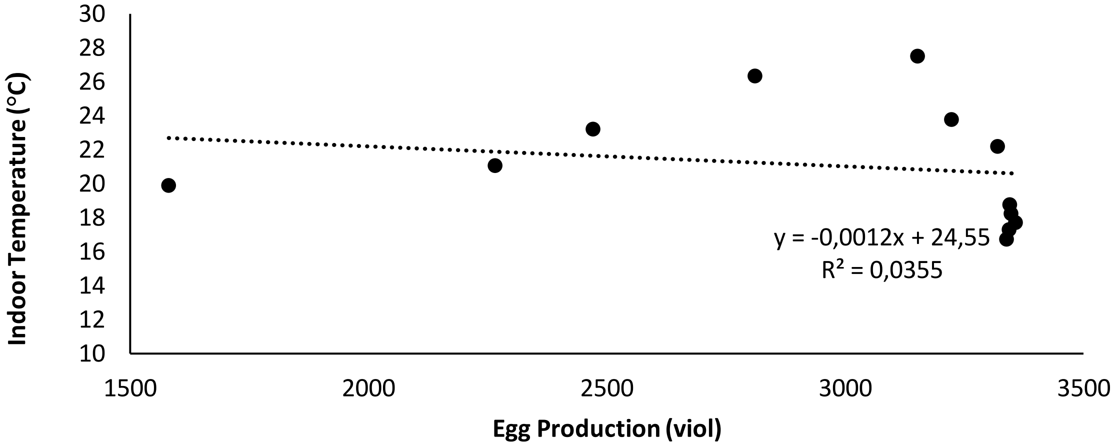

Figure 5. Interaction between egg production and indoor temperature in Spring, Summer and Autumn

Behura et al. (2016), in their study on broiler breeder pullets in hot climatic conditions, stated that the thermal comfort of chickens does not occur, especially in the summer months, and that the energy needs of chickens are significantly affected because they remain above the comfort zone, which harms their performance and welfare.

Cunha et al. (2019) aimed to evaluate a poultry house's distribution of environmental variables and thermal comfort in their study in Brazil. For this purpose, they characterized the indoor environment by calculating temperature-humidity-air velocity index values using air temperature, relative humidity and air velocity. The measured values for the chicken coop are outside the comfort zone and in the alarm zone. It has been stated that air, temperature and relative humidity values are outside the recommended ranges.

In a study by Jongbo (2020), he estimated heat stress in a battery cage chicken coop using the temperature-humidity index. He stated that since chickens spend most of their lives in hot conditions in the coop and the airspeed is very low (0.07 ms-1 to 0.58 ms-1), it may impact their performance. He also stated that the THI value of chickens under heat stress in the chicken coop is higher because they are affected by high relative humidity rather than high temperature.

Yayli and Kilic (2023) determined heat stress in hens using temperature-humidity index values in a laying henhouse with an enriched cage type. According to the study results, it is in the alarm zone during the summer months (July and August) and is inversely proportional to egg production. They stated that chickens are in their comfort zone at other times of the year.

Conclusions

Climatic factors (such as temperature, relative humidity, and air speed) significantly impact the performance and welfare of chickens. High temperatures and relative humidity in the surrounding of hens create thermal stress on animals, stay out them from their comfort zones and causing adverse effects on their metabolic energy and vitality activities and economic losses. Temperature-humidity index one of the most popular heat stress indicators. There are a lot of studies on THI.

Appropriate management strategies and indoor climatic conditions can be maintained at optimum levels in poultry house environments to reduce heat stress. In modern facilities, climatic conditions are more easily controlled by systems such as cooling pads, exhaust fans, air conditioners, and cold perches provided in the hen house design, and they are effective in preventing the adverse effects of heat stress. Providing and operating this equipment can be costly. Therefore, changes to be made in feed formulations (antioxidants such as organic selenium and phytogenic feed additives) and feeding systems may offer a more economical solution for poultry producers to eliminate the adverse effects of heat stress and minimize performance losses.

In the future, the hens' body temperatures and activities will be monitored using remote mechanical and electrical sensing technology, allowing more effective individual monitoring. This will allow more accurate and controlled use of THI, body temperature and other indices in scientific evaluations.

Declarations: The study is not within the scope of any project or thesis. No artificial intelligence tool was used in the study.

Conflict of interest:
The authors declare no conflict of interest.

Author contributions:
All authors contributed equally.

References

Akyuz, A., & Boyaci, S. (2010). Determination of heat and moisture balance for broiler house. Journal of Animal and Veterinary Advances, 9(14), 1899-1901. DOI: https://doi.org/10.3923/javaa.2010.1899.1901

Akyuz, A., Boyaci, S., & Cayli, A. (2010). Determination of critical period for dairy cows using temperature humidity index. Journal of Animal and Veterinary Advances, 9(13), 1824-1827. DOI: https://doi.org/10.3923/javaa.2010.1824.1827

Angelo, M. S. P. de, Nääs, I., & Vendrametto, O. (2014). Programa computacional para a estimativa de conforto térmico na produção intensiva de suínos e frangos de corte. Engenharia na Agricultura, (22),535-542. DOI: https://doi.org/10.13083/1414-3984.v22n06a04

Anonymous, 2023. Ensotek, Yaş Termometre Sıcaklığı Hesaplama. Retrieved from: https://www.ensotek.com/yas-termometre-sicakligi-hesaplama

Behura, N. C., Kumar, F., Samal, L., Sethy, K., Behera, K., & Nayak, G. D. (2016). Use of Temperature-Humidity Index (THI) in energy modeling for broiler breeder pullets in hot and humid climatic conditions. Journal of Livestock Science, 7, 75-83.

Bohmanova, J., Misztal, I., & Cole, J. B. (2007). Temperature-humidity indices as indicators of milk production losses due to heat stress. Journal of dairy science, 90(4), 1947-1956. DOI: https://doi.org/10.3168/jds.2006-513

Cunha, G. C. D. A., Lopes, J. P., Furtado, D. A., Borges, V. P., Freire, E. A., & Nascimento, J. W. D. (2019). Diagnosis and validation by computational fluid dynamics of poultry house with negative pressure ventilation. Revista Brasileira de Engenharia Agrícola e Ambiental, 23(10), 761-767. DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v23n10p761-767

Donkoh, A. (1989). Ambient temperature: a factor affecting performance and physiological response of broiler hens. International Journal of Biometeorology, 33(4), 259-265. DOI: https://doi.org/10.1007/BF01051087

Gates, R. S., Zhang, H., Colliver, D. G., & Overhults, D. G. (1995). Regional variation in temperature humidity index for poultry housing. Transactions of the ASAE, 38(1), 197-205. DOI: https://doi.org/10.13031/2013.27830

Herbut, P., Angrecka, S., & Walczak, J. (2018). Environmental parameters to assessing of heat stress in dairy cattle—a review. International Journal of Biometeorology, 62(12), 2089-2097. DOI: https://doi.org/10.1007/s00484-018-1629-9

Jongbo, A. O. (2020). Evaluation of the environmental parameters of battery-caged poultry house in the humid tropical climate. Revista Colombiana de Ciencia Animal-RECIA, 12(2), e753. DOI: https://doi.org/10.24188/recia.v12.n2.2020.753

Kumari, K. N. R., & Nath, D. N. (2018). Ameliorative measures to counter heat stress in poultry. World's Poultry Science Journal, 74(1), 117-130. DOI: https://doi.org/10.1017/S0043933917001003

Narmilan, A., Puvanitha, N., Ahamed, A. S., & Santhirakumar, S. (2021). Relationship between temperature-humidity index and milk production of dairy cows in tropical climate. Asian Journal of Dairy and Food Research, 40(3), 246-252. DOI: https://doi.org/10.18805/ajdfr.DR-213

NFACC, 2013. The National Farm Animal Care Council, Code of Practice for the Care and Handling of Sheep. https://www.nfacc.ca/codes-of-practice/sheep (Accesed on 22 May 2024).

Purswell, J. L., Dozier III, W. A., Olanrewaju, H. A., Davis, J. D., Xin, H., & Gates, R. S. (2012). Effect of temperature-humidity index on live performance in broiler chickens grown from 49 to 63 days of age. In 2012 IX International Livestock Environment Symposium (ILES IX) (p. 3), American Society of Agricultural and Biological Engineers.

Şentürk, Y. E., Şekeroğlu, A., & Duman, M. (2020). The Effect of Heat Stress on Egg Quality Properties: A Review. International Journal of Poultry-Ornamental Birds Science and Technology, 1(1), 30-33.

Tao, X., & Xin, H. (2003). Acute synergistic effects of air temperature, humidity, and velocity on homeostasis of market–size broilers. Transactions of the ASAE, 46(2), 491. DOI: https://doi.org/10.13031/2013.12971

Wasti, S., Sah, N., & Mishra, B. (2020). Impact of heat stress on poultry health and performances, and potential mitigation strategies. Animals, 10(8), 1266. DOI: https://doi.org/10.9734/IJECC/2022/v12i111360

Yayli, B., & Kilic, I., (2023). Determination of Heat Stress by Temperature-Humidity Index in Enriched Cage System Laying Hens: A Bursa Case Study. V. International Agricultural, Biological & Life Science Conference, Edirne, Turkey. https://agribalkan.congress.gen.tr/files/site/16/files/AGBIOL%202023%20FULL%20PROCEEDING%20BOOK(18).pdf

Zulovich, J. M., & DeShazer, J. A. (1990). Estimating egg production declines at high environmental temperatures and humidities. Paper-American Society of Agricultural Engineers, (90-4021).