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RESEARCH ARTICLE

Effects of Heat Stress on Egg Yield and Mortality Rates of Caged Poultry Houses

Ahmet Kamil BAYHAN [1] Sedat KARAMAN [2] Özgür KOŞKAN [3]

[1] Department of Agricultural Machinery, Faculty of Agriculture, Suleyman Demirel University, TR- 32260 Isparta - TURKEY
[2] Department of Biosystems Engineering, Faculty of Agriculture, Gaziosmanpasa University, TR-60240 Tokat - TURKEY
[3] Department of Animal Science, Faculty of Agriculture, Suleyman Demirel University, TR- 32260 Isparta - TURKEY

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Summary

In present study, effects of heat stress due to variations in indoor temperature and relative humidity on egg yield and mortality rates of hens in caged poultry houses were investigated between the months April and August (5 months). The experimental poultry house has automated feeder and waterer and operates at 90% capacity. Each cage has 5 hens and there were a total of 9900 Isa Brown hens in the poultry house before the experiments. Hens were 27th weeks old in the beginnings of the experiment. During the experiments, indoor and outdoor climate parameters such as temperature and relative humidity, daily egg production and mortalities were continuously recorded. Structural characteristics of the poultry house were also determined. Heat and moisture gains/losses, temperature humidity index (THI), egg production rates (EPR) and mortality rates (MR) were calculated. Results revealed significantly increasing and strong relationships between indoor temperature and THI – MR and significantly decreasing relationships between indoor temperature and EPR (P<0.01). Indoor temperature increased from 20.7°C in April to 29.4°C in August, THI values increased from 66.1 to 77.0 during the same period. Therefore, mortality rates increased from 0.36% in April to 1.59% in August. While EPR was 88.7% in April, the value decreased to 79.4% in August. Without sufficient wall and roof insulation, it was found to be impossible to provide an indoor temperature of neither 18°C to keep EPR at high levels nor 21°C to keep MR≤‰0.1.

Keywords: *Poultry house, Temperature, Humidity, Heat stress, Egg production rate, Mortality rate*

Kafesli Kümeste Sıcaklık Stresinin Yumurta Verimi ve Mortalite Üzerine Etkileri

Özet

Bu araştırmada Nisan-Ağustos döneminde (5 ay) kafesli tip yumurta tavuğu kümesinde kümes içi sıcaklık ve bağıl nem değişimine bağlı olarak ısı stresinin tavuklarda yumurta verimi ve mortalite üzerine etkisi incelenmiştir. Otomatik yemleme ve sulama sistemiyle donatılan, %90 kapasite kullanım oranına sahip olan kümeste her kafese 5 tavuk yerleştirilmiş olup, deneme başlangıcında kümeste 27 haftalık yaşta 9900 adet Isa Brown ırkı tavuk bulunmaktadır. Araştırma boyunca kümes içi ve dış ortam sıcaklık ve bağıl nemi, kümeste günlük yumurta üretimi, günlük ölen tavuk sayısı sürekli kaydedilmiştir. Ayrıca, kümese ait yapısal özellikler ölçülmüştür. Kümese ait ısı ve nem dengeleri, Sıcaklık Nem İndeksi (THI), Yumurta Verimi (EPR) ve Ölüm Oranı (MR) hesaplanmıştır. Araştırma sonuçlarına göre; kümes iç sıcaklığı ile THI ve MR arasında artan, kümes iç sıcaklığı ile EPR arasında ise azalan istatistik yönden çok önemli (P<0.01) ve kuvvetli ilişkiler tespit edilmiştir. Bu ilişkilere göre Nisan ayından Ağustos ayına doğru kümes sıcaklığının 20.7°C'den 29.4°C'ye ve THI'nin 66.1'den 77.0'a artışı sonucu aylık MR Nisanda %0.36 iken aylara göre artarak Ağustosta %1.59'a kadar çıkmıştır. EPR ise aynı dönemde aylık olarak Nisan'da %88.7 iken Ağustos ayında %79.4'e kadar gerilemiştir. Bu nedenle çatı ve duvarda yeterli izolasyon olmadan ve serinletme yapmadan kümes sıcaklığını ne yüksek EPR için gerekli olan optimum 18°C sıcaklıklarda, ne de günlük MR≤‰0.1 olduğu 21°C kümes içi sıcaklık bandında tutmanın mümkün olmadığı görülmüştür.

Anahtar sözcükler: *Kümes, Sıcaklık, Bağıl nem, Sıcaklık stresi, Yumurta verim randımanı, Ölüm oranı*

INTRODUCTION

In poultry facilities, beside sufficient feeding and proper genotypes, indoor environmental conditions should also be kept at optimum levels to provide "animal welfare" and consequently optimize the operation and thus maximize

İletişim (Correspondence)
+90 246 2118614
akbayhan@hotmail.com

the income. It is not possible to reach the desired yield levels only by selecting high-yield genotypes and implementing the best feeding programs. Improper indoor environmental conditions definitely hinder the expected outcomes from the facility.

Environmental conditions play a significant role in laying hen facilities to provide desired productivity levels. Especially indoor temperature and relative humidity have direct impacts on physiological activities of hens. Hens are able to keep body temperatures and some mechanisms only within certain temperature intervals and they can not adapt to high temperatures. Their higher production performance and feed conversion efficiency make today's chickens more susceptible to heat stress than ever before [1].

High temperatures create some health effects on hens such as vaso-dilatation, decrease in blood flow rates toward glands forming the shell, increase in respiration rates, respiratory alkalosis, decrease in blood ionic Ca level, decrease in carbonic anhydrate enzyme activities in kidney and egg-shell glands, decrease in Ca mobilization from bone-deposits. All these health-effects decrease egg yields [2-5].

Researches to determine upper (18-32.2°C) and lower (7.2-19°C) limits of proper indoor temperatures and to determine optimum growth temperatures vary based on the region where the poultry house is located, type of housing, animal species and growing periods [6-17]. In case of exceeding lower and upper heats, different effects and following physical changes can be observed on chickens: i) decrease in egg weight with heat stress [6]; ii)heat stress increases with increasing temperature and relative humidity, egg yield and feed consumption decrease [7,8]; iii) decrease Egg Yield Rate and increase Mortality Rate with increasing inside temperature and/or with increasing Temperature Humidity Index [9-14]; iv) distinctive negative effects of heat stress on yield and mortality rates [15]; v) strains in metabolism, ultimate changes in sensible heat and latent moisture production [16]; vi) a 44% decrease in egg yield at 21°C poultry house [17]; and vii) decrease trend in egg production [18].

Hens perform better at constant temperatures (21-22°C) than varying temperatures (17-35°C) and health problems are less in constant temperatures [18]. Each 1°C increase in temperatures between 25-30°C results in 1.5% decrease in egg yield [19].

Relative humidity generally does not have significant impacts on hens at temperatures between 15.6-26.6°C, but relative humidity above 50% at temperatures between 26.6-37.7°C endangers the life of hens. High temperatures together with 70-75% relative humidity speed up the growth of microorganism populations. Therefore, relative humidity of poultry houses should always be kept below 80% [20]. Optimum relative humidity ranges for laying hen poultry houses are recommended as between 50-75% [21], 50-80% [22] and 60-80% [15].

Combined effect of temperature and relative humidity on poultry houses is explained by Temperature-Humidity Index (THI). A growing atmospheres with a THI value ≤70 is defined as "comfort zone", a value between 75-78 is defined as "stress zone" a value ≥78 is classified as "extreme stress zone" [23].

There are some laboratory studies about the negative impacts of temperature and relative humidity on animals. However, in-situ researches are not preferred due to population sizes, difficulties in control of animals, higher labor needs and similar reasons. Therefore, evaluations about the effects of heat stress on animal performance and yield are mostly depend on limited data. In present study, indoor and outdoor climate factors (temperature and relative humidity) of a caged poultry house were regularly measured and effects of heat stress on EPR and MR were investigated under actual conditions. Furthermore effects of aging on EPR and MR are also included to the regression models and compared to ISA Brown commercial layer production recording chart.

MATERIAL and METHODS

Caged poultry house, selected for experimental purposes, is located in Tokat Province (39°51' N and 40°55' E) of Middle Black Sea Region of Turkey. It has a capacity of 11.000 hens with automated feeder and waterer and operated at 90% capacity. Each cage has 5 hens and there were a total of 9900 Isa Brown hens aged 189 days aged (27 weeks) in the poultry house before the initiation of experiments. Although EPR and MR values are usually calculated via "age in weeks"; in this study, statistic analyses were done using "age in days". Thus

Long term average temperatures are 12.5, 16.4, 19.8, 22.4 and 22.3°C, and relative humidities are 60.0, 61.0, 59.0, 57.0 and 58.0 for April-August period (1961-2011) in the research region according to the Turkish State Meteorological Service [24,25].

Experimental poultry house is oriented along east-west direction and it is 40 m long, 11 m wide and 2.75 m high. The house is operated with natural ventilation system with 6 air outlets and 22 windows along the long axes.

Walls were constructed with 19 x 19 x 13.5 cm hallow tiles, 2 cm inner and 3 cm outer lime-cement plaster were applied over the walls. The roof was insulated by 3 cm Styrofoam over wood siding and covered by corrugated asbestos-cement roofing.

During the experimental period, daily feed consumptions, lighting and ventilation levels were kept constant. EPR and MR values were recorded daily. Indoor and outdoor temperature and relative humidity values of

April - August period were periodically measured with a "Datalogger" (HOBO RH/Temp, Type: HO8-003-02, USA) as to have 1 data/h and variations in temperature and relative humidity were monitored. Heat - moisture balance calculations were performed by using hourly and daily averages of measured data.

Criteria specified by NIH (National Institute of Health Guide for the Care and Use of Laboratory Animals) were obeyed during the experiments carried on animals.

Heat transfer coefficients of constructional members, heat - moisture balance and ventilation capacities heat and moisture production of hens were all determined by using relevant calculation procedures [9,13,15,22,24,26-28].

According to pentant principle, minimum design outdoor temperature of Tokat Province is -15°C [29] and placed into the 2nd Climate Zone. Calculated heat transfer coefficients by using these assumptions benchmarked with the recommended values for roofs and walls based on climate zone and type of housing [30,31].

Sensible heat production (SHP) and moisture production rate (MPR) of the poultry house were calculated as follows [32,33].

$$SHP = \rho \times V \times C_p \times (T_e - T_{out}) + U\,(T_{in} - T_{out}) - Q_{Sup} - Q_{Equip} \quad (1)$$

Where;

SHP : Sensible heat production rate, W

ρ : Density of inlet air, kg/m^3

V : Ventilation rate, m^3/s

Cp : Specific heat of inlet air, J/ (kg.K)

T_e, T_{out}, T_{in} : Exhaust, outdoor and indoor air temperature, respectively, °C

U : Building heat transfer coefficient, W/K

Q_{Sup}, Q_{Equip} : Heat from supplementary heaters and other internal equipment, respectively, W

$$MP = \rho \times V \times (W_e - W_o) \quad (2)$$

Where;

MPR : Moisture production rate, kg/s

W_e, W_o : Humidity ratio of exhaust and outdoor, respectively, kg/kg

Temperature-Humidity Index (THI) was calculated by [23];

$$THI = 1.8 \times T_{in} - (1 - j_{in}) \times (T_{in} - 14.3) + 32 \quad (3)$$

Where;

THI : Temperature-Humidity Index

T_{in} : Poultry house indoor temperature, °C

j_{in} : Poultry house indoor relative humidity

Descriptive statistics, correlation analysis, principle components and factorial analysis, single and multiple regression analyses were performed between treatments by using SPSS 18 statistical analysis package [34]. Furthermore effects of aging on EPR and MR also included to the model regression analyses.

RESULTS

Unit heat gains/losses were calculated by using surface areas of constructional members and their heat transfer coefficients. Results revealed the roof and walls as the largest winter/summer heat gain/loss sources *(Table 1)*.

Indoor and outdoor hourly temperature and relative humidity values for the experimental period are provided in *Table 2*.

By taking heat losses and heat production of hens into consideration, irradiative heat-up (Q_{rad}), maximum natural

Table 1. *Area, heat transfer coefficient and unit heat loses for constructional members*

Tablo 1. *Kümes yapı elemanlarına ilişkin alan, ısı geçirme katsayısı ve birim ısı kayıpları*

Construction Member	Wall	Windows	Doors	Roof
Area (m^2)	260.0	16.2	4.2	495.0
Coefficient of Heat Transfer (W/m^2K)	1.60	5.88	6.04	0.99
Building heat transfer coefficient (W/K)	416.0	95.3	25.4	490.1

Table 2. *Variation of hourly outdoor and indoor temperature and relative humidity values between April and August period*

Tablo 2. *Nisan-Ağustos döneminde iç ve dış sıcaklık ve nispi nem değişimi*

Month	Outdoor Temperature (°C)			Outdoor RH (%)			Indoor Temperature (°C)			Indoor RH (%)		
	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average
April	-2.9	30.8	13.3	22	96	55	12.3	26.5	20.7	23	81	50
May	11.2	31.0	16.6	24	97	64	17.6	27.6	22.8	32	72	52
June	12.8	32.4	19.9	29	99	67	17.9	30.4	23.9	21	76	52
July	16.8	34.8	23.8	22	93	56	18.3	33.7	26.0	23	79	49
August	21.5	38.8	25.1	33	97	61	21.8	38.5	29.4	18	78	48
Apr-Aug	-2.9	38.8	19.8	22	99	60.8	12.3	38.5	24.6	18	81	49.9

Table 3. *Irradiative heat-up, natural ventilation capacity, ventilation capacity provided per hen and THI, EPR and MR as monthly average values*
Tablo 3. *Aylara göre kümeste radyasyonla ısı artışı, sağlanan doğal havalandırma kapasitesi, tavuk başına sağlanan havalandırma kapasitesi, THI, EPR ve MR ortalama değerleri*

Month	Q_{rad} (W)	V_{max} (m^3/h)	V_{max}/hen (m^3/h.hen)	THI	EPR (%)	MR (‰)
Apr	8393	52361	5.29	67.3	88.7	3.6
May	9711	58959	5.96	68.8	85.7	7.5
Jun	10185	64310	6.50	70.6	83.9	8.9
Jul	11289	91353	9.23	72.5	81.8	13.1
Aug	12948	98500	9.95	76.0	79.5	15.9
Average				71.1	83.9	9.7
Total						49.0

Table 4. *Pearson correlation coefficients between daily average values of parameters and significance levels (Probability: P-Value)*
Tablo 4. *Araştırma parametrelerine ilişkin günlük ortalama değerlerin "Pearson Correlation" katsayıları ve istatistik önem düzeyleri (Olasılık: P-değeri)*

Parameters	T_{in} (°C)	j_{in} (%)	T_{out} (°C)	j_{out} (%)	MR (‰)	EPR (%)
j_{in}	-0.189 (P<0.05)			0.116 (NS)		
T_{out}	**0.786** (P<0.01)	-0.119 (NS)				
j_{out}	0.118 (NS)	0.031 (NS)	-0.134 (NS)			
MR	**0.793** (P<0.01)	-0.160 (P<0.05)	**0.658** (P<0.01)			
EPR	-0.688 (P<0.01)	0.065 (NS)	-0.594 (P<0.01)	-0.127 (NS)	-0.613 (P<0.01)	
THI	**0.987** (P<0.01)	-0.034 (NS)	**0.781** (P<0.01)	0.128 (NS)	**0.779** (P<0.01)	-0.687 (P<0.01)

NS: *Non-Significant*

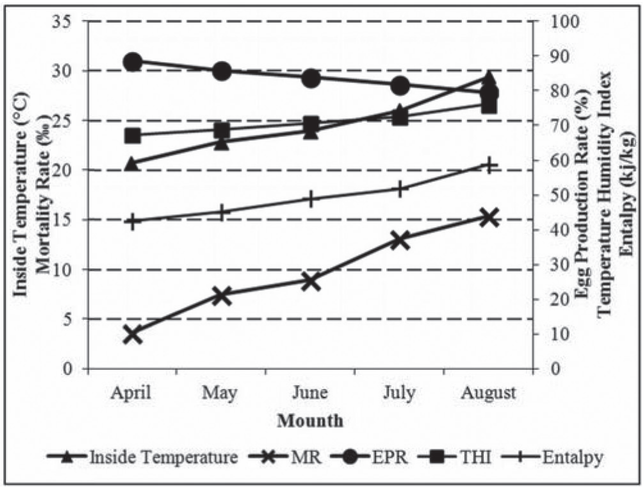

Fig 1. Variation of indoor air temperature, enthalpy, THI, EPR and MR for April-August period

Şekil 1. Araştırma kümesinde Nisan-Ağustos dönemi kümes içi sıcaklık, entalpi, THI, EPR ve MR değişimi

ventilation capacity (V_{max}), and maximum ventilation capacity per hen (V_{max}/hen) were calculated. THI was found to be as 71.1 (67.3-76.0), EPR as 83.9 (88.7-79.5) and MR as 9.5 (3.6-15.9) in monthly average values (*Table 3* and *Fig 1*).

Indoor temperature during the experimental period was ≥20°C at 91.1% of total time, ≥25°C at 40.9%, ≥27°C at 25.0%, ≥30°C at 10.6% and ≥33°C at 3% of the total time. Average indoor relative humidity was ≥50% at 51.4% and ≥%60 at 16.4% of the total time.

About 56% of THI values during the experimental period were above the threshold value of ≥70. Monthly evaluations revealed that 11.0, 40.3, 61.3, 85.4 and 99.9% of THI values respectively of the months April, May, June, July and August were above 70.

Daily values were used to see the variations in indoor and outdoor air temperatures, RH, THI, EPR and MR values. Average daily indoor air temperature was 24.60°C, indoor RH was 49.97%, THI was 71.10, EPR was 83.87% and MR was ‰0.32.

Pearson correlation coefficients between investigated parameters were calculated and significance levels were determined. The highest correlation (0.987) was observed between indoor temperature and THI *(Table 4)*.

Principal component analysis and factor analysis were performed and corresponding factor loadings were determined. Results revealed that the first 3 factors were able to explain 86.5% of the total variation. Factor 1 explained 57.1%, factor 2 explained 15.5% and factor 3 explained 13.9% of the total variation. Single evaluation of factor 1 revealed the loadings as 0.965 for daily average indoor temperature, 0.955 for THI, 0.867 for MR, 0.853 for daily average outdoor temperature and -0.796 for EPR. In factor 2, daily average outdoor relative humidity was the parameter with a loading (-0.882) value over 0.5. In factor 3, only daily average indoor relative humidity had a loading value (-0.861) of over 0.5 *(Table 5)*.

Table 5. *Unrotated factor loadings and communalities on principal component factor analysis of the correlation matrix*

Tablo 5. *Korelasyon matris faktör analizi yapılan değişken parametreler ve yükleri*

Source of Variation	Factor 1	Factor 2	Factor 3
Daily Average Indoor Air Temperature (T_{in})	0.965	-0.005	0.034
Daily Average Indoor RH (j_{in})	-0.168	-0.476	-0.861
Daily Average Outdoor Air Temperature (T_{out})	0.853	0.247	-0.168
Daily Average Outdoor RH (j_{out})	0.106	-0.882	0.431
MR (‰)	0.867	-0.025	0.060
EPR (%)	-0.796	0.115	0.045
THI	0.955	-0.083	-0.101
Variance	3.9949	1.0866	0.9727
% Variance	0.571	0.155	0.139
Total Variance (%)	0.865 (86.5%)		

Table 6. *The single and multiple regression equations hit ratings (R^2) and probabilities (P)*

Tablo 6. *İkili ve çoklu regresyon eşitliklerinin isabet oranları (R^2) ve olasılıkları (P)*

Regression Equation	R^2	P
$THI = 40.1 + 1.26\,T_{in}$	97.4 %	<0.01
$EPR = 73.8 - 1.45\,T_{in} - 0.163 j_{in} - 0.105\,T_{out} - 0.0365\,j_{out} - 3.12\,MR + 1.00 THI - 0.0439 Age$	51.4 %	<0.01
$EPR = 67.7 - 2.38\,T_{in} - j_{in} - 0.148\,T_{out} - 0.0386\,j_{out} - 41.4\,MR + 1.34\,THI$	50.3 %	<0.01
$EPR = 116 - 0.256\,THI - 0.0528 Age$	49.8 %	<0.01
$EPR = 105 - 0.254\,T_{in} - 0.0574\,Age$	48.5 %	<0.01
$EPR = 109 - 1.03\,T_{in}$	47.3 %	<0.01
$EPR = 141 - 0.804\,THI$	47.2 %	<0.01
$MR = 0.124 + 0.00933\,T_{in} + 0.000418\,j_{in} + 0.000346\,T_{out} + 0.000082\,j_{out} - 0.000428\,EPR - 0.00448\,THI$	64.3 %	<0.01
MR‰ = $- 0.784 + 0.0449\,T_{in}$	62.8 %	<0.01
MR‰ = $- 2.14 + 0.0346\,THI$	60.6 %	<0.01

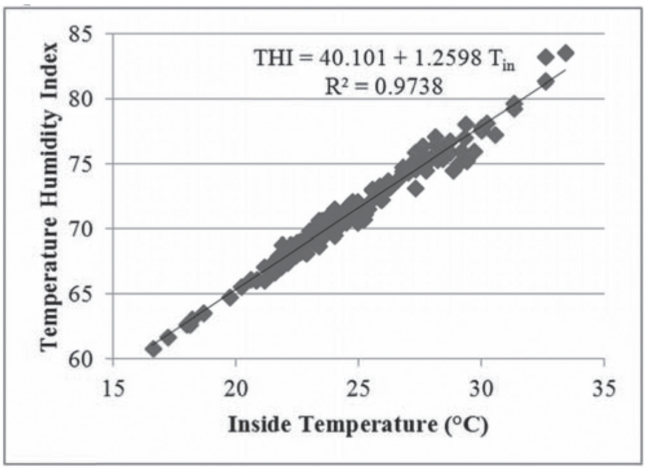

Fig 2. Relationship between THI and indoor temperature (T_{in})

Şekil 2. THI ile kümes içi sıcaklık (T_{in}) ilişkisi ve regresyon denklemi

Single and multiple regression analyses were performed between the parameters and regression equations were determined. Hit ratings of estimations made by regression equations were calculated and probability significance levels were determined *(Table 6)*. Results revealed the highest hit as R^2 97.4% between THI and inside temperature (T_{in}) (P<0.01) (*Table 6* and *Fig. 2*).

Multiple regression analysis performed to estimate EPR revealed a hit rating of 50.3% when the entire parameters are included into the model. The hit rating was observed as 47.3% when the daily average indoor temperature was included into the model and as 47.2 when THI included into the model *(Table 6; Fig. 3, Fig. 4)*.

Standard characteristic values of EPR vs Age was reported as 96% for 189 days (27 weeks) aged layers and 91% for 329 days aged layers (47 weeks) in standard performance characteristic chart from breeder company [35]. Thus it can be observed that at optimum conditions, aging of layers between 27th to 47th weeks affects EPR at 5% decreasing level. However EPR at 27th week and 47th week was recorded as 91% and 76% respectively. Thus regression analyses were done to determine which factors are related to this catastrophic decrease on EPR. Analyses results revealed that; when regression model includes T_{in}, j_{in}, T_{out}, j_{out}, MR, THI and Age hit rating was 51.4 while Age factor excluded from model hit rating decreased to 50.3% *(Table 6)*. Similarly, when model includes T_{in} and Age factors, hit rating value was determined as 48.5 whereas the model includes only T_{in}, R^2 value was calculated as 47.3%.

Multiple regression analysis performed to estimate MR revealed a hit rating of 64.3% when the entire parameters are included into the model. The hit rating was observed as 62.8% when the daily average indoor temperature was included into the model and as 60.6% when THI included into the model *(Table 6, Fig. 3, Fig. 4)*.

DISCUSSION

Heat balance calculations of the poultry house were performed by taking the climate zone of Tokat Province

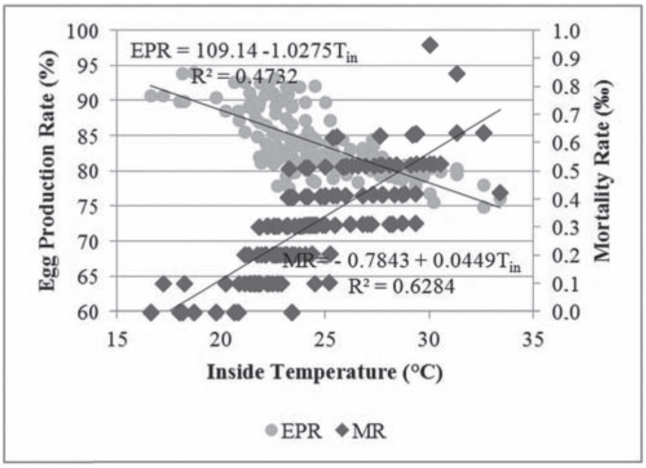

Fig 3. Relationship between EPR and MR based on variations in daily average indoor temperatures

Şekil 3. Ortalama günlük kümes içi sıcaklık değişimine göre EPR ve MR ilişkisi

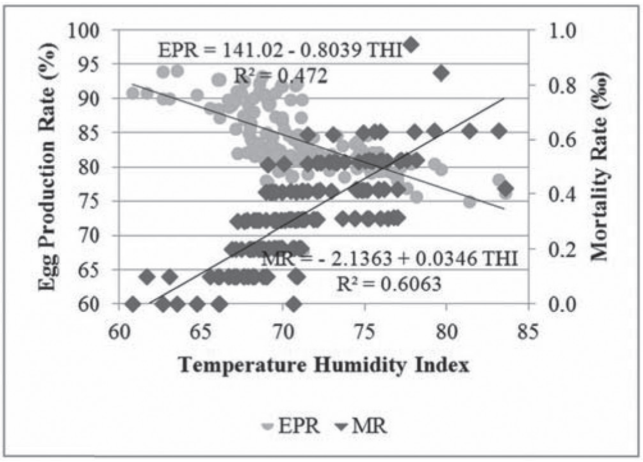

Fig 4. Relationships between THI and EPR-MR

Şekil 4. THI ile yumurta verim randımanı ve ölüm oranı arasındaki ilişki

into consideration and heat transfer coefficients of walls and roof were respectively determined as 1.60 W/m²K and 0.99 W/m²K. The ideal values should be 0.91 W/m²K and 0.33 W/m²K. Therefore, walls were found to be 78% insufficient and roof was found to be 300% insufficient compared to ideal values. Such deficiencies result in excessive heat loss during the winter months and heat gain in summer months. Supplementary insulation over the outer wall surfaces and additional roof insulation may bring the wall heat transfer coefficients to ideal values. Proper insulation and consequent heat gain/loss balance may prevent excessive THI values and fluctuations during summer/winter months. Such a case may also prevent undesired decreases in EPR and increases in MR.

Each 1°C increase in indoor temperatures between 25-30°C results in 1.5% decrease in egg yield [19]. While daily EPR of the present study was over 90% when the indoor temperatures were ≤ 20°C, the value decreased to 82.5% at 25°C and to 75% at 30°C with a 1.5% decrease corresponding to each unit increase in temperature.

A growing atmosphere for poultry houses with a THI value of ≤70 is defined as "comfort zone", a value between 75-78 is defined as "stress zone" and a value ≥78 is classified as "extreme stress zone" [23]. While EPR was >90% when the THI was ≤70, the value decreased to 80% when the THI increased to 75. Similarly, EPR rapidly decreased to 73% when the THI increased to 83. A unit increase in THI or poultry house indoor temperature may result in 1-1.5% decrease in EPR. Since the hens subjected to heat stress are not able to consume sufficient feed to present optimum performance, a decrease in egg yield is evident. Hence, EPR values over 90% in "comfort zone" (THI 60-65) decreased to 70% by moving away from comfort zone (THI 80-85), corresponding about 20% decrease in egg yield.

While daily MR was around 0.2‰ under THI values of 65-70, the value reached to 0.6-0.8‰ levels under THI value of 85 over the threshold value. If such a high THI value is persistent in poultry house, daily MR may reach to 1‰ level.

The positive high correlation (0.793) between indoor temperature and MR of present study was found to be significant (P<0.01) and indicated increased mortalities parallel to increasing temperatures.

The correlation between T_{out} and T_{in} (0.786) was also found to be significant (P<0.01). This correlation indicates insufficient acclimatization and increase or decrease of indoor temperatures with increasing or decreasing outdoor temperatures.

Positive correlations between T_{out} and THI (0.781) (P<0.01), between THI and MR (0.779) (P<0.01) and negative correlation between T_{in} and EPR (-0.688) (P<0.01) indicated that increasing THI values moved the growing atmosphere away from the "comfort zone" and decreased EPR accordingly.

The negative correlation between THI and EPR (-0.687) was found to be significant (P<0.01). Similar relationship between THI and EPR and between T_{in} and EPR (-0.688) (P<0.01) was an expected case and considered as the result of psychrometric relation between indoor temperature and THI. A 65.8% correlation (P<0.01) was observed between outdoor temperature and MR. Indoor temperature was mostly depend on outdoor temperature because of insufficient acclimatization and ventilation. Increasing outdoor temperatures rapidly increase indoor temperatures and move the growing atmosphere away from the "comfort zone" and consequently increase the mortality rates. A decreasing relationship was observed between egg yield and outdoor temperatures (59.4%) (P<0.01). Such a relationship again indicates the negative impacts of outdoor temperature on animal comfort and consequent egg yields for poultry houses without sufficient climate control.

Furthermore, it is well known fact that EPR performance losses down to 75% is an economic break-even point. According to genetic company performance charts [35], EPR values at week 27 and 47 are 96% and 91% respectively. In addition 75% EPR value occurs at week 80 for ISA Brown layers. However the results of this study showed that exceeding optimum conditions can cause more adverse effects than aging resulting an EPR value of 91% at week 27 and 76% at week 47.

Heat stress is the most significant factor to be considered in laying hen poultry houses. Beside the construction and equipments, climate-related environmental factors play a critical role in performance and yields of hens. Therefore, heat transfer coefficients of constructional members, especially of walls and roof, should be kept as low as possible to prevent excessive cooling in winter months and heat-up in summer months. Measures should be taken not only against cold stress but also against heat stress.

Indoor temperatures should be prevented not only against seasonal changes in temperatures but also against daily sudden changes in temperatures. Since it is impossible to totally eliminate heat stress-related economic losses due to physiological and metabolic changes, some kind of measures may be taken for constructional members, indoor production techniques and/or feeding practices to minimize such losses.

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