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# The Effects of Heat Stress on Egg Production and Quality of Laying Hens

Ilker Kilic and Ercan Simsek
Department of Biosystems Engineering, Faculty of Agriculture,
Uludag University, 16059 Nilufer, Bursa, Turkey

**Abstract:** The aim of this study was to determine effects of heat stress on egg production and quality characteristics, revealed THI distribution among cage blocks. Ambient dry bulb temperature and relative humidity measurements were recorded for cages and all of layer house in 31 days during July and August. The egg production in selected cages was recorded daily in this study. To determine egg weight, shape index, shell thickness, albumen index, yolk index and Haugh units scores, 30 eggs were collected daily from selected each cages. For indoor temperatures and relative humidity, average values were obtained as 31.15°C and 44.68%, respectively. The average outdoor temperature and relative humidity were about 34.11°C and 59.91%, respectively during study period in region conditions. The differences between cage rows, cage tiers and direction were not statistically significant for THI value ($p>0.05$). When the THI values increased from 25-29, heat stress reduced egg production by 25%. The converse effect of heat stress was most likely mediated through a reduction in feed consumption, reducing the available nutrients for egg production. Based on results of statistical analysis, variation on egg quality characteristics versus THI values is not statistically significant for whole study period.

**Key words:** Heat stress, THI, laying hens, egg production, egg quality

## INTRODUCTION

Environmental conditions, such as indoor temperature and relative humidity are important stressors in poultry production. The body temperature of hen is maintained 40.0-42.2°C by thermoregulatory mechanism when the environmental temperature is within the thermoneutral zone since poultry are homoeothermic. The biophysical defense mechanism against heat stress such as frequently panting and reduced energy intake intervene in poultry when indoor temperatures in house rises above thermoneutral zone. If the thermoregulation mechanism is insufficient to maintain homoeothermy, the body temperature begins to rise and eventually cause to death from heat stress (Lin *et al*., 2006; Tao and Xin, 2003).

Some intensive production systems designed for laying hens cause to heat stress in laying hens. Especially in egg production with cages, caged laying hens are exposed to desirable and boring indoor environmental conditions (Ugurlu *et al*., 2002).

The resultant heat stress comes from the interactions among air temperature, humidity, radiant heat and air speed, where the air temperature plays the major role. The optimum indoor temperature for production performance is likely to be 19-22°C for laying hens and 18-22°C for growing broilers (Charles, 2002; MAF and Spratt, 1993). Laying hens can produce more number and more big eggs in indoor environmental temperature between 13-24°C (Lindley and Whitaker, 1996). The adverse effects of heat stress include high mortality, decreased feed consumption, poor laying rate, egg weight, shell quality in laying hens (Sterling *et al*., 2003; Lin *et al*., 2004; Mashaly *et al*., 2004; Yahav *et al*., 1998).

To assess the effect thermal conditions on farm animals, certain environmental indices based on animal physical status and production performance have been documented. Among them, the Temperature and Humidity Index (THI) is a linear combination of dry-bulb and wet-bulb temperature and consider the adverse effect of high relative humidity levels together with dry bulb temperature (Zulovich and Deshazer, 1990). Also, THI equations describe the relative importance of dry-bulb and wet-bulb temperature for species based on physiological parameters (e.g., respiration rate or pulse rate), heat production or production performance (e.g., milk production, egg production or weight gain). Today THI is most popular to estimate effects of heat stress, such as decline of quantity and quality of animal products. Therefore, different THI equations have been developed for various livestock species (Tao and Xin, 2003).

**Correponding Author:** Ercan Simsek, Department of Biosystems Engineering, Faculty of Agriculture, Uludag University, 16059 Nilufer, Bursa, Turkey

The objective of this study was to determine effects of heat stress on egg production and quality characteristics, revealed THI distribution among cage blocks. This study also examined the relationship between THI and egg production in caged laying hens in a layer house with deep-pit in Western Turkey.

## MATERIALS AND METHODS

**Egg production facility:** The study was conducted in a commercial layer house with cage system in Bursa. Bursa which located in Western Turkey is a 4th big city of Turkey. The width and length of commercial layer house are 15 and 36 m, respectively and height of building walls were 3.82 m. In house, cage system used was Californian (compact) cage system and cage size was 40×50×40 cm. There were 5 cage blocks which has three tier in the building. Each individual cage in first and second tiers placed 5 and 4 hens were placed to reduce effects of heat stress in cages in 3 tier. In deep-pit, manure of laying hens was collected by scraper under cage rows and was stayed in this place until end of the production period. The mechanically ventilation system was used in layer house which have automatic feeding and nipple systems for water requirement. The light regime which is 14 h $day^{-1}$ was performed in layer house. In the experiment, 222 Isa Brown layers were used. The layers age were 25 week old in the beginning of experiment.

**Measurements, analysis and THI equation:** Ambient dry bulb temperature and relative humidity measurements were recorded for cages and all of layer house in 31 days during July and August. Dry bulb temperature measurements for layer house was done continuously with 5 min interval from different five points by electronic thermometer with data logging device (Thies Clima, Germany) while relative humidity was measured hourly by three thermo-hygrographs. Electronic thermometer and thermo-hygrographs were located 1.5 m above from the ground and in the middle place of between cage rows. The three cages on each cage tiers which placed North, Central and South of each cage rows were selected to measure temperature, humidity values in cage units and to determine egg production and quality characteristics. Dry bulb temperature and humidity in selecting cages were measured daily between 13:00 and 17:00 each experiment day by thermo-hygrometer (Oregon Scientific Inc., Portland, Oregon USA).

The egg production in selected cages was recorded daily in this study. To determine egg weight, shape index, shell thickness, albumen index, yolk index and Haugh units scores, 30 eggs were collected daily from selected each cages. Feed intake and feed conversion efficiency and mortality were recorded daily. Rectal temperature and body mass were determined weekly in each selected cages. Rectal temperature was measured by inserting a electronic digital thermometer into the rectum for 60 sec (Microlife, Turkey, Model No: MT 3001).

Daily THI values were determined for the experimental period using the equation which was described by Zulovich and Deshazer (1990):

$$THI_{lh} = 0.40T_{wb} + 0.60T_{db}$$

Where:

$THI_{lh}$ = Temperature-humidity index for laying hens
$T_{wb}$ = Wet bulb temperature (°C)
$T_{db}$ = Dry bulb temperature (°C)

**Data analysis:** Analysis of Variance (ANOVA) was performed on all of the measurement data to determine the effects of thermal variables and THI at 0.05 and 0.01 significance levels. THI differences for selected cages were tested using general linear model. Finally, a regression equation was developed between egg production and THI. All analyses were conducted using Jump 7.0. Significant treatment effects were detected by Duncan's multiple range tests. Results were expressed as means with their standard deviations.

## RESULTS AND DISCUSSION

**Environmental conditions:** The averages, maximum and minimum values of indoor temperature, relative humidity and outdoor temperature, relative humidity data measured during experiment period are shown in Table 1. For indoor temperatures and relative humidity, average values were obtained as 31.15°C and 44.68%, respectively. The average outdoor temperature and relative humidity were about 34.11°C and 59.91%, respectively during study period in region conditions. About sufficiency of indoor environmental conditions, the differences between average and minimum, maximum indoor temperature and relative humidity are an important indicator. In layer house, the differences between average and minimum, maximum indoor temperature were 2.18 and 2.41°C while for indoor relative humidity it were 10.91 and 13.44%, respectively. Butcher and Miles (1996) stated that the indoor environmental temperatures exceed 30°C cause to

Table 1: Environmental conditions measured during study period

| Parameters | Mean | Minimum | Maximum | SD |
|---|---|---|---|---|
| Indoor temperature (°C) | 31.15 | 28.97 | 33.56 | 1.12 |
| Outdoor temperature (°C) | 34.11 | 32.86 | 35.01 | 0.81 |
| Indoor humidity (%) | 44.68 | 33.77 | 58.12 | 6.36 |
| Outdoor humidity (%) | 59.91 | 50.11 | 67.25 | 6.71 |
| THI | 27.00 | 25.00 | 29.00 | 1.00 |

heat stress for laying hens and than laying hens pant to release heat from her bodies. Optimum production could be in temperatures between 19 and 24°C and also optimum ambient temperature 21°C for caged laying hens (Webster, 2003). Feed consumption of layers decrease, egg production diminishes and egg size and shell qualities deteriorate in temperatures between 29 and 32°C (Anderson, 1998). Ugurlu *et al.* (2002) reported that optimum indoor relative humidity should be between 65 and 70% for caged laying hens. Consequently, according to data obtained during study period, indoor environmental conditions in experimental layer house are not sufficient to supply temperature and humidity demands of laying hens for optimum production. Particularly, indoor ambient temperatures are quite high level and can cause heat stress.

The situation of laying hens causing indoor temperature and relative humidity measured in experimental layer house presented in Fig. 1. The indoor temperatures and humidity obtained during study period were danger level for heat stress in temperature and humidity stress index chart for laying hens. Also,

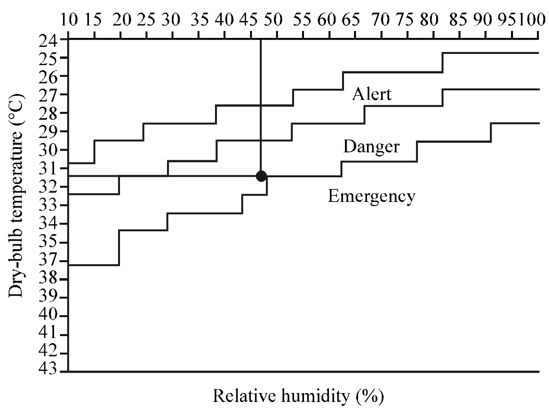


Fig. 1: The location of monitored layer house in the heat stress chart

Table 2: The variation of THI values in experimental layer house

| Variations | Temperature (°C) | Relative humidity (%) | THI |
|---|---|---|---|
| **Cage rows** | | | |
| 1 | 30.78 | 45.93 | 27.2 |
| 2 | 31.08 | 45.02 | 27.4 |
| 3 | 31.02 | 44.27 | 27.3 |
| 4 | 31.01 | 43.55 | 27.2 |
| 5 | 31.05 | 43.93 | 27.3 |
| 6 | 30.81 | 41.75 | 26.9 |
| **Cage tiers** | | | |
| 1 | 30.84 | 43.70 | 27.2 |
| 2 | 31.07 | 44.59 | 27.4 |
| 3 | 30.97 | 43.80 | 27.2 |
| **Direction of cages** | | | |
| West | 30.82 | 43.24 | 27.0 |
| Central | 31.03 | 43.94 | 27.3 |
| South | 31.01 | 44.91 | 27.3 |

THI values calculated daily for layer house and average THI value was found as 27 according to data measured (Table 1).

**The variations of THI in layer house:** Table 2 shows THI values of cage blocks and tiers. In this study, according to temperature and humidity measured in cage, THI values for each experimental cage were found. The differences between cage rows, cage tiers and direction were not statistically significant for THI value ($p>0.05$). The differences of temperature and humidity measured in monitored cages overall layer house were inefficient level creating a variation between THI values. Therefore, everywhere in monitored layer house have same environmental conditions for laying hens based on calculated THI values.

**The variations of egg production parameters in heat stress:** Descriptive statistics on egg production parameters obtained from experimental layer house appear in Table 3. The mean of individual production parameters is the sum of all the daily observations divided by number of laying hens in experimental cages represented by those production parameters. Table 4 shows variation on egg production parameters with min and max THI. Feed consumption of laying hens in experimental cages decreased 18 g or 16%. On the other hand, feed conversion increased 10% in parallel of raise on THI values. These findings agree with those Mashaly *et al.* (2004) who found that feed intake was reduced proportion to the severity and length of heat stress

Table 3: Descriptive statistics of egg production parameters

| Parameters | Units | Mean | Minimum | Maximum | SD |
|---|---|---|---|---|---|
| Feed consumption | g/hen day | 106.40 | 92.55 | 118.45 | 9.36 |
| Body weight | kg | 1.86 | 1.61 | 2.12 | 0.13 |
| Body weight gain | g/week | 7.67 | -75.00 | 44.00 | 27.55 |
| Feed conversion | kg feed/ dozen eggs | 1.54 | 1.35 | 1.74 | 0.10 |
| | | - | - | - | - |
| Feed/egg ratio | g feed/g egg | 1.91 | 1.70 | 2.15 | 0.12 |
| Egg production | %/day | 84.34 | 68.65 | 95.63 | 6.25 |
| Egg mass | g/hen day | 47.81 | 37.04 | 55.92 | 4.33 |
| Rectal temp. | °C | 41.40 | 41.00 | 42.20 | 0.22 |
| Mortality | %/week | 2.25 | 1.33 | 4.56 | 0.33 |

Table 4: Egg production parameters in minimum and maximum THI

| Parameters | Units | THI-25 | THI-29 |
|---|---|---|---|
| Feed consumption | g/hen day | 110.9±10.320* | 92.87±12.460 |
| Body weight | kg | 1.87±0.110 | 1.80±0.1300 |
| Body weight gain | g/week | 25.56±59.34 | 12.78±123.77 |
| Feed conversion | kg feed/ dozen eggs | 1.46±0.010 | 1.62±0.0800 |
| | | - | - |
| Feed/egg ratio | g feedg egg | 1.86±0.010 | 1.75±0.1100 |
| Egg production | %/day | 95.24±0.390 | 71.20±2.3900 |
| Egg mass | g/hen day | 55.32±0.600 | 39.10±0.6000 |
| Rectal temperature | °C | 41.0±0.1500 | 41.81±0.2300 |
| Mortality | %/week | 1.89±0.270 | 6.78±0.4500 |

*Mean±SD

exposure; laying hens in heat stress group consumed 52% less feed than control group. Ciftci *et al.* (2005) investigated the possible beneficial effects of dietary vitamin E and C supplementation on laying hens exposed to a chronic heat stress. Their results show that feed intake for control group (92 g) was lower than for vit. E (93 g), vit. C (93 g) and vit. E+C (94 g). Franco-Jimenez and Beck (2007) stated that feed consumption was reduced about 35, 27 and 28% for brown, W98 and W36 strains during heat stress.

Heat stress has not any important impact on body weight in this study. But, body weight gain of laying hens in experimental cages decreased 50%. The similar results for body weight gains during heat stress were reported by other researchers. Liveweights of laying hens in experimental room were dropped to 1890 g with indoor temperature by 35°C (Sahin and Kucuk, 2001). Ciftci *et al.* (2005) found that the body weight gains in laying hens during heat stress were 190 g for control group, 230 f for vit. E, 235 g for vit. C and 251 g for vit. E+C. Body weight loss for laying hens was about 137.5 g in heat stress when indoor temperature was elevated rapidly to 32°C for 28 days experiment (Ma *et al.*, 2005).

When the THI values increased from 25-29, heat stress reduced egg production by 25%. The converse effect of heat stress was most likely mediated through a reduction in feed consumption, reducing the available nutrients for egg production. The findings are in agreement with those of Whitehead *et al.* (1998). Egg production is inversely related to high temperature (Mashaly *et al.*, 2004). They found a 36% loss in hen-day egg production for hens exposed to the constant hot temperature. Franco-Jimenez and Beck (2007) stated that egg production was differentially affected by heat stress. According to their results, diminutions in egg production were ranged between 13 and 35% for three strains.

Moreover, egg mass was decreased about 16 g or 29% with increasing THI values. These results agree with those of Kirunda *et al.* (2001) who found that high and cyclic temperatures decrease egg weight. Mashaly *et al.* (2004) stated that eggs from hens in the heat stress weighed about 10 g or 17% less than eggs from control group. Ciftci *et al.* (2005) expressed that the lightest and heaviest eggs obtained from control group (58.7 g) and vit. E+C group (60 g). When indoor temperature in temperature-controlled rooms was raised from 22-34°C for 9 h per day, average egg weight was dropped 3 g or 5% for heat stress group and also hen-day egg production for heat stress group was as low as about 69% throughout study period (Seven, 2008).

Rectal temperature is a suitable indicator of thermal balance and may be used to assess the negative effects of heat stress on egg production of laying hens. Overall this study, rectal temperature increased approximately 1°C when the THI values leaped from 25-29.

Mortality in experimental cages increased about 5% with heat stress. Sterling *et al.* (2003) found that there is a significant ($p<0.05$) negative linear correlation between mortality and temperature. When temperature increased from 22-35°C in the layer house, mortality rates in Brown, W98 and W36 strains were 8, 4 and 16%, respectively. The more severe impact on mortality of Brown hens was result from their larger body with heavier feather cover (Franco-Jimenez and Beck, 2007). Seven (2008) indicated that mortality rate was higher about 6.67% in the heat stress group than the thermoneutral group.

**THI and egg quality characteristics:** Table 5 shows egg quality characteristics in different THI values. Based on results of statistical analysis, variation on egg quality characteristics versus THI values is not statistically significant for whole study period. The thickness of the shell usually decreases as the temperature raises (Deaton *et al.*, 1981; Tanor *et al.*, 1984) but not always significantly (Grover and Anderson, 1980). The literature often gives different and variable temperatures that are considered to provide the best egg quality because increasing environmental temperature does not always correspond with any significant differences in egg quality characteristics.

**THI-egg production relationship:** The egg production obtained during study period is given in Fig. 2 as total weight and count. The egg production lines versus THI are negative slope in the graph as it can be seen in Fig. 2. The negative slope of lines points out that egg production decreases with increasing THI values. Different trendline/regression types were used to find

Table 5: Egg quality characteristics in different THI values

| | THI | | | | | |
|---|---|---|---|---|---|---|
| Characteristics | 25 | 26 | 27 | 28 | 29 | p |
| Egg weight (g) | 57.25±0.52 | 57.91±2.10 | 57.04±1.42 | 58.49±0.92 | 59.04±0.94 | NS |
| Shape index | 77.38±1.46 | 77.81±0.91 | 77.18±0.58 | 77.49±0.62 | 77.18±0.52 | NS |
| Albumen index | 8.45±1.78 | 11.09±1.49 | 10.03±1.20 | 9.53±1.13 | 9.20±0.35 | NS |
| Yolk index | 46.98±1.18 | 48.21±1.14 | 47.33±1.21 | 47.27±2.07 | 46.72±0.54 | NS |
| Haugh Unit | 78.28±6.91 | 89.63±7.43 | 86.77±5.92 | 83.94±5.12 | 81.99±1.51 | NS |
| Shell thickness (mm) | 0.32±0.01 | 0.36±0.08 | 0.33±0.02 | 0.32±0.02 | 0.31±0.01 | NS |

Table 6: The regression equations between egg production and THI

| Regression | Equation | $R^2$ |
|---|---|---|
| **Egg production** | | |
| **Weight (kg)** | | |
| Polynomial | $y = -3E\text{-}08\,x^6+2E\text{-}06\,x^5-2E\text{-}05\,x^4-0.002\,x^3+0.046\,x^2-0.489\,x+14.426$ | 0.9510 |
| Linear | $y = -0.1105\,x+13.817$ | 0.8471 |
| Exponential | $y = 13.95\,e^{-0.009\,x}$ | 0.8271 |
| Logarithmic | $y = -1.052\ln(x)+14.699$ | 0.6758 |
| Power | $y = 14.969\,x^{-0.088}$ | 0.6328 |
| **Count** | | |
| Polynomial | $y = 2E\text{-}06\,x^6-0.0002\,x^5+0.008\,x^4-0.149\,x^3+1.614\,x^2-10.219\,x+249.99$ | 0.9401 |
| Linear | $y = -1.5524\,x+237.39$ | 0.8019 |
| Exponential | $y = 238.87\,e^{-0.007\,x}$ | 0.7859 |
| Logarithmic | $y = -14.87\ln(x)+250.02$ | 0.6482 |
| Power | $y = 253.01\,x^{-0.07}$ | 0.6124 |

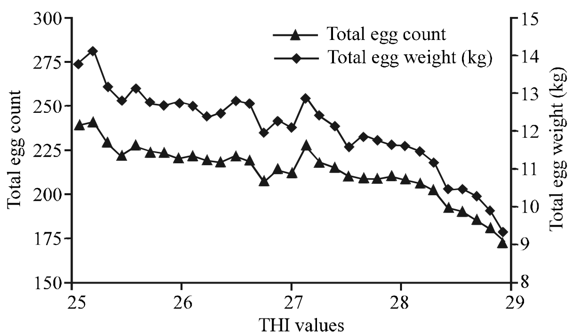


Fig. 2: The egg production as weight and count versus THI

best expression of relationship between egg production and THI (Table 6). Polynomial regression equation explains more clearly relationship and has highest $R^2$ value in the all of regression types used this study. The value of relationship for predictive purposes is relatively high as depicted by an $R^2$ value of 0.95. This regression represent that in general, for each point increase in the THI value above 25, there was a decrease in egg production of 11.56 g $egg^{-1}$ or 15 eggs $day^{-1}$ in monitored cages. A major part of the variation in egg production could, therefore be associated with heat stress.

Table 7 shows decrease rate in egg production among THI values. The highest decrease rate of egg production as weight was occurred in 28 of THI while highest decrease rate of egg production as count was occurred in 29 of THI value. When the exposure time of laying hens to heat stress was long, THI and decrease rate of egg production increased during study period.

In the study, increased THI values during study period resulted in long-term alterations in egg production as weight and count in monitored cages. This aligns with the literature, in which THI during the laying period was

Table 7: The decrease rates in egg production and weight along with heat stress monitored cages

| | Egg production | | | |
|---|---|---|---|---|
| | Weight | | Count | |
| THI | g $day^{-1}$ | % | No. $day^{-1}$ | % |
| 25 | 0.00 | 0.00 | 0.00 | 0.00 |
| 26 | 10.50 | 1.19 | 15.20 | 6.33 |
| 27 | 0.47 | 0.12 | 6.89 | 3.07 |
| 28 | 18.11 | 2.78 | 11.24 | 5.18 |
| 29 | 17.17 | 1.20 | 24.67 | 11.97 |

observed to result in variations in egg production and it reflected impact of high indoor temperature (Whitehead *et al*., 1998; Mashaly *et al*., 2004; Franco-Jimenez and Beck, 2007).

## CONCLUSION

Summer heat stress significantly decreased egg production while egg quality did not affect during study period in a laying hen house managed under subtropics climatic conditions. As the THI values increased from 25-29, total egg production decreased by 4.8 kg as weight or by 68 eggs as count. The regression equation obtained under the conditions of the present work point out that milk yield drops by 12 g/egg/day for each point increase in the value of THI above 25.

Consequently, management strategies are needed to minimize heat stress and attain optimal animal productivity for monitored layer house.

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