Analysis of Indoor Climatic Data to Assess the Heat Stress of Laying Hens

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Abstract

Heat stress for laying hens means the adverse effects of high indoor thermal environments on their egg production (i.e. fewer eggs, reduced egg mass and thinner eggshells) and feed consumption and health. A commonly-used measure of heat stress for animals is Temperature-Humidity Index (THI). The values of temperature-humidity index above 70 indicate the existence of heat stress for the laying hens. Based on this fact, the decreases in both egg production and dry matter intake (DMI) were separately predicted by using daily total THI load as the driving variable of the mathematical models. THI load is the added values of excessive difference of hourly THI values from the threshold THI value (70) during a day. The daily loss of egg production ranged from 18.48 to 51.32 g egg per hen per day while the daily decrease of DMI ranged from 27.07 to 75.23 g DMI per hen per day for a commercial egg production facility located in Tokat, Turkey during summer seasons of 2003 and 2004. Predictions agreed with real data. Heat stress should be alleviated by modifying feed composition and applying special management strategies.

Key words: THI, Egg production, laying hens, heat stress.

INTRODUCTION

The well-being and productivity of commercial farm animals depend on the climatic conditions surrounding them [1, 2]. The temperature and moisture of air are two major environmental factors controlling the heat stress of livestock [3, 4]. A temperature-humidity index (THI) is commonly used as an environmental factor to predict production losses of an animal exposed to hot humid climatic conditions. The temperature and humidity in summer season (average THI values:78 ±3.23) under Mediterranean climatic conditions in Kairouan, Tunisia reduced milk production by 21% and DMI by 9.6 % while it increased rectal temperature by 0.5 °C, heart rate by 6 beats and respiration rate by 5 inspirations per min of lactating Friesian-Holstein cows compared to those of spring season (average THI values: 68±3.75) [3]. THI values are not directly measured but calculated by different equations whose independent variables are dry bulb temperature-relative humidity [3, 4] dry bulb temperature-wet bulb temperature[5, 6].

A hen can convert dietary energy into eggs more efficiently under less stressful environment. Heat stress adversely affects the egg size, laying percentage, mortality, body weight gain, egg shell durability in different extents [7, 8, 9]. The air temperature above 21 °C was reported to initiate heat stress on white leghorn layers [7]. Adverse climatic conditions also inhibit the proper immune function of hens [10].

An early mathematical modeling study attempting to predict the effect of adverse environment on the performance parameters of layers considered only the dry bulb air temperature as independent variable [7]. Later, dry bulb temperature was replaced with temperature-humidity index in the models to consider the adverse effect of high air moisture levels together with dry bulb temperature [5]. The analysis of performance data (weekly averages of hen-day egg production, egg weight, feed and water consumption, dietary ME, indoor dry bulb air temperature, and mortality) on 203 commercial White Leghorn flocks (approximately 14.7 million hens) located in various parts of the U.S. revealed the existence of heat stress over some of those layers in commercial facilities [8]. In another study conducted in Konya, Turkey, it was reported that feed intake of layers decreased from 113.3 g/hen to 96.5 g/hen in also egg production reduced from 84.6 % to 77.3 when the environmental temperature increased from 21.4 °C to 27.6 °C [11]. Temperature rise from 20 °C to 32 °C resulted in a decrease in eggshell thickness from 346.5±5.8 µm to 326.6±5.4 µm, increase in egg breakage from 8.7±6.0 % to 33.3±9.2 % and unchanged egg shape index [9].

About $ 2.4 billion annual economic losses from heat stress of US livestock industries were predicted based on the daily weather records from 257 weather stations starting between 1871 and 1932 [4]. In the same study, the possible heat stress-related losses of the laying hens were predicted by the mathematical models using outdoor weather data. However, the indoor weather data should be used to have better predictions since the laying hens are normally kept indoor in cages.

The aim of the current study is to develop and evaluate a practical computational method to make the quick assessment of the performance decrease of laying hens under heat stress using the hourly dry bulb temperature and relative humidity values of indoor air.

MATERIALS AND METHODS

Egg Production Facility

The research was conducted in a commercial caged egg poultry house in Yesilyurt (Tokat), Turkey. Yesilyurt is a city located in the Central Black Sea Region of Turkey. Its latitude, longitude and elevation (in m) are 40.18, 36.54 and 1050, respectively. The experimental poultry house was 12 m wide and 40 m long. The building walls were 2.70 m high. The poultry house has a roof with 11 chimneys having each 0.75 m^2 cross-sectional area. The outdoor air entered the building through the windows placed along two long side walls. There were four cage blocks which had four floors in the building. Each individual cage housed five hens. Automatic feeding and watering systems were working in the facility. Commercial layer hen feed was used. There were 11000 White Izabrown layers in this building. The hourly dry bulb temperature and relative humidity values of indoor air were measured by an electronic measurement and data logging device (HOBO RH/Temp, Type: HO8-003-02, USA). The device was placed 1.5 meters above from the ground and in the middle place of the building.

Heat Stress Mathematical Model

Hourly THI (Temperature-humidity index) values were determined using the following equation [3]:

$$THI = 1.8 \times T - (1 - RH) \times (T - 14.3) + 32 \quad (1)$$

where T is the dry bulb temperature of indoor air hourly measured (°C); RH is the relative humidity of indoor air hourly measured (as a fraction of the unit).

The following equations were used to estimate the effects of heat stress on the performance of the laying hens [4]:

$$EGG_{loss} = 0.048 - \left(\begin{array}{l} (0.8 - (0.00034 \times THILoad)) \times \\ (0.06 - (0.0000123 \times THILoad)) \end{array} \right) \quad (2)$$

$$DMI_{red} = \frac{0.12 \times (0.0366 \times THILoad)}{100} \quad (3)$$

where EGG_{loss} is the daily loss in egg production from heat stress per hen (kg per hen per day); DMI_{red} is the daily reduction in dry matter intake per hen (kg per hen per day); THILoad was the daily total of differences between hourly THI values only exceeding 70 and 70. It was formulated as follows:

$$THILoad = \sum_{i=1}^{24} \left(THI_{i,>70} - 70 \right) \quad (4)$$

where $THI_{i,>70}$ is the i^{th} hourly THI value only exceeding 70 for a given day; i is the hour of a day. Number 70 in equation 4 is the threshold value of THI above which heat stress occurs in laying hens [4].

The values of DMI_{loss} for each month were summed to find monthly reduction of dry matter intake. The values of EGG_{loss} for each month were summed to find monthly loss of egg. The unit of monthly egg loss was converted from kg to number by considering the weight of a standard egg as 0.06 kg. EGG_{loss} incorporates the negative effects of heat stress on both the percent hen-day production and egg size [4].

RESULTS AND DISCUSSION

Monthly average values of indoor air dry bulb temperature and relative humidity are presented in Table 1.

The monthly average values of indoor air dry bulb temperature increased towards august. The trend in indoor air moisture is diverse. Above all, average THI value is also higher in august than in other two months. The maximum level of all hourly THI values was found to be 80. The magnitude of heat stress depends on how much calculated THI is higher than threshold THI value (70) and how long it exists. Based on this fact, the characteristics of heat stress were determined as given in Table 2.

THILoad values were given as both daily and monthly bases. Daily THI load value increased up to 55.26 in August, 2004. Daily THILoad values were used to predict the daily egg

Table 1. Indoor climatic data of laying hen structure

Item		Year 2003			Year 2004		
		Temp (°C)	RH (%)	THI	Temp (°C)	RH (%)	THI
June	Max	32.3	67.2	79	30.3	70.8	77
	Min	17.1	23.2	62	15.6	23.9	60
	Average	23.9	43.0	69.4	23.5	52.6	69.8
July	Max	34.0	71.9	78	32.8	73.1	79
	Min	15.2	22.6	59	16.8	22.8	61
	Average	23.7	48.3	69.5	24.3	47.1	70.2
Aug	Max	32.8	69.8	79	32.3	73.5	80
	Min	17.9	22.9	63	19.4	22.9	65
	Average	24.6	47.21	70.6	25.4	50.0	71.9

Table 2. The various indicators of thermal heat stress of laying hens

Item		June		July		August	
		Ave	Total	Ave	Total	Ave	Total
Year 2003	THIload	20.53	616	28.26	876	36.32	1126
	Duration (h)	8.37	251	9.81	304	12.52	388
	Ratio	2.45	2.45	2.88	2.88	2.90	2.90
Year 2004	THIload	28.77	863	34.26	1062	55.26	1713
	Duration (h)	9.50	285	10.61	329	15.77	489
	Ratio	3.03	3.03	3.23	3.23	3.50	3.50

loss and dry mater intake reduction. Monthly average values represent the added values of Daily THILoad. Average duration values show the time length in which THI values are above the threshold THI value in a day. In August of 2004, the hens were exposed to heat stress for almost 16 hours during the day. The third indicator of heat stress used in this study is the ratio of THI load to the duration of heat stress in a day. The rise of this ratio intensifies the undesired effect of heat stress on the laying hens in a given time period. Its value rose up to 3.5 in August of 2004.

The effects of heat stress on the performance of the laying hens were given in Figure1.

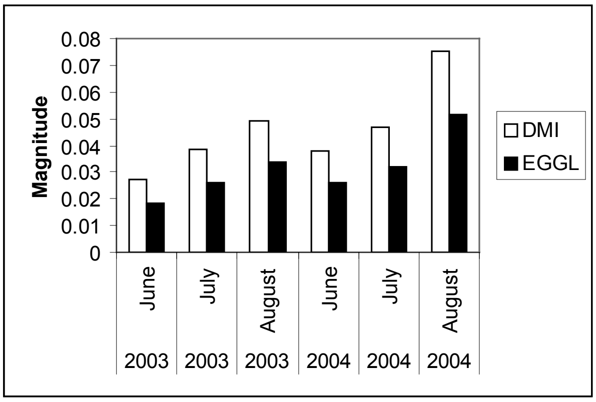

Figure 1. Daily loss of egg production and DMI decrease of a standard laying hen.

Two different performance measures were used in this study. They are the decrease of dry matter intake and the decrease of egg production by a standard laying hen. The decrease of dry matter intake varied between 27.07 and 75.23 g DMI per hen per day. The feeding records of the egg production facility showed that on the average, a hen consumed 0.120 kg feed a day in winter while it consumed 0.110-0.115 kg feed a day in summer. The differences between these consumption rates are similar to the predicted results. Our predicted results agree with the findings of a previous study conducted in Konya-Turkey [11]. That study reported the reduction of 16.8 g feed per hen because of heat stress. The decrease (loss) of egg production varied between 18.48 and 51.32 g egg per hen per day. According To the data given in Figure 1, monthly decrease in dry matter intake and monthly loss in egg production were calculated for 11000 laying hens. The calculation results are presented in Table 3.

Monthly decrease in DMI of 11000 laying hens increased up to 827.53 kg while monthly loss of egg production of 11000 laying hens increased up to 9409 eggs. Daily laying percentage of a laying hen changes from 10 % to 92.7 % per hen per day based on its age [7]. It reaches a peak value and then decreases. By getting the daily laying percentage value as 0.865 egg per hen per day, 11000 hens are predicted to lay 9515 eggs a day. Based on this prediction the monthly egg loss varied between 1.19 to 3.19 %. The egg production data obtained from the cage house were given Table 4.

Table 4. Real egg production data in 2004.

Item	June	July	August
Real egg production	272970	282120	241800
Theoretical egg production	285450	294965	294965
Real egg loss	12480	5395	12845
Real egg loss percentage	4.37	1.83	4.35

Real egg production data were 1.83 to 4.37 % less than theoretical egg production. These differences between real egg production and theoretical egg production were expected to be partially caused by heat stress, aging and some other uncontrolled reasons (deaths, eggshell breakage and acclimatization, etc.).

The undesired effects of heat stress on laying hens can be alleviated by various nutrition and management strategies. Environmentally-modified buildings have been shown to be especially advantageous for commercial layers that are housed in high density cage facilities [12]. A standard hen can produce 3.0 to 7.0 $Kcal \cdot h^{-1} \cdot kg^{-1}$ heat while it can produce 1.5 to 5.1 $g \cdot h^{-1} \cdot kg^{-1}$ water moisture depending on the dry bulb temperature of surrounding air. The rise of air dry bulb temperature increases moisture loss from hen but decreases heat loss of hens [13]. If the cooling system of poultry house is not adequate, the differences between indoor climatic parameters and outdoor climatic parameters increase and cause more heat stress on the layers. On the other hand, when the aeration system of poultry house is adequate, the differences between indoor climatic parameters and outdoor climatic parameters are small and reduce heat stress on the layers. However, when the outdoor climatic conditions are much more above the optimum climatic values for the layers, the outdoor air should be taken into the building after being cooled by an evaporative cooling system or a mechanical refrigeration system. The evaporative cooling systems can work in hot but relatively dry climates since its working principle is to convert the sensible heat of air into its latent heat by increasing its relative humidity. A well-designed evaporative cooling system can be expected to achieve up to 80 % of the "wet-bulb depression" [14]. In a previous study, it was reported that evaporative cooling in cage house reduced indoor temperature by 6.3-7.8 °C when outdoor temperature was over 30 °C in summer [15]. The wet-bulb depression is defined as the difference between the dry-bulb and wet-bulb temperatures. As seen in the temperature humidity index equation (equation 1), dry bulb temperature increase THI value much more than

Table 3. Predicted results related to the performance of laying hens

Item		June	July	August	Total
Year 2003	Monthly DMI_{red} (kg)	297.77	423.17	543.84	1264.78
	Monthly $EGGl_{oss}$ (number)	3388	4813	6188	14389
Year 2004	Monthly DMI_{red} (kg)	417.12	512.93	827.53	1757.58
	Monthly EGG_{loss} (number)	4743	5832	9409	19984

relative humidity. Therefore, decreasing dry bulb temperature is a plausible strategy even though relative humidity increases.

Some possible nutritional manipulations of the diet to overcome heat stress are to increase the intake of protein relative to energy during moderate heat stress or to add ascorbic acid, sodium bicarbonate and vitamin E to hen dietary supplementation [12]. A supply of cool drinking water [16], preventing sun light from entering the hen houses [17] and night feeding benefiting from temperature differences between night and day [18] are some other techniques having been shown to be technically effective in alleviating the undesired effects of heat stress. In hot and humid summer months, the egg producers should determine the level of heat stress in their facilities and also choose appropriate control strategies to alleviate heat stress. This study provides a mathematical tool to determine the level of heat stress in hen houses.

CONCLUSIONS

A practical computational method was developed to make the quick assessment of the performance decrease of laying hens under heat stress using the hourly dry bulb temperature and relative humidity values of indoor air. The predicted results showed that Monthly decrease in the dry matter intake of 11000 laying hens reached 827.53 kg while monthly loss of egg production of 11000 laying hens reached 9409 eggs for the egg production facility located in Tokat, Turkey.

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