Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2024, 11(11):143-149

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

A Study on Determining the Amount of Heat and Water Vapor Emitted by Leghorn Egg-Laying Hens in Closed Type Poultry Houses

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Abstract This research was conducted to determine the amount of heat and water vapor emitted by Leghorn breed laying hens housed on the ground and in cages in closed type poultry houses, based on the climatic conditions of the Thrace region of Turkey. As a result of the research, depending on the ambient temperature, the total amount of heat, sensible heat, latent heat and water vapor emitted by the chickens housed on the ground and in the cage were calculated and given in tables. It is suggested that the calculated values be used in calculations related to monitoring the climatic environment in closed type poultry houses, sizing ventilation systems, selecting material layouts and determining the insulation needs of poultry houses.

Keywords Poultry houses, leghorn laying hens, animal welfare, total heat.

1. Introduction

The main purpose of animal husbandry for economic purposes is to obtain the highest yield under economic conditions in return for a certain expense. In order to ensure this situation, the appropriate genotype for the animal husbandry activity should be used, animals should be cared for and fed in accordance with scientific techniques, necessary health protection measures should be taken and environmental conditions within the shelter should be kept at optimum levels. In order to increase productivity in animal husbandry activities, genotype improvement and feeding conditions are mostly emphasized, and the control of environmental conditions inside the shelter is left to the background. However, if the environmental conditions in the shelters where farm animals with high genotypic value and good care and nutrition are kept are not adequately controlled, the desired productivity level cannot be achieved in these animals. Therefore, in order to obtain the desired efficiency from the animals, in addition to the genotype and care-feeding, the environmental conditions inside the shelter must also be kept at optimum levels [1, 2]. The main purpose of building poultry houses for chickens is to eliminate the negative effects of the environment (climatic, structural, social, microbiological and chemical) on the behaviour and productivity of chickens, to provide more suitable and more comfortable living conditions and to protect them from predators. When suitable environmental conditions are created in the poultry house, the genotypic capacity of chickens and feed utilisation can be increased and economic losses due to mortality caused by various reasons can be reduced [2]. In order to keep the bioclimatic environment in the poultry houses at the optimum limit or to minimize deviations from the optimum limits, heat exchanges through conduction, convection and radiation must be kept at optimum levels in addition to the structural properties of the poultry house. Therefore, in the planning phase of the poultry houses, the insulation levels of the building elements, the size and internal details of the poultry house should be determined according to the climatic conditions of the region where the poultry house will be built and the bioclimatic requirements of the chickens.

The task of the breeder in animal husbandry is to know the relationship between the animals he/she breeds and the environment and to meet all environmental and bioclimatic needs of the animals accordingly. If these needs are met, animals can reach the productivity level allowed by their genotype [3]. However, in order to control the climatic environment in poultry houses within economic limits and to keep animal welfare in the comfort zone, the amount of heat and water vapor emitted by chickens into the poultry environment needs to be known. The aim of this study was to determine the amount of heat and humidity emitted to the poultry house environment depending on the ambient temperature of laying hens housed in closed type poultry houses.

2. Material and Method

The study was conducted for Leghorn breed laying hens housed on the ground and in cages, based on the climate conditions of the Thrace region of Turkey. The Thrace region, which is the study area, is located between 26°-29° east longitudes and 40°-42° north latitudes in the European continent of Turkey. It is under the influence of Mediterranean climates along the coasts and continental climates in the inland areas. Its average altitude above sea level is between 50-150 m. According to meteorological records for many years, its annual average temperature is 13-14.6 ℃ and its annual average relative humidity is 70-75% [4].

In the study, Leghorn breed chicken, whose homeland is Italy, was selected because it is one of the most important and common chicken breeds in the world. The average annual egg production of Leghorn breed chickens is 320 pieces and the weight of one egg is 55 g on average. The average weight of itself is between 1.5 kg and 2.5 kg [5]. Considering the morphometric characteristics of the chickens and the climatic conditions of the study area, it is inevitable that the poultry houses should be constructed as closed type shelters. In closed type shelters, heat-humidity balance calculations for controlling the climatic environment are generally made based on the total heat, sensible heat, latent heat and water vapor values given to the shelter environment by the animals. These values were calculated with the help of equations suggested for laying hens by CIGR [6], Pedersen [7] and Mutaf [2].

Total amount of heat (For ambient temperature 20 ℃)

Housing laying hens on the ground

$$q_T = 6.8 \text{ x } m^{0.75} + 25 \text{ x } Y \quad (1)$$

Housing laying hens in cages

$$q_T = 6.28 \text{ x } m^{0.75} + 25 \text{ x } Y \quad (2)$$

Corrected total heat radiated by animals for conditions where the ambient dry bulb temperature is 20 ℃ below or above:

$$q_{T.cor.} = q_T \text{ x } t_{cor.fac.} \quad (3)$$

The correction factor (when the indoor temperature is between 0 and 30 ℃):

$$t_{cor.fac.} = [1+2 \text{ x } 10^{-2} (20 - t_{db})] \quad (4)$$

The amount of sensible heat

Housing laying hens on the ground

$$q_{sen.} = q_{T.cor} \text{ x } [(0.64 \text{ x } t_{cor.fac.}) - (2.4 \text{ x } 10^{-4} \text{ x } t_{db}^2)] \quad (5)$$

Housing laying hens in cages

$$q_{sen.} = q_{T.cor} \text{ x } [(0.64 \text{ x } t_{cor.fac.}) - (9.8 \text{ x } 10^{-11} \text{ x } t_{db}^6)]$$

The amount of latent heat

$$q_{lat.} = q_{T.cor.} - q_{sen.} \quad (6)$$

The amount of water vapor

$$W_{wat.vap} = q_{lat.} / 0.680 \quad (7)$$

In the equations; q_T=total heat amount (W), m=live weight (kg), Y=daily egg production (kg/day), t_{db}=dry bulb temperature (℃), $q_{T.cor}$= corrected total heat amount (W), $t_{cor.fac.}$= correction factor, $q_{sen.}$= sensible heat amount

(W), $q_{lat.}$= latent heat amount (W), $w_{wat.vap.}$=amount of water vapor emitted by animals by sweating and respiration (g/h), 0.680= heat of evaporation of water (W).

3. Results and Discussion

Since the aim of chicken farming is to obtain the most economical yield, in addition to appropriate breeding and effective nutrition, optimum environmental conditions are also a requirement and inevitable condition for profitable production. Our country is at the forefront in the world in terms of laying hen breeding. A significant portion of the laying hens raised are Leghorn chickens. According to the data of TÜİK [8] there are approximately 115 million laying hens in Turkey and 21 billion chicken eggs are produced annually. In order to increase the production and ensure animal welfare, it is essential to keep the climatic environment in the shelters where the hens are kept at optimum levels. Before calculating the heat and water vapour emitted by the chickens to the environment depending on the ambient temperature, it is useful to give information about the environmental conditions such as temperature, relative humidity, illumination, composition of the shelter air, ventilation rate and flow rate, which constitute the basic data for controlling the climatic environment in chicken coops.

a. Climatic environment in laying hen houses

Poultry are warm-blooded animals. They need a constant body temperature to continue their physiological functions. They maintain their body temperature at the same level provided that the ambient temperature is within certain limits. The body temperature for adult birds is approximately 41-42 ℃. However, the ability of chickens to maintain a uniform body temperature is more effective at certain ambient temperatures. When animals are exposed to a hot environment, they start to activate the body's cooling mechanism to remove excess heat. When they are exposed to a cold environment, they try to keep their body temperature within certain limits by producing heat through metabolic processes and activating their insulation mechanisms [5].

The optimum temperature range for laying hens varies between 12.8-21.1 ℃ [9]. The optimum temperature for chickens kept in cages is 21 ℃ [10]. Daghir [11] reported that a temperature range of 18–22 ℃ is required for raising broilers. Holik [2] stated that the environmental temperature of 18–24 ℃ for chickens has a positive effect on animal productivity and welfare. It is stated that when the ambient temperature is 28-35 ℃, the difference between the body temperature of the chickens (41 ℃) and the environment they are in is small, which reduces sensible heat loss and that the efforts of the animal to increase heat loss, such as opening its wings, are not sufficient, and in this case, the respiratory rate of the chickens increases 10 times compared to normal, increasing latent heat loss by evaporation. The effect of heat stress on chickens is as follows; When the temperature rises above 27 ℃, the feed intake of the hens decreases and the decrease in feed consumption first causes the egg weight to decrease. When the temperature is above 32-35℃, the food intake is insufficient for normal egg laying and the egg production decreases [13].

Relative humidity in coops, especially together with high ambient temperature, has an effect on the performance of chickens. High ambient temperature and high relative humidity reduce the heat loss of animals, making it difficult for animals to adapt to the environment and causing changes in their behavior. When relative humidity falls below the desired limits in coops, it causes Marek's disease due to dust, and when it increases, it causes coccidiosis in chickens due to increased ammonia. High relative humidity in laying hen coops can cause chicken feathers to get dirty, excessive amounts of ammonia from manure to mix into the coop air, and high rates of dirty eggs to be produced [14]. Excessive humidity can cause various damages in coops. Stains that occur due to moisture condensation on the walls spoil the appearance and cause the wooden structural elements to rot. In addition, the moisture of the walls reduces the insulation properties of the structural elements. The main source of humidity in coops is the humidity that the animals give off to the air by breathing. The humidity should be removed as much as possible in parallel with the speed of its formation and its condensation on the surfaces and inside the structural elements should be prevented [15]. In order to prevent chickens from being harmed by high relative humidity, it is necessary to keep the relative humidity at an optimum level. For this purpose, adequate ventilation and moisture insulation should be provided in the shelters. Under optimum temperature conditions, the relative humidity in laying hen houses should be between 65-75%. However, in cold regions, it can be allowed to rise to 80% for proper heat balance [3].

Proper temperature and relative humidity can only be achieved in the coop with adequate ventilation. The amount of air flow and the related capacity of ventilation chimneys and ventilators should be determined according to regional conditions. The important point to note is that animals should not be exposed to air currents during ventilation. In winter, the air speed should not exceed 0.2-0.3 m/s at the level where chickens are located, and 0.1-0.2 m/s for chicks and pullets. On hot summer days, the ventilation rate can be 1-2 m/s. The required air flow rate in the coops can be accepted as 0.5-1.0 m3/h in winter and 3.0-3.5 m3/h in summer for 1 kg live weight. However, the air flow rate should not exceed 10 m3/h in caged systems, 7 m3/h in grid systems and 5 m3/h in butcher chicken coops for each chicken [15]. The required summer ventilation flow rate in chicken coops depends on the temperature inside the chicken coop, the difference between indoor and outdoor air temperatures and the insulation level of the building elements. Unless additional measures are taken to eliminate the negative effects of heat on tropical days, the air flow rate should not be increased above 5-6 m3/h kg, and especially in natural weather conditions. It emphasizes that when sizing the ventilation gaps in ventilated chicken coops, an air flow rate of 4 m3/h kg is sufficient [2]. Ventilation can be done with the help of natural and mechanical systems. However, in windowless chicken coops, the application of a mechanical ventilation system is a must [15].

When planning poultry houses, it should be endeavoured to provide adequate lighting. Although sufficient illumination is needed for daily work in buildings, the intensity of illumination depends on the situation. Firstly, natural lighting should be used in buildings. By increasing the window area, the intensity of the natural light entering the building during the day, the heat losses that will occur in the cold seasons and at night will be great. Therefore, when determining the size of the window area in agricultural buildings, the climatic conditions of the region and the function of the building should be taken into consideration. In cold regions, this problem can be solved by using double glazed and well insulated double frame windows [16]. It is stated that the ratio of the total window area to the shelter floor area should be 5% in cold regions, 10-15% in warm regions and 20-30% in hot regions. In poultry houses, at least 40 Watt lamps should be used for every 20 m2 of poultry house floor area [3].

The decomposition of faecal material of chickens produces unpleasant and dirty gases including ammonia, carbon dioxide, methane and hydrogen sulphide. These gases should be discharged out of the poultry house with appropriate ventilation depending on their rate of formation [17]. As a result, the concentration of ammonia should not be more than 25 ppm, carbon dioxide concentration should not be more than 3000 ppm, methane should not be more than 10000 ppm and hydrogen sulphide should not be more than 0.5 ppm under optimum production conditions for chickens in poultry houses [18].

b. Heat and Water Vapour Diffusion to the Poultry House Environment by Laying Hens

The two most important elements of the bioclimatic environment are temperature and relative humidity. In farm animals, all body reactions are largely dependent on temperature, and temperature is one of the most important thermal environmental criteria in making judgments about the thermal conditions of the environment. The negative effect of high temperature is much higher than low temperature. The negative effect of high temperature increases even more with high relative humidity. The reason for this is that the amount of evaporation expected from the skin surface as a result of sweating is low compared to the difference between the partial pressures of water vapor on the skin surface and the environment, and as a result, evaporation remains at almost negligible levels. Body temperature in farm animals is constant and varies within very narrow limits despite large changes in the ambient temperature. Normal body temperatures vary depending on the species and the direction of rearing and are approximately 38 °C in farm animals such as cattle and 41.7 °C in poultry such as chickens. Keeping body temperatures within the limits mentioned is possible by balancing the heat production and heat emission from the body. In cold environmental conditions, it increases metabolic heat production, while keeping heat loss at low levels. In hot environmental conditions, it decreases metabolic heat production, while increasing heat emission, especially latent heat emission. Body temperature is kept constant by metabolic heat production and heat transfer between the body and the environment and varies within very narrow limits depending on the time of day, activity, feeding and thermal environmental conditions. Heat transfer between the living being and the environment occurs as a result of the temperature and vapor pressure difference between the living being and the environment. The continuity of the stasis in body temperature is possible by ensuring the balance between the heat gain in the body and the heat emission from the body. When the body temperature is higher than the ambient air temperature and the inner surface temperature of the surrounding structural elements (winter-transition seasons), there is a continuous heat loss from the body to the external environment, while in the opposite conditions (summer in hot regions), there is a continuous heat load from the external environment to the body [2]. The amount of heat and water vapor produced by animals in the shelter varies depending on the temperature and humidity in the internal environment. For this reason, when the thermal environmental control inside the shelter is not sufficient, the effective use of genotypic potential decreases as a result of the negative effect of heat stress and causes productivity losses [19]. In high temperature and humidity conditions, as a result of the stresses in sensible and latent heat emission, it becomes difficult to keep the body temperature stable and causes heat stress. Heat stress is especially evident in the hot summer months.

The project criterion values used in the calculations for the research area are given in Table 1 for different seasons. In creating the values given in Table 1, the values recommended for Leghorn breed laying hens in Şenköylü [5] and Mutaf [3] and the climatic conditions of the region were taken into consideration. In addition, the temperature value at which heat stress begins in farm animals was taken as 25 °C and finally heat and water vapor diffusion were calculated for this value.

Table 1: Project criteria used in heat-moisture balance calculations for Leghorn breed laying hens

Season	Temperature inside the poultry house (°C)	Relative humidity in the poultry house (%)	Average live weight (kg)	Average egg production (pcs/year)	Average egg weight (g)	Daily egg production (kg/day)
Winter	8	80	2	320	55	0.048
	10	78	2	320	55	0.048
	12	76	2	320	55	0.048
Spring	14	75	2	320	55	0.048
and	16	73	2	320	55	0.048
Autumn	18	72	2	320	55	0.048
Summer	20	70	2	320	55	0.048
	22	70	2	320	55	0.048
	25	70	2	320	55	0.048

With the help of the project criteria given in Table 1 and the principles and equations given in CIGR [6], Pedersen [7] and Mutaf [2], the total heat, sensible heat, latent heat and water vapour values emitted to the poultry house environment under different seasonal conditions for laying hens housed on the floor and in cages are calculated separately and given in Table 2 and Table 3.

Table 2: Amounts of heat and water vapour emitted by Leghorn breed laying hens housed on the ground under project conditions

Season	Total heat (W)	Correction factor	Corrected total heat (W)	Sensible heat (W)	Latent heat (W)	Water vapour quantity (g/h)
Winter	12.64	1.24	15.67	12.14	3.53	5.19
	12.64	1.20	15.17	11.32	3.85	5.66
	12.64	1.16	14.66	10.34	4.32	6.35
Spring and	12.64	1.12	14.16	9.52	4.64	6.82
Autumn	12.64	1.08	13.65	8.57	5.08	7.47
	12.64	1.04	13.15	7.72	5.43	7.98
Summer	12.64	1.00	12.64	6.87	5.80	8.52
	12.64	0.96	12.13	6.04	6.09	8.95
	12.64	0.90	11.38	4.85	6.53	9.60

Table 3: Amounts of heat and water vapour emitted by Leghorn breed laying hens housed in cages under project conditions

Season	Total heat (W)	Correction factor	Corrected total heat (W)	Sensible heat (W)	Latent heat (W)	Water vapour quantity (g/h)
Winter	11.76	1.24	14.58	11.52	3.06	4.50
	11.76	1.20	14.11	10.83	3.28	4.82
	11.76	1.16	13.64	10.12	3.52	5.17
Spring and	11.76	1.12	13.17	9.47	3.7	5.44
Autumn	11.76	1.08	12.70	8.75	3.95	5.80
	11.76	1.04	12.23	8.09	4.14	6.08
Summer	11.76	1.00	11.76	7.45	4.31	6.33
	11.76	0.96	11.29	6.80	4.49	6.60
	11.76	0.90	10.58	5.84	4.74	6.97

When Table 1, Table 2 and Table 3 are evaluated together, it is seen that when the ambient temperature decreases in the winter season, the amount of sensible heat emitted from the animals to the environment increases, while the latent heat and water vapour emission decreases. In the opposite conditions, that is, when the ambient temperature increases, sensible heat decreases, whereas latent heat and water vapour diffusion increases. When Table 2 and Table 3 are evaluated together for laying hens housed on the floor and in cages, it is seen that total heat, sensible heat, latent heat and water vapour diffusion are higher in hens housed on the floor. The most important reason for this is the lack of movement restriction. Therefore, some of the energy obtained from the feed is consumed as movement energy. The ambient temperature changes the proportions of sensible and latent heat in the total heat transferred from animals to the external environment. Depending on the increase in the indoor temperature, the amount of sensible heat transferred from the animals to the indoor environment decreases, while the amount of latent heat increases. The temperature range in which the amount of sensible heat transferred to the external environment remains constant is called the thermal comfort zone. In this temperature range, feed utilisation rates of animals are at the highest level. At lower temperatures, animals spend a significant portion of the feed they consume to keep their body temperature constant and as a result of this, feed utilisation rates decrease. In hot climatic conditions, feed consumption of animals decreases, therefore, decreases in their development and productivity are observed [20]. The values calculated and given in Table 2 and Table 3 can be used as basic data for controlling the climatic environment in the poultry houses to be built in the research area, making heat-humidity balance calculations, determining the insulation needs of the poultry houses and sizing the ventilation systems. As it is known, in order to keep the climatic environment within optimum or near optimum limits in terms of animal welfare in closed type animal production structures, ventilation systems are primarily utilised and the flow rate of the system is tried to be determined according to different approaches. The larger of the calculated flow rates gives the capacity of the system and ventilation systems are sized according to this value. Considering the climatic conditions of the region where the research was conducted, there is no heat accumulation in the shelters in winter. The problem is the removal of excess moisture and harmful gases accumulated in the shelters from the environment depending on the rate of their formation [16].

In spring and autumn seasons, in some cases, humidity may be a problem in closed type poultry houses, while in some cases heat accumulation may be a problem. Therefore, the system capacity should be determined by making calculations according to heat, humidity and gas balance [3].

In closed type poultry houses in summer months, heat loss from structural elements is low, and even in some cases, heat flow from the external atmosphere to the poultry house environment causes the temperature inside the poultry house to rise well above the optimum values. Therefore, humidity is generally not a problem in summer. The problem is to eliminate the excess heat accumulated in the poultry house. For this reason, when planning ventilation systems for summer months, heat balance is taken as basis. The ventilation flow rate determined according to the heat balance in summer months gives the maximum capacity of the system. When the thermal environmental control in the poultry house is not sufficient, the effective utilisation of the genotypic potential decreases as a result of the negative effect of heat forcing and causes yield losses [3].

4. Conclusion

Considering the physiological and genetic characteristics of hens, ambient temperature and humidity have a great effect on egg production. It is necessary to know the amount of heat and water vapour emitted by the hens to the poultry house environment in order to regulate the climatic environmental conditions especially in closed type poultry houses. The study was carried out for Leghorn breed laying hens housed on the ground and in cages based on the climatic conditions of Thrace region of Turkey. Accordingly, the amounts of sensible heat, latent heat and water vapour emitted to the environment under the optimum projecting conditions accepted for the research area are calculated and given in Table 2 and Table 3. These values are suggested to be used in the calculations related to the control of climatic environment in closed type poultry houses, sizing of ventilation systems, selection of material arrangements and determination of insulation needs of poultry houses.

References

[1]. Mutaf, S., and R. Sonmez, 1984. Climatic Environmental Control in Animal Shelters. Ege University Faculty of Agriculture Publications, Publication No: 438, Izmir. 258 s.

[2]. Mutaf, S. 2012. Climatic Environment and Control Principles in Animal Shelters with Engineering Approach (1st Edition). Ankara: Ministry of Food, Agriculture and Livestock Publications.

[3]. Ekmekyapar, T. 1991. Organisation of Environmental Conditions in Animal Shelters (1st Edition). Erzurum: Atatürk University Faculty of Agriculture Publications.

[4]. Anonymous, 2024. 'Trakya Region Climate Data'. General Directorate of Meteorological Affairs, Ankara.

[5]. Senkoylu, N., 2001. Modern Chicken Production. Trakya University, Faculty of Agriculture Publications, Publication No: 47, Lecture Note No: 40, Tekirdag. 358 s.

[6]. CIGR, 2002. ''Climatization of Animal House, Heat and Moisture Production at Animal and Houses Levels'', Institute of Agricultural Sciences, 9, 68-75.

[7]. Pedersen, S. 2002. ''Heat and Moisture Production for Cattle and Poultry on Animal and House Level'' ASEA, Annual International Meeting, XVth World Congress Chicago, USA, 3, 1-10.

[8]. TUIK, 2024. Turkey livestock data, Turkish Statistical Institute, Ankara

[9]. Okuroglu, M. and L. Delibas, 1987. Projecting Principles of Building Elements in Animal Shelters. Technical Poultry Journal, Ankara. 55: 3-13

[10]. Spratt D., 1993, Basic Husbandry for Layers Ministry of Agriculture and Food Factsheet, AGDEX, Ontorino.

[11]. Dagır NJ. Piliçlerde ve piliç yetiştiricilerinde ısı stresini azaltmak için beslenme stratejileri. Lohmann Bilgileri. 2008; 44(1):6-15

[12]. Holik V. Tropikal koşullar altında yumurtlayan tavukların yönetimi yetiştirme döneminde başlar. Lohmann Bilgileri. 2015; 50(2):16-23

[13]. Bird A.N., Hunton P., Morrison D.W., Weber J.L., 1988. Heat Stress in Caged Layers. Ministry of Agriculture and Food, AGDEX 451/120, Factsheet, Ontorio.

[14]. Ozturk, T., 1992, Structural and Functional Characteristics of Egg Chicken Coops in Samsun Province (Doctoral Thesis). Ankara Univ. Institute of Science and Technology, Department of Agricultural Structures and Irrigation, Ankara.

[15]. Balaban, A., E. Sen, 1988. Agricultural Structures. Ankara University Faculty of Agriculture Publications: 1083, Textbook: 311, Ankara. 244 s.

[16]. Kocaman, I., Konukcu F., Istanbulluoglu A. 2007. ''Heat and Humidity Balance in Animal Shelters'', K.S.Ü.

[17]. Ketelaars EH. Lector, Notes on Chicken Breeding in Warm Climate Regions. 1st edition Wageningen: Agromisa Foundation; 2005. 128 pages ISBN: 90 5285 006

[18]. Hulzebosch J. What affects climate in poultry houses? World Poultry. 2004; 20:36-38

[19]. Mutaf, S., Alkan S., Seber N. 2004. ''Project Design Principles of Animal Shelters in Ecological Agriculture', 1'st International Congress on Organic Animal Production and Food Safety, 2, 212-230.

[20]. Gurdil, G.A.K.,2003. PhD Thesis with a Research on the Development of a Programme for the Design of Ventilation Systems in Poultry Houses, Adana.