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Research Article

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A Study on Determining the Amounts of Heat and Humidity Radiated by Holstein Dairy Cattle to the Shelter Environment in Climatic Conditions of Tekirdag Province

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Abstract: This research was conducted to determine the total heat, sensible heat, latent heat and water spring amounts radiated by Holstein breed dairy cattle to the barn environment under the current and optimum project conditions in the climatic conditions of Tekirdag province in the Thrace region of Turkey. The calculations were based on the head animal unit (HAU) based on 454 kg live weight. As a result of the research, Holstein breed dairy cattle receive 653 Kcal/h HAU sensible heat, 351 Kcal/h HAU latent heat and 518 g/h HAU water vapor in the shelter environment under optimum project conditions in winter, and 421 Kcal/h HAU sensible heat and 536 Kcal in summer. It is calculated to emit /h HAU latent heat and 916 g/h HAU water vapor. It is suggested that the calculated values be used in making calculations regarding the monitoring of the climatic environment in closed-type dairy cattle barns, the design of ventilation systems, the selection of building materials and the determination of insulation needs in terms of animal welfare.

Keywords: Holstein dairy cattle, animal welfare, sensible heat, latent heat, water vapor

1. Introduction

The main purpose of raising farm animals is to convert the energy given by feed into animal products used by humans, such as meat, milk, eggs, wool and leather. Increasing the income obtained within economic limits is possible by improving the genotype and keeping the environment at appropriate levels. Farm animals radiate heat and moisture to the environment they are housed in. The amount of heat and moisture they radiate varies depending on the temperature and relative humidity of the environment, and the housing, feeding and watering systems.

In farm animals, body temperature is constant and varies within very narrow limits, despite large changes in ambient temperature. Normal body temperatures vary depending on species and breeding method, and are approximately between 37-41.7 ℃ limit values in farm animals [1]. Keeping body temperature within the mentioned limits is possible by balancing heat production and heat emission from the body. Farm animals increase metabolic heat production in cold ambient conditions. On the other hand, they keep the heat loss from the body at low levels. On the other hand, they decrease their metabolic heat production in hot environmental conditions and on the other hand, they increase their latent heat release [2]. When body temperature is higher than the ambient air temperature and the inner surface temperature of the surrounding structural elements, there is a continuous heat loss from the body to the external environment in winter and transitional seasons, and in the opposite conditions, i.e. in summer, there is a continuous heat load on the body from the external environment [3].

Generally, when heat-humidity balance calculations are made in shelters, the sensible heat, latent heat and water vapor amounts emitted by animals into the shelter environment are taken as basis. Heating is not done unless absolutely necessary. If there is a heat deficit, the first step is to insulate the building elements. On the other hand, when designing ventilation systems in shelters, the minimum and maximum capacity of the system should be determined based on the amount of sensible heat for summer conditions and latent heat or water vapor for winter and transition seasons [4]. In particular, the selection of project values related to the temperature and relative humidity of the region and the determination of their effects on structural features are of great importance. The aim of determining the project criteria should be to ensure an economically appropriate balance between the inside and outside of the shelter that will not cause heat and cold stress in the animals housed.

The research was conducted in a farm with a sufficient number of Holstein breed dairy cattle in Tekirdag province, located in the Thrace part of Turkey. Considering the climate of the region, animals are kept in closed-type shelters, especially during winter and transition seasons. However, in order to control the climatic environment within economic limits in closed type shelters and to keep animal welfare in the comfort zone, it is necessary to know the amount of heat and water vapor emitted by cattle into the shelter environment. The aim of this study was to determine the amount of heat and humidity emitted by dairy cattle housed in closed type shelters into the shelter environment under current and optimum project conditions.

2. Material And Method

The research was conducted in a farm with a sufficient number of Holstein breed dairy cattle in Tekirdag province, located in the Thrace part of Turkey. The research area is geographically located between 41° 08' north latitude and 27° 30' east longitude, and its average altitude above sea level is 80 m. According to meteorological records for many years, its annual average temperature is 13.5 ºC and its annual average relative humidity is 75% [5].

In the farm, dairy cattle with equal lactation numbers and which started lactation in January-February were randomly selected from the dairy cattle which were considered to have the same genetic similarity. The selected animals were housed in a closed tie-stall shelter. The number of Holstein cattle kept in the shelter is 106 and their average live weight varies between 450-635 kg. In the calculations, the number of Head Animal Units (HAU) determined according to 454 kg live weight was taken as basis. Temperature and relative humidity values of the inside and outside air of the shelter were measured continuously, 24 hours a day for a year, at 1-hour intervals using a thermohygrometer. In addition, daily milk yield records of the cattle included in the research were kept.

Heat-humidity balance calculations made to control the climatic environment in animal shelters are generally based on the total heat, sensible heat, latent heat and water vapor values given off by the animals to the shelter environment. These values were calculated using the equations suggested by CIGR [6], Pedersen [7] and Mutaf [3] for large cattle and given below.

The amount of total heat (for 20 °C indoor temperature):

$$q_T = (5.6 \times m^{0.75} + 22 \times Y + 1.6 \times 10^{-5} \times P^3) \times 0.86$$

The amount of fixed total heat used for the conditions where the indoor dry bulb temperature is below or above 20 °C:

$$q_{T.cor} = q_T \times t_{cor.fac}$$

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

$$T_{cor.fac} = [1 + 4 \times 10^{-3} (20 - t_{db})]$$

The amount of sensible heat:

$$q_{sen} = q_{T.cor} \times [(0.71 \times t_{cor.fac}) - (0.407 \times 10^{-3} \times t_{db}^2)]$$

The amount of latent heat:

$$q_{lat} = q_{T.cor} - q_{sen}$$

The amount of water vapor:

$$w_{ani} = q_{lat} \div 0.5848$$

Here, qT is the amount of total heat (kcal/h), m is the live weight (kg), Y is the daily milk yield (kg/day), P is the gestation period (day), tdb is the dry bulb temperature (°C), qT.fix is the amount of fixed total heat (kcal/h), tfix.fac is the fixing factor., qsen is the amount of sensible heat (kcal/h), qlat is the amount of latent heat (kcal/h), wani is the amount of water vapor emitted by transpiration and respiration of animals (g/h), and the value 0.5848 is the evaporation heat of water (kcal/g).

3. Results And Discussion

Control of environmental conditions in animal shelters can be achieved by keeping the temperature and relative humidity within appropriate limits for the animals and by ensuring there is sufficient air flow within the shelter. When calculating the heat-humidity balance, especially in closed-type animal shelters, it is important to determine the current status of the temperature and relative humidity values of the indoor and outdoor air of the shelters. For this purpose, a thermohygrometer was placed at a suitable point outside and inside the shelter in the enterprise where the research was conducted. With these placed devices, temperature and humidity values were recorded at 1 hour intervals for a year. Daily minimum and maximum temperature and relative humidity values were calculated using the data obtained. The minimum and maximum mean values of the ambient temperature inside the shelter varied between 8.5 °C and 15.5 °Cin the winter season, which is a critical period for animal welfare, and between 23.0 °C and 28.8 °Cin the summer season. The values measured in the research shelter for the winter season are close to the comfort temperature values accepted for farm animals and are at levels that will not pose a problem in terms of animal welfare and productivity. In summer, the average maximum temperature measured in the shelter is slightly above 25 °C, which is considered the temperature at which heat stress begins in farm animals. As a matter of fact, Mutaf [3] gives the temperature at which heat stress begins in farm animals as 25 °C. Likewise, Wathes and Charles [8] and Ekmekyapar [9] give the appropriate temperature limits for farm animals as 4-25 °C. The daily minimum and maximum temperature values for outdoor air were measured as -7.5 °C to 14.8 °C in winter and 17.8 °C to 26.3 °C in summer, respectively.

The minimum and maximum mean values of relative humidity inside the shelter varied between 74.9% and 75.2% in winter and between 69.7% and 71.3% in summer. Relative humidity values in all seasons are at levels that do not pose a problem in terms of animal welfare. Minimum and maximum average relative humidity values of outdoor air vary between 67.4% and 78.5% in winter and 65.2% and 68.4% in summer, respectively. The effect of relative humidity on animals in shelters should be considered together with temperature. It is recommended that the relative humidity value be between 40-80% within the appropriate temperature limits. The relative humidity value should never be less than 30% and more than 90% [10,3]. Based on this value, the minimum and maximum average relative humidity values measured in the research shelter are at levels that do not pose a problem in terms of animal welfare. Indeed, Maton et al. [11] and Olgun [12] recommended that the relative humidity value inside the barn for cattle should be between 55% and 80% under optimum temperature conditions, while they reported that the relative humidity can be allowed to rise up to 85% in cold periods in order to economically control the climatic environment.

When calculating the heat-humidity balance in closed-type shelters, the total heat, sensible heat, latent heat and water vapor amounts emitted by the animals to the shelter environment must be known. For this purpose, the minimum and maximum daily temperature averages, which are considered as critical values, were determined for different seasons by utilizing the temperature data recorded during the research. With these determined values, the amounts of heat and moisture emitted by Holstein dairy cattle into the shelter environment for HAU were calculated in line with the equations and principles proposed by CIGR [6], Pedersen [7] and Mutaf [3]. The data used in the calculations are given in Table 1, and the amounts of heat and humidity currently emitted by Holstein dairy cattle to the barn environment are given in Table 2.

Table 1: Data used to calculate heat and humidity levels measured on days when the average temperature in the shelter is minimum and maximum in the current situation

Season	Critical value	Indoor temp. t_i (°C)	Indoor relative humidity (%)	Outdoor temp. t_d (°C))	Outdoor relative humidity (%)	Live weight HAU (kg)	Average gestation period P (day)	Daily milk yield Y (kg)
Winter	min.	8.5	75.2	-7.5	67.4	454	280	20
	max.	15.5	74.9	14.8	78.5	454	280	32

Spring	min.	11.5	70.6	8.5	76.4	454	280	18
	max.	23.5	67.9	20.8	73.3	454	280	28
Summer	min.	23.0	71.3	17.8	68.4	454	280	13
	max.	28.8	69.7	26.3	65.2	454	280	26
Autumn	min.	12.3	75.8	7.2	78.3	454	280	7.0
	max.	24.5	72.7	24.6	80.2	454	280	16

Table 2: The amount of heat and humidity released into the shelter environment for HAU in the current situation.

Season	**Critical value**	**Indoor temp. t_i (°C)**	**Total heat q_T (Kcal/h)**	**Correction factor $t_{cor.fac}$**	**Corrected total heat $q_{T.cor}$ (Kcal/h)**	**Sensible heat q_{sen} (Kcal/h)**	**Latent heat q_{lat} (Kcal/h)**	**Water vapor W_{ani} (g/h)**
Winter	min.	8.5	1154.1	1.046	1207.2	861.5	345.7	591.1
	max.	15.5	1381.2	1.018	1406.1	879.1	527.0	901.2
Spring	min.	11.5	1116.3	1.034	1154.3	785.2	369.1	631.1
	max.	23.5	1305.5	0.986	1287.2	611.4	675.8	1155.6
Summer	min.	23.0	1021.7	0.988	1009.4	490.3	519.1	887.6
	max.	28.8	1267.6	0.964	1221.9	437.5	784.4	1341.3
Autumn	min.	12.3	908.2	1.030	935.4	625.2	310.2	530.4
	max.	24.5	1078.4	0.982	1058.9	479.4	579.5	990.9

When Table 2 is examined, it is seen that the amounts of heat and humidity emitted to the barn environment by Holstein dairy cattle for HAU vary depending on the ambient temperature. In other words, when the ambient temperature decreases, the amount of sensible heat emitted increases, the amount of latent heat and water vapor decreases, and when the ambient temperature rises, the amount of latent heat and water vapor emitted increases and the amount of sensible heat decreases. For this reason, when the thermal environmental control inside the shelter is not sufficient, the effective utilization of the genotypic potential decreases and causes productivity losses as a result of the negative effect of heat stress [13].

In the planning of animal shelters, a suitable and economical balance must be achieved between the optimum environmental conditions inside the shelter and the climatic conditions of the region. Therefore, one of the most important issues in ensuring optimum environmental conditions in closed animal shelters, in calculations regarding heat and humidity balance and in determining the economical construction for the structure is the determination of climatic project criteria regarding the air inside and outside the shelter. For this purpose, the data obtained within the scope of the research, meteorological records, temperature and relative humidity project criteria were determined for different seasons in line with the principles stated in Ekmekyapar [9] and Mutaf [3] and are given in Table 3. In addition, the average gestation period and critical milk yield values of Holstein dairy cattle are also given in Table 3.

Table 3: Project criteria used in heat-humidity balance calculations for different seasons.

Season	**Indoor project temp. (°C)**	**Indoor project relative humidity (%)**	**Outdoor project temp. (°C)**	**Outdoor project relative humidity (%)**	**Live weight (kg)**	**Average gestation period (day)**	**Minimum daily milk yield (kg)**
Winter	10	75	-1	81	454	280	7
Spring	18	80	10	85	454	280	7
Summer	25	70	26.6	65	454	280	7
Autumn	18	80	10	85	454	280	7

Using the optimum project criteria given in Table 3, the total heat, sensible heat, latent heat and water vapor values emitted by Holstein dairy cattle to the barn environment in different seasonal conditions were calculated for HAU and given in Table 4.

Table 4: Amounts of heat and water vapor emitted by Holstein dairy cattle for HAU under project conditions

Season	Total heat q_T (Kcal/h)	Correction factor $t_{cor.fac}$	Corrected total heat $q_{T.cor}$ (Kcal/h)	Sensible heat q_{sen} (Kcal/h)	Latent heat q_{lat} (Kcal/h)	Water vapor W_{ani} (g/h)
Winter	908.2	1.04	944.5	658.6	285.9	488.9
Spring	908.2	1.01	917.3	536.7	380.6	650.8
Summer	908.2	0.98	890.1	392.9	497.2	850.2
Autumn	908.2	1.01	917.3	536.7	380.6	650.8

When Table 4 is examined, according to the optimum design criteria in closed type shelters, Holstein dairy cattle emit 658.6 Kcal/h sensible heat, 285.9 Kcal/h latent heat and 488.9 g/h water vapor into the shelter environment for 454 kg HAU in winter, and 392.9 Kcal/h sensible heat, 497.2 Kcal/h latent heat and 850.2 g/h water vapor in summer. These calculated values can be used for humidity balance in winter and heat balance in summer in closed type dairy cattle barns, and the climatic environment can be controlled at optimum levels. For this purpose, the amounts of heat and water vapor emitted by Holstein dairy cattle to the environment under current and optimum conditions were calculated according to live weight for HAU. The data obtained from the study can be used in sizing the ventilation systems and determining the insulation needs of structural elements in closed type dairy cattle barns to be built in the region.

4. Conclusion

Considering the physiological and genetic characteristics of cattle, ambient temperature and humidity have a great effect on milk yield. Too hot or too cold weather negatively affects milk quantity. Especially in closed type shelters, when regulating climatic environmental conditions, it is necessary to know the amount of heat and water vapor that animals emit to the shelter environment. The research was conducted to calculate the amount of heat and water vapor emitted by Holstein dairy cattle into the shelter environment under current and optimum conditions in the climate conditions of Tekirdag province. Accordingly, under the optimum project conditions accepted for the research area, 658.6 Kcal/h sensible heat, 285.9 Kcal/h latent heat and 488.9 g/h water vapor in the shelter environment for 454 kg HAU in the winter season, and 392.9 Kcal/h sensible heat in the summer season. It emits 497.2 Kcal/h of latent heat and 850.2 g/h of water vapor. These values are recommended to be used in calculations related to the control of the climatic environment, the dimensioning of ventilation systems, the selection of building materials and the determination of insulation needs in closed-type dairy cattle barns.

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