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Determination of heating and cooling day data for broiler housing: Isparta case

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Abstract

In this study, heating and cooling day data were calculated by employing the degree-day method using long-term climate data belonging to Isparta (Turkey) and its districts, and the inside temperature recommended for broiler chickens. The recommended inside temperatures during a raising period of broiler chickens were chosen as equilibrium temperature. Heating Degree Day (HDD), Cooling Degree Day (CDD), Heating Degree Day Number (HDDN) and Cooling Degree Day Number (CDDN) were calculated by the equations given in the study using long-term temperature records of 16 stations obtained from the General Directorate of State Meteorology Works for Isparta and its districts. It was determined that the HDD number is higher than the number of CDD in almost all raising periods in Isparta and its districts. Therefore, the inside temperature recommended for broiler chickens, i.e. the equilibrium temperature, increases when the HDD values also increase. As a conclusion it is considered that more proper conditions for the animals in the house can be provided and the enterprise can be operated economically by taking obtained heating and cooling day data into account in the project design stage.

Key words: Broiler, degree day, cooling, heating, Isparta.

Introduction

Climate is the primary factor among other physical factors which affect the planning of settlements and structural design. Air temperature, relative humidity, wind, solar radiation and rainfall, which constitute climate, directly affect the outdoor thermal comfort of people as well as indirectly affecting indoor environments. The radiation effect of the sun and the effect of air temperature, in particular, are important in terms of indoor thermal comfort in hot and cold weather conditions [1].

When the efficiencies of heating, ventilation and air conditioning systems and usage of the building are constant, degree-day methods are utilized as the simplest energy analysis method [2]. An important parameter that should be known in the evaluation of operating cost of any building is annual energy consumption. The annual energy consumption can be designed for the purpose of heating and cooling of a building. Even though several different methods available in the literature can be employed in the design of annual fuel requirement the most basic one is the degree-day or degree-hour method [3].

The degree-day method can be employed for the prediction of natural gas consumption for heating purposes as well as in the prediction of energy consumption of the equipment used for cooling and heating of houses and commercial buildings in hot and cold seasons, respectively [3].

Today, it has become compulsory to perform detailed energy analysis and to design heating and cooling systems in detail [4, 5]. The simplest analysis method is the degree-day method. The degree-day method gives sensitive and accurate results in terms of energy analysis when the use of heating, cooling and ventilation systems is fixed, i.e. their efficiencies are constant. Energy consumption for heating and cooling can be easily determined by the degree-day method. The degree-day values depend on the temperature of the equilibrium point chosen. The temperature of the equilibrium point is the outside temperature at which no heating or cooling is needed in a building. The basis of the degree-day method is the equilibrium point temperature. The energy requirement of any building is proportional to the difference between equilibrium point temperature and outside temperature [6]. The fuel and energy requirements for the heating and cooling of broiler chickens at hot and cold weathers are proportional to air temperature. One of the most common methods used in heating and cooling of the buildings is Degree-Day (DD). There are many usage areas of DD values. Some are calculation of fuel and energy requirements, design of heating and cooling equipment and structural design [7-9].

In order to keep environmental conditions of animal houses at optimum levels, heat losses, particularly due to conduction and radiation, must be limited. Having a temperature below or above the optimum temperature in animal houses negatively affects the productivity of animals and the effect of higher temperatures on productivity is greater than that of lower temperatures [10]. Temperature, humidity, air velocity and atmospheric pressure are physical factors affecting the efficiency of poultry [11].

Many researchers have reported on temperature in broiler houses that the temperature should be between 30 and 33°C in the first week, and then the temperature should be gradually decreased by between 2 or 3°C until the 5th or 6th week and when it reaches a temperature of 18-21°C it should be maintained until the slaughtering [12-14].

In this study, by using recommended inside temperatures for broiler chickens and average daily temperatures measured in different meteorology stations in Isparta (Turkey), heating and cooling values were calculated by the degree-day method for broiler houses which are either currently available or for proposed constructions. Energy requirements for heating and cooling can be calculated by using these data and can provide producers with indications on whether raising broiler chickens in the region is economical.

Materials and Methods

In the study, the annual temperature data of Isparta and its 16 stations were used as material. Attempts were made to determine heating and cooling degree day numbers by examining equilibrium temperatures depending on the weekly development of broiler chickens (Table 1) [13-15].

Table 1. Recommended inside temperatures and equilibrium temperatures chosen for broiler chickens.

Week	Recommended Inside Temp. (°C)	Equilibrium Chosen Temp. (°C)
1	30 – 32	31
2	28 – 30	29
3	26 – 24	25
4	23 – 24	23.5
5	22 – 23	22.5
6	20 – 21	20.5

Degree-Day (DD) method: The simplest energy analysis method in building is the degree day method. By this method, energy consumption required for heating and cooling can be easily calculated. The calculation of degree day values depends on the equilibrium temperature chosen. Equilibrium point temperature is defined as the outside temperature at which no heating and cooling is needed in any building [6]. Inside temperature can be defined as the desired temperature of the environment and it can change according to animals, region, latitudes and topographic properties. The equilibrium point temperatures chosen according to the raising weeks for broiler chickens are given in Table 1. Accordingly, it was determined that the broiler chickens needed heating and cooling below and above the recommended inside temperatures, respectively. The daily DD value of a broiler house is the difference between average daily outside temperature and inside equilibrium temperatures recommended for broiler chickens. DD value for a specific period is the cumulative sum of the differences between daily averages outside temperature and recommended inside equilibrium temperatures, depending on the raising weeks in the broiler house.

Heating Degree-Day (HDD) method: Heating loss of an animal house depends on various factors. The primary ones are thermal conductivity for various parts of the animal house and temperature differences between inside and outside temperatures [16]. A temperature difference of one degree Celsius between the average daily temperature and the recommended inside equilibrium temperature, when the former decreases below the latter, is expressed as one HDD [3]. In general, Heating Degree-Day (HDD) values are calculated by the equation below:

$$for\,(T_O < T_b) \quad , \quad HDD = \sum_{i=1}^{n} (T_b - T_O) \tag{1}$$

where HDD is the cumulative sum of heating degree-days belonging to the day n, n denotes the total number of days in the period, T_b represents recommended inside equilibrium temperature, and T_o stands for average outside temperature. HDD values during a raising period were calculated as the cumulative sum of differences between the outside temperatures and recommended inside equilibrium temperatures on the days the former is below the latter [17].

Cooling Degree-Day (CDD) method: In cold weather, the indoor comfort of the animal house is compromised when the outside temperature exceeds the chosen equilibrium temperature. In order to recover indoor comfort the environment must be cooled and ventilated. Cooling equipment of a suitable size and capacity must be installed to meet cooling and ventilation needs. Thus, the cooling requirement must be determined. The Cooling Degree-Day (CDD) index, similar to HDD, has been developed for the determination of the cooling needs of an animal house and respective size and capacities of cooling and ventilation equipment.

Cooling Degree-Days (CDDs) is the cumulative sum of differences between average outside temperature and the recommended equilibrium temperature given in Table 1 according to the raising weeks and it is calculated by the equation below [18].

$$for\,(T_O > T_b) \quad , \quad CDD = \sum_{I}^{n} (T_O - T_b) \tag{2}$$

where CDD is the cumulative sum of cooling degree-days belonging to day n, n denotes the total number of days in the period, T_b represents the recommended inside equilibrium temperature given in Table 1, and T_o stands for average outside temperature [17, 19].

On the days when the average outside temperature is equal to or below the chosen inside equilibrium temperature animal houses do not need artificial cooling, i.e. CDD values are zero (0). As the average daily temperature increases, cooling degree-days also increase. This shows that the energy requirement for cooling increases.

Heating Degree-Day Number (HDDN) method: It is calculated for Heating Degree-Days (HDDs) in a specific period as the number of days on which the average outside temperature is below the recommended equilibrium temperature for the broiler house concerned during the raising period. Heating Degree-Day Number (HDDN) was calculated by Equation 3 given below.

$$HDDN = \sum_{i=1}^{n} HDD \tag{3}$$

where n is the total number of days in the period chosen and HDD represents the number of days when HDD occurs [20].

Cooling Degree-Day Number (CDDN) method: In this method, developed in a similar way to HDDN values, CDDN was calculated by Equation 4 given below for CDDs in a specific period as the number of days on which the average outside temperature is over the recommended equilibrium temperature for the broiler house concerned during the raising period:

$$CDDN = \sum_{i=1}^{n} CDD \quad (4)$$

where n is the total number of days in the period chosen and CDD represents the number of days when CDD occurs [20].

Results and Discussion

The equilibrium temperature of the building is needed to be able to calculate Degree day values. This temperature differs from one building to another. Considering these for an agricultural structure, since either vegetative or animal production would be done within the structure temperature varies according to the production and the structural properties of the building. In order for the values given in this study to be calculated, the variations of Degree Day values according to the long-term climate data of the study area and the equilibrium temperatures recommended according to the raising period of broiler chickens were determined. HDD and CDD values belonging to the study area were calculated using Equation 1 and 2 (Table 2).

Heating the broiler chicken flock to a lesser degree is possible if the outside temperature is lower than the recommended inside temperature. In other words, temperature difference $(T_b - T_o)$ must be positive (+). The HDD value, an expression of the differences between outside temperature and the recommended inside temperature, is used in the determination of the heating need in the heating industry. When the average daily outside temperature drops below the inside temperature, heating is needed in the animal house. Ventilation (cooling) is needed in the broiler house in the opposite case. If the outside temperature is equal to the recommended inside temperature, it shows that optimum condition in broiler houses is reached by recommended heating. However, in terms of Table 2, the HDD values are high in the first 3 and 4 weeks of the raising periods. HDD and CDD values can give indications to producers about heating and fuel costs while planning a broiler house.

It can be deduced from Table 2 that a high level of heating would be required during rising periods for broiler houses operated in Isparta and its district. It can be seen that HDD values started to decrease after the first two weeks, depending on the development of broiler chickens, whereas CDD values rise. Therefore, as the indoor temperature, i.e. equilibrium temperature increases, the HDD values also increase.

Equations 3 and 4 were used in the calculations in Table 3. Degree day values can also give information about the harshness

Table 2. Heating degree day and cooling degree day values of stations.

Station Name	31.0°C		29.0°C		25.0°C		23.5°C		22.5°C		20.5°C	
	HDD	CDD	HDD	CDD	HDD	CDD	HDD	CDD	HDD	CDD	HDD	CDD
Aksu	7425.4	0	6693.4	0	5229.4	0	4680.4	0	4314.9	0.5	3651.3	68.9
Atabey	6767.1	0	6035.1	0	4571.3	0.3	4058.2	36.5	3748.7	89.1	3159.6	235.5
Bağkonak	7380.7	0	6648.7	0	5184.7	0	4635.7	0	4274.3	4.8	3627.7	84.6
Barla	6914.4	0	6182.4	0	4718.8	0.4	4191.2	22.2	3866.3	63.3	3264.2	193.0
Eğirdir	6702.9	0	5970.9	0	4507.1	0.2	3982.7	24.9	3665.0	73.0	3081.7	221.8
Gelendost	6968.2	0	6236.2	0	4772.2	0	4223.2	0	3860.3	3.8	3269.6	144.4
Isparta	6924.1	0	6192.1	0	4728.1	0	4185.7	6.5	4846.2	43.1	3249.2	168.1
Kasımlar	6617.6	0	5885.6	0	4426.8	5.2	3924.4	51.8	3610.4	103.8	3032.0	257.4
Keçiborlu	6792.9	0	6060.9	0	4597.7	0.8	4072.3	24.4	3746.3	64.4	3153.8	203.9
Kumdanlı	6771.1	0	6039.1	0	4576.0	0.8	4053.5	27.4	3737.4	77.3	3152.9	224.8
Senirkent	6788.8	0	6056.8	0	4594.2	1.4	4082.2	38.5	3772.6	94.8	3192.0	246.2
Sütçüler	6506.0	0	5774.0	0	4310.0	0	3789.1	28.2	3470.5	75.6	2890.1	227.1
Şarkîkaraağaç	7480.6	0	6748.6	0	5284.6	0	4735.6	0	4369.6	0	3638.5	47.9
Uluborlu	7058.7	0	6326.7	0	4862.7	0	4314.5	0.8	3963.4	15.7	3342.2	126.6
Yalvaç	7277.8	0	6545.8	0	5081.8	0	4534.5	1.7	4190.6	23.7	3564.4	131.7
Yenişarbademli	7258.7	0	6526.7	0	5062.7	0	4514.8	1.1	4161.7	14.0	3523.9	108.2

Table 3. Heating degree day number and cooling degree day number values of stations.

Station Name	31.0°C		29.0°C		25.0°C		23.5°C		22.5°C		20.5°C	
	HDDN	CDDN	HDDN	CDDN	HDDN	CDDN	HDDN	CDDN	HDDN	CDDN	HDDN	CDDN
Aksu	365	0	365	0	365	0	365	0	363	2	307	58
Atabey	365	0	365	0	364	1	322	43	302	63	279	86
Bagkonak	365	0	365	0	365	0	365	0	353	12	307	58
Barla	365	0	365	0	363	2	334	31	314	51	289	76
Eğirdir	365	0	365	0	364	1	330	35	304	61	278	87
Gelendost	365	0	365	0	365	0	365	0	363	2	307	58
Isparta	365	0	365	0	365	0	340	25	320	45	291	74
Kasımlar	365	0	365	0	351	14	324	41	303	62	271	94
Keçiborlu	365	0	365	0	362	3	335	30	316	49	282	83
Kumdanlı	365	0	365	0	363	2	328	37	305	60	276	89
Senirkent	365	0	365	0	359	6	325	40	301	64	278	87
Sütçüler	365	0	365	0	364	1	331	34	309	56	272	93
Sarkıkaraagaç	365	0	365	0	365	0	365	0	365	0	315	50
Uluborlu	365	0	365	0	365	0	362	3	337	28	294	71
Yalvac	365	0	365	0	365	0	361	4	332	33	294	71
Yenisar-Bademli	365	0	365	0	365	0	362	3	341	24	299	66

of climatic conditions in the region concerned [2]. Since energy needs of a building can be predicted by using HDD and CDD, the values obtained from climate data in any region in which broiler house construction is proposed can enable the prediction of energy consumption not only for heating or cooling equipment but also for air conditioning equipment that use other energy sources such as electricity, because degree-day, the number of days, degree-hour, and the number of hours are taken into account in developed countries in energy planning and project design for the determination of future fuel and energy needs [2, 3]. An important parameter which must be known in the evaluation of the operational costs of any building is annual energy consumption[3]. Therefore, such calculations done in any region cannot only give us information about the cost of heating and cooling of that particular animal barn but also shows the need for the proper planning of units such as heating, cooling, insulation and ventilation in the planning and design of a proposed animal barn, because 35-40% of the energy is consumed in buildings in Turkey and 85% of this is used for heating purposes in buildings [21, 22]. The development of technology, development of industry and the rise in world population increase the demand for energy. Continuous increase in this demand leads to fossil fuel consumption and thus environmental pollution [22]. Therefore, in the planning of buildings, proper planning of the units increasing the conservation of energy such as insulation, ventilation and heating is important in terms of conservation of energy and environmental pollution.

Conclusions

In this study, Heating and Cooling Degree-Day values which best reflect the heating and cooling period were calculated for the Isparta region by using long-term meteorological data belonging to the study area. The long-term average daily temperature data of 16 stations of the General Directorate of State Meteorology Works in Isparta were used. HDD, CDD, HDDN and CDDN values were determined by using average temperature data of these 16 stations according to the equilibrium temperature which is needed for broiler chickens during 6 week raising periods. Prior knowledge can be gained by heating and cooling degree day methods about the energy consumption of a proposed agricultural structure in any region. In this study performed for the Isparta region, having a higher number of heating days indicated that the energy need for proposed broiler houses will be high in the region and thus the fuel cost will be an important cost element in the production. It is considered that by taking obtained heating and cooling day values into account, more suitable conditions for the animals in the house as well as economic operation of the facility can be achieved by the most appropriate planning and design.

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