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Determination of poultry house indoor heating and cooling days using degree-day method

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Abstract. In poultry production, degree-day values are used as fundamental design parameters considered among others in determining the extent of heating and cooling of poultry housing. In this study, heating and cooling data values for each of broiler production period were determined using the degree-day method. The total length of the experiment was 123 days which corresponds to 3 growing periods. The inside and outside air temperatures of the poultry house were measured using air temperature data loggers positioned at different points and heights within and outside broiler house. Knowledge of heating and cooling day values is important as it necessitates the provision and maintenance of ideal bird's production conditions and ensuring the economic viability of the enterprise through optimized energy consumption.

Key words: Broiler, energy, production period, temperature.

INTRODUCTION

Poultry, has recently become one of the a largest growing agricultural commodity in Turkey. The country is the world's 10th largest poultry producer, processing about 1.900 million tonnes in 2014 (USDA, 2015) and aims to be the one of the top three producers of world in the next decade. This can be achieved through not only planning the appropriate genetic breeding programs, but also ensuring availability of suitable environmental conditions (indoor and outdoor) during birds rearing process.

Improved environmental control of poultry houses plays a significant role in ensuring and maintaining effective poultry production. In order to ensure maintenance of optimal indoor environmental conditions, poultry houses must be properly designed in the farmstead, due consideration need to be given to environmental factors (Barre, 2012), such as temperature (Charles, 1986; Kic, 2016), relative humidity (Longhouse et al., 1968; Xin et al., 1994), movement of the air (Drury, 1966; Luck et al., 2014), ventilation (Miragliotta et al., 2006; Cemek et al., 2016) and intensity of light (Araújo et al., 2015; Patel et al., 2016).

The control of poultry houses' indoor environmental conditions requires careful consideration of the energy input which depends on numerous parameters, such as species, method of breeding, thermal characteristics of the building, internal microclimate, external microclimate. Failure to accurately take note of the energy input has serious repercussions on the cost of production. Degree-days (DDs), on the other hand, provide a simplified avenue to energy estimation for both heating and cooling requirement determination. The DDs method uses less input data, and can be used as a quick assessment tool for decisions relating to design, such as, levels of insulation assumptions about infiltration, building thermal capacity, (CIBSE TM41, 2006).

Heating degree days (HDDs) and cooling degree days (CDDs) mathematical formulations that reflects are the amount of energy needed to heat or cool a building to a known optimal temperature, considering the extent of hotness or coolness of the outside temperature. A 'degree day' indicates that the daily average outdoor temperature was one degree higher or lower than some known benchmark temperature of that particular day. The sum of the number of HDDs or CDDs over a year is roughly proportional to the annual amount of energy that is required to heat or cool a building in that particular location (Quayle & Diaz, 1980). Thus, HDDs and CDDs are rough surrogates for how climate change is likely to affect energy use for heating and cooling.

In this study, inside and outside temperatures were measured using data loggers. The broiler house HDD and CDD values for each production period (in summer, winter and end of the spring) were determined using the degree-day method. Energy requirements for heating and cooling can be determined by using these data and can provide producers with indications on whether raising broiler chickens in the region is economical.

MATERIALS AND METHODS

Materials

The study was conducted in a commercial broiler house during three production periods (in summer, winter and end of the spring) located in Samsun province (Northern Hemisphere, Latitude 41°70', Longitude 36°30'), northern Turkey. The broiler house, with a capacity of 20,000 birds, with a width of 14 m, length measuring 90 m, and ceiling height of 4.40 m (Fig. 1). Sawdust was used as a litter material within the broiler house. Feeding, watering, lighting, heating and ventilation were operated automatically. The roof and sidewalls of the poultry house is made of sandwich panels (5. mm), while the floor is constructed using lean concrete XPS construction materials. The broiler house was equipped with seven large (diameter 1.38 m) and five small exhaust fans (diameter 0.92 m). The house had sixty-six air inlets measuring 32.50 × 52.50 cm, placed along with the side walls of the building. The heating system comprised an external heat source with a dual-tube system.

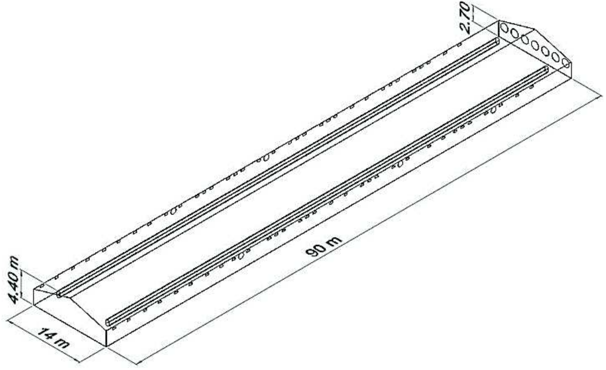

Figure 1. Broiler house dimensions.

Feeding dates, production period and number of the birds housed during the experiment is given Table 1.

Table 1. Feeding dates, production period and number of the birds housed during the experiment

Growing period no	Feeding dates	Production period	The number of birds
1	23.04.2016–03.05.2016	End of the spring	19,360
2	12.07.2016–22.08.2016	Summer	18,400
3	13.10.2016–23.11.2016	Winter	18,000

Methods

To monitor indoor temperature distribution, fifty-nine automatically operated temperature data loggers (NDI 320B) were used (Fig. 2). These air temperature data loggers have a resolution of ±0.1 °C with a 30-minute data capturing interval. The data loggers were positioned in broiler house to capture indoor air temperature data at three heights namely birds (0.25 m), human (1.80 m) and roof heights (2.50 m) as shown in Fig. 3. Air temperature measurements were recorded automatically at an interval of 30 minutes by these data loggers. An outdoor air temperature was monitored by a data logger that was placed beneath the outside eaves of the building for protection against direct sunlight and rain.

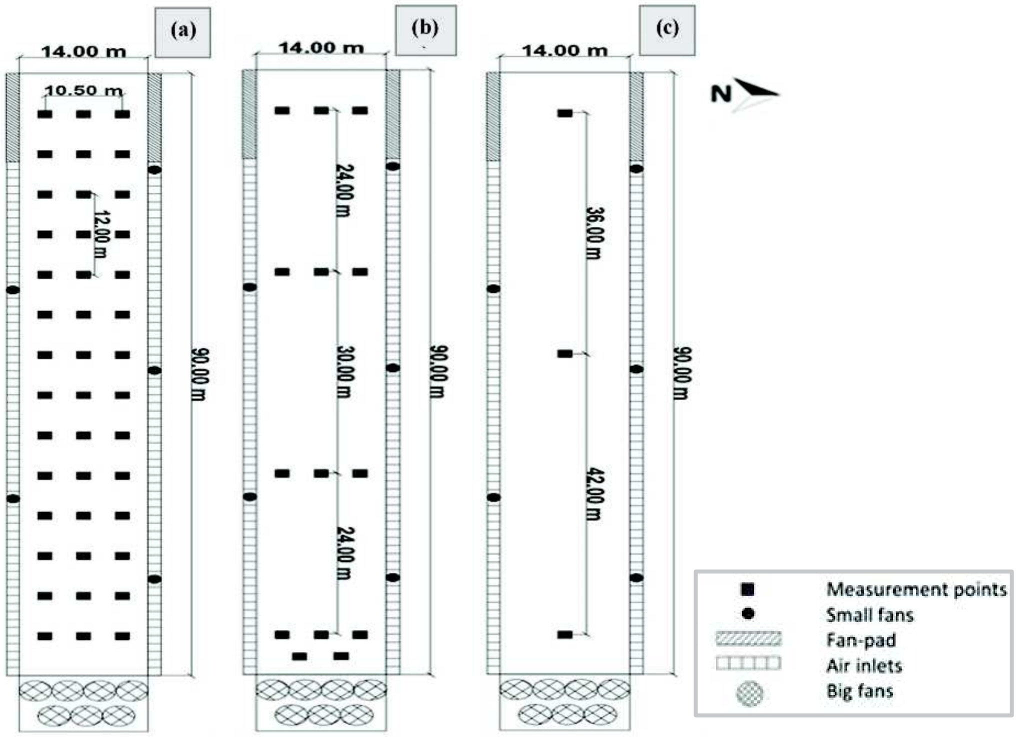

Figure 2. Broiler house measurement points (a) birds' height, (b) human height, (c) roof height.

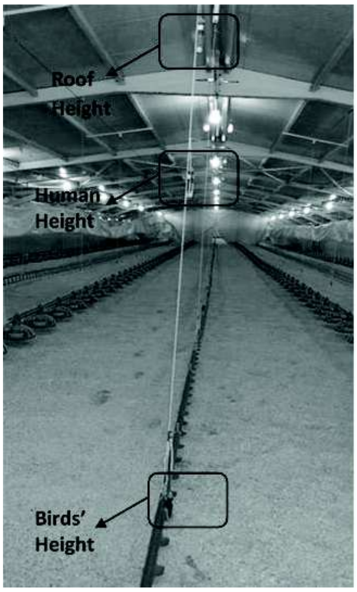

Figure 3. Measurement levels in the broiler house.

To determine HDD and CDD values, base temperature values dependent on broilers' weekly growth development were used for the six-week periods under study (Table 2) (Lindley & Whitaker, 1996).

Table 2. Recommended weekly base temperature for broiler chicken

Weeks	Base temperature, °C
1	31.00
2	29.00
3	25.00
4	23.50
5	22.50
6	20.50

Degree days (DDs) method

Degree days' values represent a simplified representation of outdoor air-temperature data. The DDs method has found common use in areas that estimate and target energy consumption for heating and cooling as a key parameter. This method has successfully been used in residential, commercial, and industrial buildings, greenhouses, livestock facilities, and storage facilities mainly for determining energy requirements for heating and cooling (Yildiz & Sosaoglu, 2007).

HDDs are a measure of by what amount (in degrees), and for which period (in days), outside air temperature was lower than a specific 'base temperature'. Calculations concerning energy requirement for purposes of heating the building generally make use of HDDs.

CDDs are a measure of how much (in degrees), and for how long (in days), outside air temperature was higher than a specific base temperature. They are used to measure the demand for energy needed to cool buildings.

HDDs and CDDs are calculated by summing the temperature differences between a known specific base temperature and the average daily outside dry-bulb temperature for a given time period (weekly, monthly and annual) (Eto, 1988). HDD and CDD values in each production period are calculated using Eqs 1 and 2 (Buyukalaca et al., 2001; Christenson et al., 2006; Atilgan et al., 2012; Yucel et al., 2014):

$$For\ T_{out} < T_{base}, \qquad HDD = \sum_{i=1}^{n} (T_{base} - T_{out}) \tag{1}$$

$$For\ T_{base} < T_{out}, \qquad CDD = \sum_{i=1}^{n} (T_{out} - T_{base}) \tag{2}$$

Where HDD and CDD are the cumulative sum of the heating and cooling degree-days for n days, n is the total number of days in the period, T_{base} is the base temperature recommended for the broiler chicken and T_{out} is the average outdoor air temperature. These equation indicates that only positive values are summed.

RESULTS AND DISCUSSION

The results of long time measurements of indoor and outdoor temperatures in three growing periods are presented in Table 3. These results show that measurement temperatures are closer to ideal temperatures for chickens.

Table 3. Average values and standard deviation of the indoor and outdoor temperatures in three growing periods

Growing period no	Inside temperature (°C ± SD)	Outside temperature (°C ± SD)
1	25.71 ± 2.85	00 ± 3.89
2	26.06 ± 2.92	43 ± 2.04
3	25.12 ± 3.99	11 ± 1.74

SD – Standard deviation.

The heating and cooling degree-day values for 3 growing periods were calculated using equations 1 and 2 (Table 4).

As shown in the Table 3, it is expected that maximum heating requirement observed in winter period emanating from the very low outdoor temperatures. The lower the average daily outdoor air temperature, the more the HDDs resulting more energy consumption during this period. The opposite is true of cooling requirement during summer. The higher the average daily air outdoor temperature, the more CDDs occur necessitating higher cooling energy requirement through ventilation.

Table 4. The heating degree-day and cooling degree-day values for different production periods

Temperature	31		29		25		23.5		22.5		20.5	
Growing period no	HDD	CDD	HDD	CDD	HDD	CDD	HDD	CDD	HDD	CDD	HDD	CDD
1	126.3	--	67.3	--	57.9	--	53.8	--	53.1	--	4.5	16.9
2	51.9	--	54.1	--	15.1	--	5.7	2.8	4.7	7.6	3.8	8.0
3	99.9	--	93.4	--	75.6	--	68.8	--	71.1	--	59.1	--

The daily average inside temperature (T_{in}), outside temperature (T_{out}) and base (suggested) inside temperature (T_{base}) of poultry house are presented in Fig. 4. As shown in Fig 4 (a, b), T_{in} is lower than T_{base} during the first and second weeks of production, indicating that the poultry house was not adequately heated. On the other hand, during the third, fourth and sixth weeks, T_{in} is greater than T_{base}, implying that the broiler house was not optimally cooled. During winter production period, high level of heating is required during the first, second, fifth and sixth weeks because of the average indoor temperatures are lower than recommended temperatures. Conversely, during the third and fourth weeks, the house is need to be cooled (Fig. 4, c). The smaller the difference between the indoor and base temperatures, the more energy will be saved. In other words, the lower the average daily outside temperature, the more heating degree-days and the greater consumption of fuel. In general, three production periods are examined, it can be said that indoor temperatures are close to recommended temperatures.

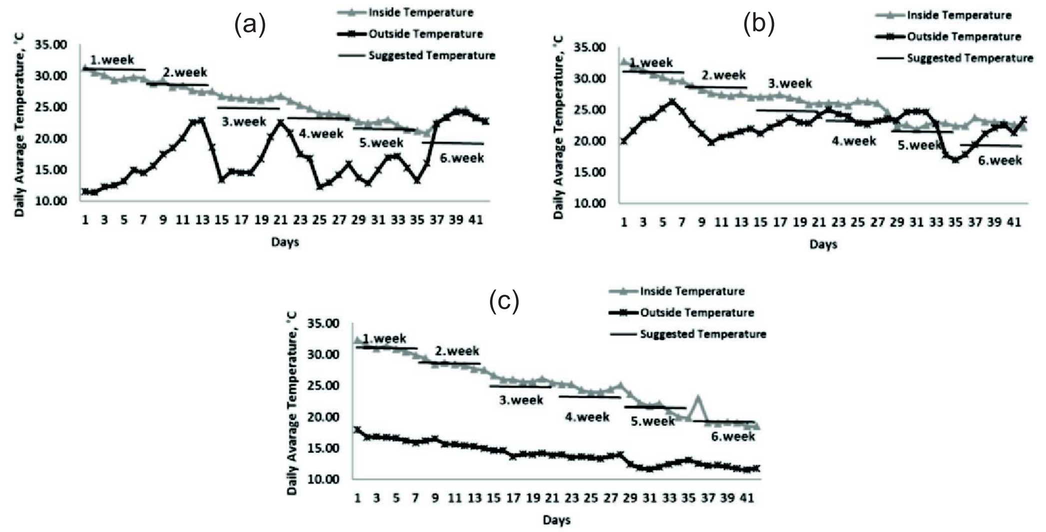

Figure 4. The daily average inside temperature, outside temperature and suggested inside temperature of poultry house (a, end of the spring; b, summer; c, winter).

CONCLUSIONS

In this study, heating degree-days and cooling degree-days were calculated for Samsun province during three broiler rearing periods. Knowledge of the number of HDDs and CDDs in a poultry house allows an engineer to plan and design appropriate type of equipment and materials which should be installed to provide adequate heating and cooling to broiler facilities. Furthermore, calculated HDDs and CDDs offers producers opportunity to reliably predict energy consumption. Apart from the technical benefits mentioned above, a well-designed broiler house also carries a positive benefit on broiler performance and welfare, feed efficiency and overall economic operation of the facility.

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