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RESEARCH ARTICLE

Determination of Fuel Consumption for Poultry Farms in Balıkesir by Heating and Cooling Degree Days

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HIGHLIGHTS

- *Heating and cooling degree days were investigated for poultry farms*
- *Degree-day method was used*
- *Heating and cooling costs were calculated per unit area*
- *Highest fuel cost was obtained in the Dursunbey*

Keywords:

- Degree Days
- Fuel Consumption
- Poultry Farm
- Balıkesir

GRAPHICAL ABSTRACT

In this study, heating and cooling degree days were investigated for poultry farms using the degree-day method for regions where there are large numbers of poultry farms in the Balıkesir province (City Center, Bandırma, Edremit, Dursunbey, Susurluk, Burhaniye, Ayvalık, Bigadiç, Manyas, Erdek, Gönen). In Figure A, HDD and CDD values are given. The highest HDD value was obtained in Dursunbey as 3725, while the lowest HDD value was obtained in Edremit as 2554.

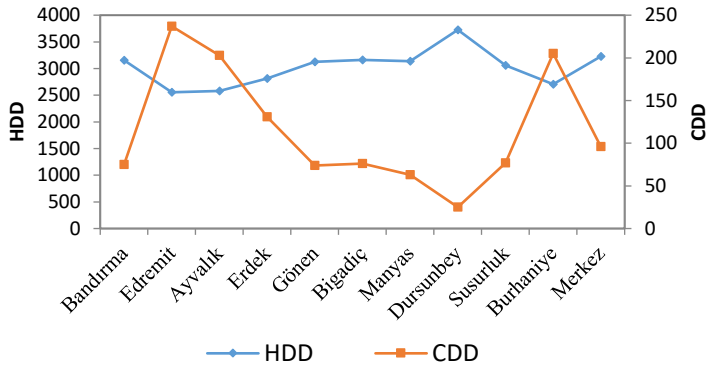

Figure A. *HDD and CDD degree days*

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Aim of Article: *Poultry farming is an important activity in Balıkesir. In this study, heating and cooling degree days (HDD and CDD) were investigated for poultry farms using the degree-days method. Heating and cooling costs were calculated per unit area, according to the use of natural gas, coal, LPG, fuel oil in heating and electrical energy in cooling.*

Theory and Methodology: *Heating and cooling degree days were investigated using degree-days method for poultry farms.*

Findings and Results: *HDD and CDD varied between 3725 and 2554 and between 237 and 25, respectively.*

Conclusion: *HDD and CDD values are important indicators for estimating energy consumption.*

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ABSTRACT

Poultry farming is an important activity in Balıkesir. Approximately 12% of broilers produced in Turkey are produced in the province. There are about a hundred facilities within the provincial borders including the center and districts. In this study, heating and cooling degree days (HDD and CDD) were investigated for poultry farms using the degree-days method. Determination of HDD and CDD is important in terms of calculating the amount of energy needed during heating or cooling. Meteorological data for 2005-2018 obtained from the Turkish State Meteorological Service were used. The equilibrium temperature, on which the calculations were based, was the temperature required by broilers during the 6-week production season (T_{base}= 31, 29, 25, 23.50, 22.50 and 20.50°C). Heating and cooling costs were calculated per unit area, according to the use of natural gas, coal, LPG, fuel oil in heating and electrical energy in cooling. The results showed that the HDD and CDD values varied between 3725 and 2554 and between 237 and 25, respectively. The lowest fuel costs were obtained in the Edremit district when natural gas was used, while the highest fuel costs were obtained in the Dursunbey district when LPG was used. This study is expected to contribute to the literature and guide investments to be made in this region within this field.

Keywords: *Degree days, fuel consumption, Poultry farm, Balıkesir*

I. INTRODUCTION

Due to population and economic growth, the demand for energy is increasing rapidly, especially in developing market economies. As welfare increases, increased demand creates new challenges. Additionally, higher fossil fuel consumption leads to higher emissions of greenhouse gasses, especially carbon dioxide (CO_2), which causes global warming. These reasons necessitate the efficient use of energy.

Although there are many methods and techniques for energy analysis in buildings, the degree-day method, a simpler technique, is known as the most preferred method. Determination of heating and cooling degree-day numbers is important in terms of calculating the amount of energy needed during the heating and cooling of a building. In the degree-day method, the indoor temperature is directly proportional to the difference between the equilibrium temperature and the outdoor temperature [1-2].

In the field of animal husbandry, environmental conditions, especially temperature, mainly affect both the health and productivity of the animals [3]. While planning a well-organized facility, it should be noted that the facility must be protected from the cold in winter and the heat in summer, as well as from sudden changes of temperature and moisture condensation. Moreover, the optimum temperature must be kept indoor. Providing the optimum conditions for protecting poultry from the effects of unfavorable climatic conditions and increasing productivity depends on the accurate planning and design of houses. Providing the desired environmental conditions in poultry houses throughout the year effectively is also important in terms of economic aspects [4].

There are many studies in the literature to determine heating and cooling degree-day numbers. Dombaycı et al. made an energy consumption estimation by using different base temperatures in cooling months for ten cities in Turkey. As a result of their calculations, they concluded that the highest and the lowest degree-days for cooling were in Şanlıurfa and Ardahan, respectively. The energy consumption for the cooling of Şanlıurfa was 16 times greater than that of Ardahan [5]. Baytorun et al. investigated the statistical correlations between data on heating degree-day and heat energy requirements for provinces where greenhouses are widely used in Turkey. The results they obtained indicated that HDD values facilitate determination of heat energy requirements [6]. Pusat et al. determined degree-hour and degree-day data for the province of Karabük in Turkey. They obtained the meteorological data they used from the Turkish State Meteorological Service. They performed detailed analyses for the equilibrium temperatures of 5,10 and15 °C [7]. Boyacı determined the heating and cooling degree days in poultry houses for the province of Kırşehir and its districts. The degree days ranged from 2678.47 to 7846.63 for heating and from 0 to 441.76 for cooling. Since heating degree days are high, heating costs are also important for production costs [8]. Boyacı et al. determined the heating and cooling degree days of a laying quail henhouse. They concluded that, depending on the temperature outside, there was a need for heating in the henhouse for 74 days, and the HDD value was about 1175, while there was no need for cooling [9]. Harvey recommended three reference temperatures and corresponding indices for both HDD and CDD in their study. The first reference temperature they proposed was the indoor thermostat setting. The second was the outdoor temperature at which the heat loss balances the internal heat gain. The third was the outdoor temperature at which the indoor and solar heat gains are balanced with the heat loss. In the results, the author stated that, if the differences between reference temperatures are known, these differences can be used to calculate the internal and solar heat gain for a given building [10]. D'Amico et al. determined the relationship between heating degree-day and heating energy performance with some simple correlations to obtain a preliminary assessment of energy demands. In their results, the authors stated that the proposed methodology could be expanded and used to increase the reliability of any decision support tool based on climate indices [11]. Karaağaç et al. planned a facility that aimed to meet electrical energy needs by placing solar panels on the roof of apoultry farm. The monthly average generation of the system to be installed on the roof was 2,875 kWh, and the total annual electricity generation was 34,510 kWh. The photovoltaic panels they used on the roof were calculated have a 6-year depreciation period, and 32,439.4 kg of CO_2 emission was prevented thanks to this solar power plant design [12].

In this study, heating and cooling degree days were investigated for poultry farms using the degree-day method for regions where there are large numbers of poultry farms in the Balıkesir province (Center, Bandırma, Edremit, Dursunbey, Susurluk, Burhaniye, Ayvalık, Bigadiç, Manyas, Erdek, Gönen) in Turkey. The meteorological data of 2005-2018 obtained from the Turkish State Meteorological Service were used in the study. The heating or cooling needs of poultry farms were determined by equilibrium temperatures. Heating and cooling costs were calculated per unit area, according to the use of natural gas, coal, LPG, fuel oil in heating and electrical energy in cooling.

II. METHOD

A. Heating and cooling degree-days

Generally, DD is considered one of the simplest methods for energy calculation during heating and cooling buildings [1]. Degree-days are characterized with the sum of temperature differences between the average outdoor air temperature over a given period of time and a known reference temperature. In this study,

the HDD and CDD were determined during poultry production based on equations (1) and (2) [13, 14].

For $T_{out}<T_{base}$,

$$HDD = \sum_{1}^{n}(T_{base} - T_{out}) \quad (1)$$

For $T_{base}<T_{out}$,

$$CDD = \sum_{1}^{n}(T_{out} - T_{base}) \quad (2)$$

where n is the days total number during the period. T_{base} and T_{out} are the broilers base temperature and the mean temperature of outside air, respectively.

Broiler production time is recommended to be 41 and 42 days for maximum profit. In this study, production for 42 days and downtime and annual rotation were taken as 7 (Table 1). Optimum internal temperature values, which poultrys in poultry need on a weekly basis, are the equilibrium temperature values recommended by researchers for poultry breeding (Table 2).

TableI.
Periods and dates of poultry production [13, 15].

Annual rotation	Dates	Number of days
Production 1	1 Jan - 11 Feb	42
Closed	12 Feb-23 Feb	12
Production 2	24 Feb-6 Apr	42
Closed	7 Apr - 18 Apr	12
Production 3	19 Apr -30 May	42
Closed	31 May- 11 Jun	12
Production 4	12 Jun-23 Jul	42
Closed	24 Jul -4 Aug	12
Production 5	5 Aug - 15 Sep	42
Closed	16 Sep -27 Sep	12
Production 6	28 Sep -8 Nov	42
Closed	9 Nov- 20 Nov	12
Production 7	21 Nov - 31 Dec	42

TableII.
Weekly base temperaturere commended for broilers [13, 15].

Time	T_{base}(°C)
Week 1	31.00
Week 2	29.00
Week 3	25.00
Week 4	23.50
Week 5	22.50
Week 6	20.50

B. Calculating the Heat Load

The heat loss from unit surface:

$$q = U\Delta T \quad (3)$$

where U is the overall heat transfer coefficient. The annual heat losses from unit area can be approximately calculated depending on the degree-days number as the following:

$$q_A = 86400\ U\ DD \quad (4)$$

where DD is the degree days. The annual energy requirement for heating (E_A) can be obtained approximately by dividing the annual heat loss to the efficiency of the heating system (η_s):

$$E_A = \frac{86400\ U\ DD}{\eta_s} \quad (5)$$

The annual heating cost $C_{A,H}$ ($/m^2-year) per unit area can be calculated by the equation (6):

$$C_{A,H} = \frac{86400\ U\ HDD\ C_f}{H_u\ \eta_s} \quad (6)$$

where C_f is fuel cost ($/kg) and H_u is the lower heating value of the fuel (J/kg; J/m^3). The annual cooling cost per unit area can be calculated using equation (7). COP is the performance coefficient of the cooling system and it was taken as 2.5 in this study [8]:

$$C_{A,C} = \frac{86400\ U\ CDD\ C_f}{COP} \quad (7)$$

The data used to calculate the heating and cooling costs are given in Table 3.

TableIII.
Properties of fuels and system efficiency [16, 17].

Fuel	Cost	Lower Heating Value, H_u	System Efficiency (η_s)(%)
Natural gas	0.2868 $/m^3	34.542x106J/m^3	93
Coal	0.1921 $/kg	25.122x106 J/kg	65
LPG	1.75 $/kg	46.442x106 J/kg	88
Fuel-Oil	0.73 $/kg	41.317x106 J/kg	80
Electricity	0.1252 $/kWh	(COP)	2.5

III. RESULTS AND DISCUSSION

In this study, heating and cooling degree days were investigated for poultry farms using the degree-day method for regions where there are large numbers of poultry farms in the Balıkesir province (City Center, Bandırma, Edremit, Dursunbey, Susurluk, Burhaniye, Ayvalık, Bigadiç, Manyas, Erdek, Gönen) of Turkey. Table 4 presents the calculated HDD and CDD values. The presented HDD and CDD values were the annual total values. The calculations were made by accounting for a total of 7 production periods in each year and 6 weeks in each period. In each production period, the equilibrium temperature of the relevant week was taken as a basis (T_{base} = 31, 29, 25, 23.50, 22.50 and 20.50 °C). The periods when the system was turned off were not taken into account. (Tables 1, 2).

The highest HDD value was obtained in Dursunbey as 3725, while the lowest HDD value was obtained in Edremit as 2554.The highest and lowest CDD values were obtained in Edremit as 237 and in Dursunbey as 25, respectively.

Table 5 shows the HDD and CDD values according to the equilibrium temperatures. According to the given annual rotation table, while heating was required at all equilibrium temperatures except those corresponding to summer months, cooling was required at equilibrium temperatures corresponding to summer months.

Table 6 shows the HDD and CDD numbers that were obtained. Figure 1 graphically displays the HDD and CDD values according to the equilibrium temperatures in all districts.

TableIV.
Annual HDD and CDD degree days.

	HDD	CDD
Bandırma	3155	75
Edremit	2554	237
Ayvalık	2581	203
Erdek	2816	131
Gönen	3123	74
Bigadiç	3159	76
Manyas	3137	63
Dursunbey	3725	25
Susurluk	3062	77
Burhaniye	2707	205
Merkez	3227	96

TableV.
HDD and CDD values according to base temperature for all production periods

	31 °C		29 °C		25 °C		23.5 °C		22.5 °C		20.5 °C	
	HDD	CDD	HDD	CDD	HDD	HDD	HDD	CDD	HDD	CDD	HDD	CDD
Bandırma	805	0	715	0	502	1	429	11	402	20	299	43
Edremit	672	0	568	0	404	30	351	50	324	60	233	95
Ayvalık	682	0	575	0	405	25	353	42	328	50	235	85
Erdek	736	0	631	0	446	10	385	23	360	34	255	62
Gönen	791	0	700	0	497	1	430	10	402	18	300	44
Bigadiç	802	0	701	0	505	0	436	10	408	21	303	44
Manyas	793	0	706	0	502	0	431	6	407	17	295	39
Dursunbey	912	0	795	0	613	0	528	0	497	3	378	21
Susurluk	778	0	690	0	488	0	421	11	393	21	289	44
Burhaniye	702	0	596	0	430	24	371	43	348	51	254	86
Merkez	804	0	710	0	516	4	449	17	423	25	323	49

TableVI.
HDD and CDD numbers according to base temperature for all production periods

	31 °C		29 °C		25 °C		23.5 °C		22.5 °C		20.5 °C	
	HDD	CDD	HDD	CDD	HDD	CDD	HDD	CDD	HDD	CDD	HDD	CDD
Bandırma	49	0	49	0	43	7	38	11	37	14	35	14
Edremit	49	0	49	0	35	11	35	14	35	14	29	27
Ayvalık	49	0	49	0	35	14	35	14	35	14	28	21
Erdek	49	0	49	0	42	7	35	14	35	14	35	20
Gönen	49	0	49	0	44	5	37	12	37	11	33	16
Bigadiç	49	0	49	0	45	0	38	11	38	12	31	18
Manyas	49	0	49	0	49	0	38	11	38	11	31	18
Dursunbey	49	0	49	0	49	0	49	0	45	4	42	7
Susurluk	49	0	49	0	46	3	37	12	35	12	30	18
Burhaniye	49	0	49	0	35	14	35	14	35	14	28	21
Merkez	49	0	49	0	42	7	35	14	35	14	35	14

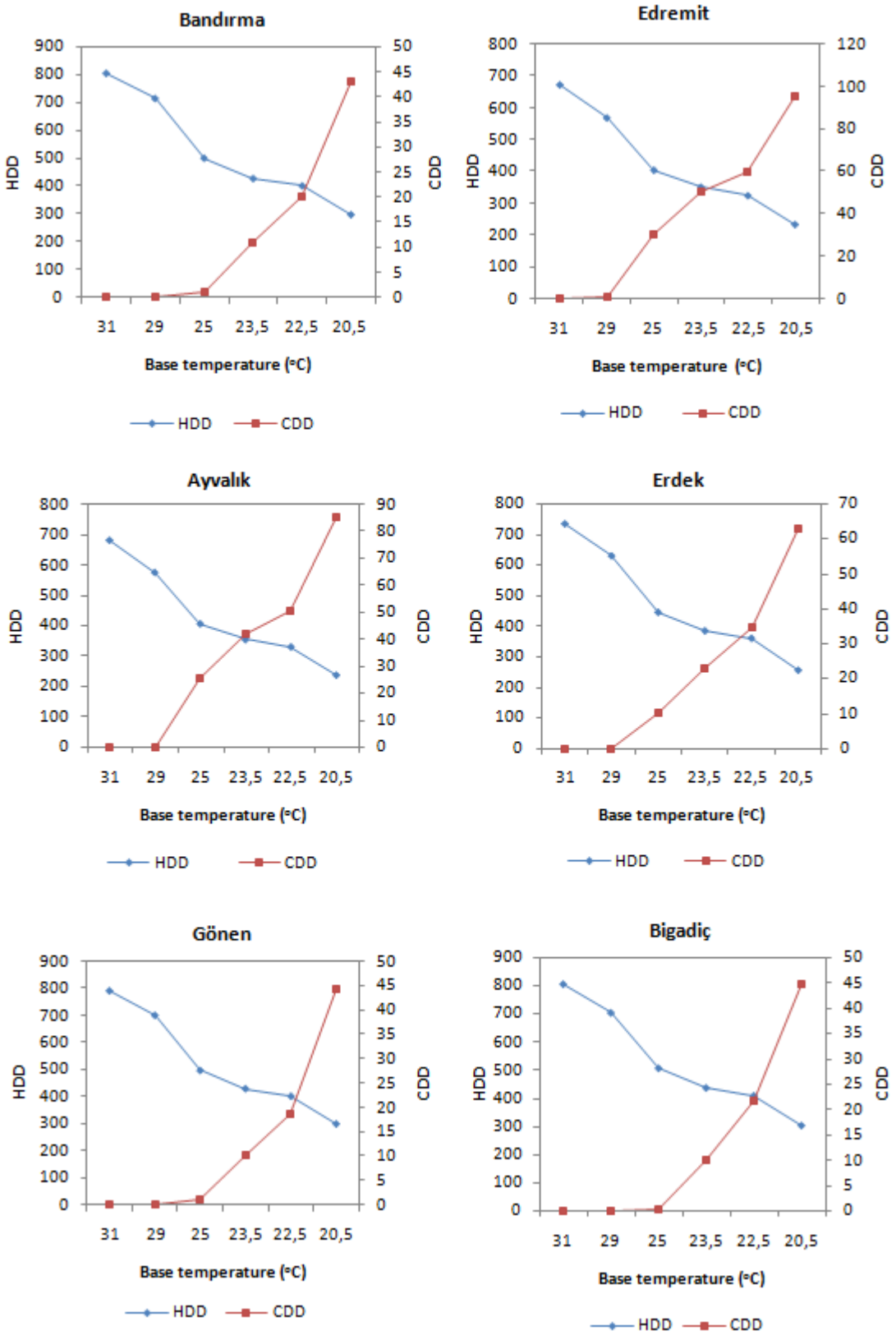

Figure 1. HDD and CDD according to base temperature.

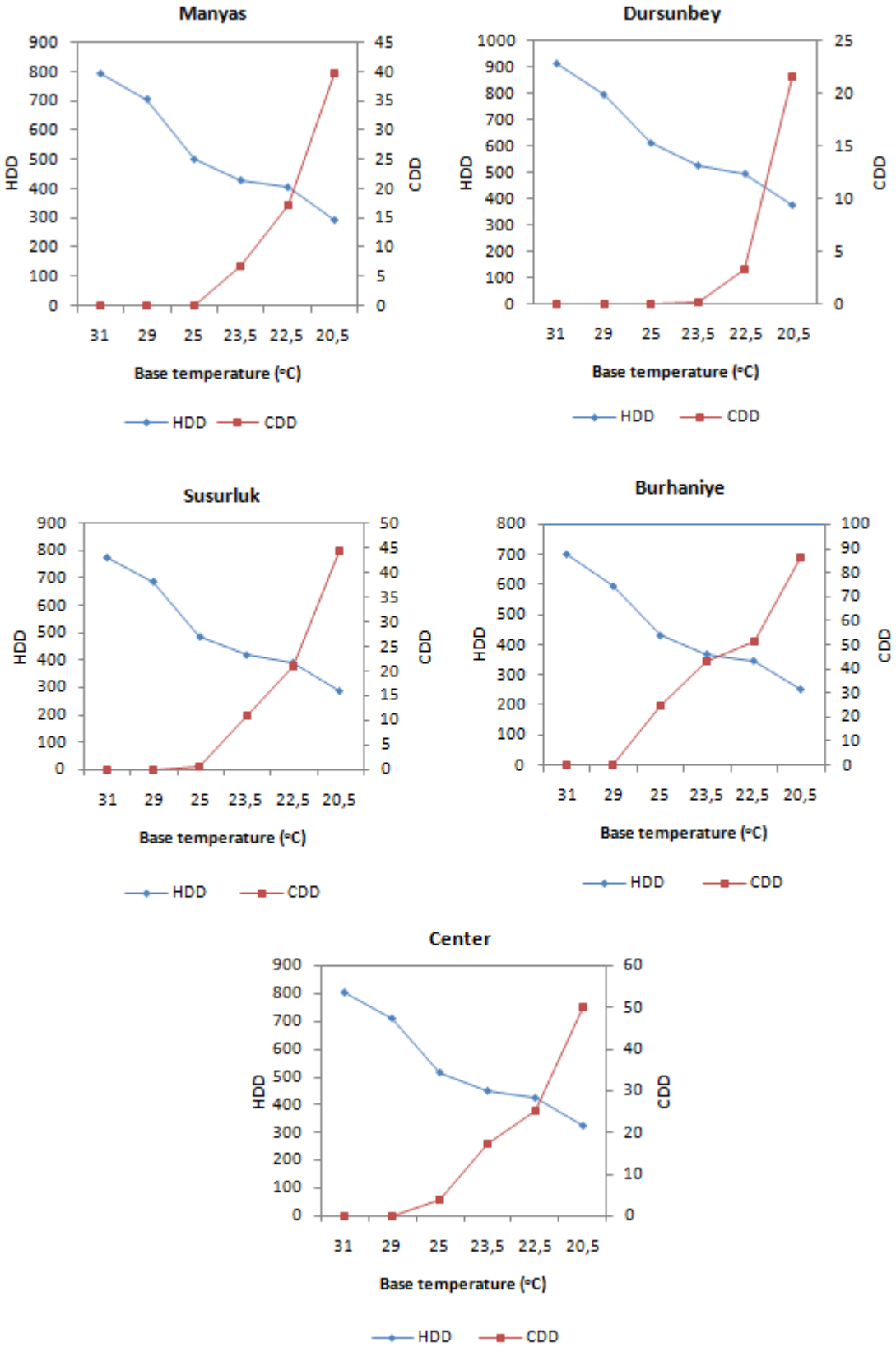

Figure 1. (continued)

Tables 7 and 8 show the costs of energy required per unit area by the equilibrium temperatures and the annual total value. Calculations were made for natural gas, coal, LPG and fuel oil in heating and for electrical energy in cooling. In the comparison on the basis of fuels, it was found that the most economical fuel was natural gas, while the highest cost was seen in LPG. In terms of heating, the highest and lowest energy costs were obtained in Dursunbey and in Edremit, respectively. The high energy costs in heating revealed the importance of facility planning.

In terms of cooling, the energy cost in the region was generally low. This cost was obtained relatively higher in the gulf districts of Edremit, Burhaniye and Ayvalık. It was observed that the production periods that coincided only with the summer season in other regions also required energy for the high equilibrium temperatures.

TableVII.
Heating costs per unit area ($/m^2)

	31 ^{O}C	29 ^{O}C	25 ^{O}C	23.5 ^{O}C	22.5 ^{O}C	20.5 ^{O}C	Annual
				Natural gas			
Bandırma	0.62	0.55	0.38	0.33	0.31	0.23	2.43
Edremit	0.51	0.43	0.31	0.27	0.25	0.18	1.97
Ayvalık	0.52	0.44	0.31	0.27	0.25	0.18	1.99
Erdek	0.56	0.48	0.34	0.29	0.27	0.19	2.17
Gönen	0.61	0.54	0.38	0.33	0.31	0.23	2.40
Bigadiç	0.61	0.54	0.39	0.33	0.31	0.23	2.43
Manyas	0.61	0.64	0.38	0.33	0.31	0.22	2.42
Dursunbey	0.70	0.61	0.47	0.40	0.38	0.29	2.87
Susurluk	0.60	0.53	0.37	0.32	0.30	0.22	2.36
Burhaniye	0.54	0.46	0.33	0.28	0.26	0.19	2.08
Merkez	0.62	0.54	0.39	0.34	0.32	0.24	2.48
				Coal			
Bandırma	0.81	0.72	0.51	0.43	0.40	0.30	3.20
Edremit	0.68	0.57	0.41	0.35	0.33	0.23	2.59
Ayvalık	0.69	0.58	0.41	0.35	0.33	0.23	2.62
Erdek	0.74	0.64	0.45	0.39	0.36	0.26	2.86
Gönen	0.80	0.71	0.50	0.43	0.40	0.30	3.17
Bigadiç	0.81	0.71	0.51	0.44	0.41	0.30	3.21
Manyas	0.80	0.71	0.51	0.43	0.41	0.30	3.18
Dursunbey	0.92	0.80	0.62	0.53	0.50	0.38	3.78
Susurluk	0.79	0.70	0.49	0.42	0.40	0.29	3.11
Burhaniye	0.71	0.60	0.43	0.37	0.35	0.25	2.74
Merkez	0.81	0.72	0.52	0.45	0.43	0.32	3.28
				LPG			
Bandırma	2.98	2.64	1.85	1.58	1.49	1.10	11.68
Edremit	2.48	2.10	1.49	1.30	1.20	0.86	9.45
Ayvalık	2.52	2.13	1.50	1.30	1.21	0.87	9.55
Erdek	2.72	2.33	1.65	1.42	1.33	0.94	10.42
Gönen	2.92	2.59	1.84	1.59	1.49	1.11	11.56
Bigadiç	2.97	2.59	1.87	1.61	1.51	1.12	11.69
Manyas	2.93	2.61	1.85	1.59	1.50	1.09	11.61
Dursunbey	3.37	2.94	2.26	1.95	1.84	1.40	13.79
Susurluk	2.88	2.55	1.80	1.56	1.45	1.07	11.33
Burhaniye	2.59	2.20	1.59	1.37	1.29	0.94	10.01
Merkez	2.97	2.63	1.91	1.66	1.56	1.19	11.94
				Fuel-oil			
Bandırma	1.89	1.68	1.17	1.00	0.94	0.70	7.40
Edremit	1.57	1.53	0.94	0.82	0.76	0.54	5.99
Ayvalık	1.60	1.35	0.95	0.82	0.77	0.55	6.06
Erdek	1.73	1.48	1.04	0.90	0.84	0.60	6.61
Gönen	1.85	1.64	1.16	1.01	0.94	0.70	7.33
Bigadiç	1.84	1.64	1.18	1.02	0.96	0.71	7.41
Manyas	1.86	1.66	1.17	1.01	0.95	0.69	7.36
Dursunbey	2.14	1.86	1.44	1.24	1.16	0.88	8.74
Susurluk	1.82	1.52	1.14	0.99	0.92	0.68	7.19
Burhaniye	1.64	1.40	1.01	0.87	0.91	0.59	6.35
Merkez	1.89	1.67	1.21	1.05	0.99	0.75	7.57

TableVIII.
Cooling costs per unit area ($/m^2)

	31 ^{O}C	29 ^{O}C	25 ^{O}C	23.5 ^{O}C	22.5 ^{O}C	20.5 ^{O}C	Annual
				Electricity			
Bandırma	0.00	0.00	0.00	0.03	0.06	0.13	0.22
Edremit	0.00	0.00	0.09	0.15	0.18	0.29	0.72
Ayvalık	0.00	0.00	0.07	0.12	0.15	0.25	0.61
Erdek	0.00	0.00	0.03	0.07	0.10	0.19	0.39
Gönen	0.00	0.00	0.00	0.03	0.05	0.13	0.22
Bigadiç	0.00	0.00	0.00	0.03	0.06	0.13	0.23
Manyas	0.00	0.00	0.00	0.02	0.05	0.12	0.19
Dursunbey	0.00	0.00	0.00	0.00	0.01	0.06	0.07
Susurluk	0.00	0.00	0.00	0.03	0.06	0.13	0.23
Burhaniye	0.00	0.00	0.07	0.13	0.15	0.26	0.62
Merkez	0.00	0.00	0.01	0.05	0.07	0.15	0.29

Calculation of HDD and CDD values provides important information in the planning phase of facilities. This calculation will allow selection of the appropriate system and material to meet the energy need and design of the structure. Besides, accurately estimating the energy need will allow broilers to be bred under suitable conditions and thus increase productivity.

Besides, HDD and CDD values are also important indicators for estimating energy consumption. This is because it is known that energy consumption increases as the number of heating and cooling degree days increases and decreases as the number of days decreases.

It was observed that the HDD values were higher than the CDD values throughout the region. The low energy costs for cooling were an important advantage. To make heating energy consumption more economical, on the other hand, utilization of renewable energy resources may be considered. The existence of geothermal resources in the Edremit, Gönen and Bigadiç districts may provide an opportunity to utilize geothermal energy in these regions.

Furthermore, thermal insulation is a critical factor in reducing energy costs. Insulation of the external walls and roofs of facilities with proper insulation materials will reduce the energy need and provide energy savings. Insulation will contribute to both making savings and environmental factors.

IV. CONCLUSION

In this study, HDD and CDD values for raising broiler were calculated, using the meteorological data obtained from the General Directorate of Meteorology for the city center and districts of the province of Balıkesir in Turkey. The daily average outdoor temperature data between 2005 and 2018 were used. Calculations were made based on the required equilibrium temperatures for the annual rotation and 6-week broiler breeding periods. Given the HDD and CDD values, it was considered that four different fuels (natural gas, coal, LPG and fuel oil) would be used for heating, and electrical energy would be used for cooling. The results showed that the heating costs were higher than the cooling costs. It was concluded that insulation would be a significant factor in reducing energy costs for the current facilities and new facilities planned to be established in the region. Insulation is highly important for reducing emissions, as well.

CONFLICTS OF INTEREST

They reported that there was no conflict of interest between the authors and their respective institutions.

RESEARCH AND PUBLICATION ETHICS

In the studies carried out within the scope of this article, the rules of research and publication ethics were followed.

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