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ANALYSIS OF TREND CHANGES IN DEGREE-DAY VALUES OF HEATING AND COOLING: BROILER BREEDING CASE

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Abstract

An ideal broiler house should be designed to minimize the effects of weather changes and to keep indoor conditions at the comfort temperature of the animals. In this case, this should be done with minimum cost and possible lowest operating costs. Degree-day methods are used in order to have knowledge of the energy need of any structure. With this method, the measured values or meteorological data can be used to give information about the heating and cooling energy quantities of structures. Depending on the climate change in recent years, the changes need to be examined that have taken place in order to provide optimum comfort in animal barn. Isparta province and districts were selected as the study area. The long-term average daily temperature values are used from meteorological stations of the selected region. The heating and cooling degree day values were calculated for selected balance temperatures in broiler breeding. Linear Regression Analysis and Spearman Rank Correlation Test were conducted to determine the changes of these values due to climate change. In conclusion, it was determined that there were statistically significant trends at 5% significance level in Egirdir (21°C), Isparta (31-29-25 and 23°C), Kasimlar (18°C), Senirkent (31-29-25-23 and 21°C), Sutculer (all selected balance temperature values) and Yalvac (31-29-25-23 and 21°C) in terms of heating degree-day values, and in Atabey (29-25-23-21 and 18°C), Barla (25-23 and 21°C), Isparta (23-21 and 18°C), Senirkent (29-25-23-21 and 18°C), Sutculer (29-25-23-21 and 18°C), Sarkikaraagac (25-23-21 and 18°C), Uluborlu (25-23-21 and 18°C) and Yalvac (25-23-21

and 18°C) in terms of cooling degree-day values. As a result, it has been concluded that more energy consumption will be a concern for heating and cooling of the broiler house that will be built in the province of Isparta.

Key words: Broiler, Linear Regression Analysis, Spearman Rank Correlation Test, Temperature, Trend analysis

INTRODUCTION

Controlling indoor temperatures in broiler breeding in all seasons increases the comfort and productivity of living beings. The main duty of an agricultural structure is to protect the creatures living in it against the climate. An ideal agricultural structure must minimize climatic changes and regulate the indoor weather conditions according to the optimum requirements of the creatures living inside it all the time.

The degree-day method is commonly used in residential, commercial and industrial buildings as well as greenhouses, breeding facilities, storage facilities to estimate the energy consumption for heating and cooling (Yildiz and Sosaoglu, 2007). The heating and cooling degree-day method depends on providing optimum climatic conditions in broiler poultry houses and interpreting the climatic conditions in the region where the structure is located in a good way (Kuehn *et al*. 1998).

Information on temperature which is the main element of the climate has great importance in determining the characteristics of global climatic variations. The temperature phenomenon indicates great variability on both spatial and temporal scales. These changes reveal significant hints for understanding the general structure of the climate. Therefore, recently, studies on climatic changes have focused on the trend analyses of this parameter (Turkes, 1996; Kadıoglu, 1997; Turkes, 2002; Bagdatli *et al*. 2014).

Recently, some non-parametric statistical tests such as the Sen's T-test, Spearman's Rho test, Linear Regression, Mann-Kendall, Seasonal Kendall, Mann-Whitney and Kruskal-Wallis H tests have been commonly used to identify temperature change trends and to take due precautions for changes (Kalayci and Kahya 1998; Demir *et al*., 2016).

The aim of this study was to determine the trend changes in the degree-day values prepared by examining the long-term meteorological data. Linear regression analysis and Spearman rank correlation test were applied to determine trends in heating and cooling degree-day values.

MATERIAL AND METHOD

In the study, long-term (1929-2015) average daily temperature values belonging to 16 meteorological stations including Isparta and districts were used (Table 1). Heating and cooling values were calculated using the degree-of-day method for the current or future broiler breeding in the region. Most common and easy parametric method Linear Regression Analysis (LRA) and non-parametric method Spearman Rank Correlation Test (SRCT) were applied in order to determine the trend changes in the calculated heating and cooling degree-day values.

Table 1. Characteristics of meteorological stations and observation lengths

Meteorological stations	Observation lengths	Latitude (Degree)	Longitude (Degree)	Elevation (m)
Aksu	1983 – 2003	37°47’	31°04’	1240
Atabey	1968 – 2015	37°57’	30°38’	1000
Bagkonak	1987 – 1996	38°14’	31°17’	1397
Barla	1987 – 1992	38°01’	30°78’	1085
Egirdir	1968 – 2015	37°50’	30°52’	917
Gelendost	1983 – 1988	38°07’	31°01’	952
Isparta Center	1929 – 2015	37°47’	30°34’	997
Kasımlar	1987 – 1993	37°53’	31°19’	1070
Keciborlu	1971 – 1990	37°57’	30°18’	996
Kumdanli	1984 – 1995	38°32’	30°97’	1029
Senirkent	1970 – 2015	38°06’	30°33’	959
Sutculer	1968 – 2015	37°30’	30°59’	975
Sarkikaraagac	1976 – 2015	38°05’	31°22’	1180
Uluborlu	1968 – 2015	38°05’	30°27’	1025
Yalvac	1972 – 2015	38°16’	31°10’	1096
Yenisarbademli	1983 – 1994	37°42’	31°23’	1183

In our country, an average 6 week growing period is applied in broiler breeding. Heating and cooling degree-day values are calculated according to the recommended and selected balance temperature (Table 2) values during these growing periods (Lindley and Whitaker, 1996; Atilgan *et al*., 2012; Anonymous, 2015)

Table 2. Recommended values for inside and selected balance temperatures for broiler chickens.

Week	Recommended inside temp. (°C)	Selected balance temp. (°C)
1	32-30	31
2	30-28	29
3	26-24	25
4	24-22	23
5	22-20	21
6	19-17	18

Degree-Day Method

In the degree-day method, a certain value of the balance point temperature must first be determined. The balance temperature is the outside temperature when no heating or cooling is needed. Energy calculations are performed for periods where the outdoor temperature is lower and higher than the balance point temperature. Depending on the selected different balance temperature (T_b) values for broiler breeding, it can be assumed that the energy required for heating and cooling is directly proportional to the difference between the outside temperatures (T_o). Thus, during the growing season, the amount of energy required for heating or cooling according to different average balance temperature values can be estimated in each growing period. Heating and cooling degree-day (HDD, CDD) can be calculated via this equation 1 and 2, respectively (Gultekin, 1995; Satman and Yalcinkaya, 1999; Buyukalaca *et al*., 2001; Krese *et al*., 2012; Yucel *et al*., 2014; Aydin *et al*., 2015; Erturk *et al*., 2015).

$$HDD = \sum_{I=1}^{n} (T_b - T_o)^{+} \quad (1)$$

$$CDD = \sum_{I=1}^{n} (T_o - T_b)^{+} \quad (2)$$

Here; T_o outside temperature (°C), T_b the recommended inside and selected balance temperatures (°C) given in Table 1, n the days of the year, (+) the mark in the equations above suggests that only the positive values will be used.

Linear Regression Analysis (LRA)

LRA is a parametric test that determines the relationship between two or more dependent and independent variables that have a causal link. It is also a mathematical model designed to make predictions (Helsel and Hirsch, 1993;

Hamdi *et al*., 2009; Shammugasundram, 2012; Singh *et al*., 2015). Simple linear regression equation:

$$Y = a + bX \tag{3}$$

Here, Y, X, a, and b indicate dependent variable, independent variable, interceptor and trend respectively. The significance of the analysis is tested by the t test, a parametric test that assumes that the data are normally distributed. With this test, it is determined whether there is a relationship between variables (Haan, 1977; Sneyers, 1990; Xu, 2002; Onoz and Bayazit, 2003; Bulut *et al*., 2006).

Spearman Rank Correlation Test (SRCT)

The SRCT is the nonparametric version. It is a fast and simple test used to determine whether there is a significant trend among the observed values. This test is effective, simple and distributed independent in determining the linear and non-linear trends. The test is based on the calculation and testing of the statistic (Sneyers, 1990; Helsel and Hirsch, 1993).

$$R_{sp} = 1 - \frac{6 * \sum_{i=1}^{n} D_i^2}{(n^3 - n)} \tag{4}$$

Here; n number of cases, D_i difference in paired ranks. The calculated Rsp value is tested (t) at the degree of freedom and at the 5% significance level (Kottegoda, 1980; Dahmen and Hall, 1990; Kendall and Gibbons, 1990; Sneyers, 1990; Sen, 2002; Kanji, 2006).

$$t = R_{sp} * \sqrt{\frac{n-2}{1-R_{sp}^2}} \tag{5}$$

RESULT AND DISCUSION

In the study, the meteorological stations in Isparta province and districts (16) were selected and the long-term average daily temperature values were used. Heating and cooling degree-day values for all indoor comfort temperatures suggested in Table 2 for broiler breeding were calculated. They were examined with the parametric LRA to determine the changes in these values and the results are presented in Table 3. The a and b regression coefficients, t statistical t-test, p probability significance level ($p<0.05$) and r correlation coefficient are indicated in Table 3.

Table 3. Results of LRA of heating and cooling degree-day values

Name of the meteorological station	Selected balance temperatures **(°C)**					
	31	29	25	23	21	18
Aksu						
HDD						
a	– 7,800	– 7,000	– 7,530	– 0,00604	– 0,00643	– 0,00639
b	22969,0	20656,0	20235,0	2020,410	2017,890	2011,980
t	1,460	1,360	1,300	64,900	71,440	85,310
p	0,160	0,191	0,208	0,000	0,000	0,000
r	0,221	0,205	0,217	0,197	0,197	0,182
CDD						
a	---	---	0,235	0,0695	0,0259	0,0175
b	---	---	– 465,0	1991,580	1990,860	1988,010
t	---	---	– 1,220	973,320	614,860	325,530
p	---	---	0,237	0,000	0,000	0,000
r	---	---	0,272	0,207	0,164	0,190
Atabey						
HDD						
a	– 2,110	– 2,540	– 1,390	– 0,00541	– 0,0001	0,00192
b	10950,0	11083,0	7356,0	2012,990	1991,830	1986,620
t	2,560	2,660	1,850	43,100	46,900	56,760
p	0,014	0,011	0,070	0,000	0,000	0,000
r	0,145	0,176	0,100	0,224	0,000	0,000
CDD						
a	0,000212	0,0388	0,713	0,129	0,0942	0,0629
b	– 0,415	– 76,4	– 1380,0	1975,980	1967,650	1956,080
t	– 0,460	– 2,37	– 2,520	412,770	293,070	168,300
p	0,649	0,022	0,015	0,000	0,000	0,000
r	0,707	0,333	0,358	0,459	0,477	0,405
Bagkonak						
HDD						
a	– 27,500	– 28,100	– 28,000	– 0,00376	– 0,00439	– 0,00465
b	62232,0	62645,0	61072,0	2008,610	2008,610	2008,550
t	0,980	1,010	0,970	120,200	134,510	136,940
p	0,356	0,342	0,359	0,000	0,000	0,000
r	0,292	0,303	0,300	0,341	0,375	0,381

CDD						
a	---	---	– 0,407	– 0,100	– 0,0281	– 0,00494
b	---	---	814,0	1994,220	1994,360	1989,820
t	---	---	0,870	1176,850	676,420	362,330
p	---	---	0,412	0,000	0,000	0,000
r	---	---	0,292	0,549*	0,341	0,110
Barla						
HDD						
a	76,800	74,900	70,700	0,00361	0,00371	0,00380
b	– 145775,0	– 142876,0	– 135988,0	1994,670	1976,530	1979,300
t	– 1,170	– 1,200	– 1,100	142,970	153,290	181,860
p	0,306	0,298	0,334	0,000	0,000	0,000
r	0,522	0,529	0,494	0,478	0,451	0,425
CDD						
a	---	– 0,0429	– 5,670	– 0,0629	– 0,0349	– 0,00240
b	---	85,300	11296,0	1994,730	1996,820	2001,390
t	---	1,730	4,210	1521,990	840,050	463,370
p	---	0,158	0,014	0,000	0,000	0,000
r	---	0,655	0,903*	0,901*	0,843*	0,811*
Egirdir						
HDD						
a	4,490	4,020	4,540	0,0145	0,0165	0,0161
b	-2283,0	– 2077,0	– 4534,0	1935,820	1937,910	1951,910
t	-0,410	– 0,370	– 0,850	61,350	69,180	83,170
p	0,683	0,711	0,397	0,000	0,000	0,000
r	0,230	0,207	0,243	0,253	0,272	0,243
CDD						
a	---	0,00147	0,0310	0,00307	0,0168	– 0,0160
b	---	– 2,790	– 36,000	1988,510	1987,620	2000,050
t	---	– 0,320	– 0,090	376,940	248,000	-152,670
p	---	0,751	0,928	0,000	0,000	0,000
r	---	0,045	0,032	0,089	0,071	0,095
Gelendost						
HDD						
a	10,100	11,500	10,400	0,00282	0,00438	0,00527
b	-13228,0	– 16688,0	– 15950,0	1974,110	1970,560	1971,880

t	-0,150	– 0,190	– 0,190	80,860	92,020	111,930
p	0,886	0,861	0,859	0,000	0,000	0,000
r	0,114	0,126	0,122	0,228	0,330	0,361
CDD						
a	---	---	0,100	0,0291	0,0182	0,0122
b	---	---	– 190,0	1983,720	1982,550	1980,240
t	---	---	– 0,040	1017,690	732,220	326,450
p	---	---	0,973	0,000	0,000	0,000
r	---	---	0,010	0,445	0,492	0,401
Isparta						
HDD						
a	-12,100	– 11,700	– 12,600	– 0,0238	– 0,0226	– 0,0211
b	30268,0	28808,0	29087,0	2068,230	2049,330	2026,860
t	0,600	0,580	0,600	43,490	46,830	55,280
p	0,563	0,576	0,568	0,000	0,000	0,000
r	0,161	0,161	0,173	0,214	0,190	0,161
CDD						
a	---	– 0,0085	– 0,624	0,277	0,162	0,101
b	---	16,500	1222,0	1950,460	1940,610	1925,090
t	---	0,550	0,800	389,590	257,500	154,950
p	---	0,597	0,448	0,000	0,000	0,000
r	---	0,190	0,268	0,470	0,431	0,386
Kasimlar						
HDD						
a	1,600	6,700	4,500	0,00274	0,00549	0,00858
b	– 1813,0	– 6654,0	– 3868,0	1977,850	1969,350	1965,500
t	– 0,040	– 0,160	– 0,080	51,390	66,910	112,630
p	0,971	0,883	0,937	0,000	0,000	0,000
r	0,084	0,138	0,084	0,045	0,300	0,532*
CDD						
a	---	---	– 0,068	0,0442	0,0408	0,0240
b	---	---	137,0	1989,110	1986,570	1983,340
t	---	---	0,150	927,310	1028,250	883,580
p	---	---	0,889	0,000	0,000	0,000
r	---	---	0,063	0,197	0,647*	0,807*
Keciborlu						

HDD						
a	3,520	4,040	3,640	0,0992	0,0118	0,0131
b	– 187,0	– 1940,0	– 2598,0	1943,870	1941,050	1947,030
T	– 0,020	– 0,160	– 0,220	48,470	53,190	64,350
p	0,988	0,874	0,828	0,000	0,000	0,000
r	0,130	0,155	0,141	0,210	0,247	0,253
CDD						
a	---	– 0,0041	0,102	0,0267	0,0145	0,00665
b	---	8,200	– 174,0	1977,940	1977,350	1977,140
t	---	0,170	– 0,170	470,610	352,170	198,260
p	---	0,865	0,869	0,000	0,000	0,000
r	---	0,045	0,045	0,148	0,134	0,077
Kumdanli						
HDD						
a	– 10,200	– 9,300	– 10,900	– 0,00186	– 0,00120	– 0,000015
b	27125,0	24522,0	26326,0	1996,850	1993,520	1989,540
t	0,580	0,540	0,580	108,470	115,160	128,490
p	0,578	0,603	0,577	0,000	0,000	0,000
r	0,134	0,126	0,148	0,126	0,071	0,000
CDD						
a	---	– 0,0231	– 0,870	0,00859	0,0163	0,0143
b	---	46,200	1768,0	1988,530	1985,440	1981,450
t	---	0,550	0,710	520,330	436,520	300,420
p	---	0,592	0,496	0,000	0,000	0,000
r	---	0,170	0,214	0,084	0,279	0,363
Senirkent						
HDD						
a	– 7,690	– 8,180	– 6,500	-0,0213	– 0,0202	– 0,0192
b	22031,0	22295,0	17625,0	2076,310	2059,950	2041,560
t	4,150	4,250	3,550	61,090	65,540	77,800
p	0,000	0,000	0,001	0,000	0,000	0,000
r	0,399	0,424	0,367	0,349	0,308	0,272
CDD						
a	0,00594	0,0580	1,190	0,125	0,0935	0,0721
b	– 11,800	– 114,0	– 2318,0	1975,380	1966,500	1950,390
t	– 1,930	– 2,190	– 3,610	460,810	326,910	198,460

p	0,061	0,034	0,001	0,000	0,000	0,000
r	0,281	0,318	0,487	0,548*	0,561*	0,549*
Sutculer						
HDD						
a	– 5,690	– 6,280	– 4,780	– 0,0318	– 0,0301	– 0,0313
B	17741,0	18200,0	13779,0	2106,430	2082,020	2061,290
t	4,860	5,060	4,030	49,540	53,040	66,200
p	0,000	0,000	0,000	0,000	0,000	0,000
r	0,416	0,456	0,381	0,370	0,374	0,316
CDD						
a	0,00370	0,0599	0,900	0,143	0,104	0,0737
b	– 7,320	– 118,0	– 1754,0	1974,230	1964,230	1948,550
t	– 1,490	– 1,770	– 3,440	434,430	291,680	157,900
p	0,144	0,084	0,001	0,000	0,000	0,000
r	0,214	0,255	0,460	0,519*	0,525*	0,460
Sarkikaraagac						
HDD						
a	– 5,060	– 5,350	– 4,770	– 0,0116	– 0,0108	– 0,0919
b	17579,0	17427,0	14813,0	2048,730	2037,820	2023,480
t	2,710	2,730	2,310	55,180	60,160	69,730
p	0,010	0,009	0,026	0,000	0,000	0,000
r	0,245	0,263	0,235	0,226	0,063	0,155
CDD						
a	---	---	0,274	0,270	0,123	0,0682
b	---	---	– 541,0	1987,180	1962,910	1974,280
t	---	---	– 3,540	661,900	439,780	259,400
p	---	---	0,001	0,000	0,000	0,000
r	---	---	0,501*	0,474	0,438	0,421
Uluborlu						
HDD						
a	– 4,410	– 4,850	– 4,010	– 0,0162	– 0,0150	– 0,0137
b	15758,0	15936,0	12804,0	2058,440	2044,240	2028,020
t	3,350	3,410	2,790	53,650	58,910	70,740
P	0,002	0,001	0,008	0,000	0,000	0,000
r	0,265	0,292	0,249	0,249	0,219	0,184
CDD						

a	0,000868	0,0166	0,382	0,199	0,118	0,0787
b	– 1,720	– 32,700	– 741,0	1978,020	1971,740	1957,920
t	– 2,130	– 2,140	– 2,770	428,410	304,400	176,750
p	0,038	0,037	0,008	0,000	0,000	0,000
r	0,302	0,303	0,386	0,425	0,425	0,414
Yalvac						
HDD						
a	– 9,120	– 9,350	– 8,220	– 0,0239	– 0,0209	– 0,0169
b	25396,0	25138,0	21417,0	2097,790	2071,650	2042,190
t	4,870	4,860	4,250	58,090	60,170	68,670
p	0,000	0,000	0,000	0,000	0,000	0,000
r	0,474	0,486	0,448	0,407	0,332	0,077
CDD						
a	0,000571	0,0310	0,893	0,177	0,117	0,0844
b	– 1,130	– 61,400	– 1761,0	1981,200	1973,570	1958,210
t	– 1,060	– 2,240	– 4,090	736,440	560,880	335,590
p	0,296	0,030	0,000	0,000	0,000	0,000
r	0,161	0,329	0,538*	0,647*	0,691*	0,694*
Yenisarbademli						
HDD						
a	4,700	6,000	4,500	0,001430	0,00268	0,00477
b	– 1982,0	– 5290,0	– 3892,0	1982,190	1978,360	1975,730
t	– 0,040	– 0,120	– 0,090	96,600	108,240	132,990
p	0,966	0,908	0,932	0,000	0,000	0,000
r	0,063	0,084	0,063	0,095	0,173	0,249
CDD						
a	---	---	– 0,095	0,0178	0,0309	0,0225
b	---	---	197,0	1987,730	1984,480	1980,130
t	---	---	0,160	884,590	666,200	402,010
p	---	---	0,874	0,000	0,000	0,000
r	---	---	0,045	0,122	0,120	0,467

* ($p<0.05$)

The statistical characteristics of each meteorological station are provided in Table 3 and when the heating degree-day values, calculated according to the selected balance temperature values, the results of the LRA and the probability ($p<0,05$) and correlation coefficients (r) at 5% significance level were compared at the same time, it was identified that there were statistically significant trends

at 18°C in Kasimlar, at 23°C in Bagkonak, at 18-21-23-25°C in Barla, at 21-18°C in Kasimlar, at 18-21-23°C in Senirkent, at 21-23°C in Sutculer, at 25°C in Sarkikaraagac and at 18-21-23-25°C in Yalvac, according to the results of cooling degree-day values. Statistically significant trends at 5% significance level were not found in the heating and cooling values calculated for the other selected balance temperature values for broiler breeding. The calculations of the SRCT were performed for each meteorological station and the results are presented in Figure 1 at 5% significance level to be compared visually.

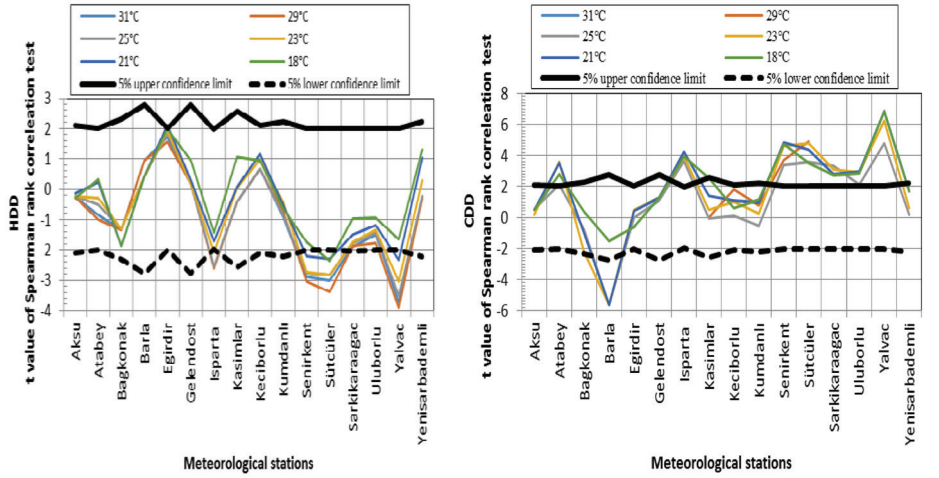

Figure 1. SRCT graphics for heating and cooling degree-day values

The results of the SRCT of the heating degree-day values calculated according to the selected balance temperature values indicated that there were statistically significant trends in Egirdir at 21°C, in Isparta at 31-29-25-23°C, in Senirkent at 31-29-25-23-21°C, in Sutculer at 31-29-25-23-21-18 °C, in Yalvac at 31-29-25-23-21°C. The results of the SRCT of the cooling degree-day values calculated indicated statistically significant trends in Atabey at 29-25-23-21-18°C, in Barla at 25-23-21°C, in Isparta at 23-21-18°C, in Kasimlar at 18°C, in Senirkent at 31-29-25-23-21-18°C, in Sutculer at all selected balance temperature values, in Sarkikaraagac at 25-23-21-18°C, in Uluborlu at 29-25-23-21-18°C, in Yalvac at 29-25-23-21-18°C. According to the selected balance temperature values, the heating and cooling degree-day values calculated for each meteorological station were examined with the LRA and SRCT and it was determined that the results of the trend were parallel to each other. The studies conducted by Gultekin and Kadioglu (1996) and Kadioglu *et al*. (2001) are similar to our

findings. The heating and cooling degree-day values calculated were examined together with the latitude, longitude and elevations of the meteorological stations indicated in Table 1. It was determined that the heating degree-day value calculated at meteorological stations with a low elevation was low, the cooling degree-day value was high, and the heating degree-day value calculated at meteorological stations with a high elevation was high, and the cooling degree-day value was low.

CONCLUSIONS

The meteorological stations in Isparta province and districts (16) were selected as the study area and the long-term average daily temperature values were used. Heating and cooling degree-day values for all indoor selected balance temperatures in broiler breeding were calculated. The LRA and SRCT were conducted to identify whether there were changes depending on the climatic changes in these values. In conclusion, it was determined that there were statistically significant trends at 5% significance level in Egirdir (21°C), Isparta (31-29-25 and 23°C), Kasimlar (18°C), Senirkent (31-29-25-23 and 21°C), Sutculer (all seleceted balance temperature values) and Yalvac (31-29-25-23 and 21°C) in terms of heating degree-day values, and in Atabey (29-25-23-21 and 18°C), Barla (25-23 and 21°C), Isparta (23-21 and 18°C), Senirkent (29-25-23-21 and 18°C), Sutculer (29-25-23-21 and 18°C), Sarkikaraagac (25-23-21 and 18°C), Uluborlu (25-23-21 and 18°C) and Yalvac (25-23-21 and 18°C) in terms of cooling degree-day values. This indicated that more energy consumption would be in question in heating and cooling the animal barns to be established in Isparta province depending on the climatic change. Thus, it was determined that the users should be more careful when using the trend values to provide the optimum conditions in the planning and projecting studies of poultry housing they would conduct by using heating and cooling degree-day values.

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