RESEARCH ARTICLE

International Journal of Agriculture, Environment and Food Sciences 2022; 6(4): 694-703
DOI: https://doi.org/10.31015/jaefs.2022.4.25

The effect of temperature and relative humidity on milk yield of holstein dairy cattle raised in agricultural enterprises under different climatic conditions

Gökhan Gelir[1] • **Ali Murat Tatar**[2]

[1] Dicle University, Natural and Applied Science Institute, Animal Science, Diyarbakır, Türkiye
[2] Dicle University, Agriculture Faculty, Animal Science Department, Diyarbakır, Türkiye

Citation: Gelir, G., Tatar, A.M. (2022). The effect of temperature and relative humidity on milk yield of holstein dairy cattle raised in agricultural enterprises under different climatic conditions. International Journal of Agriculture, Environment and Food Sciences, 6 (4), 694-703

Received: 01 November 2022
Revised: 12 December 2022
Accepted: 14 December 2022
Published Online: 24 December 2022

Correspondence: Gökhan Gelir
E-mail: g.gelir.17@gmail.com

Abstract

This study was conducted to investigate the effect of air temperature and relative humidity on milk yield of the Holstein dairy cattle raised in Agricultural Enterprises under different climatic conditions in Turkey (Çukurova, Polatlı and Türkgeldi) and to examine the differences between the enterprises. Records of milk yield on the test day for the years 2014-2020 obtained from the General Directorate of Agricultural Enterprises (TİGEM) were utilised in the study. The data set related to milk yields included the number of Holstein cows, data on different lactation orders, control records of milk yield and information of the animals for some environmental factors. In the study, values of four temperature-humidity indices (THI) consisting of different combinations of daily maximum and minimum temperature and humidity values were examined in order to assess the effect of temperature stress on milk yield. Consequently, the difference between the enterprises in terms of the combinations of the temperature-humidity index was found to be statistically significant ($P<0.05$). The THI value calculated for the agricultural enterprises varied between 10 and 102. It was determined that dairy cattle were exposed to heat stress between May and November in Türkgeldi and Polatlı Agricultural Enterprises in the cold climate zone and between April and July in Çukurova Agricultural Enterprises in the temperate climate zone. While the THI value with low humidity weight was the optimal indicator in a humid climate, the THI value with high-temperature weight was the best indicator of heat stress in a semi-arid climate.

Keywords: Holstein, Heat stress, Temperature-humidity index, Milk yield, Different climatic condition

INTRODUCTION

Turkey is geographically located between the temperate zone and the subtropical zone, surrounded by seas on three sides, the extension of the mountains and the diversity of landforms allow the formation of climate types with different characteristics. While milder climate characteristics are observed in the coastal regions due to the effect of the seas, the Northern Anatolian Mountains and the Taurus Mountains do not allow the effects of the sea to flow inland and cause continental climate characteristics to be observed in the interior of Turkey. In Turkey, continental climate, Black Sea climate, Mediterranean climate and Marmara (transitional) climate are seen. More than 900 cattle breeds exist which live in almost everywhere in the world, except for the poles, and can produce meat

and milk at various levels. However, a limited number of breeds meet most of the world's milk and meat production (Anonymous, 2015). According to 2020 data, there are 1.526 million cattle worldwide. Brazil has the highest number of cattle with 218 million heads, followed by India with 194 million heads. The USA, Ethiopia, and China follow these countries respectively, and Turkey ranks 19th with approximately 19 million cattle. In addition to these data, approximately 887 million tonnes of milk were produced in the world in 2020, India ranked first with 184 million tonnes, followed by the USA with 101 million tonnes and Pakistan with 61 million tonnes. Turkey ranked 10th with 22 million tonnes (FAO, 2021). The number of cattle in Turkey was determined as 18 million 124 thousand heads according to TSI (Turkish Statistical Institute)'s 2021 data. Turkey's share of cow's milk in total milk production is 92%. Although all regions of Turkey with different climatic characteristics have areas suitable for animal husbandry, the data indicate that while the number of bovine and ovine animals is sufficient, milk production is sufficient for the domestic market. The existence of an informal economy in milk and dairy products and the postponement of milk and dairy products in consumption habits cause disadvantages in this sector. Moreover, the rise in meat prices has increased the number of animals going to slaughter (TSI, 2021). Despite the postponement of milk and dairy products that have high nutritional value and appeal to all age groups, the rise in their prices is a bitter reality. As with all living beings, the effects of environmental conditions on dairy cattle show a diverse and complex structure. In the simplest sense, care, feeding and climatic factors can be listed among those. Temperature, humidity, air movements and cleanliness of the air come to the forefront among climatic factors (Mutaf and Sönmez, 1984). Although the temperature is a climatic factor that negatively affects the performance of dairy cattle, heat stress is induced by environmental factors such as solar radiation, high air temperature and relative humidity. This becomes more intense with the cow's own body temperature. In general, the higher the milk production, the higher the heat released after digestion and metabolism of nutrients (West, 2003). Therefore, animals with high milk yields generate more heat and are more susceptible to environmental factors that produce heat stress than animals with low milk yields. In other words, such animals are at a greater risk. The way to indicate the presence of heat stress in cattle is the use of the temperature humidity index (THI). Table 1 shows the THI values for different combinations of temperature and relative humidity. THI values that exceed 72 in the table are considered as the onset of heat stress. Higher values result in a decrease in feed consumption in cattle. A value above 77 causes a sudden and sharp drop in feed intake. Some environmental modifications should be made and different feeding methods should be adopted in order to prevent this condition (West, 1995; Johnson, 1987). More recently, Zimbelman et al. (2009) documented that productivity of high-producing cows begins to be negatively affected by heat stress at temperatures of 23 °C and 35% relative humidity, with corresponds to a THI value as low as 68. Moreover, Cook et al. (2007), has documented that as the THI increases from 56 to 74, behavioral adaptations are observed. Lying time decreases from 10.9 to 7.9 h per day, standing increases from 2.6 to 4.5 h per day, and drinking increases from 0.3 to 0.5 h per day. Collectively these studies indicate that a THI of 68 is the threshold for initiation of negative outcomes on milk production, behavior, and physiology due to heat stress. Milk yield reduction and behavioural changes are the first indicators of heat stress in dairy cattle. When heat stress is moderate, dairy cattle breathe rapidly, and sweat, and their feed consumption and milk yield decrease by approximately 10% (Kadzere et al., 2002; West, 2003; Shebab-El-Deen, 2010). When the stress becomes severe, the decrease in feed consumption and milk yield is more than 25% (Yavuz and Biricik, 2009). The temperature for the comfort zone in dairy cattle ranges between -15 °C and 25 °C (NADIS, 2022). As the air temperature rises above 25 °C, heat stress emerges in animals and consequently, while dry matter consumption decreases by 2-12%, milk yield is lost by 20-30% and this loss can reach 5-12 litres per day when the air temperature exceeds 30 °C (West, 2003). It has been reported that milk yield decreases in Holstein cows when the critical temperature exceeds 25-25 °C and the THI value exceeds 72, beyond the comfort level (Johnson, 1980; Berman et al., 1985).

This study was conducted to investigate the effect of air temperature and relative humidity on the milk yield of the Holstein dairy cattle reared in TİGEM Agricultural Enterprises (Polatlı,Türkgeldi,Çukurova) and to examine the differences between the enterprises.

MATERIALS AND METHODS

The material of the study consisted of the control records of milk yield kept in Türkgeldi, Çukurova and Polatlı Agricultural Enterprises of the General Directorate of Agricultural Enterprises and meteorological records including minimum and maximum temperature values as well as minimum and maximum daily humidity values obtained from the General Directorate of Meteorology of these enterprises.

The control records of milk yield obtained from agricultural enterprises belong to Holstein cows in various lactation stages and cover the period between 01/01/2014 - 31/12/2020. A total of 17899 of milk yields on the control from 914 cows were assessed in Çukurova, 55794 from 2785 cows in Türkgeldi and 29918 from 1593 cows in Polatlı between the given dates.

Some information on the Agricultural Enterprises where the study was carried out

Table 1. Temperature-humidity index (SNI) at varying temperature and relative humidity

Temperature °C	Relative humidity%																				
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	
10	55	54	54	54	54	53	53	53	53	52	52	52	52	51	51	51	51	50	50	50	No Heat Stress
11	55	55	55	55	55	54	54	54	54	54	54	53	53	53	53	53	52	52	52	52	
12	56	56	56	56	56	56	55	55	55	55	55	55	55	54	54	54	54	54	54	54	
13	57	57	57	57	57	57	57	57	56	56	56	56	56	56	56	56	56	56	55	55	
14	58	58	58	58	58	58	58	58	58	58	58	58	58	57	57	57	57	57	57	57	
15	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	
16	60	60	60	60	60	60	60	60	60	60	60	60	60	60	61	61	61	61	61	61	
17	61	61	61	61	61	61	61	61	61	62	62	62	62	62	62	62	62	62	62	63	
18	61	62	62	62	62	62	62	63	63	63	63	63	63	63	64	64	64	64	64	64	
19	62	63	63	63	63	63	64	64	64	64	64	65	65	65	65	65	66	66	66	66	
20	63	63	64	64	64	64	65	65	65	65	66	66	66	66	67	67	67	67	68	68	
21	64	64	65	65	65	66	66	66	66	67	67	67	68	68	68	69	69	69	69	70	
22	65	65	66	66	66	67	67	67	68	68	68	69	69	69	70	70	71	71	71	72	Modarete Heat Stress
23	66	66	67	67	67	68	68	69	69	69	70	70	71	71	71	72	72	73	73	73	
24	67	67	68	68	68	69	69	70	70	71	71	72	72	72	73	73	74	74	75	75	
25	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76	77	Severe Heat Stress
26	68	69	69	70	71	71	72	72	73	73	74	74	75	76	76	77	77	78	78	79	
27	69	70	70	71	72	72	73	73	74	75	75	76	76	77	78	78	79	79	80	81	
28	70	71	71	72	73	73	74	75	75	76	77	77	78	79	79	80	80	81	82	82	
29	71	72	72	73	74	74	75	76	77	77	78	79	79	80	81	81	82	83	84	84	
30	72	73	73	74	75	76	76	77	78	79	79	80	81	82	82	83	84	85	85	86	
31	73	73	74	75	76	77	77	78	79	80	81	81	82	83	84	85	85	86	87	88	
32	74	74	75	76	77	78	79	79	80	81	82	83	84	85	85	86	87	88	89	90	Dead Cows
33	74	75	76	77	78	79	80	81	82	82	83	84	85	86	87	88	89	90	91	91	
34	75	76	77	78	79	80	81	82	83	84	85	86	87	88	88	89	90	91	92	93	
35		77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	
36	77	78	79	80	81	82	83	84	85	86	87	88	89	91	92	93	94	95	96	97	
37	78	79	80	81	82	83	84	85	87	88	89	90	91	92	93	94	95	96	98	99	
38	79	80	81	82	83	84	86	87	88	89	90	91	92	94	95	96	97	98	99	100	
39	80	81	82	83	84	85	87	88	89	90	91	93	94	95	96	97	99	100	101	102	
40	80	82	83	84	85	87	88	89	90	92	93	94	95	97	98	99	100	102	103	104	
41	81	83	84	85	86	88	89	90	92	93	94	95	97	98	99	101	102	103	105	106	
42	82	83	85	86	87	89	90	91	93	94	96	97	98	100	101	102	104	105	106	108	
43	83	84	86	87	89	90	91	93	94	95	97	98	100	101	102	104	105	107	108	109	
44	84	85	87	88	90	91	92	94	95	97	98	100	101	103	104	105	107	108	110	111	
45	85	86	88	89	91	92	94	95	97	98	100	101	103	104	106	107	109	110	112	113	
46	86	87	89	90	92	93	95	96	98	99	101	102	104	106	107	109	110	112	113	115	
47	86	88	90	91	93	94	96	98	99	101	102	104	105	107	109	110	112	113	115	117	
48	87	89	91	92	94	95	97	99	100	102	104	105	107	109	110	112	113	115	117	118	
49	88	90	91	93	95	97	98	100	102	103	105	107	108	110	112	113	115	117	119	120	
50	89	91	92	94	96	98	99	101	103	105	106	108	110	112	113	115	117	119	120	122	

SNI=(1,8 x T + 32 - [(0,55 – 0,0055 x N) x (1,8 x T – 26,8)] (Ravagnolo et al., 2000)

Çukurova Agricultural Enterprise

The Enterprise was established in 1927 as Lentil Stallion Warehouse under the Agricultural Enterprises has been operating under TİGEM since 1984. The enterprise is located in the Kadirli-Kozan Highway Adana Province. When the long-term temperature means of Çukurova Agricultural Enterprise were analysed, the highest temperature mean was 30 ^{0}C, the mean highest temperature was 34.8 ^{0}C, the average sunshine duration per day was 12.6 hours, and the highest temperature was 46.8 ^{0}C in July. The 20-year mean precipitation on cultivated crops was 612.2 mm. The cattle-raising activities are carried out with Holstein which are adapted to the region. In 2021, 2.897 tonnes of milk were produced from 1.01 cattle.

Türkgeldi Agricultural Enterprise

The enterprise was established in 1938 under the name of State Seed and Sample Farm, carried out activities as State Production Farm in 1950 and has been operating under TİGEM since 1984. The enterprise is located within the borders of Lüleburgaz in Kırklareli Province, 9 km away from the district and 65 km away from the provincial centre. The 20-year mean precipitation on cultivated crops is 383.3 mm. The cattle-raising activities are carried out with Holstein and Simmental breeds which are adapted to the region. In 2021, 6,675 tonnes of milk were produced from 2.192 cattle.

Polatlı Agricultural Enterprise

The enterprise was established in 1937 under the name of Polatlı Group, carried out activities as State Production Farm in 1950 and has been operating under TİGEM since 1984. The enterprise is located in the Upper Sakarya section of the Central Anatolia Region, within the borders of Polatlı District and 54 km south of the district. The geographical location is at GPS coordinates 39° 8′ 57″ North and 32° 7′ 20″ East. The mean annual rainfall is 360 mm. The mean highest temperature is 29.6 °C (July) and the mean lowest temperature is -3.6 °C (January).

In the study, the maximum and minimum temperature and humidity values were used to calculate the THI value in four combinations. Maximum temperature and maximum humidity (THIa), minimum temperature and minimum humidity (THIb), maximum temperature and minimum humidity (THIc) and minimum temperature and maximum humidity (THId) values were calculated by using the following equation (NRC, 1971).

SNI=(1,8 x T + 32(- [(0,55 – 0,0055 x N) x (1,8 x T – 26,8)]

SNI : Temperature humidity index,

T : Air temperature measured with a dry thermometer (°C),

N : It expresses the relative (relative) humidity in the air (%).

In the study, the model created for the data set consisting of the values related to THI types of the day that precedes the control day (Ravagnolo et al., 2000) and calculated by the equation above and the information related to fixed effects such as milk yield value, lactation order, month and year for each control day are given below to calculate the effect that would be caused by the temperature and relative humidity conditions one day before the control day of the milk yield of the cows in the enterprises.

$Y_{ijklm}=\mu+\alpha_i+\beta_j+\gamma_k+SNI_i+e_{ijklm}$

Y_{ijklm}= I. during lactation, j. per year, k. per month, l. m at the SNI level, milk yield on the control day,

μ = Control milk yield average,

α_i= I. the effect of lactation order,

B_j = Effect of the year,

γ_k= k. Effect of the month,

[THI] _l= l. Effect of SNI level (SNIa, SNIb, SNIc, SNId)

eijklm= i. during lactation, j. year, n. month, l. m at the SNI level. refers to the effect of random environmental factors on the control day.

Milk loss =0.0695 (SNImak-SNIthreshold)2 x D

D: It represents the ratio of the total stress duration to 24 hours during the day (at SNImax > SNIthreshold). For dairy cattle in this equation, the SNI threshold value was taken as 72.

Statistical analyses were done as GLM using the IBM SPSS Statistics for Windows, Version 25.0. Tukey's test was used to compare the means.

RESULT AND DISCUSSIONS

Table 2 shows the maximum and minimum temperature and humidity values determined in the agricultural enterprises throughout the study.

Table 3 presents the descriptive statistics of the control

Table 2. Maximum temperature and humidity values determined during the working period of agricultural enterprises

Enterprisees	Max. Temprature	Min. Temprature	Max. Humidity	Min. Humidity
Çukurova Agricultural Enterprise	47,4 (19.07.2019)	-7,8 (3.01.2016)	100 (9-15.04.2018)	0 (19.04.2018)
Polatlı Agricultural Enterprise	38,6 (3.07.2017)	-19,1 (9.01.2015)	100 (January– July 2014, 2017-2019)	5 (23.09.2018)
Türkgeldi Agricultural Enterprise	39,8 (1.07.2017)	-16,7 (13.01.2017)	100 (January 2014-Agust 2018)	0 (13.09.2018)

Table 3. Descriptive statistics on records kept in agricultural holdings

	Çukurova			Türkgeldi			Polatlı			
Lactation Order	**N**	**Milk Yield (kg)**	**Std. Err**	**N**	**Milk Yield (kg)**	**Std. Err**	**N**	**Milk Yield (kg)**	**Std. Err**	**Average Milk Yield (kg)**
1	8551	23,15	0,086	23360	22,19	0,049	13030	24,14	0,060	22,94±0,035^{b}
2	5036	26,92	0,157	17615	24,60	0,074	8911	26,48	0,093	25,50±0,055^{a}
3	2750	25,82	0,205	9100	24,86	0,114	4748	26,92	0,138	25,61±0,082^{a}
4	1154	24,44	0,341	3793	24,41	0,183	2068	26,49	0,200	25,03±0,128^{a}
5	306	23,19	0,450	1440	22,29	0,286	819	25,02	0,324	23,27±0,200^{b}
6	84	21,35	0,911	417	20,49	0,460	247	24,54	0,557	21,92±0,338^{c}
7	18	25,51	1,433	69	19,47	0,972	95	22,79	1,015	21,80±0,674^{c}
Year										
2014	1610	19,76	0,155	5488	22,96	0,112	2388	22,24	0,148	22,24±0,080^{f}
2015	2481	24,38	0,143	6128	24,03	0,110	3115	26,51	0,129	24,76±0,074^{c}
2016	2429	29,14	0,167	5793	27,50	0,132	3653	25,98	0,121	27,36±0,082^{a}
2017	2860	29,59	0,197	7662	25,44	0,108	4358	24,03	0,118	25,83±0,077^{b}
2018	2452	28,03	0,257	10021	23,01	0,091	4959	25,68	0,114	24,48±0,073^{d}
2019	2746	20,79	0,158	10504	22,42	0,092	5079	25,62	0,125	23,06±0,068^{e}
2020	3321	20,63	0,131	10198	21,47	0,090	6366	26,55	0,114	22,96±0,065^{e}
Month										
January	1511	26,31	0,261	4650	22,41	0,138	2351	25,48	0,165	23,95±0,101
February	1585	26,25	0,264	4576	23,08	0,139	2210	25,94	0,168	24,44±0,102^{c}
March	1609	26,35	0,271	4053	23,85	0,153	2455	26,17	0,169	25,05±0,107^{b}
April	1663	27,26	0,254	4496	24,27	0,141	2311	26,40	0,167	25,44±0,102^{a}
May	1597	26,62	0,251	5220	24,88	0,130	2279	25,28	0,178	25,28±0,097^{ab}
June	1533	25,94	0,240	4396	25,05	0,138	2376	25,41	0,170	25,32±0,098^{ab}
July	1424	23,48	0,211	4823	23,97	0,127	2458	25,08	0,166	24,20±0,091^{cd}
August	1293	21,46	0,213	4873	22,91	0,128	2674	24,95	0,163	23,32±0,093^{gh}
September	1332	21,43	0,242	4783	22,69	0,129	2781	24,73	0,164	23,14±0,094^{h}
October	1255	22,23	0,252	3817	23,22	0,151	2809	26,21	0,164	24,13±0,103^{d}
November	1506	22,27	0,239	5147	23,05	0,129	2744	25,32	0,146	23,59±0,092^{fg}
December	1591	24,82	0,243	4960	22,96	0,143	2470	24,75	0,160	23,78±0,100^{ef}
General	17899	24,695±0,073^{b}		55794	23,525±0,040^{c}		29918	25,463±0,048^{a}		

records of the milk yields that were kept in the agricultural enterprises by lactation order, control month and year.

In table 3, the difference between the agricultural enterprises in terms of milk yield on the control day was significant (P<0.01). Accordingly, the highest mean was found in Polatlı Agricultural Enterprise (25.4630.048), followed by Çukurova (24.6950.073) and Türkgeldi Agricultural Enterprises (23.525).

The difference between the enterprises in terms of lactation order, control month and the year was found to be statistically significant (P<0.01). In terms of lactation order, the highest mean values were found in Polatlı (over 26 litres) and Türkgeldi (over 24 litres) in the 2nd-4th lactation, while Çukurova (over 25 litres) was found in the 2-3th lactation.

As for the year, the highest milk yield means on the control day were determined in Çukurova (29.5910.52) in 2017, in Türkgeldi (27.5010.04) in 2016 and in Polatlı (26.559.06) in 2020.

As for the month in which the study was conducted, the highest mean milk yield on the control day was determined in April in Çukurova (27.2610.35), in June in Türkgeldi (25.059.12) and in April in Polatlı (26.408.02).

Table 4 shows the least mean squares and standard deviation values calculated for the milk yield on the control day according to different THI (a, b, c, d) values of the enterprises. The tables indicated that although they varied in terms of enterprises, the THIa values obtained by using

Table 4. The least squares averages and standard errors of control milk yields according to different types of THI values in Çukurova Agricultural Enterprise

THIa	Controls Num	Controls MY	STD Err	THIb	Controls Num	Controls MY	STD Err	THIc	Controls Num	Controls MY	STD Err	THId	Controls Num	Controls MY	STD Err
48	11183	25,31	0,098	40	176	23,31	0,532	50	11359	25,28	0,097	35	166	19,12	0,480
50	176	23,31	0,532	41	166	19,12	0,480	55	175	21,77	0,500	38	3685	24,51	0,162
55	270	21,34	0,377	43	11183	25,31	0,098	56	143	21,34	0,674	40	11359	25,28	0,097
56	143	21,34	0,674	45	107	19,22	0,623	57	95	20,54	0,542	42	95	20,54	0,542
62	3744	24,42	0,160	46	3578	24,66	0,165	61	3851	24,27	0,157	45	100	22,12	0,694
63	107	19,22	0,623	47	143	21,34	0,674	63	100	22,12	0,694	46	186	22,64	0,506
66	299	22,54	0,416	49	469	21,93	0,311	64	199	22,75	0,519	47	545	23,81	0,323
68	186	22,64	0,506	50	286	22,46	0,408	65	186	22,64	0,506	49	175	21,77	0,500
70	190	24,96	0,408	51	203	26,60	0,451	68	190	24,96	0,408	51	110	21,03	0,468
73	50	17,98	1,052	54	110	21,03	0,468	70	50	17,98	1,052	53	137	22,31	0,654
77	367	23,46	0,377	55	187	21,16	0,572	71	504	23,15	0,328	55	50	17,98	1,052
78	137	22,31	0,654	57	244	23,11	0,448	76	183	24,36	0,333	56	244	23,11	0,448
82	136	25,33	0,767	61	309	25,80	0,323	77	136	25,33	0,767	62	309	25,80	0,323
83	183	24,36	0,333	64	250	22,83	0,520	78	240	24,07	0,482	65	136	25,33	0,767
87	114	19,85	0,569	66	132	19,79	0,414	82	132	19,79	0,414	66	114	19,85	0,569
92	258	23,74	0,434	68	51	17,09	0,874	84	135	18,19	0,429	69	132	19,79	0,414
93	305	23,54	0,384	72	135	18,19	0,429	85	221	25,32	0,450	71	51	17,09	0,874
95	51	17,09	0,874	74	170	27,78	0,345					77	135	18,19	0,429
												79	170	27,78	0,345

the maximum temperature and maximum relative humidity values ranged between 30-102; however, fluctuations in the values related to milk yield ranged between 37-75. When the THIa value exceeds 75, the milk yield began to decrease, but it tends to raise slightly above 87. In this range, milk yield dropped from 29.65±0.535 kg to 22.84±0.154 kg with a loss of 6.81 kg milk yield ($P<0.01$). Also, the point where the drop in milk yield began was 75 instead of 72, the critical value.

Decreases in milk yield due to heat stress

It was determined that the milk yield decreased at Çukurova in the range of 70-82 when THIa was used and the number of days within this range was 123-183 days, the THIa value decreased at Türkgeldi in the range of 75-84. The number of days within this range was 61-214 days although it varied over the years. The THIa value decreased at Polatlı in the range of 71-82 and the number of days within this range was 122-183 days although it varied over the years.

If the mean THIa value in the range of 70-82 at Çukurova Agricultural Enterprise is accepted as 76, the difference between this value and 70, the critical value, at which the milk yield begins to decrease is 6 units, and since this value was exceeded for 123-183 days, the animals were exposed to heat stress. When the THIa value was 70, the mean control milk yield was 24.96±5.62 kg and the mean control milk yield which corresponds to the mean THIa value was 23.46±7.23 kg and the difference was 1.50 kg. Based on this, it is possible to conclude that the mean

Table 5. The least squares averages and standard deviations of milk yields according to different types of THI values in Türkgeldi Agricultural Enterprise

THIa	Controls Num	Controls MY	STD Err	THIb	Controls Num	Controls MY	STD Err	THIc	Controls Num	Controls MY	STD Err	THId	Controls Num	Controls MY	STD Err
30	362	24,46	0,543	15	362	24,46	0,543	33	362	24,46	0,543	10	362	24,46	0,543
35	899	25,36	0,331	27	512	25,90	0,432	39	899	25,36	0,331	15	452	25,76	0,466
37	452	25,76	0,466	28	400	25,95	0,528	43	1003	24,15	0,266	17	400	25,95	0,528
38	671	24,56	0,332	30	452	25,76	0,466	44	452	25,76	0,466	22	512	25,90	0,432
42	1017	21,57	0,269	31	685	20,71	0,332	46	1021	21,41	0,267	24	671	24,56	0,332
43	400	25,95	0,528	32	387	24,63	0,514	47	400	25,95	0,528	25	685	20,71	0,332
45	336	22,83	0,438	33	671	24,56	0,332	48	979	22,41	0,295	27	387	24,63	0,514
47	979	22,41	0,295	34	687	22,20	0,329	49	1505	20,72	0,237	28	136	26,90	1,065
48	2282	20,42	0,190	35	1016	24,37	0,267	50	794	20,30	0,339	29	1164	26,12	0,277
50	794	20,30	0,339	37	1802	21,00	0,223	51	777	19,83	0,317	30	684	24,87	0,333
52	384	23,43	0,475	38	633	20,64	0,342	53	741	24,02	0,320	31	2770	21,55	0,173
53	357	24,65	0,423	39	2275	22,76	0,199	55	302	26,80	0,553	32	332	23,33	0,441
54	994	25,90	0,295	40	2079	24,21	0,215	56	1379	23,86	0,243	33	1709	21,97	0,233
56	1377	21,97	0,241	42	396	23,49	0,382	57	690	21,73	0,353	34	396	23,49	0,382
57	633	20,64	0,342	43	1594	21,27	0,223	58	633	20,64	0,342	36	783	20,73	0,329
58	472	27,00	0,454	44	883	27,67	0,330	59	2670	24,28	0,184	37	809	19,81	0,298
59	1603	22,95	0,230	45	1918	24,00	0,215	60	1785	23,32	0,221	38	11978	23,72	0,086
60	1427	23,53	0,241	46	13095	23,36	0,082	61	11970	23,28	0,086	39	1410	22,22	0,237
61	953	24,52	0,320	47	1421	24,59	0,247	62	684	22,11	0,358	40	1376	23,32	0,258
62	11970	23,28	0,086	48	1008	24,93	0,314	63	981	25,35	0,326	41	481	28,68	0,481
63	684	22,11	0,358	49	669	20,62	0,321	64	876	24,70	0,319	42	1896	24,08	0,210
65	1857	25,05	0,229	50	2300	25,22	0,183	65	1408	24,32	0,247	43	1316	25,87	0,279
67	1619	23,91	0,244	51	2162	24,49	0,208	66	1088	25,37	0,307	44	1026	22,02	0,263
68	481	28,77	0,442	52	1133	24,74	0,251	67	2729	24,79	0,181	45	1497	21,81	0,235
69	1707	23,37	0,211	53	1473	23,96	0,241	68	681	23,44	0,324	46	928	25,63	0,280
70	396	23,49	0,382	55	1085	24,71	0,250	69	1368	24,35	0,251	47	641	27,08	0,402
71	1712	25,58	0,248	56	1798	24,22	0,238	70	412	24,47	0,386	48	2920	25,05	0,163
72	681	23,44	0,324	57	1803	23,34	0,221	71	2164	25,09	0,214	49	819	21,09	0,318
74	1090	25,11	0,248	58	2713	22,97	0,171	72	287	25,86	0,477	50	634	25,77	0,376
75	381	29,65	0,535	59	766	24,13	0,342	73	974	21,17	0,296	51	839	22,60	0,306
76	1783	24,11	0,227	60	2419	22,34	0,189	75	898	24,28	0,294	53	1085	24,71	0,250
77	664	20,15	0,327	61	1659	23,58	0,228	76	2786	23,68	0,167	55	1798	24,22	0,238
79	287	25,86	0,477	62	691	25,51	0,336	78	2383	23,74	0,188	56	1113	23,42	0,269
80	1011	21,79	0,294	63	1363	20,08	0,222	79	999	24,09	0,300	57	1671	24,08	0,235
81	656	23,20	0,361	64	1484	24,26	0,215	80	713	25,26	0,346	58	1732	22,00	0,206
84	568	23,20	0,361					81	2872	21,34	0,154	59	432	22,31	0,364
85	982	24,60	0,307					82	1771	24,05	0,223	60	1702	22,92	0,231
86	1796	23,99	0,196					83	667	23,04	0,346	61	1051	22,72	0,302
87	2111	22,47	0,197					85	691	25,51	0,336	62	1011	23,54	0,304
88	776	21,87	0,243									63	1339	24,60	0,241
89	634	25,77	0,376									64	707	20,96	0,326
90	708	26,88	0,337									65	1106	19,91	0,217
91	656	19,13	0,296									66	1034	25,67	0,267
92	1361	23,10	0,241												
93	667	23,04	0,346												
94	1473	24,49	0,253												
102	691	25,51	0,336												

Table 6. The least squares averages and standard deviations of milk yields according to different types of SNI values in Polatlı Agricultural Enterprise

THIa	Controls Num	Controls MY	STD Err	THIb	Controls Num	Controls MY	STD Err	THIc	Controls Num	Controls MY	STD Err	THId	Controls Num	Controls MY	STD Err
38	262	23,42	0,394	30	258	24,68	0,476	40	446	25,58	0,292	21	132	23,09	0,602
39	184	28,65	0,317	31	609	27,03	0,278	41	425	26,33	0,370	23	292	27,31	0,418
40	1166	25,67	0,251	32	262	23,42	0,394	43	440	23,68	0,466	24	301	27,63	0,423
41	474	23,71	0,451	33	132	23,09	0,602	44	258	24,68	0,476	26	258	24,68	0,476
42	258	24,68	0,476	34	1192	25,23	0,253	45	1192	25,23	0,253	28	474	23,71	0,451
44	248	20,75	0,507	36	732	25,13	0,332	46	248	20,75	0,507	29	793	23,62	0,263
45	417	25,21	0,388	37	248	20,75	0,507	48	370	29,55	0,357	30	425	26,33	0,370
46	560	23,83	0,320	39	767	26,13	0,292	49	428	24,06	0,375	31	692	23,00	0,339
47	370	29,55	0,357	40	370	29,55	0,357	50	132	23,09	0,602	33	1454	25,98	0,213
50	623	27,53	0,296	41	750	23,09	0,276	51	734	26,11	0,266	35	248	20,75	0,507
51	403	24,80	0,327	42	853	25,66	0,277	53	292	27,31	0,418	36	998	27,51	0,245
53	777	26,52	0,293	43	667	27,40	0,302	54	364	28,03	0,434	37	1721	26,00	0,193
55	919	24,62	0,278	44	916	24,79	0,247	55	413	25,19	0,387	40	1578	25,01	0,191
56	642	24,58	0,308	45	1076	24,34	0,233	56	1214	25,61	0,227	41	726	28,49	0,250
57	1562	26,47	0,203	46	1182	25,62	0,243	57	897	23,11	0,249	42	1189	26,61	0,216
58	293	22,98	0,338	47	739	27,86	0,287	58	1305	26,57	0,225	43	452	26,11	0,317
59	910	25,49	0,262	48	2154	26,56	0,155	59	910	25,49	0,262	44	601	24,97	0,321
60	628	25,30	0,325	49	509	27,86	0,436	60	1047	25,47	0,253	45	691	24,94	0,268
61	419	25,72	0,404	50	580	25,40	0,307	61	562	25,42	0,299	46	1204	25,83	0,264
63	1760	26,30	0,198	51	1043	23,63	0,244	62	1633	26,40	0,219	48	182	21,32	0,486
64	435	25,54	0,432	52	1188	26,45	0,256	63	599	24,99	0,303	49	471	27,23	0,398
65	599	24,99	0,303	53	557	27,10	0,293	64	505	26,12	0,415	50	1345	25,63	0,233
66	505	26,12	0,415	54	1655	24,98	0,183	65	576	23,46	0,301	51	972	25,81	0,214
67	394	23,56	0,379	55	376	23,63	0,475	66	1391	26,78	0,191	52	598	26,02	0,322
68	341	26,66	0,356	56	2301	24,87	0,173	68	1370	27,02	0,264	53	376	23,63	0,475
69	634	25,29	0,270	57	813	25,07	0,312	69	1199	25,20	0,266	54	1629	24,92	0,194
70	200	29,27	0,536	58	1871	26,26	0,199	70	666	24,44	0,280	55	961	24,40	0,283
71	1078	28,49	0,263	59	2467	25,34	0,176	71	1898	24,95	0,188	56	780	25,57	0,322
72	477	26,65	0,480	60	1719	25,19	0,219	72	1242	25,96	0,252	57	386	24,35	0,397
73	1156	25,53	0,259	61	503	23,08	0,336	73	1677	26,50	0,203	58	2153	26,15	0,181
74	609	22,60	0,344	62	607	27,45	0,357	74	886	23,40	0,270	59	1054	24,78	0,255
76	784	25,69	0,283	63	822	23,89	0,275	75	1538	24,48	0,203	60	2302	25,43	0,193
77	1074	25,56	0,231					76	1167	25,18	0,241	61	548	25,54	0,401
78	1334	24,79	0,235					77	1894	24,92	0,187	62	503	23,08	0,336
79	794	25,59	0,320									64	607	27,45	0,357
81	711	23,11	0,331									65	496	23,56	0,393
82	2304	25,31	0,169									66	326	24,39	0,348
85	427	25,72	0,471												
86	326	24,39	0,348												
87	967	23,98	0,261												
88	1127	26,35	0,232												
89	264	27,16	0,457												
92	503	23,08	0,336												

milk yield loss per cow may range between 1884-3353 kg per year. In other words, as each unit increases from 73, which is the critical value, to 81 it means 1.67 kg milk loss per animal. Similarly, the mean milk yield loss per cow in Türkgeldi and Polatlı Agricultural enterprises ranges between 1030-1601 kg and 476-1408 kg, per year, respectively.

Many studies done around the world support us; investigated the effect of heat stress on milk yield on the daily milk test records (33600) of Holstein cows in Egyptian conditions, in a study where the THI value reached the critical threshold of 79 and a daily milk yield of approximately 14.20%. found a decrease (Nasr and El-Tarabany, 2017). In another study found that the negative effect of heat stress on milk yield in Holstein cows raised in the Marmara region could be noticed at THI 65, but after THI 70, milk yield decreased irreversibly (Duru et al., 2018). In their study with 23,296 thousand brown Swiss cows in Italy between 2009 and 2018, determined that THI values greater than 74 were accepted as the beginning of heat stress in milk yield. In addition, they stated that for a unit change in the THI, 0.39 kg decrease occurred in the milk yield of each cow (Maggiolino et al., 2020)

It was determined that milk yield losses per animal were 712, 735, and 740 kg for THIb, 592, 861, and 1848 kg for THIc and 363, 340, and 441 kg for THId in the same order in Çukurova, Polatlı, Türkgeldi, respectively.

CONCLUSION

Milk losses that may result from heat stress in enterprises are highly significant. When the annual milk yield loss per animal in all enterprises was considered, the lowest loss was observed at the THId value.

The results of the research enable dairy cattle breeders to take the necessary precautions by keeping in mind the critical periods that the study considered. It is important for the breeders to pay attention to the steps from the shelter type to the content of the ration (energy, protein) and the use of showers and fans to cool the animals.

As global warming, which has recently attracted attention and made its effects stronger each passing day, will increase in the future, the importance of developing genotypes resistant to heat stress in livestock as well as in plant products in agriculture and considering them as selection criterion raises.

Therefore, the inclusion of THI as a selection criterion in a selection index is recommended, especially for dairy cattle raised in hot environments in which profitability may continue to deteriorate over time.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest

The authors declared that for this research article, they have no actual, potential or perceived conflict of interest.

Author contribution

The contribution of the authors to the present study is equal. All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

Ethical approval

Ethics committee approval is not required.

Funding

No financial support was received for this study.

Data availability

Not applicable.

Consent for publication

Not applicable.

REFERENCES

Anonymous, (2015). TMMO Ziraat Mühendisleri Odası. (in Turkish). [URL]

Berman A., Folman Y., Kaim M., Mamen M., Herz Z., Wolfenson D., ArieliA., Graber Y. (1985). Upper critical temperatures and forced ventilation effects for high yielding dairy cows in a subtropical climate, J. Dairy Sci. 68 1488–1495. [CrossRef]

Cook, N., Mentink, R., Bennett, T. ve Burgi, K. (2007). Isı stresi ve topallığın emziren süt ineklerinin zaman bütçeleri üzerindeki etkisi, J. Dairy Sci., 90, 1674–1682, 2007. (in Turkish) [CrossRef]

Duru,S. (2018). Bursa İli Holştayn İneklerde Günlük Süt Veriminde Isı Stresinin Başlangıç Düzeyinin Belirlenmesi , 65 , Ankara Üniv Vet Fak Derg, s. 193 – 198. (İn Turkish) [CrossRef]

FAO, (2021). Food and Agriculture Organization of the United Nations. [URL]

Johnson H.D. (1980). Environmental management of cattle to minimize the stress of climate changes, Int. J. Biometeor. 24 (Suppl. 7, Part 2) 65–78.

Johnson, H.D. (1987). Bioclimatology and the Adaptation of Livesstock, World Animal Science B5: 279

Kadzare, C. T., Murphy, M. R., Silanikove, N., Maltz, E. (2002). Heat stress in lactating dairy cows: a review.Livestock Production Sci. 77:59-91. [CrossRef]

Maggiolino A, Dahl GE, Bartolomeo N, Bernabucci U, Vitali A, Serio G, Cassandro M, Centoducati G, Santus E, De Palo P. (2020). Estimation of maximum thermo-hygrometric index thresholds affecting milk production in Italian Brown Swiss cattle. Journal of Dairy Science 103:8541-8553. [CrossRef]

Mutaf, S., Sonmez, R. (1984). Climatic environment and control in animal shelters. Aegean. Univ. Faculty of Agriculture Publications. Publication No: 438. Izmir

NADIS, (2022). National Animal Disease Information Service. Managing Heat Stres İn Dairy Cows. [URL]

Nasr, M.A.F. and El-Tarabany, M. S. (2017). Impact of three thı

levels on somatic cell count, mik yield and composition of multiparous holstein cows in a subtropical region. Journal of Thermal Biology, 64: 73-77. [CrossRef]

Ravagnolo O, Misztal I (2000) Genetic component of heat stress in dairy cattle, parameter estimation. Journal of Dairy Science 83: 2126-2130. [CrossRef]

Shehab-El-Deen, M.A.M.M., Leroy, J.L.M.R., Fadel, M.S., Saleh, S.Y.A., Maes, D., Van Soom, A. (2010). Biochemical changes in th follicular fluid of the dominant follicle of high producing dairy cows exposed to heat stress early post-partum. Anim Reprod Sci. 117: 189-200. [CrossRef]

SPSS, (2017). SPSS for Windows, Version 25.0, SPSS Inc. Chicago.

TUİK, (2021). Turkish Statistical Enstitute. [URL]

West, J.W. (2003). Effect of heat-stress on production in dairy cattle. J.Dairy Sci. 86: 2131-2144. [CrossRef]

Yavuz, H.M., Biricik, H. (2009). Süt sığırlarının sıcak stresinde beslenmesi. Uludağ Univ. J.Fac. Vet. Med.28 :1-7. (in Turkish). [Google Scholar]

Zimbleman, RB, Rhoads, RP, Rhoads, ML, Duff, GC, Baumgard, LH, Collier, R.J. (2009). A re-valuation of the impact of temperature humidity index (THI) and black globe humidity index (BGHI) on milk production in high producing dairy cows. Proceedings of the 24th Annual Southwest Nutrition and Management Conference, pp. 158–168.