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Seasonal and Annual Changes of Some Climate Factors in Different Areas of Loose Dairy Cattle Barns

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ABSTRACT

This study was conducted to determine the changes of some climatic factors throughout the year in different barn areas in a loose system dairy cattle shelter. For this, digital temperature-humidity meters were placed on different shelter areas, and measurements were made for a year. By developing a different and new model as well as the maximum, minimum and average values in a certain time period in five different areas of the shelter, the temperature and humidity values were categorized into specific groups (stressful, slightly stressful, suitable, etc.) and it was determined how long the animals were exposed to what temperature and humidity values. According to the results, the animals were exposed to temperatures between 5-25 °C for approximately 80% of their time in the spring and autumn seasons, 40% in the winter season, and 50-55% in the summer season. At optimum temperatures (10-20 °C), the animals spent approximately 50% of their total time in spring and autumn, 20% in summer, and 15% in winter. Animals were exposed to heat stress (ti≥32 °C) for only 5-7% of their total time in summer and to cold stress (ti <-5 °C) for only 6-14% of the time in winter. Dairy cattle were found to spend 60% of their annual total time in the appropriate temperature range and approximately 33% of the annual time in the optimum temperature range. Animals were exposed to heat stress and cold stress for about 6-7% and 2-3%, respectively of their total time per year. Animals were exposed to the relative humidity in the range of 40-90%, for approximately 50-60% of their total time throughout the year. According to the results of the research, it was determined that open system shelters planned to protect animals from cold in winter and heat in summer, not create a significant climatic stress on animals.

1. Introduction

The main purpose in planning dairy cattle shelters having a very important place in milk production, is to protect animals from poor environmental conditions or to create a suitable and comfortable habitat. To increase the yield per animal, to start with, stress factors in the living environment must be controlled. Sahin & Ugurlu (2017) reported the stress factors causing low productivity in dairy cattle were as structural, climatic and social. Climatic environmental conditions having an important effect on the metabolic and physiological activities of animals can turn into stress factors due to the tension on the organism. Environmental conditions include temperature, air speed, relative humidity, solar radiation and light (Sahin et al 2019). Undesirable temperature is an important factor causing low milk production by dairy cattle, particularly of high genetic value (Nardone et al 2010).

The air surrounding the animal has an important effect on the regulation of body temperature as it affects the heat dissipation and heat gain between the animal and its environment. For example, dairy cattle lose more heat from their bodies in the winter months and try to balance their body temperature by converting some of consumed feed to heat energy to maintain the heat balance in their bodies. However, they convert more nutrients into heat to maintain their body temperature at low temperatures, and this case is defined as cold stress. High yield losses may be observed depending on the food intake of the animal. In hot summers, sensible heat dissipation decreases in animals. The animal tries to dissipate latent heat to expel excess heat accumulated in its body. As a result of these events, the animal to enters the heat stress. During this period, the animal's feed consumption decreases, and consequently, there is notable

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yield loss. The optimum temperature range for adult dairy cattle's is 10-20 °C (Sainsbury & Sainsbury 1988; Webster 1994). Temperatures in the range -6 °C and 25 °C (Sainsbury & Sainsbury 1988), -5 °C to 25 °C (Knížková et al 2002), and -0.5 °C to 20 °C (Herbut & Angrecka 2012) exerts little effect on the performance of dairy cattle.

The range of suitable temperature is wider than the optimum temperature, and at the appropriate temperature below and above optimum temperatures, animals do not face any stress factors as they can easily achieve body heat balance by increasing heat production or heat dissipation. There is generally a negative and significant correlation between milk production and climatic factors and for maximum milk yield, the appropriate temperature range needs to be between 7 °C and 25 °C (Shinde & Taneja, 1986). The suitable temperature range for dairy cattle in lactation is 5-25 °C (Roenfeldt 1998). Temperatures in the range of 10–22 °C and relative humidity values between 50–90% were found to be suitable for animals and had no negative effects on animals (Vtoryi et al. 2018).

With the reduction in temperature difference between the animal and its environment, the temperature at, which sensible heat emission from the body decreases and becomes difficult can be defined as the maximum temperature. When the issue of excessive heat starts to occur in the living body, the animal enters the live heat stress, and its efficiency reduces as the degree of heat stress increases. According to Kadzere et al (2002), if the animals are unable to discharge excess heat accumulated in their bodies through latent heat dissipation, their body temperature increases, and uncontrolled situation, they may die from hyperthermia. The upper critical temperature for dairy cattle is 25-26 °C regardless of milk production or previous climate adaptation, and a slight decrease in feed intake and milk yield can be observed at these temperatures (Berman et al 1985; NRC 1989; Keown & Grant 1997; West 2003), while milk yield decreases at temperatures above 30 °C (NRC 1981; NRC 1989). Kume et al (1998) reported that 25 °C is a high temperature for lactating dairy cattle, and when the relative humidity is greater than 80%, it affects the temperature. Brouček et al (2009) observed that the critical maximum temperature for cows is 24-27 °C. When the environmental temperature rises above 26 °C, dairy cattle reach a point where they cannot cool themselves sufficiently for a long time, and heat stress begins (Kadzere et al 2002). If the temperature exceeds 27 °C, the optimum production range is exceeded (Brouček 1997; Novák et al 2000). When the environmental temperature rises to the upper critical temperature (27-28 °C), the feeding status and energy balance of the animals deteriorate (Gaafar et al 2011). Heat stress causes a decrease in milk yield in dairy cattle. The yield decreases by 10% at a temperature of 27-32 °C and relative humidity of 50-90%, and decreases by more 25% at a temperature of 32-38 °C and relative humidity of 50-90% (OACC 2014). The level of heat stress strongly depends on daily fluctuations in average temperature, and if the temperature drops below 21 °C for 3-6 hours at night, the animal has sufficient opportunity to lose the excess heat gained from the previous day (Igono et al 1992; Muller & Botha 1994). The temperature at, which the lost heat from the body begins to increase, the animal performs intensive metabolic activities to maintain body heat balance, and at the minum temperature, the yield losses are inevitable due to cold stress. According to WMO (1989), the lowest critical temperature for dairy cattle is -15 °C, while according to FAO (2016), it is -10 °C unless there are very sudden temperature fluctuations.

In this study, seasonal temperature and humidity changes were analyzed in a free dairy shelter planned as an alternative design. Especially for the open system shelter, it has been tried to determine how the temperature and relative humidity change in different building areas and how much of their total time annual the animals spend in which temperature-humidity range. The climatic comfort performance of open-free system shelters was also researched.

2. Materials and Methods

This research was carried out in the commercial dairy cattle barn planned as a combination of micro-structure systems in Konya, Turkey (Ugurlu & Uzal, 2010). The shelter has a total capacity of 140 heads, including 54 dairy cows, 15 dry period, 20 heifers, 15 calves and 14 beef cattle (Table 1). In the semi-open free shelter as an alternative design, from 1 September 2015 to 1 September 2016 to analyze the monthly, seasonal and annual temperature and humidity changes, in certain shelter sections (two in the resting areas, one in the courtyard, one in the feeding area and one in the outdoor area) electronic temperature-humidity measurement devices with hourly measuring were installed 2m above ground. Properties of the devices used for measurements; included 1. Temperature: measurement range was between -40 and 100 °C, with a resolutin of 0.03 °C and sensitivity of 0.33 °C. 2. Relative humidity: the measurement range was 0-100%, with a resolution of 0.4% and sensitivity of ± 3%. The perspective view and floor plan of the shelter where the research was conducted, and the locations of temperature-humidity meters are presented in Figure 1 and Figure 2.

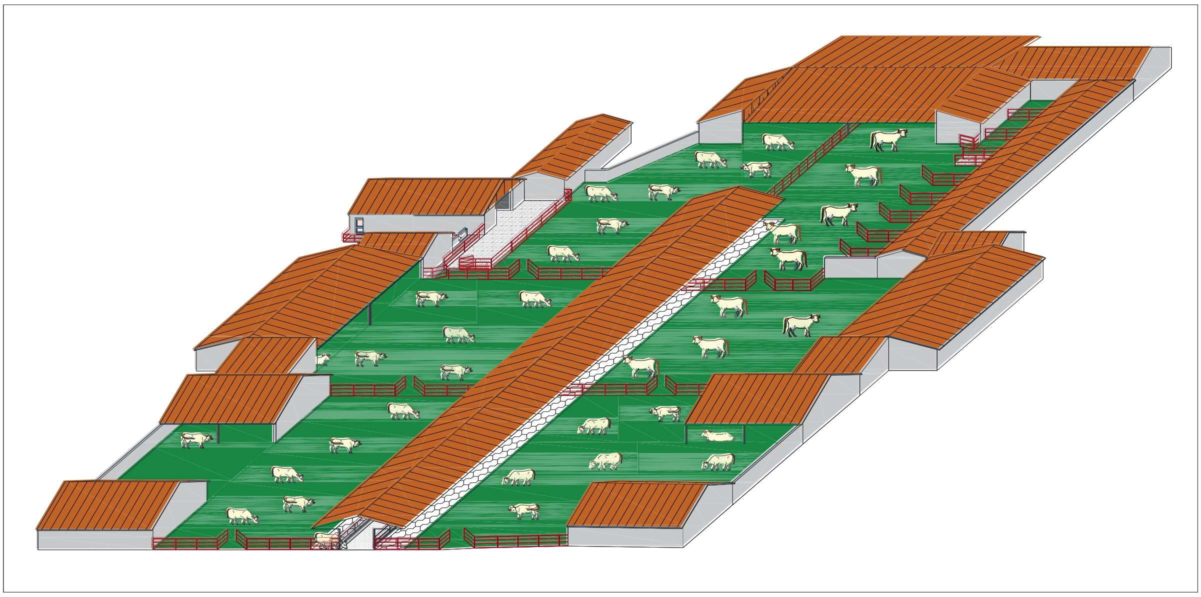

Figure 1
Perspective view of the free system dairy cattle shelter

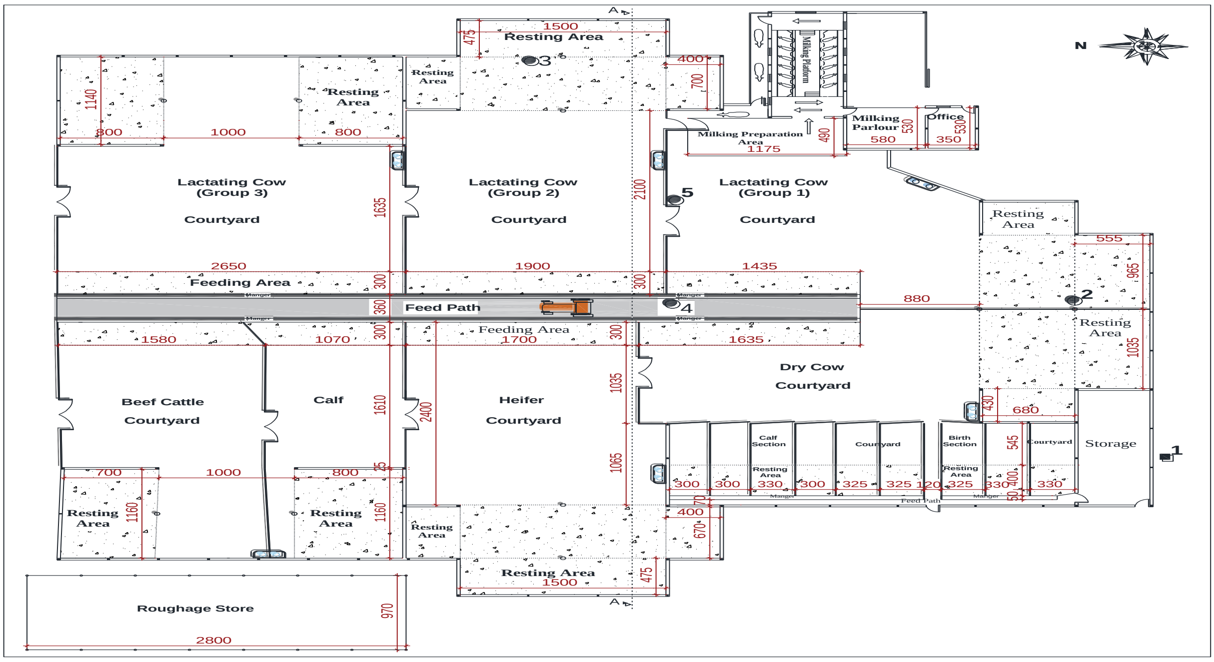

Figure 2
Floor plan of the shelter and layout of devices of loose housing system (•; Climatic measurement points inside the shelter, ■; Out of shelter climatic measurement point

In this study, apart from the maximum, minimum, average, etc. criteria where climatic data are classically evaluated, it has been determined how long the creature was exposed to that climate parameter in a certain time period (day, month, season, and year). Thus, an alternate point of view was developed to evaluate the climatic comfort of an animal and the effects of climate. For this purpose, a different and new model was developed after a detailed literature review to understand the effect of temperature and relative humidity, particularly on milk production and the comfort of animals. A total of 175 680 climate parameters (temperature, and relative humidity) were categorized in certain groups (Table 1 and Table 2). Eight categories were created by making use of previous results in NRC (1981), Berman et al (1985), Shinde & Taneja (1986), Sainsbury & Sainsbury (1988), NRC (1989), WMO (1989), Igono et al (1992), Muller & Botha (1994), Webster (1994), Brouček (1997), Keown & Grant (1997), Kume et al (1998), Roenfeldt (1998), Novák et al (2000), Kadzere et al (2002), Knížková et al (2002), West (2003), Brouček et al (2009), Gaafar et al (2011), Herbut & Angrecka (2012), OACC (2014), FAO (2016), and Vtoryi et al (2018) considering the temperatures to which animals are exposed (Table 1). It was tried to determine how much of their one-year total times of dairy cattle spent at which temperature and humidity values. In addition, it were classified seven categories by making use of Yüksel (1984), Maton et al (1985), Olgun (1988), Ekmekyapar (1991), Okuroğlu & Yağanoğlu (1993), Ekmekyapar (2001), OACC (2014) ve Vtoryi et al (2018) vb. publications regarding the relative humidity values to which animals are exposed (Table 2).

Table 1
Temperature ranges to which animals are exposed and their effect on animals

Temperature ranges exposed by animals (°C)	Effect on animals
<-5 °C	Cold Stress
-5 ^{0}C - 0 °C	Mild Cold Stress
0 ^{0}C – 5 °C	Cold Tension
5 ^{0}C – 25 °C	Suitable Temperature
10 ^{0}C – 20 °C	Optimum Temperature
25 ^{0}C – 28 °C	Heat Tension
28 ^{0}C – 32 °C	Heat Stress
> 32 °C	Excessive Heat Stress

Table 2
Relative humidity ranges to which animals are exposed and their effect on animals

Relative humidity ranges exposed by animals (%)	Effect on animals
< %20	Extremely Dry
% 20-40	Dry
% 40-60	Low humidity
% 65-75	Optimum
% 60-80	Suitable
% 80-90	Humid
>%90	Excessively Humid

Monthly, seasonal, and annual temperatures and humidity changes were analyzed in the free system structure developed as an alternative design. Especially for the open system shelter, the effects of temperatures in different building areas on animal welfare and the formation and results of climate criteria on the open system were evaluated.

3. Results and Discussion

The dairy cattle spent 80% of their total time in the autumn season at 5-25 °C, which is a suitable temperature range. During this period, the animals spent about 50% of their time at the optimum temperature range of 10-20 °C. In the autumn season, dairy cattle were at temperatures between 28-32 °C which is heat stress range in only 5% of their total time, especially in resting areas. In this period, animals were exposed to temperatures in the 0-5 °C range, which is defined as the cold tension range, in only 10% of their time (Table 3). According to Figure 3, there was no significant difference between building areas. Since only the number 2 resting area was located to the south, the temperature was 2-3 °C higher than that in the outside environment and the courtyard. According to Shinde & Taneja (1986), Sainsbury & Sainsbury (1988), Roenfeldt (1998), Webster (1994), Novák et al. (2000), West (2003), Herbut & Angrecka (2012), OACC (2014), FAO (2016) and Vtoryi et al (2018), a comfortable shelter environment was provided for dairy cattle. In the shelter where the research was conducted, semi-closed resting areas were designed to protect animals from cold, air currents and rain, especially in winter. In such a season, temperatures measured in resting areas were higher than in all other areas (Figure 3).

In winter, animals spent about 40% of their total time at 5-25 °C (suitable temperature range) in resting areas that they used extensively to protect from cold. In this period, dairy cattle spent approximately 15% of their time at 10-20 °C (optimum temperature range) (Table 4). In this season, while dairy cattle were exposed to temperatures lower than -5 °C, which causes cold stress, in 11% of their total time in the feeding area and in 13% of their total time in the walking yard, this rate decreased up to 6% in the rest area no 2 (Table 4). In this season, it has been observed that the resting area no 2, which is protected from weather drafts and rains, is used intensely by animals. It has been determined that temperatures (<-5°C) that cause cold stress occurring in a very short time period do not create a climatic stress on animals. According to WMO (1989), Knížková et al (2002), Herbut & Angrecka (2012) and FAO (2016), this tempereture is compatible with the lower limit of the effective temperatures for dairy cattle, in this period the resting areas, which were planned as stagnant areas sheltered from air currents, protected the animals against cold to a large extent. The negative impact of low temperatures on animals can be significantly reduced by keeping the bedding ground as dry as possible and feeding the animals with a high energy diet.

The graphical distribution of temperatures to which the animals were exposed in the spring season is presented in Figure 5. In the spring season, dairy cattle spent 80% of their total time at 5-25 °C being the appropriate temperature range, and 50% of their total time at 10-20 °C being the optimum temperature range. In this season, although the animals were exposed to temperatures between 25-28 °C, which are categorized as heat tension range, while in 6-7% of their total time in resting areas (areas 2 and 3), this rate reduced up to 3-4% in the open shelter area (courtyard and feeding area). In the same season, animals were exposed to temperatures between 28-32 °C, which is the heat stress range, for only 4% of their total time in resting areas, while these temperatures were almost never experienced in the open areas of the shelter (Table 5, Figure 5). Associated with the temperatures rise animals prefer open and draft areas, temperatures in the heat stress range seen over a very short period of time did not exert a negative effect on animals. According to NRC (1981), Shinde & Taneja (1986), NRC (1989), Blackshaw & Blackshaw (1994), Brouček (1997), Novák et al (2000), Kadzere et al (2002), West (2003), Brouček et al (2009), Gaafar et al (2011), OACC (2014), FAO (2016) and Vtoryi et al (2018), a comfortable sheltering environment, which doesn't cause heat stress on dairy cattle, was provided for animal welfare.

Table 3
Distribution of Temperatures Exposed by Animals in the autumn season

Percentage Distribution of Temperatures Exposed by Animals (%)																								
MONTHS	SEPTEMBER						OCTOBER					NOVEMBER						Autumn Season Average						
Temperature Ranges (°C)	(0-5)	(5-25)	(10-20)	(25-28)	(28-32)	(>32)	(0-5)	(5-25)	(10-20)	(25-28)	(28-32)	(-5-0)	(0-5)	(5-25)	(10-20)	(25-28)	(28-32)	(-5-0)	(0-5)	(5-25)	(10-20)	(25-28)	(28-32)	(>32)
1.Outdoor Area	0	84	55	9	6	0	5	91	61	4	0	7	27	66	36	0	0	2	11	80	51	4	2	0
2. Resting Area	0	71	48	7	10	11	1	85	57	7	6	0	17	82	42	0	0	0	6	80	49	5	5	4
3. Resting Area	0	74	50	8	10	8	1	86	56	7	6	1	19	79	42	0	0	0	7	80	49	5	5	3
4. Feeding Area	0	80	52	9	9	1	4	89	59	6	1	6	26	68	37	0	0	2	10	79	50	5	3	1
5. Courtyard	0	83	55	10	7	0	5	91	61	4	0	9	26	65	37	0	0	3	10	80	51	5	2	0

Table 4
Temperatures Exposed by animals in the winter season

Percentage Distribution of Temperatures Exposed by Animals (%)																				
MONTHS	DECEMBER					JANUARY					FEBRUARY					Winter Season Average				
Temperature Ranges (°C)	(<-5)	(-5-0)	(0-5)	(5-25)	(10-20)	(<-5)	(-5-0)	(0-5)	(5-25)	(10-20)	(<-5)	(-5-0)	(0-5)	(5-25)	(10-20)	(<-5)	(-5-0)	(0-5)	(5-25)	(10-20)
1.Outdoor Area	15	55	22	8	0	23	23	30	24	8	3	12	23	61	28	14	30	25	31	12
2. Resting Area	3	33	49	15	5	15	19	31	34	10	0	8	21	71	32	6	20	34	40	16
3. Resting Area	6	41	41	13	3	18	21	29	32	8	0	10	20	70	31	8	24	30	38	14
4. Feeding Area	11	49	31	9	2	21	23	29	27	8	2	12	23	63	28	11	28	28	33	13
5. Courtyard	14	55	23	8	1	22	22	30	25	9	3	13	23	61	28	13	30	26	31	12

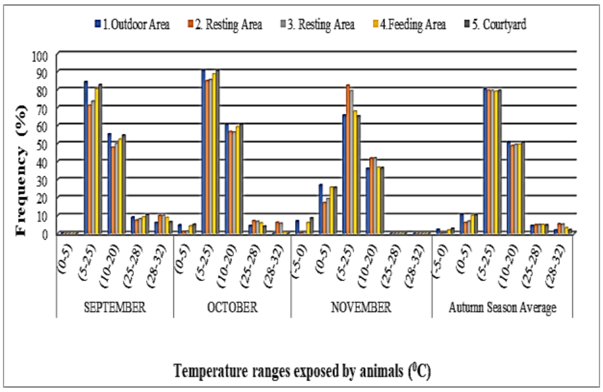

Figure 3
Distribution of temperatures exposed by animals in the autumn season

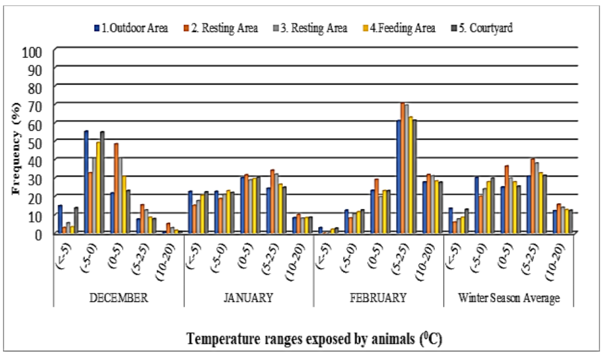

Figure 4
Distribution of temperatures exposed by animals in the winter season

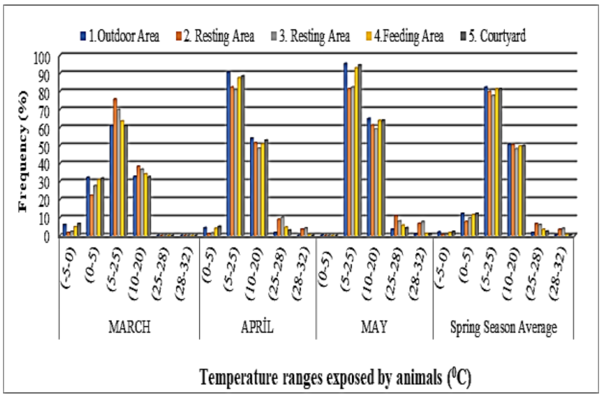

Figure 5
Graphical distribution of temperatures exposed by animals in the spring season

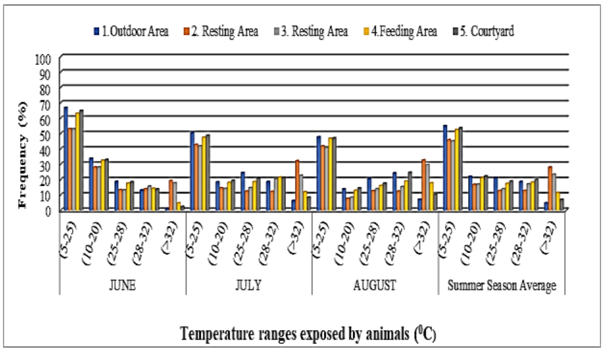

Figure 6
Graphical distribution of temperatures exposed by animals in the summer season

In the summer season, dairy cattle were exposed to temperatures in the range of 5-25 °C for 55% of their total time, especially in the feeding area and the courtyard. During this period, the animals spent about 20% of their time at 10-20 °C, the optimum temperature range (Table 6). As shown in Figure 6, although the ratio of the optimum temperatures to which the animals were exposed in the summer decreased up to 20% in the total time, the animals spent nearly 75% of their total time in suitable (5-25 °C) and optimum (10-20 °C) temperature ranges. In the summer season, dairy cattle were exposed to temperatures between 28-32 °C, which is the heat stress range, for about 17% of their total time.

During this period, animals were exposed to temperatures higher than 32 °C (extreme stress range) for only 5-7% of their total time in open shelter areas (Table 6). In addition, it has been observed that, animals preferred open areas with air flow in the summer season. According to NRC (1989), Blackshaw & Blackshaw (1994), Brouček (1997), Novák et al (2000), Kadzere et al (2002), West (2003), Brouček et al (2009), Gaafar et al (2011), OACC (2014), FAO (2016) and Vtoryi et al (2018), the open shelter system provided a comfortable shelter environment that did not create climatic heat stress on animals in the summer season.

Table 5
Percentage Distribution of Temperatures Exposed by animals in the spring season

Percentage Distribution of Temperatures Exposed by Animals (%)																								
MONTHS	MARCH						APRİL						MAY						Spring Season Average						
Temperature Ranges (°C)	(-5-0)	(0-5)	(5-25)	(10-20)	(25-28)	(28-32)	(0-5)	(5-25)	(10-20)	(25-28)	(28-32)	(>32)	(0-5)	(5-25)	(10-20)	(25-28)	(28-32)	(>32)	(-5-0)	(0-5)	(5-25)	(10-20)	(25-28)	(28-32)	(>32)
1.Outdoor Area	6	32	61	33	0	0	5	94	54	2	0	0	0	96	65	3	1	0	2	12	83	51	2	0	0
2. Resting Area	2	22	76	38	0	0	1	85	52	9	4	1	0	82	61	11	7	1	1	8	81	50	7	4	0
3. Resting Area	2	28	70	37	0	0	1	84	49	10	4	0	0	82	59	8	8	2	1	10	79	49	6	4	0
4. Feeding Area	5	31	64	34	0	0	4	90	51	5	0	0	0	93	64	6	1	0	2	12	82	50	4	1	0
5. Courtyard	7	32	61	33	0	0	5	91	53	3	0	0	0	95	64	4	1	0	2	12	82	50	3	0	0

Table 6.
Percentage Distribution of Temperatures Exposed by animals in the summer season

Percentage Distribution of Temperatures Exposed by Animals (%)																				
MONTHS	JUNE					JULY					AUGUST					Summer Season Average				
Temperature Ranges (°C)	(5-25)	(10-20)	(25-28)	(28-32)	(>32)	(5-25)	(10-20)	(25-28)	(28-32)	(>32)	(5-25)	(10-20)	(25-28)	(28-32)	(>32)	(5-25)	(10-20)	(25-28)	(28-32)	(>32)
1.Outdoor Area	67	34	19	13	1	50	18	25	19	6	48	14	21	24	7	55	22	21	19	5
2. Resting Area	53	28	13	14	19	43	15	12	12	32	42	8	13	12	33	46	17	13	13	28
3. Resting Area	53	28	13	16	18	42	14	15	20	23	41	9	14	15	30	45	17	14	17	23
4. Feeding Area	63	33	18	14	5	48	18	19	22	12	47	13	16	19	18	53	21	17	18	12
5. Courtyard	65	33	19	14	2	49	19	21	21	9	47	14	18	25	10	54	22	19	20	7

The temperatures to which dairy cattle are exposed changed considerably in terms of months and seasons in different shelter areas. However, when the average temperatures throughout the year were examined, there was no significant difference between the building areas (Figure 7). Dairy cattle spent about 60% of their total time at 5-25 °C being the appropriate temperature range throughout the year. During the year, the animals were exposed to temperatures in the range of 10-20 °C, which is the optimum temperature range, for approximately 33% of their time. Animals are estimated to be exposed to heat stress in approximately 6-7% and cold stress in 2-3% of their annual total time. To understand exactly the effects of climatic environmental conditions on animal welfare in dairy cattle shelters, this study revealed that annual distribution is important rather than distribution within a period. According to studies by Shinde & Taneja (1986), Sainsbury & Sainsbury (1988), Webster (1994), Roenfeldt (1998), Novák et al (2000), Kadzere et al (2002), Knížková et al. (2002) Broucek et al (2009), Gaafar et al (2011), Herbut & Angrecka (2012), FAO (2016) and Vtoryi et al (2018), the year-round open shelter system provides a suitable shelter environment that does not create climatic stress in terms of animal welfare.

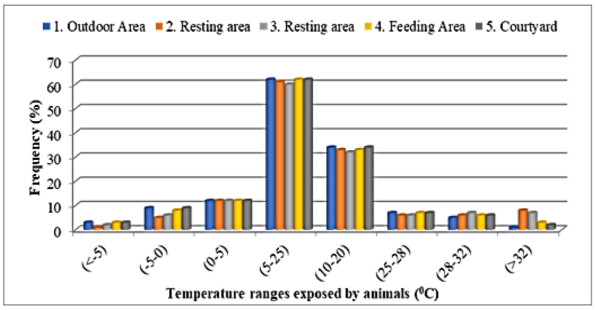

Figure 7
% Distributions of temperatures exposed by animals throughout the year

Graphical and proportional distributions of relative humidity values in autumn, winter, spring and summer seasons in the shelter are given in Figure 8 and Table 7. According to this study, dairy cattle spent about 7% of their total time in the optimum humidity range (65-75%) and 15% of the total time in the appropriate humidity range (60-80%) in the autumn season. During this season, animals were exposed to the relative humidity range of 40-60% for about 24% of their total time and to the relative humidity in the range of 80-90% for about 4% of their total time. In the autumn season, animals were exposed to relative humidity lower than 20% categorized as extremely dry, for 68% of their total time, especially in the resting area number 2 (Table 7). Generally, the moisture content of the air (excluding high humidity at high temperatures) is often not a problem in assessing climatic comfort for animals. Only low moisture content can cause some breathing problems as it increases the dust content of the air in closed buildings. However, such a problem is not observed in open shelters due to continuous air circulation. In the winter season, dairy cattle were exposed to the optimum humidity range of 65-75% for nearly 9% of their total time. In this period, the animals spent about 17% of their time in the appropriate humidity range of 60-80%. The moisture holding capacity decreases as the air cools down in the winter season and consequently approaches its saturation capacity. For 75% of their total time, the animals are exposed to relative humidity greater than 90%, which is categorized as excessively humid, especially in the resting area numbere 2 (Table 7). Cause of the relative humidity is higher in this area than in other areas, it can be explained as creating a stagnant housing environment protected from winds which has a significant effect on the moisture content of air; this may be due to the increase in the intensity of use by animals in cold periods. This can explain the increase in the moisture content of the environment by increasing evaporation in wet areas created by manure. The shelter environment is suitable for animals in terms of humidity, if very small measures are taken for certain periods of this season. Generally, the negative effect of moisture is enhanced with increasing temperatures.

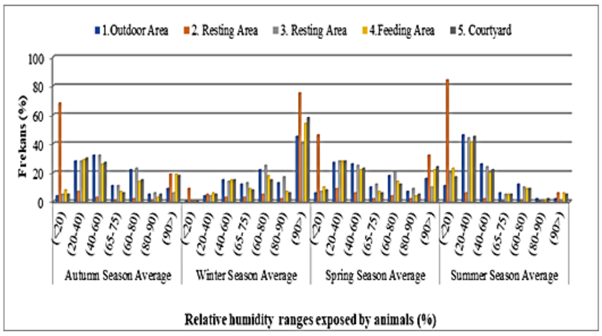

Figure 8
Graphical distribution of relative humidity values categorized in autumn, winter, spring and summer

Dairy cattle were exposed to optimum (65-75%) and suitable range of humidity (60-80%), respectively, in approximately 7% and 17% of their total time in the spring season. In this season, animals were exposed to relative humidity values lower than 20%, which is categorized as extremely dry, for 46% of the total time, especially in the resting area number 2 (Table 7). In summer, dairy cattle wereexposed to 65-75% humidity, which is the optimum humidity range, for about 5% of their total time. In this period, the animals spent about 10% of their time in the appropriate humidity range of 60-80%. In addition, relative humidity values of less than 20% observed for more than 80% of the total time in the resting area no 2 and this season fell to 15-20% in other areas as animals began to prefer open areas with more wind flow and the effects of these values on the physiological activities of the animals were greatly reduced. Low humidity at high temperatures has no adverse effects on animals in the open shelter system. Several researchers (Yüksel, 1984; Maton et al., 1985; Olgun, 1988; Ekmekyapar, 1991; Okuroğlu & Yağanoğlu, 1993; Ekmekyapar, 2001; OACC, 2014; Vtoryi et al., 2018) opine that the relative humidity values determined throughout the year provide a suitable shelter for dairy cattle. During the year, dairy cattle spent approximately 15-20% of their total time in the appropriate humidity range (60-80%), and were exposed to a humidity range of 65-75%, which is categorized as the optimum humidity range for approximately 6-10% of their time (Table 8).

Table 7
Percentage Distributions of hourly relative humidity values measured in autumn, winter, spring and summer seasons

	Frequency (%)																											
SEASONS	Autumn Season Average							Winter Season Average							Spring Season Average							Summer Season Average						
Relative Humidity Ranges (%)	(<20)	(20-40)	(40-60)	(65-75)	(60-80)	(80-90)	(90>)	(<20)	(20-40)	(40-60)	(65-75)	(60-80)	(80-90)	(90>)	(<20)	(20-40)	(40-60)	(65-75)	(60-80)	(80-90)	(90>)	(<20)	(20-40)	(40-60)	(65-75)	(60-80)	(80-90)	(90>)
1.Outdoor Area	4	28	32	11	22	5	9	0	4	15	12	22	13	45	6	27	26	10	18	7	16	11	46	26	6	12	2	2
2. Resting Area	68	7	3	1	2	1	19	9	5	3	3	5	2	75	46	9	6	2	4	2	32	84	6	2	0	1	0	6
3. Resting Area	5	28	32	11	23	6	6	0	4	14	13	25	17	40	7	28	25	12	21	9	10	20	44	24	5	10	1	1
4.Feeding Area	8	29	26	7	14	3	19	0	6	15	9	18	7	54	10	28	22	7	14	4	22	23	41	20	5	9	1	6
5. Courtyard	5	30	27	6	15	5	18	0	5	15	8	15	6	58	8	28	23	6	12	5	24	17	45	22	5	9	2	5

Table 8
Percentage distributions of hourly relative humidity values measured throughout the year

Percentage Distribution of Relative Humidity Exposed by Animals (%)							
Relative Humidity Ranges (%)	(<20)	(20-40)	(40-60)	(65-75)	(60-80)	(80-90)	(90>)
1.Outdoor Area	5.2	26.7	24.7	9.7	18.4	6.9	18.2
2. Resting Area	51.7	6.7	3.8	1.6	3.2	1.3	33.3
3. Resting Area	7.9	26.0	23.8	10.3	19.8	8.3	14.3
4. Feeding Area	10.3	26.1	20.7	7.1	13.7	3.8	25.4
5. Courtyard	7.4	27.1	21.9	6.3	12.7	4.4	26.5

In Figure 9, the resting area no 2 had quite dry environments for animals to continue their physiological activities in terms of moisture content throughout the year. During the year, dairy cattle were exposed to less than 20% relative humidity for approximately 52% of their total time in the resting area numbere 2 (Table 8). The reason why this area, which was designed to protect animals from cold, is drier than other shelter areas, may be because over-drying manure absorbs moisture from the air as both are warm (relative humidity decreases as temperature increases; known as a psychometric law) and due to the less use by animals during hot periods. In addition, dairy cattle were exposed to greater than 90% humidity, especially in the resting area numbere 2, for approximately 33% of their total time (Table 8). We also observed that the animals are exposed to relative humidity values in the range of 40-90% at 50-60% of their total time throughout the year. Several studies (Wathes et al., 1983; Yüksel, 1984; Ekmekyapar, 1991; OACC, 2014; Vtoryi, 2018) have reported that the shelter environment is suitable for animal welfare as long as the animals are not permanently exposed to environments with 40-90% relative humidity.

4. Conclusion and Suggestions

When designing shelters, environmental conditions, which have an impact on animal welfare throughout the year rather are important rather than instantaneous or over a specific period. If resting areas planned to create warm and stagnant areas in winter in open shelter systems are planned so that the ground is soft and dry, the effect of cold stress seen in a short period in the winter months can be significantly alleviated or completely eliminated. With the rise in temperatures, unlike resting areas, breezy and covered shadow areas should be created for the animals to have sufficient climatic comfort. In fact, it can be concluded that to build no shelter may be more comfortable for animals in terms of climate than poorly planned shelters. In the climatic conditions of Konya region, it would be appropriate to prefer semi-open barn type for animal welfare for dairy cattle. To conclude, the idea that temperature, which is the main factor for avoiding open systems in animal breeding, especially during cold periods, creates unfavorable environments for animals and that animals are harmed by winter chills has been refuted with this study.

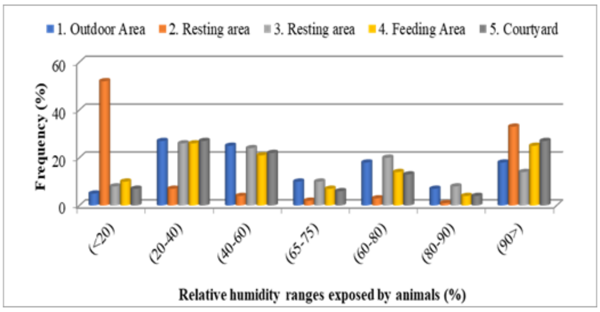

Figure 9
The graphical distribution of relative humidity values categorized throughout the year

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