2023, Scienceline Publication
World's Veterinary Journal
World Vet J, 13(1): 134-143, March 25, 2023
ISSN 2322-4568
DOI: https://dx.doi.org/10.54203/scil.2023.wvj14

The Relationship between Warm Weather and Milk Yield in Holstein Cows

Roman Mylostyvyi[1]*, Olena Izhboldina[2], Svitlana Midyk[3], Bogdan Gutyj[4], Oleh Marenkov[5], and Volodymyr Kozyr[6]

[1]*Department of Animal Products Processing Technology, Dnipro State Agrarian and Economic University, S. Efremov Str. 25, 49600 Dnipro, Ukraine*
[2]*Department of Livestock Production Technology, Dnipro State Agrarian and Economic University, S. Efremov Str. 25, 49600 Dnipro, Ukraine*
[3]*Ukrainian Laboratory of Quality and Safety of Agricultural Products, National University of Life and Environmental Sciences of Ukraine, Heroiv Oborony Street, 15, 03041 Kyiv, Ukraine*
[4]*Department of Hygiene, Sanitation, and General Veterinary Prevention, Faculty of public development and health, Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies Lviv, Pekarska Str., 50, 79010 Lviv, Ukraine*
[5]*Faculty of Biology and Ecology, Department of General Biology and Aquatic Bioresources, Oles Honchar Dnipro National University, Gagarin av., 72, 49010 Dnipro, Ukraine*
[6]*Institute of Grain Crops of National Academy of Agrarian Sciences, Volodymyr Vernadskyi Str., 14, Dnipro, 49027, Ukraine*

*Corresponding author's Email: mylostyvyi.r.v@dsau.dp.ua

ORIGINAL ARTICLE
pii: S232245682300014-13
Received: 18 January 2023
Accepted: 01 March 2023

ABSTRACT

The increasing variability of weather conditions associated with global climate change is becoming a major problem for dairy farming. The present article provided the results of studies on the relationship between the milk production of Holstein cows and environmental parameters during the warm season. The study investigated whether the relationship between weather conditions (air temperature, relative humidity, wind direction, wind strength, and insolation) and daily milk yield, as well as its components (milk fat yield and milk protein), depended on the conditions comfortable for the cows. The temperature-humidity index was calculated based on air temperature and relative humidity data, which were recorded by the nearest weather station to the farm, which is subordinate to the Ukrainian Hydrometeorological Center. It was found that the relationship between environmental parameters and milk yield was weak concerning the increase in proportion to the growth of heat load. However, the factorial analysis indicated that the total influence of weather factors on milk yield, milk fat, and protein yield was 42-46%. Moreover, weather conditions could significantly impact dairy productivity when cows are kept in naturally ventilated barns. This suggests further investigation of issues related to the microclimate improvement in cowsheds in hot seasons using sprinkler systems for cooling dairy cows.

Keywords: Components of milk, Correlation, Cows, Hot weather, Milk yield, Naturally ventilated

INTRODUCTION

The dairy industry is susceptible to global climate change (Smith et al., 2007; Escarcha et al., 2018). In recent years, this has become a challenge for countries with hot climates and European countries with temperate continental climates (Tomczyk et al., 2019). The increasing variability of weather conditions and high summer temperatures lead to a drop in cow milk yields and a deterioration of milk quality as the main raw material for the dairy processing industry (Zazharska et al., 2018; Maggiolino et al., 2020).

An increase in the frequency of thermal stresses in the summer produces noticeable effects on dairy cattle, including various physiological and metabolic disorders (Polsky and von Keyserlingk, 2017; Danchuk et al., 2021). The reduced feed consumption by animals decreases milk yield during persistent heat (Nardone et al., 2010). However, this is only 35% associated with decreased appetite in cows, while the remaining 65% of losses are due to the direct effect of heat stress related to hormonal imbalance, rumen dysfunction, and decreased absorption of nutrients (Rhoads et al., 2009).

Dairy cattle are directly affected by extreme environmental factors when kept year-round in naturally ventilated barns (NVB) without the use of pastures during warm periods of the year (Hempel et al., 2019; Mylostyvyi et al., 2019). Natural ventilation (through the pulled-up blinds and skylights) and mechanical ventilation (using accelerating axial flow fans) during the summer heat cannot provide comfortable conditions for cows. Therefore, their milk yield can be reduced to one liter per head per day (Izhboldina et al., 2020; Mylostyvyi et al., 2021).

Therefore, an investigation into the impact of environmental parameters on dairy cow performance can anticipate the scale of losses in the dairy industry during high summer temperatures (Binsiya et al., 2017). Predictions based on such studies will pursue strategies to mitigate the adverse effects of global warming on milk production promptly (Gunn et al., 2019; Avtaeva et al., 2021).

To cite this paper: Mylostyvyi R, Izhboldina O, Midyk S, Gutyj B, Marenkov O, and Kozyr V (2023). The Relationship between Warm Weather and Milk Yield in Holstein Cows. *World Vet. J.*, 13 (1): 134-143. DOI: https://dx.doi.org/10.54203/scil.2023.wvj14

Considering the direct impact of environmental factors on the physiological state of productive animals, the comfort conditions for dairy cattle are assessed using particular indices. For example, the temperature and humidity index (THI) based on measurements of air temperature (AT) and relative humidity (RH) has been widely used to determine the severity of heat stress. The THI is informative and easy to calculate (Sejian et al., 2021). According to Rodriguez-Venegas et al. (2022), temperature-humidity index (THI) values classify heat stress in dairy cows as 68-71 THI (light stress), 72-76 THI (moderate stress), 77-79 THI (intense stress), and ≥80 THI (extreme stress). Data on the relationship between the productive qualities of cattle and environmental factors need constant clarification and supplementation under conditions of rapid global warming. On their basis, all new thermal indices are created, which have recently become the focus of many researchers (Mbuthia et al., 2022).

Therefore, this study aimed to determine the relationship between environmental parameters and milk productivity of Holstein cows kept in NVB during the warm season.

MATERIALS AND METHODS

Ethical approval

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Commission on Bioethics of the Institute of Biotechnology and Animal Health (protocol No. 5 dated May 29, 2018).

Study design

The study was conducted on dairy cows at one of the largest commercial dairy complexes for breeding Holstein cattle in central Ukraine (48°28′44″ N, 35°36′46″ E). The work involved the study of the relationship between the dairy productivity of cows and environmental parameters for two years (2017, 2018), taking into account only the warm season (May to September).

Keeping, feeding, and recording the milk productivity of cows

Dairy cows were kept in NVB without tethering. These were Holstein cows of medium lactation (90-150 days of lactation) with an average milk yield of 25-26 kg/day. The cows' milk yield and the number of animals (ranging from 700 to 800 cows) did not differ significantly yearly. The barns had a four-row arrangement of cubicles (length of 2.25 m and width of 1.1 m), and sand was used as bedding. The cows received a total mixed ration, including corn silage, alfalfa hay, grain hay, wheat straw, barley grain, oats, and corn. Rapeseed, sunflower, and soybean meal, dried cellulose, and mineral and vitamin supplements were also included in the rations. The rations were balanced for essential nutrients according to the recommendations of the National Research Council (NRC, 2001). Feeding alleys and group water troughs were readily available in the facility. The ration was not changed during the year. The animals were kept indoors during the study without grazing. Information on the dairy productivity of cows at a commercial dairy complex was obtained using the DairyComp 305 herd management system (VAS, USA). Average milk production values for the herd of cows (daily milk yield [DMY]; milk fat [MF]; milk protein [MP]; percentage of milk fat [PMF] and protein [PMP]) were calculated using a standard set of statistical functions, recording the indicators daily after milking.

Recording of weather conditions and systematization of the data obtained

Weather data from the nearest weather station was taken from the website of the Ukrainian Hydrometeorological Center, receiving data from all meteorological stations in the country. The distance from the dairy farm to the meteorological station in Pavlograd (Dnipropetrovsk region) did not exceed 25 km in a straight line. Weather data (insolation conditions [IC], wind direction [WD], wind strength [WS], air temperature [AT], and relative humidity [RH]) were recorded continuously at one-hour intervals. Then, the average value of these indicators for a day was calculated (the data was used to find the Pearson correlation). Various meteorological data were systematized using codes described in more detail in the previously published study (Mylostyvyi and Chernenko, 2019). For example, the coding for wind strength (m/s) proceeded from gradually increasing values of the Beaufort wind strength scale, starting from calm (point 0) to high wind (point 7). A similar principle was employed by assigning numerical values as codes to each environmental parameter. The calculations of the THI (Kibler, 1964) and THI index for NVB (THI_{CHT}), which was tested by Mylostyvyi et al. (2020), were made according to the given equations:

$$THI = 1.8 \times T - (1 - RH/100) \times (T - 14.3) + 32$$

$$THI_{CHT} = 46.00549 + 1.04460 \times T,$$

Where, THI is the temperature-humidity index, THI_{CHT} denotes the temperature-humidity index in a hangar-type barn, T is air temperature (°C), and RH signifies relative humidity (%).

It should be noted that a similar approach to the systematization of data covering the warm period of 2017 has been previously outlined in the form of a data descriptor (Mylostyvyi and Chernenko, 2019). The decision to use this dataset again was driven by the need to combine the 2018 and datasets of the previous year. This is a distinctive feature of this article. The originality of the approach in this study was to determine the extent to which weather factors influence the dairy performance of cows using factorial ANOVA, as well as a new approach to determine the relationship between

To cite this paper: Mylostyvyi R, Izhboldina O, Midyk S, Gutyj B, Marenkov O, and Kozyr V (2023). The Relationship between Warm Weather and Milk Yield in Holstein Cows. *World Vet. J.*, 13 (1): 134-143. DOI: https://dx.doi.org/10.54203/scil.2023.wvj14

these traits, taking into account the extent to which cows were under heat stress (according to THI value), or they were in comfortable conditions.

Statistical analysis

The mean values (Mean) and standard deviations (SD) were calculated for each of the above weather and cow productivity indicators. Correlation analysis was performed using Spearman's rank correlation coefficient. A factorial ANOVA was used to determine the effect of environmental parameters on the dairy productivity of cows. The percent of exposure (%) of the meteorological factors on the productivity of dairy cows was determined by the method of biometric analysis (Kovalenko et al., 2010) based on the results of ANOVA in the program Statistica 12 (StatSoft, Inc., Tulsa, OK, USA). The difference with values of $p < 0.05$ was considered statistically significant.

RESULTS

Weather conditions during the study period from May 1 to August 31, 2018, are shown in Table 1. Of these 123 days (or 2952 hours) of warm weather, 2662 hours were estimated, representing about 90.2% of the duration of the specified warm period. It was found that clear weather, cloudy, rainy hours, and overcast conditions accounted for 2253 (84.6%), 294 (11.0%), 103 (3.9%), and 12 (0.5%) hours, respectively. May was the month with the most clouds, July was the rainiest, and the largest number of clear days was seen in August.

In some months of the year, the predominant wind was East (E) in May, North-East (NE) in June, and North (N) in July and August. During the warm period, the prevailing winds were in N, NE, and E directions (31.1, 25.1, and 23.9%, respectively). The total amount of time when the wind strength corresponded to 0 was 120 hours (4.5%), 1-7 denoted 58 (5.9%), 932 (35.0%), 844 (31.7%), 352 (13.2%), 103 (3.9%), 6 (0.2%) and 147 hours (5.5%), respectively. May was the windiest month when the period of wind strength from 3 to 7 lasted for 492 hours (64.7%) of the total time. The duration of the calm air period was the greatest in July (8.2%).

It should be noted that a rather large variability characterized the weather conditions during the warm period of years since the differences in clear days were up to 13%, in the strength and direction of the wind – up to 21%. The mean values of air temperature and relative humidity in the warm season are shown in Table 2. These data indicated the inconstancy of weather conditions during the warm period. Mean temperatures from May to July exceeded the indicators of the previous year by 0.9-3.4°C, while August was slightly cool (by 0.4°C). The same dynamics were observed in the mean indicators of the temperature and humidity index, and the differences were 1.6-4.6 and 1.0 units, respectively.

For a clearer picture of the duration of dairy cows under heat stress of varying severity, the data for the two-year observation period are presented in Table 3. It should be noted that the number of hours during which animals experienced heat load (THI > 68) during the warm season increased from 1,160 hours in 2017 to 1,351 hours in 2018 (by 191 hours). At the same time, the period during which cows could be under heat stress when kept in NVB (based on THI_{CHT} values) increased by 106 hours in 2018, compared to the previous year.

Compared with May as the most comfortable month for the cows, there were significant changes in the composition of cow milk during the summer heat of 2018 (Table 3). In some summer months, milk fat yield decreased by 38 g, milk protein yield decreased by 33 g, and percent milk fat and milk protein decreased by 0.1% and 0.02%, respectively ($p < 0.05$). The drop in daily milk yield during the summer months ranged from 0.3 to 0.9 kg/day, echoing last year's similar dynamics of milk production of cows on the dairy complex under the influence of heat stress (Table 4).

It was found that the correlation between insolation conditions and the milk productivity of cows was weak (Table 5). The correlation was expressed only between insolation conditions and milk fat percentage ($r = +0.3$; $p < 0.05$). The relationship between wind strength and daily milk yield was weak ($r = +0.2$; $p < 0.05$). The relationship between air temperature and daily milk yield/milk fat was weakly negative ($r = -0.2$-0.3; $p < 0.05$); the relationship between relative humidity and milk fat yield/percentage ($r = -0.2$-0.4; $p < 0.05$) was similar. The relationship between temperature and humidity indices (THI and THI_{CHT}) and milk fat yield was strongest (from $r = -0.3$ to $r = -0.5$; $p < 0.05$) in different years.

It should be noted that the strength of general trends in the relationships between weather factors and cows' milk productivity both in 2018 and in the previous year, was generally low, although reliable.

We hypothesized that the relationship between meteorological parameters and the milk production of cows should have depended on whether the animals were under conditions of comfort or heat stress of varying severity. The correlation between the indicators was assessed using data for two years (246 tests) by distributing them according to the value of the temperature and humidity index. Out of 246 tests, 138 tests belonged to the comfort zone; 72 tests corresponded to light heat stress and 36 tests corresponded to moderate heat stress, in which cows were kept for 138, 72, and 36 days during the hot period, respectively (Table 6).

Indeed, the data obtained indicated that weather conditions had a different relationship with cow productivity, depending on the conditions, in which the animals were kept. For example, IC positively correlated with milk yield and milk components during the period of thermal comfort, while during periods of low and especially moderate stress, the negative relationship between the indicators increased.

To cite this paper: Mylostyvyi R, Izhboldina O, Midyk S, Gutyj B, Marenkov O, and Kozyr V (2023). The Relationship between Warm Weather and Milk Yield in Holstein Cows. *World Vet. J.,* 13 (1): 134-143. DOI: https://dx.doi.org/10.54203/scil.2023.wvj14

A similar situation was observed with respect to wind strength when under conditions of low heat stress, the relationship between WS and DMY/MP became negative. The WD negatively correlated with the cows' milk productivity in the temperature comfort zone; however, this relationship was weakened, losing its significance under heat stress. The negative correlation between AT and DMY, and milk components (MF/MP) increased with higher heat stress on the animals, while the positive correlation between RH and milk yield/components decreased. With the increase of heat load beyond temperature comfort, the negative relation between temperature and moisture indices and milk productivity of the animals gradually increased. In this respect, THI_{CHT} was the most informative indicator, which correlates well with milk yield and milk components during heat stress.

Since the influence of weather conditions in hot periods of the year on milk yield/composition of milk was significant (although in some cases with a rather low correlation), it decided to determine the impact of meteorological factors on the milk productivity indicators based on the comfort state of animals, using four-factor analysis for this purpose.

It was found that the total impact of environmental factors on cow milk yield was 46% (Figure 1). The impact of individual factors did not exceed 1–10%, namely WD (10%) and WS (7%) had a sound effect on the daily milk yield. The effect of IC and THI on DMI (9%) was not proven.

The total impact of weather factors on milk components (MF/MP) was 42–45% (Figure 2 and Figure 3). The effect of WD, WS, and THI on MF was 5-8% ($p < 0.05$). The impact of the combination of IC and THI and WD and THI was slight (4-5%), and it was insignificant ($p > 0.05$). The individual influence of WD, WS, and THI on MP was within 4-5% ($p < 0.05$), while the combination of IC and THI (9%) and WD and THI (5%) had no significant effect ($p > 0.05$).

It should be noted that only THI values had a significant ($p < 0.05$) influence on PMP and PMF (7% and 4%, respectively), while the percentage of individual factors fluctuated within 2-3%. Generally, the effect of weather factors on the percentage of fat and protein in cow's milk was estimated at 30-36%.

Regarding the design features of the premises (which are already included in THI_{CHT}), they had a significantly greater effect on cows' milk productivity. The microclimate of the barn also affects the productivity of cows, along with environmental factors. Indeed, the obtained results indicated an increase in the effect of indoor temperature and humidity on DMI by 7.2%, MF by 4.2%, MP by 4.3%, and PMF by 5.7% (Figure 4).

Table 1. Environmental conditions at a Holstein cattle dairy farm in central Ukraine from May to August 2018

Parameters	May		June		July		August	
	hours	(%)	hours	(%)	hours	(%)	hours	(%)
Weather characteristic								
Clear	598	83.8	381	80.4	550	74.7	724	98.1
Mostly cloudy	81	11.3	63	13.3	138	18.8	12	1.6
Mostly cloudy, rain	26	3.6	27	5.7	48	6.5	2	0.3
Overcast	9	1.3	3	0.6	-	0	-	0
Wind direction								
North	195	27.3	136	28.7	263	35.7	234	31.7
North-East	170	23.8	152	32.1	131	17.8	215	29.1
East	240	33.6	76	16.0	95	12.9	225	30.5
South-East	-	0	-	0	-	0	-	0
South	37	5.2	32	6.8	29	3.9	14	1.9
South-West	32	4.5	30	6.3	35	4.8	2	0.3
West	28	3.9	18	3.8	120	16.3	21	2.8
North-West	12	1.7	30	6.3	63	8.6	27	3.7
Wind strength, forces[1]								
0	26	3.7	7	1.5	60	8.2	27	3.7
1	31	4.3	22	4.6	62	8.4	43	5.8
2	165	23.1	160	33.8	323	43.9	284	38.5
3	185	25.9	151	31.9	196	26.6	312	42.3
4	100	14.0	104	21.9	77	10.5	71	9.6
5	54	7.6	30	6.3	18	2.4	1	0.1
6	6	0.8	-	0	-	0	-	0
7	147	20.6	-	0	-	0	-	0

[1]Numerical values from 0 to 7 characterize the wind force, similar to the Beaufort wind strength scale described earlier (Mylostyvyi and Chernenko, 2019).

Table 2. Temperature and humidity conditions at a Holstein cattle dairy farm in central Ukraine in 2018

Month	Air temperature	Relative humidity	THI	THI_{CHT}
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
May	19.0±3.05	56.2±14.23	63.4±3.93	65.9±3.19
June	22.3±3.49	52.4±11.08	67.9±4.59	69.3±3.65
July	22.5±1.66	69.5±9.58	69.4±2.27	69.5±1.73
August	23.8±1.87	47.3±9.36	68.9±2.62	70.6±1.94

THI: Temperature–humidity index (Kibler, 1964), THI_{CHT}: Temperature–humidity index in the hangar-type barn (Mylostyvyi et al., 2020). SD: Standard deviation

To cite this paper: Mylostyvyi R, Izhboldina O, Midyk S, Gutyj B, Marenkov O, and Kozyr V (2023). The Relationship between Warm Weather and Milk Yield in Holstein Cows. *World Vet. J.*, 13 (1): 134-143. DOI: https://dx.doi.org/10.54203/scil.2023.wvj14

Table 3. Distribution of temperature-humidity index values depending on the severity of heat stress in the center of Ukraine in the warm months of 2017[1]/2018

Month	THI (hours)				THI_{CHT} (hours)			
	<68	68.0-71.9	72.0-79.9	80.0-89.9	<68	68.0-71.9	72.0-79.9	80.0-89.9
May	649 / 502	73 / 132	15 / 80	-/-	606 / 476	87 / 95	44 / 143	-/-
June	429 / 224	152 / 97	133 / 146	1 / 7	418 / 217	123 / 89	168 / 154	6 / 14
July	386 / 276	146 / 220	188 / 238	5 / 2	391 / 324	131 / 175	184 / 237	19 / -
August	288 / 309	148 / 186	245 / 243	54 / -	253 / 295	156 / 130	206 / 290	120 / 23

[1]The data of 2017 in the table were taken from the data descriptor (Mylostyvyi and Chernenko, 2019). THI: Temperature–humidity index (Kibler, 1964), THI_{CHT}: Temperature–humidity index in the hangar-type barn (Mylostyvyi et al., 2020). The gradation of temperature and humidity index values was as follows, values below 68 corresponded to comfortable conditions for cows, 68-71 to light stress, 72-79 to moderate stress, and 80-89 to strong stress. No data (-) indicates that no hours have been recorded with this temperature and humidity index value

Table 4. Average daily milk yield and milk components of Ukrainian Holstein cows

Month	Daily milk yield (kg)	Milk fat yield (kg)	Milk protein yield (kg)	Milk fat content (%)	Milk protein content (%)
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
May	25.1 ± 0.12	0.888 ± 0.02	0.803 ± 0.02	3.53 ± 0.09	3.20 ± 0.07
June	25.2 ± 0.14	0.874 ± 0.02	0.804 ± 0.02	3.46 ± 0.08	3.19 ± 0.08
July	24.8 ± 0.76	0.850 ± 0.03	0.788 ± 0.03	3.43 ± 0.04	3.18 ± 0.09
August	24.2 ± 0.23	0.852 ± 0.02	0.770 ± 0.02	3.53 ± 0.06	3.18 ± 0.08

SD: Standard deviation

Table 5. Correlation between environmental conditions and milk productivity of Ukrainian Holstein cows for 2017[1]/2018

	DMY	MF	MP	PMF	PMP
IC	-0.20*/-0.12	-0.17/+0.11	-0.11/+0.003	-0.09/0.27*	-0.05/+0.11
WD	+0.09/+0.19	+0.02/-0.01	-0.01/+0.16	-0.02/-0.21	-0.04/+0.04
WS	-0.41*/+0.18*	-0.21*/+0.09	-0.19*/+0.08	-0.05/-0.06	-0.06/-0.06
AT	-0.19*/-0.23*	-0.46*/-0.26*	-0.37*/-0.17	-0.44*/-0.11	-0.33*/-0.02
RH	+0.40*/+0.08	+0.23*/-0.20*	+0.13/-0.05	+0.07/-0.35*	-0.01/-0.14
THI	-0.113/-0.21*	-0.45*/-0.33*	-0.35*/-0.19*	-0.46*/-0.22*	-0.35*/-0.06
THI_{CHT}	-0.19*/-0.22*	-0.47*/-0.26*	-0.37*/-0.16	-0.44*/-0.11	-0.33*/-0.02

The data of 2017 in this table were taken from the data descriptor (Mylostyvyi and Chernenko, 2019). DMY: Daily milk yield, MF: Yield of milk fat, MP: Yield of milk protein, PMF: Percentage of milk fat, PMP: Percentage of milk protein, IC: Insolation conditions, WD: Wind direction, WS: Wind strength, AT: Air temperature, RH: Relative humidity, THI: Temperature–humidity index (Kibler, 1964), THI_{CHT}: Temperature–humidity index in the hangar-type barn (Mylostyvyi et al., 2020).

Table 6. Correlation between weather conditions and cows' milk productivity depending on the THI values of Ukrainian Holstein cows for 2017[1]/2018

	DMY	MF	MP	PMF	PMP
Comfort zone. THI<68.0[1]					
IC	+0.17*	+0.12	+0.14	-0.01	+0.04
WD	-0.20*	-0.25*	-0.23*	-0.13	-0.13
WS	+0.20*	+0.07	+0.12	-0.10	-0.02
AT	+0.29*	-0.04	+0.09	-0.35*	-0.15
RH	-0.15	-0.12*	-0.24*	-0.10	-0.19*
THI	+0.28*	-0.07	+0.05	-0.39*	-0.19*
THI_{CHT}	+0.29*	-0.04	+0.09	-0.35*	-0.15
Light heat stress (THI = 68.1-72.0[2])					
IC	-0.14	+0.05	-0.09	+0.28*	0.00
WD	-0.05	-0.15	-0.05	-0.17	-0.02
WS	-0.23*	-0.19	-0.32*	+0.03	-0.26*
AT	-0.44*	-0.28*	-0.36*	+0.18	-0.11
RH	+0.40*	+0.16	+0.33*	-0.32*	+0.09
THI	-0.22	-0.22	-0.19	-0.04	-0.06
THI_{CHT}	-0.44*	-0.28*	-0.36*	+0.18	-0.11
Moderate to severe heat stress (THI = 72.1 and>[3])					
IC	-0.45*	-0.36*	-0.16	+0.05	+0.17
WD	0.00	-0.01	-0.03	-0.02	-0.04
WS	+0.12	-0.03	+0.09	-0.26	+0.02
AT	-0.32	-0.37	-0.22	-0.16	-0.04
RH	+0.17	+0.19	+0.09	+0.08	-0.03
THI	+0.27	-0.34*	-0.23	-0.18	-0.10
THI_{CHT}	-0.32	-0.37*	-0.23	-0.16	-0.04

[1]n=138, [2]n=72, [3]n=36. *$p<0.05$. DMY: Daily milk yield, MF: Yield of milk fat, MP: Yield of milk protein, PMF: Percentage of milk fat, PMP: Percentage of milk protein. IC: Insolation conditions, WD: Wind direction, WS: Wind strength, AT: Air temperature, RH: Relative humidity. THI: Temperature–humidity index (Kibler, 1964), THICHT: Temperature–humidity index in the hangar-type barn (Mylostyvyi et al., 2020).

To cite this paper: Mylostyvyi R, Izhboldina O, Midyk S, Gutyj B, Marenkov O, and Kozyr V (2023). The Relationship between Warm Weather and Milk Yield in Holstein Cows. *World Vet. J.,* 13 (1): 134-143. DOI: https://dx.doi.org/10.54203/scil.2023.wvj14

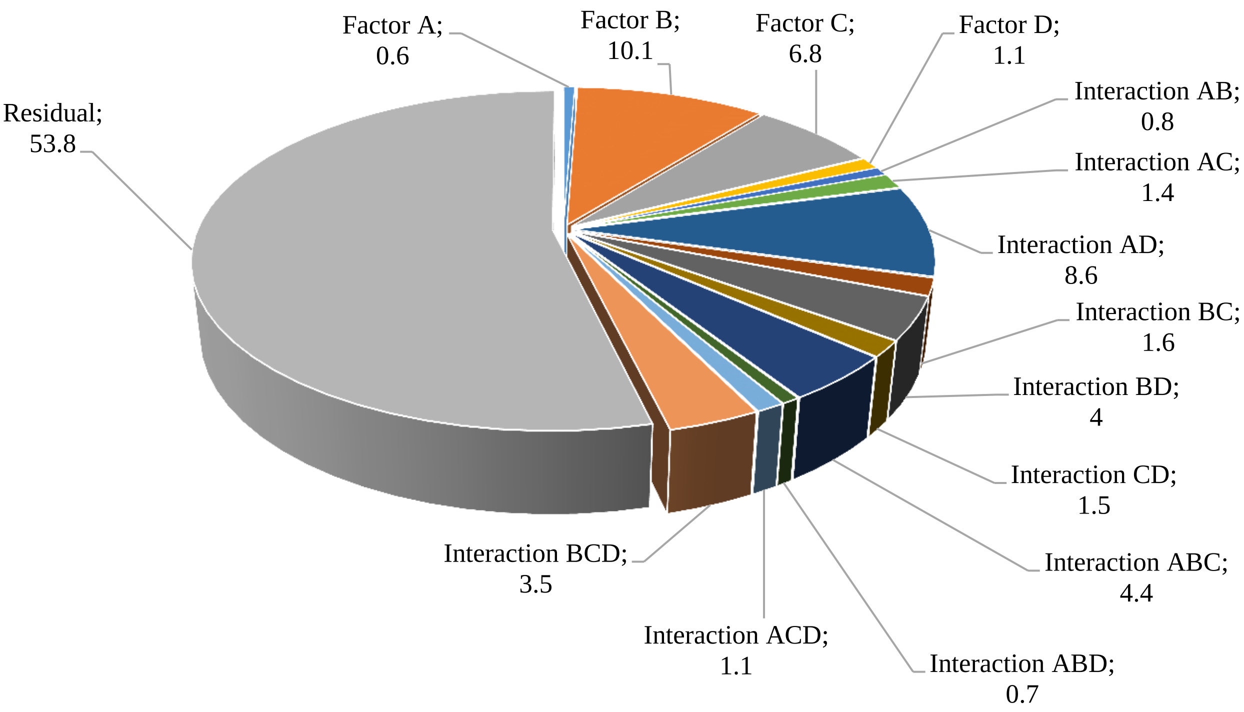

Figure 1. The influence (percentage) of weather factors on daily milk yield of Ukrainian Holstein cows. Factor **A**: Insolation conditions, Factor **B**: Wind direction, Factor **C**: Wind force, Factor **D**: Temperature and humidity index

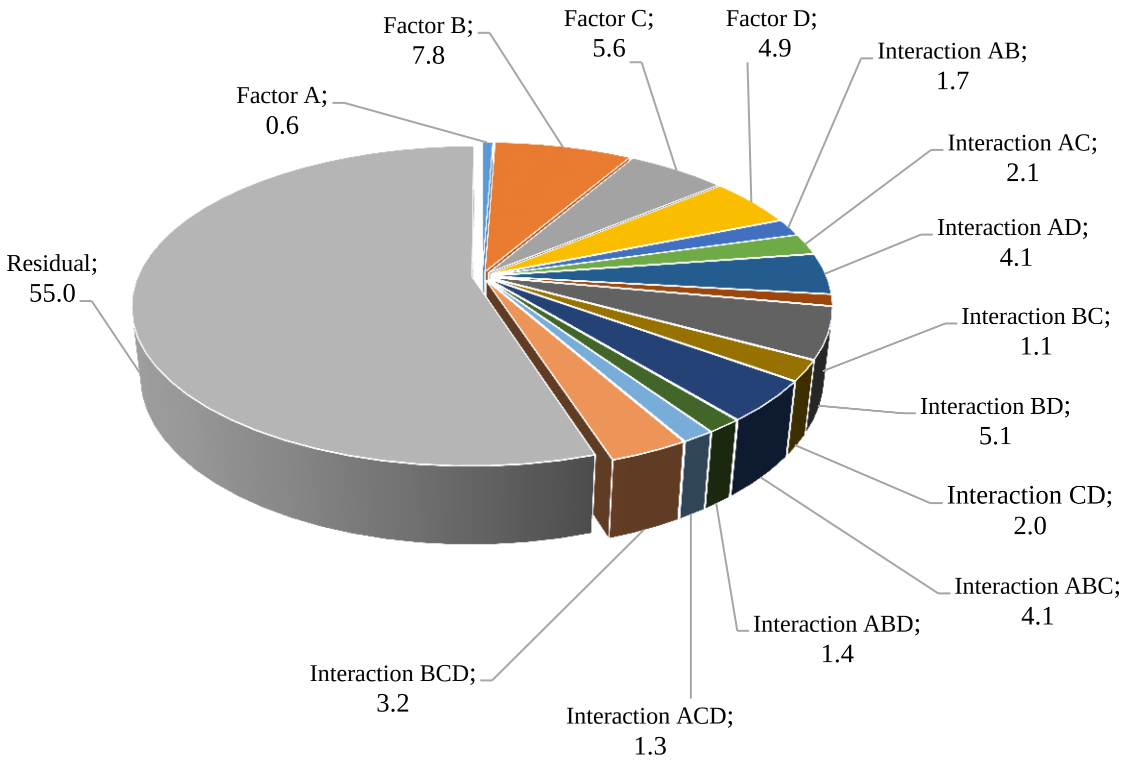

Figure 2. The influence (percentage) of weather factors on the milk fat yield of Ukrainian Holstein cows. Factor **A**: Insolation conditions, Factor **B**: Wind direction, Factor **C**: Wind force, Factor **D**: Temperature and humidity index

To cite this paper: Mylostyvyi R, Izhboldina O, Midyk S, Gutyj B, Marenkov O, and Kozyr V (2023). The Relationship between Warm Weather and Milk Yield in Holstein Cows. *World Vet. J.*, 13 (1): 134-143. DOI: https://dx.doi.org/10.54203/scil.2023.wvj14

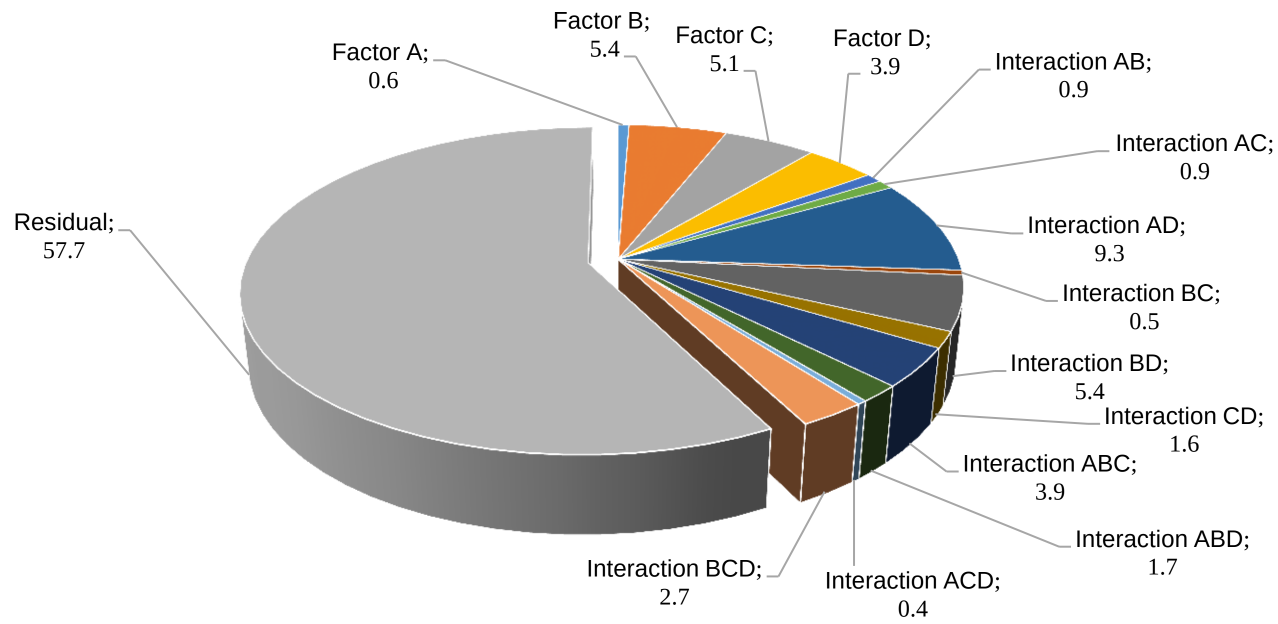

Figure 3. The influence (percentage) of weather factors on the milk protein yield of Ukrainian Holstein cows. Factor **A**: Insolation conditions, Factor **B**: Wind direction, Factor **C**: Wind force, Factor **D**: Temperature and humidity index

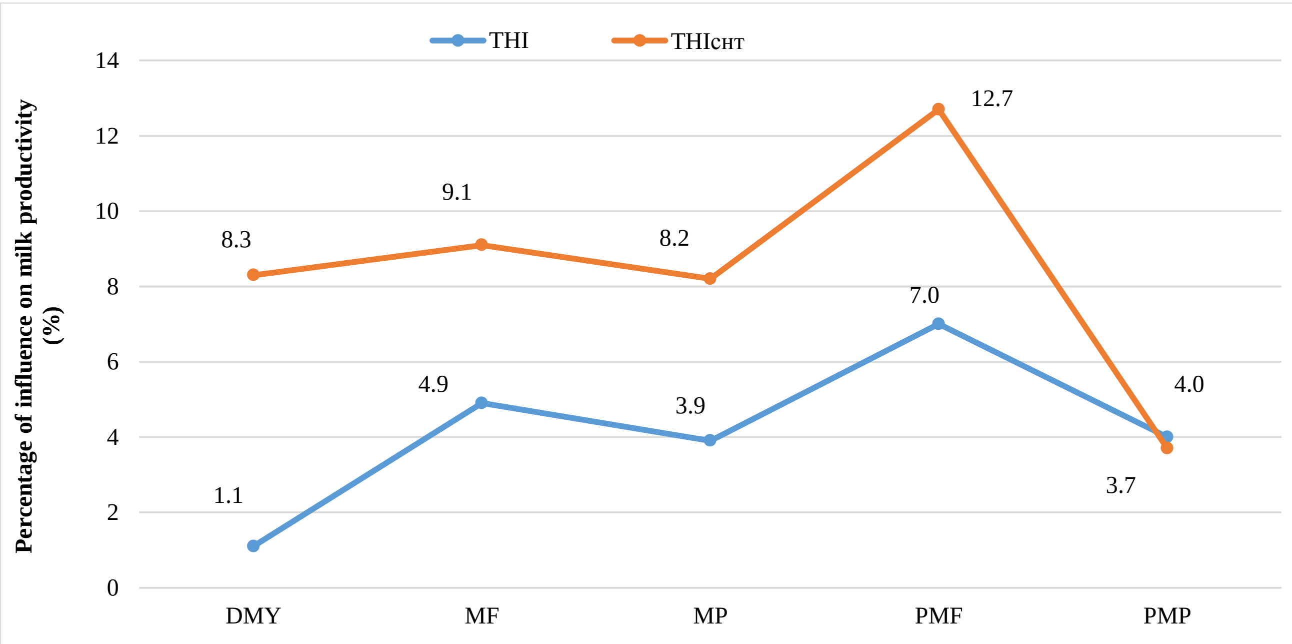

Figure 4. The percentage of temperature and humidity indices influence the milk productivity of Ukrainian Holstein cows. DMY: Daily milk yield, MF: Yield of milk fat, MP: Yield of milk protein, PMF: Percentage of milk fat, PMP: Percentage of milk protein. THI: Temperature–humidity index, THI_{CHT}: Temperature–humidity index in the hangar-type barn

DISCUSSION

The growth of average global temperatures and changing rainfall patterns contribute to extreme weather events that significantly challenge agriculture. More extreme conditions and greater regional climate variability are predicted, accompanied by an increase in the number of heat waves and their duration in the eastern and southeastern regions of Europe (Tomczyk et al., 2019). In Ukraine, critical temperatures in cold and hot seasons negatively impact the degree of realization of the genetic potential of cattle (Baschenko et al., 2020). Therefore, optimization of the indoor microclimate with year-round intensive loose housing of dairy cows in conditions of seasonal hypo- and hyperthermia is a reserve for the development of animal breeding.

To cite this paper: Mylostyvyi R, Izhboldina O, Midyk S, Gutyj B, Marenkov O, and Kozyr V (2023). The Relationship between Warm Weather and Milk Yield in Holstein Cows. *World Vet. J.*, 13 (1): 134-143. DOI: https://dx.doi.org/10.54203/scil.2023.wvj14

The body of an animal can homeostasis and regulate physiological processes. In a certain range of conditions, it manages to compensate for changes and disturbances in physiological equilibrium and, therefore, maintain physiological constancy. However, a significant increase in air temperature was followed by heat stress, leading to a decrease in milk yield and changes in milk components (Polsky and von Keyserlingk, 2017).

In addition to managerial decisions (Kismul et al., 2018), feeding strategies (Conte and al., 2018) and technical means (Gunn et al., 2019) aimed at reducing exposure to high temperatures by creating comfortable conditions for animals during short-term heat waves, great attention is also paid to the selection of livestock for resistance to high temperatures in the long term (Izhboldina et al., 2020).

In this case, the practical significance of the correlation analysis of the indices lies in the fact that, when selecting animals, it leverages positive qualities and reduces the undesirable ones and selects a smaller number of traits, which significantly accelerates the rate of genetic improvement of the herd.

The literature provides rather contradictory reports on the correlation between weather conditions and cows' productivity. For example, a weak negative correlation (r = -0.28) was found between air temperature and milk yield (Baschenko et al., 2020), while Herbut et al. (2018) reported a strong relationship between cow productivity and ambient temperature (r = -0.89). It was also reported by Baschenko et al. (2020) that the relationship between the fat content of cows' milk and high air temperature (r = -0.63), relative humidity (r = -0.38), and atmospheric pressure (r = -0.22), while the correlation between milk fat and air movement was relatively low (r = -0.06). It was reported that there was a strong negative correlation between THI and milk yield (r = -0.88), protein (r = -0.79), and fat (r = -0.86) in the hot season (Cheruiyot et al., 2020).

The discrepancies in the data reported by the researchers may be due to the fact that weather conditions are characterized by great variability and inconstancy, which complicates the assessment of the influence of individual parameters on the animals' productivity.

It should also be noted that the impact of weather on animals depends on the animal management system, especially if the cows are in naturally ventilated premises, the climate directly depends on environmental conditions (Hempel et al., 2019). Despite the high correlation between the temperature and humidity conditions in non-insulated premises and the ambient conditions (r = 0.95; R^2 = 0.90) reported by Mylostyvyi et al. (2019), the influence of premises factor on cows' milk productivity turned out to be quite significant (Figure 4). However, it should be taken into account when assessing the relationship between the indices.

On a final note, science recognizes climate change as one of the key causes of changes in the productivity of dairy cattle (Sejian et al., 2021). However, the complexity of the relationships between weather conditions and individual indicators of animal productivity makes it difficult to assess their impact on future losses since the impacts associated with climate change can be very diverse (Lees et al., 2022). Recent studies indicated an increase in the strength of the correlation between the productivity of dairy cows and the environmental conditions in connection with global warming, which confirms the demand for further research in this direction (Cheruiyot et al., 2020). To solve the problem of global climate change associated with the anthropogenic factor, it is necessary to rethink the relationship of the world community to the planet and the emergence of a new Culture of humanity.

CONCLUSION

It has been established that the productivity of dairy cows can be conditioned by almost 50% by environmental conditions when kept in naturally ventilated barns in the warm period of the year. The combination of meteorological parameters and microclimate conditions associated with barn design can increase the influence of these factors on milk yield and milk components. This shows the importance of using indices considering the combined effects of different environmental factors on dairy cattle to find effective strategies for mitigating global climate change.

DECLARATIONS

Acknowledgments

We are thankful to the Czech Government support provided by the Ministry of Foreign Affairs of the Czech Republic, which allowed this scientific cooperation to start within the project "AgriSciences Platform for Scientific Enhancement of HEIs in Ukraine".

Authors' contribution

All authors approved the final version of the article before publication in the journal. Conceptualization, writing-original draft preparation, Roman Mylostyvyi, and Olena Izhboldina; developed an experiment, analyzed data, Svitlana Midyk, and Bogdan Gutyj; writing-review and editing and supervision, Oleh Marenkov, and Volodymyr Kozyr.

To cite this paper: Mylostyvyi R, Izhboldina O, Midyk S, Gutyj B, Marenkov O, and Kozyr V (2023). The Relationship between Warm Weather and Milk Yield in Holstein Cows. *World Vet. J.*, 13 (1): 134-143. DOI: https://dx.doi.org/10.54203/scil.2023.wvj14

Ethical consideration

Consent to publication and misconduct, plagiarism, data fabrication and double submission of the manuscript, and redundancy and other ethical issues were checked by the authors.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Funding

This research did not receive external funding.

Competing interests

The authors declare no conflict of interest.

REFERENCES

Avtaeva TA, Sukhodolskaya RA, and Brygadyrenko VV (2021). Modeling the bioclimating range of *Pterostichus melanarius* (Coleoptera, Carabidae) in conditions of global climate change. Biosystems Diversity, 29(2): 140-150. DOI: http://www.doi.org/10.15421/012119

Baschenko M, Bojko O, Gonchar O, Sotnichenko Yu, and Tkach Ye (2020). Influence of genotypical and paratypical factors on the productivity of dairy cattle. Visnyk Agrarnoi Nauky (Bulletin of Agricultural Science), 98(3): 55-60. DOI: https://www.doi.org/10.31073/agrovisnyk202003-08

Binsiya TK, Sejian V, Bagath M, Krishnan G, Hyder I, Manimaran A, Lees A, Gaughan J, and Bhatta R (2017). Significance of hypothalamic-pituitary-adrenal axis to adapt to climate change in livestock. International Research Journal of Agriculture and Food Science, 2(1): 1-20. Available at: https://www.semanticscholar.org/paper/Significance-of-Hypothalamic-Pituitary-Adrenal-Axis-Binsiya-Sejian/3df1ca59f3ab2ac5ecfd097d1d19b4cde3e4dc51

Cheruiyot EK, Nguyen TTT, Haile-Mariam M, Cocks BG, Abdelsayed M, and Pryce JE (2020). Genotype-by-environment (temperature-humidity) interaction of milk production traits in Australian Holstein cattle. Journal of Dairy Science, 103(3): 2460-2476. DOI: https://www.doi.org/10.3168/jds.2019-17609

Conte G, Ciampolini R, Cassandro M, Lasagna E, Calamari L, Calamari L, Bernabucci U, and Abeni F (2018). Feeding and nutrition management of heat-stressed dairy ruminants. Italian Journal of Animal Science, 17(3): 604-620. DOI: https://www.doi.org/10.1080/1828051X.2017.1404944

Danchuk V, Ushkalov V, Midyk S, Vygovska L, Danchuk O, and Korniyenko V (2021). Milk lipids and subclinical mastitis. Food Science and Technology, 15(2): 26-41. DOI: https://www.doi.org/10.15673/fst.v15i2.2103

Escarcha JF, Lassa JA, and Zander KK (2018). Livestock under climate change: A systematic review of impacts and adaptation. Climate, 6(3): 54. DOI: https://www.doi.org/10.3390/cli6030054

Gunn KM, Holly MA, Veith TL, Buda AR, Prasad R, Rotz CA, Soder KJ, and Stoner AMK (2019). Projected heat stress challenges and abatement opportunities for U.S. milk production. PLoS ONE, 14(3): e0214665. DOI: https://www.doi.org/10.1371/journal.pone.0214665

Hempel S, Menz C, Pinto S, Galán E, Janke D, Estellés F, Müschner-Siemens T, Wang X, Heinicke J, Zhang G et al. (2019). Heat stress risk in European dairy cattle husbandry under different climate change scenarios – uncertainties and potential impacts. Earth System Dynamics, 10(4): 859-884. DOI: https://www.doi.org/10.5194/esd-2019-15

Herbut P, Angrecka S, and Godyń D (2018). Effect of the duration of high air temperature on cow's milking performance in moderate climate conditions. Annals of Animal Science, 18(1): 195-207. DOI: https://www.doi.org/10.1515/aoas-2017-0017

Izhboldina O, Mylostyvyi R, Khramkova O, Pavlenko O, Kapshuk N, Chernenko O, Matsyura A, and Hoffmann G (2020). Effectiveness of additional mechanical ventilation in naturally ventilated dairy housing barns during heat waves. Ukrainian Journal of Ecology, 10(3): 56-62. DOI: https://www.doi.org/10.15421/2020_133

Kibler HH (1964). Environmental physiology and shelter engineering. LXVII, Thermal effects of various temperature-humidity combinations on Holstein cattle as measured by eight physiological responses. Research Bulletin Missouri: Agricultural Experiment Station, 862: 1-42. Available at: https://hdl.handle.net/10355/58200

Kismul H, Spörndly E, Höglind M, Næss G, and Eriksson T (2018). Morning and evening pasture access – comparing the effect of production pasture and exercise pasture on milk production and cow behaviour in an automatic milking system. Livestock Science, 217: 44-54. DOI: https://www.doi.org/10.1016/j.livsci.2018.09.013

Kovalenko VP, Khalak VI, Nezhlukchenko TI, and Papakina NS (2010). Biometric analysis of variability of traits of farm animals and poultry. A textbook on farm animal genetics. Kherson., pp. 160-240. Available at: https://www.studmed.ru/kovalenko-v-p-halak-v-b-ometrichniy-anal-z-m-nlivost-oznak-s-lskogospodarskih-tvarin-ptic-_a95d30b7926.html

Lees JC, Lees AM, and Gaughan JB (2022). The influence of shade availability on the effectiveness of the Dairy Heat Load Index (DHLI) to predict lactating cow behavior, physiology, and production traits. International Journal of Biometeorology, 66: 289-299. DOI: https://www.doi.org/10.1007/s00484-021-02186-x

Maggiolino A, Dahl GE, Bartolomeo N, Bernabucci U, Vitali A, Serio G, Cassandro M, Centoducati G, Santus E, and De Palo P (2020). Estimation of maximum thermo-hygrometric index thresholds affecting milk production in Italian Brown Swiss cattle. Journal of Dairy Science, 103(9): 8541-8553. DOI: https://www.doi.org/10.3168/jds.2020-18622

To cite this paper: Mylostyvyi R, Izhboldina O, Midyk S, Gutyj B, Marenkov O, and Kozyr V (2023). The Relationship between Warm Weather and Milk Yield in Holstein Cows. *World Vet. J.*, 13 (1): 134-143. DOI: https://dx.doi.org/10.54203/scil.2023.wvj14

Mbuthia JM, Eggert A, and Reinsch N (2022). Cooling temperature humidity index-days as a heat load indicator for milk production traits. Frontiers in Animal Science, 3: 946592. DOI: https://www.doi.org/10.3389/fanim.2022.946592

Mylostyvyi R and Chernenko O (2019). Correlations between environmental factors and milk production of Holstein cows. Data, 4(3): 103. DOI: https://www.doi.org/10.3390/data4030103

Mylostyvyi R, Izhboldina O, Chernenko O, Khramkova O, Kapshuk N, and Hoffmann G (2020). Microclimate modeling in naturally ventilated dairy barns during the hot season: Checking the accuracy of forecasts. Journal of Thermal Biology, 93: 102720. DOI: https://www.doi.org/10.1016/j.jtherbio.2020.102720

Mylostyvyi R, Lesnovskay O, Karlova L, Khmeleva O, Kalinichenko O, Orishchuk O, Tsap S, Begma N et al. (2021). Brown Swiss cows are more heat resistant than Holstein cows under hot summer conditions of the continental climate of Ukraine. Journal of Animal Behaviour and Biometeorology, 9(4): 2134. DOI: https://www.doi.org/10.31893/jabb.21034

Mylostyvyi RV, Chernenko OM, Izhboldina OO, Pugach AM, Orishchuk OS, and Khmeleva OV (2019). Ecological substantiation of the normalization of the state of the air environment in the uninsulated barn in the hot period. Ukrainian Journal of Ecology, 9(3): 84-91. Available at: https://www.ujecology.com/abstract/ecological-substantiation-of-the-normalization-of-the-state-of-the-air-environment-in-the-uninsulated-barn-in-the-hot-pe-44428.html

Nardone A, Ronchi B, Lacetera N, Ranieri MS, and Bernabucci U (2010). Effects of climate changes on animal production and sustainability of livestock systems. Livestock Science, 130(1-3): 57-69. DOI: https://www.doi.org/10.1016/j.livsci.2010.02.011

National Research Council (NRC) (2001). Nutrient requirements of dairy cattle. National Academies Press.

Polsky L and von Keyserlingk MAG (2017). Invited review: Effects of heat stress on dairy cattle welfare. Journal of Dairy Science, 100(11): 8645-8657. DOI: https://www.doi.org/10.3168/jds.2017-12651

Rhoads ML, Rhoads RP, VanBaale MJ, Collier RJ, Sanders SR, Weber WJ, Crooker BA, and Baumgard LH (2009). Effects of heat stress and plane of nutrition on lactating Holstein cows: I. Production, metabolism, and aspects of circulating somatotropin. Journal of Dairy Science, 92(5): 1986-1997. DOI: https://www.doi.org/10.3168/jds.2008-1641

Rodriguez-Venegas R, Meza-Herrera CA, Robles-Trillo PA, Angel-Garcia O, Rivas-Madero JS, and Rodriguez-Martínez R (2022). Heat stress characterization in a dairy cattle intensive production cluster under arid land conditions: An annual, seasonal, daily, and minute-to-minute, big data approach. Agriculture, 12(6): 760. DOI: https://www.doi.org/10.3390/agriculture12060760

Sejian V, Chauhan SS, Devaraj C, Malik PK, and Bhatta R (2021). Impact of climate change on animal production and welfare. In: V. Sejian, S. S. Chauhan, C. Devaraj, P. K. Malik, and R. Bhatta (Editors), Climate change and livestock production: Recent advances and future perspectives. Springer., Singapore. pp. 85-98. DOI: https://www.doi.org/10.1007/978-981-16-9836-1_1

Smith P, Martino D, Cai Z, Gwary D, Janzen H, Kumar P, McCarl B, Ogle S, O'Mara F, Rice C et al. (2007). Agriculture. In: B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, and L.A. Meyer (Editors), Climate change 2007: Mitigation. Contribution of working group III to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press., Cambridge, United Kingdom and New York, NY, USA. pp. 497-540. Available at: https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg3-chapter8-1.pdf

Tomczyk AM, Bednorz E, and Półrolniczak M (2019). The occurrence of heat waves in Europe and their circulation conditions. Geografie, 124(1): 1-17. DOI: https://www.doi.org/10.37040/geografie2019124010001

Zazharska N, Boyko O, and Brygadyrenko V (2018). Influence of diet on the productivity and characteristics of goat milk. Indian Journal of Animal Research, 52(5): 711-717. DOI: http://www.doi.org/10.18805/ijar.v0iOF.6826

To cite this paper: Mylostyvyi R, Izhboldina O, Midyk S, Gutyj B, Marenkov O, and Kozyr V (2023). The Relationship between Warm Weather and Milk Yield in Holstein Cows. *World Vet. J.*, 13 (1): 134-143. DOI: https://dx.doi.org/10.54203/scil.2023.wvj14