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INFLUENCE OF TEMPERATURE-HUMIDITY INDEX AND FARM FACTORS ON SOME BIOCHEMICAL BLOOD PARAMETERS IN DAIRY COWS

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Abstract

A one-year study of the Temperature-humidity index (THI) was conducted in three buildings used for breeding dairy cows (farms). They were kept free in separate boxes or as a group living on a permanent litter bedding. Blood samples from 6 animals from each farm were taken and the following biochemical indicators were tested - blood sugar, total protein, urea, cholesterol, creatinine, cortisol, aspartate aminotransferase (ASAT), alanine aminotransferase (ALAT), calcium(Ca), phosphorus (P), magnesium (Mg), sodium (Na), potassium (K) and chlorine (Cl). It was found that the season has a significant effect on THI, blood sugar, total protein, urea, cholesterol, creatinine, cortisol, ASAT, ALAT, Na and K (P<0.001), and a significant effect on Ca and P (P<0.01). The change in the values of THI, cortisol (P<0.001), urea and cholesterol (P<0.01) are related to the breeding technology. The blood sugar, creatinine, P, Mg, Na, K and Cl values are not affected by the type of building and are within physiological norms. Variations of the studied parameters are related to season and breeding technology.

Key words: *biochemical blood parameters, dairy cows, farm building, temperature-humidity index (THI).*

INTRODUCTION

The influence of the climate change on domestic animals is a global problem and is bound to lie even more challenges ahead of farmers in the years to come. The seasonal changes and temperature increases may affect the domestic animals' blood indicators (Bacalov et al., 2009). Hewett (1974) reported that the most productive high-yielding dairy cows are especially susceptible to high ambient temperature and this influences their blood profile. The seasonal fluctuations in the air temperature and the relative humidity as well as other environmental conditions affect the biological system of the animals (El-Nouty et al., 1990). The morphological and biochemical blood changes most objectively indicate any deviations from the basic biophysical and biochemical functions in the organism. These examinations are particularly useful due to the fact that they provide information about the condition of animals before any clinical symptoms of a disease or stress are displayed. The analysis of the blood parameters as early response indicators may serve as the basis for diagnostics, treatment and prevention of different diseases (Otto et al., 2000; Ndlovu et al., 2007). Studies carried out by Armstrong (1994), Kadzere et al. (2002), Dikmen and Hansen (2009) point that not only THI can be used as thermal climatic conditions indicator but also as a tool reporting stress levels in cows. With suitable temperature and humidity in production premises guarantee both the comfort inside, and the health and productivity of animals (Gaughan et al., 2002; Hansen, 2007). The optimal temperature zone under Ordinance No. 44 is 10-15ºC at a minimum of 5 and maximum of 28ºC. Temperatures above 18-20ºC could potentially cause heat stress in high-yielding dairy cows.

The studies show that the temperature and humidity index (THI) can be used as an indicator of heat stress in cows (Kadzere et al., 2002; Armstrong, 1994; Dikmen and Hansen, 2009). Mazzullo et al. (2014) have proved that environmental conditions are the main stress factors having effect on animals and take into account the seasonal influence on their hematology and blood chemistry parameters. Having in mind that environmental conditions affect animals the present study aims to trace the levels of some hematological indicators of cows bred in different type of buildings during three different seasons.

MATERIALS AND METHODS

The present study comprises three periods- summer, winter and transitional one. The air temperature and humidity in the three controlled farms was measured every month of the respective period for 3 to 5 days. Farm 1 (F 1) has a capacity of 130 dairy cows, grown freely in individual cabins, divided into 2 groups of 65 animals each. The cabins are divided in four rows. The building is an open metal structure with a roof made of thermopanels. The longitudinal walls are made of concrete with a thickness of 0.25 m and a height of 1.5 m. The short walls are 3.0 m in height. The area of the feeding path has no doors and it is fully opened. The total area of the building is 1,248 m², walking area is 595.2 m² and rest area is 422.4 m².The space provided for one animal is 9.4 m².

The building is 48 m long, 26 m wide, 3 m in height to the roof structure and 8 m in height to the ridge. The floor is made of cement. The cabins are covered with a hard rubber mat with a thickness of 2 cm.

Lighting is provided through the opened space of the building with a total area of 170 m². Artificial lighting is provided by 14 luminescent laps, each consisting of 3 luminary pipes with a power of 40 W. Mechanical ventilation is provided by 8 ventilators mounted above the cabins and the walking area, at an angle of 45º. Each one of them has a power of 0.55 kW and a capacity of 60,000 L/h. Four of them are automatically started at temperatures above 18°C and the remaining four are automatically started at temperatures above 25°C.

The manure is cleaned with a delta scraper device that automatically turns on every 6 hours.

Farm 2 (F 2) has a capacity of 200 dairy cows, grown freely in individual cabins, divided into 4 groups. The total area of the building is 2,310 m² and the space provided for one animal is 11.5 m². The building is made of reinforced concrete and roof panels and its dimensions are 105/22 m. The height of the walls is 4.5 m and the height of the ridge is 5.8 m.

The individual cabins are located on both sides of the longitudinal walls with dimensions 1.10/2.10 m. There are no partitions between them. The manure paths are located between the individual cabins and the feeding area.

The floor of the whole building is made of cement. The natural light in the farm is provided by a total of 30 windows, 20 of which are with dimensions 5.80/0.90 m and 10 are with dimensions 5.80/2.00 m. At the ridge of the building there are also 12 ventilators (windows), each measuring 5.80/0.90 m. Artificial lighting is provided by 97 lamps, each consisting of 2 luminary pipes with a power of 40 W. In the winter period, the windows and the ridge ventilators are covered with polyethylene sheets. Mechanical ventilation is provided by 10 ventilators mounted above the walking and feeding areas. Each one of them has a power of 0.55 kW and a capacity of 60,000 L/h.

The manure is cleaned with a delta scraper device that automatically turns on every 3 hours.

Farm 3 (F 3) has a capacity of 67 dairy cows with a total living area of 598.5 m² and a 540 m² area used for walking and rest. The space provided for one animal is 8.06 m². The building is made of brick masonry, it is semi-opened and its dimensions are 45/12 m and a height of 3 m. The length of the short walls is 6 m and the rest 6 m are unclosed. The roof structure is made of galvanized sheet without insulation. The natural ventilation, achieved through the unclosed short walls, matches with the tunnel type. Eight rotary fans (DeLaval) are mounted above the deep litter area, at an angle of 45º, for additional mechanical ventilation. Each one of them has a power of 0.55 kW and a capacity of 60,000 L/h. Four of them are automatically started at temperatures above 18°C and the remaining four are automatically started at temperatures above 25°C.

The feeding is “at will” with an all-purpose fodder mix and constant access to water. The manure is cleaned twice a year, however litter is added periodically. Lighting is natural and its characteristics depend on the season. Artificial lighting is provided by five 100 W lamps mounted above the feeding path and three 200 W lamps mounted above the walking and rest zones.

The THI is calculated based on Thom. Blood samples were taken from six animals form each farm (in same age and physiological condition - in the first three months of lactation). The blood serum acquired was tested for: blood sugar, total protein, urea, cholesterol, creatinine, cortisol, ASAT, ALAT, calcium, phosphorus, magnesium, sodium, potassium chloride. The results were statistically processed via IBM, SPSS 21.

RESULTS AND DISCUSSIONS

In order to ascertain the extent to which the farm barn environment factors could form its comfort or discomfort, we used the temperature humidity index (THI) as defined by Thom (1959). To calculate it, we used the average temperature and humidity values.

Table 1 displays the THI values of the farms examined during the different seasons. The season has a plausible effect on the index (P<0.001) (Figure 1).

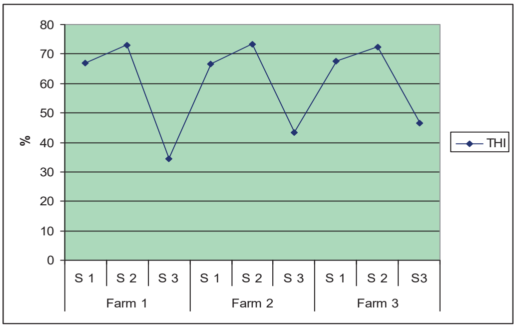

Figure 1. Seasonal dynamics in the THI values

The index values are dynamic throughout the day. The values between 77 and 87 are considered the critical THI point because it is then that the animals' lethal cases start to increase (Vitali et al., 2009).

Table 2 indicates that the blood sugar levels in the farms examined by us are close to the lower reference norms, however, the plausible influence of summer season on them is accounted for (P<0.001).

Table 1 Temperature humidity index of the buildings examined during the three seasons

Parameter	Farm	LSM	± SE	SD	Season	LSM	± SE	SD
THI	1	58.03	4.12	17.46	67.00	0.086	0.37	0.37
	2	61.07	3.11	13.21	72.80	0.105	0.45	0.37
	3	62.10	2.69	11.45	41.41	1.261	5.35	0.45

Note: LSM - average; SE - standard error; SD - standard deviation.

Table 2. Influence of the season and farm on some biochemical blood parameters in the studied cows

Parameter	F	LSM	± SE	SD	F-criteria and Sig	S	LSM	± SE	SD	F criteria and Sig
Glucose	1	2.61	0.17	0.74	0.88	1	2.82	0.024	0.10	300.21***
	2	2.64	0.22	0.93		2	1.56	0.063	0.27	
	3	2.71	0.23	0.98		3	3.57	0.086	0.36	
TP	1	70.68	1.40	5.95	5.72**	1	72.28	1.277	5.42	21.63***
	2	66.21	1.73	7.32		2	63.08	1.757	7.45	
	3	71.51	1.65	6.98		3	73.05	0.516	2.19	
Urea	1	5.23	0.36	1.54	8.89***	1	4.49	0.181	0.77	124.58***
	2	4.80	0.36	1.52		2	7.20	0.186	0.79	
	3	5.72	0.38	1.63		3	4.05	0.146	0.62	
Creatinine	1	108.8	14.74	62.54	0.53*	1	67.56	1.547	6.56	69.65***
	2	133.44	12.58	53.38		2	175.19	11.30	47.94	
	3	103.22	12.59	53.44		3	82.00	2.375	10.08	
Cholesterol	1	2.85	0.22	0.94	4.47*	1	3.59	0.082	0.35	185.41***
	2	2.76	0.24	1.01		2	1.67	0.078	0.33	
	3	3.08	0.22	0.93		3	3.42	0.097	0.41	
ASAT	1	97.66	7.90	33.52	0.47	1	86.77	3.627	15.39	10.87***
	2	91.99	6.08	25.80		2	129.67	14.047	59.59	
	3	103.61	14.30	60.67		3	76.83	2.154	9.14	
ALAT	1	22.44	1.53	6.48	4.37*	1	17.97	1.112	4.72	20.39***
	2	23.38	1.78	7.56		2	27.71	1.623	6.89	
	3	18.66	1.40	5.95		3	18.79	0.948	4.02	

Cortisol	1	65.26	4.96	21.04	51.55***	1	39.97	0.402	1.71	697.11***
	2	55.67	2.82	11.97		2	73.08	3.109	13.19	
	3	59.64	3.431	14.56		3	67.52	0.494	2.09	
Ca	1	2.44	0.03	0.13	3.96*	1	2.32	0.037	0.16	8.05**
	2	2.34	0.04	0.16		2	2.29	0.036	0.15	
	3	2.31	0.05	0.21		3	2.47	0.038	0.16	
P	1	1.93	0.06	0.27	1.22	1	1.73	0.039	0.168	8.22**
	2	1.97	0.08	0.32		2	2.04	0.062	0.265	
	3	1.85	0.05	0.21		3	1.98	0.064	0.270	
Mg	1	1.00	0.02	0.08	2.19	1	0.96	0.026	0.114	0.98
	2	0.94	0.03	0.11		2	0.97	0.023	0.099	
	3	0.99	0.02	0.09		3	0.99	0.016	0.065	
Na	1	146.50	1.75	7.44	3.62*	1	149.11	1.204	5.109	44.72***
	2	144.06	1.77	7.51		2	135.44	0.894	3.792	
	3	142.17	2.03	8.60		3	148.17	1.331	5.649	
K	1	4.78	0.11	0.48	0.19	1	5.23	0.061	0.258	108.2***
	2	4.74	0.09	0.42		2	4.27	0.030	0.128	
	3	4.75	0.11	0.44		3	4.77	0.042	0.177	
Cl	1	105.22	0.49	2.10	1.27	1	106.17	0.406	1.724	2.74*
	2	105.83	0.51	2.18		2	104.94	0.461	1.955	
	3	104.78	0.47	1.99		3	104.72	0.559	2.372	

Note: ***P<0.001; **P<0.01; *P<0.05.
Number of animals form each farm = 6, F - farm; S - season; LSM - average; SE - standard error; SD - standard deviation; F - criteria and Sig - ration of the mean sums of squares of the regression equation and the residual and significance level.

In a similar experiment Gorski and Saba (2012) also reported a decrease in glucose levels. The blood sugar is not a major source of energy for the ruminant animals, however, at the end of the pregnancy and at the beginning of the lactation, as it is in our study, a big amount of the blood sugar is used for lactose and milk fat synthesis so its values are indicative of some pre-pathological or pathological states. The studies of Darul and Kruczynska (2005) show that, the blood sugar levels decrease after birth, after beginning of active lactation and upon change in cows energy balance.

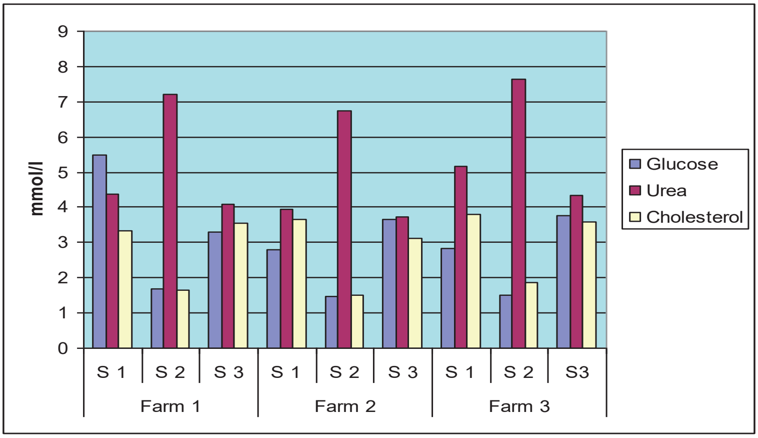

Figure 2. Seasonal dynamics in the blood serum content of glucose, urea and cholesterol of the cows from the farms examined

The blood serum urea levels (Figure 2) are a criterion for the organism protein self-sufficiency. Its high levels (P<0.001) along with these of the creatinine indicate increased kidney function, which in this case is related to the high summer temperatures and the increased metabolic activity associated with it.

The season definitely affects the cholesterol levels (Figure 2) which are the lowest during the summer (P<0.001) while the farm does not have influence on this parameter. When interpreting the lipid metabolism of ruminants, we must take into account the fact that they intake very little amount of lipids. Along with the glucose, the lipids turn into volatile fatty acids parts of which are present in the milk fat. The lactating cows have the unique quality to maintain high concentration of cholesterol in the plasma. The rich high-density lipoprotein content transports cholesterol to the liver due to which rarely does this type of animals experience any unfavorable consequences. The lower summer season values reported by us can probably be explained by the quality of the feeds or an initial stage of liver damage. This is evidenced by the higher ASAT and ALAT levels (Figure 3). Our study reveals that the enzyme activities are inherently high and affected both by the farm and the season ($P<0.001$). The less pronounced increase in ASAT when compared to ALAT levels is due to the fact that ALAT is present only in the cytoplasm while a significant part of the ALAT trans-fat is present in the mitochondria and is only released in case of very serious degenerative cell changes. Bhan et al. (2012) reported higher ASAT and ALAT levels during the winter which they explain as a result of these enzymes release form the liver cytosol into the bloodstream which in turn displays the damage and the dysfunction of the liver. The increased ASAT and ALAT function can also be associated with energy metabolism disorder in the body as well as stress (Krupczynski and Chudoba-Drozdowska, 2002; Darul and Kruczynska, 2005).

When interpreting the results, we should observe the fact that the cows which are subject to the study are highly productive animals and according to many authors their high trans-fat activity is related to the damage on their livers (Moore, 1997; Cozzi, 2011) claims that similar effect but with reference to healthy cows may be also a result of a higher productive stress. In one study, the authors Gorski and Saba (2012) presumed that the higher AST and ALT levels in cows are related to higher metabolic efforts caused by the intensified lactation.

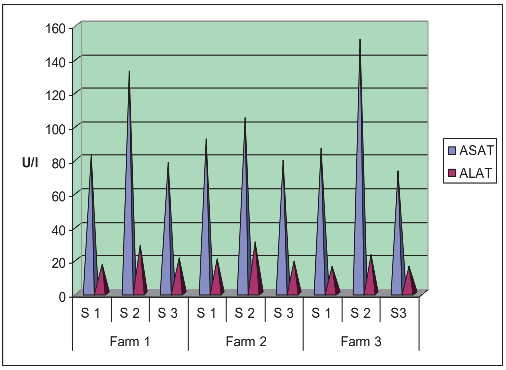

Figure 3. Seasonal dynamics of the blood serum ASAT and ALAT content of the cows from the studied farms

The total protein levels range within the lower reference values in all seasons and with reference to all farms but is considerably more noticeable in the summer. The feeding pattern is the major factor which influences the protein levels in the blood.

Creatinine is formed in the muscles and usually has a stable level which depends on the kidneys function. The creatinine levels show an interesting dynamics with the summer season influence being especially noticeable ($p<0.001$). The maintenance of high creatinine levels in this case probably has to do with the animals' physical activity. The increased creatinine levels after intensive muscle activity were observed by Sato et al. (2001), Nikolov et al. (2011; 2009).

Cortisol is considered a major biomarker upon unlocking of the animals adaptive mechanisms during heat stress. Our studies indicate that the season plausibly influences the cortisol values ($P<0.001$) (Figure 4). Johnson and Vanjonack, (1976) reported increased cortisol levels both at extremely low and very high temperatures.

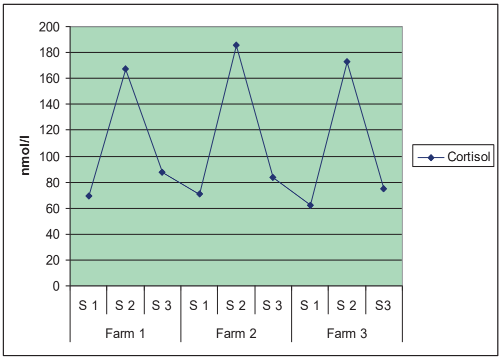

Figure 4. Seasonal dynamics in the blood serum cortisol content of the cows from the examined farms

The minerals are supplied with the food and play a structural and functional role; therefore, the change in their serum concentration affects the health and productivity of the animals.

The phosphorus takes part in the energy transport and is contained in the nucleic acids.

The potassium is involved in the muscle contractions. Our study shows that both microelements are affected by the season (phosphorus: P<0.01; potassium: P<0.001).

The sodium serves primarily for the maintenance of the osmotic stability. Its quantity in the organism is related to the water exchange. Its values (Figure 5) which are influenced dehydration state trying to compensate the low THI levels by increasing the evaporation through rapid breathing and sweating.

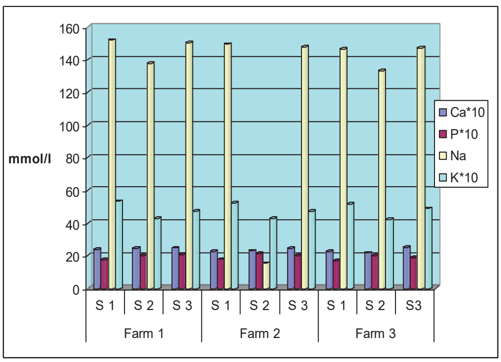

Figure 5. Seasonal dynamics of the blood serum content of calcium, phosphorus, sodium and potassium of the cows from the examined farms

CONCLUSIONS

It has been ascertained that the season has a significant effect on the THI, glucose, total protein, urea, cholesterol, creatinine, cortisol, ASAT, ALAT, sodium and potassium levels (P<0.001) and on the calcium and phosphorus levels (P<0.01). The changes found in the THI levels, cortisol, urea (P<0.001), total protein (P<0.01), creatinine, cholesterol, ALAT, Ca and Na (P<0.05) are connected with the breeding technology (farms). The glucose, ASAT, P, Mg, K and Cl in the blood of the cows are not affected by the type of building and are within the physiological reference norms.

The abovementioned gave us the reason to come to the conclusion that the variations in the examined parameters are related to the season, type of building, and the breeding technology (farms).

It was ascertained that the blood parameters examined are dependent on the THI in the premises and are mildly or not affected by the type of building and the manner of breeding.

Our results reveal differences in the hematology and blood chemistry parameters related to the changes in the ambient temperature and THI, although some of them are within their physiological diapason. Therefore, we can state that the seasonal changes may affect the metabolic processes of the dairy cows.

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