THE INFLUENCE OF HEAT STRESS ON THE MAIN QUALITY INDICATORS OF MILK PRODUCTION IN A HERD OF DAIRY COWS BELONGING OF THE ROMANIAN SPOTTED BREED

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Abstract
The aim of the study is to analyze the dynamic of the main quality indicators of milk production over the period 2023 - 2024 for a herd of dairy cows belonging to the breed Romanian Spotted exploited in condition of a farm from Iași county, NE Romania. The data were obtained from the Official Production Control and were statistically processed using the computer programs SAVC and SPSS 16.00. Under heat stress conditions, changes are observed in the chemical composition of the milk for the THI ≥ 64 threshold. Thus, the content of components such as protein and fat in milk begins to decrease from this threshold to 3.94% and 3.41%, respectively. Milk production decreases drastically for the THI ≥ 72 threshold to 9.64 kg, which also determine a reduction in lactose content to 4.66%. Casein synthesis is also affected and under the action of heat stress, its content in milk decreases to 25.44%. Heat stress is a factor that influences milk production from a quantitative but also qualitative point of view, therefore measures must be taken to minimize its effects during the summer month in particular.

Key words: *heat stress, dairy cow, THI*

INTRODUCTION

Stress is the adaptive reaction that the body exhibits to the action of situations or factors that destabilize its homeostasis. Thermal stress can be defined as the response that the body has to the action of ambient temperatures located outside the thermal comfort zone. In the case of dairy cows, the physiological response to stress is reflected in productive performance and milk quality.

In order to monitor it, the thermal discomfort index (THI) has been defined, which is calculated based on the environmental temperature and humidity values. THI values are an indicator of the presence of thermal stress and many studies have investigated the correlations between the different threshold values and changes in animal production.

The effects of global warming are becoming part of everyday life and the increase in temperatures is felt especially during the summer months. Romania, although located in a temperate zone, is not exempt from the effects of this process. Thermal stress affects dairy cows across the country for increasingly extended periods and the long-term action makes the effects manifest themselves remanently, many days after the temperatures drop.

Almost all European dairy breeds are very vulnerable to heat stress because they were traditionally bred and raised in colder climates and do not have the genetic adaptations to withstand it. In addition, in

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breeds with high milk production and extremely high metabolic rates, internal heat production increases significantly, making them more vulnerable. [1]. Most studies have been conducted on dairy herds of Holstein-Friesian breed, which is the most widespread. By analyzing the results in the present study, a contribution will be made to completing the picture of the effects of heat stress on milk production of Romanian spotted breed cows (Simmental strain).

Heat stress occurs when an animal's body is unable to dissipate its own heat due to increased ambient temperature and humidity. Heat stress is strongly correlated with increased respiratory rate and pulse rate, elevated rectal and vaginal temperatures, elevated plasma cortisol levels, decreased feed intake, and increased water intake in animals exposed to such an environment. [2, 3]

Medium- or long-term heat stress responses are observed in dairy cattle exposed to prolonged heat stress and the most common are reduced feed intake, rumination time, milk production and quality, with impairment of health, reproductive performance and immune response. [4, 5, 6, 7]

Because feed intake is reduced and the nutritional needs of cows change during heat stress, a good management measure is to reformulate the ration by increasing nutrient density without compromising normal rumen function. [8].

The effects of heat stress are the result of the combination of the duration and intensity of exposure to elevated THI values and the physiological status of the cows. [9] These not only have an impact on milk production but are also closely linked to the sustainability of production and animal welfare. [10]

MATERIAL AND METHOD

The values of the qualitative parameters of the milk from the 911 individual samples collected were obtained from the analysis bulletins provided by Official Production Control (OPC) for 2023 and 2024. The milk samples are from dairy cows belonging to the Romanian spotted breed, Simmental strain which are cows with mixed production.

The cows are husbandry on a farm located in N-E of Romania, Iassy county and are exploited in an intensive system, in permanent free stall. The animals are fed from stock and the feed is mono-diet type consisting of a basic (fibrous) ration and a supplementary (concentrate) one. In the barn, the ventilation is achieved by natural way and watering is provided with constant-level drinkers (buffets), with water supplied from the distribution network. Cows are milked twice a day, with 12 hours between milkings.

The primary data were statistically processed by PhD Prof. Vasile MACIUC from U.S.V. Iassy with the computer programs S.A.V.C. It was determine the arithmetic mean ($\bar{X}$), the arithmetic mean error ($\pm s_{\bar{x}}$), the standard deviation (s), the coefficient of variation (V%), the Fisher and the Tukey tests. Also, it was used the Graph Prisma 9 program to test the significance of the differences.

The p-value of the test, given as a number between 0 and 1, represents the probability of making an error if we reject the hypothesis H_0. If p is less than the chosen significance threshold α – usually α = 0,05 – we reject the hypothesis H_0 and accept the hypothesis H_1 as true.

The milk quality parameters for which the statistical processing was performed are: fat percentage (F %), protein percentage (P%), lactose percentage (Lact %), casein content (Caz - g/l) and urea (mg/dl).

The temperature – humidity index (THI) is a value reached with a specific formula and which is using to evaluate the effects of heat stress. (11, 12). To calculate the monthly THI values, the following formula was applied: $(1,8 \times T + 32) - (0,55 - 0,0055 \times RH) \times (1,8 \times T - 26)$ where T (°C) is the average monthly temperature and RH (%) is the average monthly value of relative humidity calculated based on meteorological local data accessible on www.wunderground.com.

RESULTS AND DISCUSSIONS

In literature, the heat stress it is indicated in dairy cattle as a threshold of 72 THI and 28°C or higher for temperature. In recent studies, the threshold for stress in dairy cattle has been set at daily THI values of 68–72, although lower values have been found for temperate areas (13).

Some authors state in their studies that dairy cows are in the comfort zone at THI < 68, slightly stressed at THI between 69-78, moderately stressed at THI 79-89 and severely stressed at THI > 90. (1). High relative humidity, in combination with elevated temperatures, can exacerbate the degree of heat stress in cows.

In this study, the values obtained were grouped into 7 categories: THI1<30, THI2=30÷56, THI3=56÷60, THI4=60÷64, THI5=64÷68, THI6=68÷72, THI7≥72, as other authors have done.

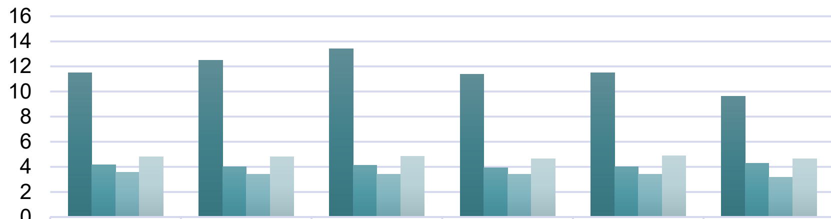
If we refer to the thermal comfort zone of cattle, it can be seen that in 2023 the warmest months were July and August for which the monthly average of daily temperatures is 23.43 ºC and 24.83 ºC, respectively. In these summer months, absolute maximum temperatures of 36 ºC and 38 ºC were recorded. During the day, average values exceeding the thermal comfort zone are recorded in addition to July and August and in May, June and September. During 2023, the highest THI values, above the threshold of 68 that triggers the adaptive mechanisms of the animals, were recorded in July (69.54) and August (71.04).

In 2024, the monthly daily averages are between -0.49 ºC in January and 25.17 ºC in august. The average daily temperatures that are higher than 20 ºC are also recorded in the summer months (June, July, August), these being slightly higher than those of the previous year. During the day, temperatures tend to be thermally uncomfortable starting from May to September, with monthly average daily temperatures being between 22.48 – 24.60 ºC. The warmest month of the year was July followed by august, with absolute maximum temperatures of 39 ºC and 34 ºC recorded, respectively. Compared to the previous year, THI values > 68 are calculated for three months, all from the summer period: June -70.03; July – 72.39 and August 71.61.(table 1).

Table 1. Monthly average values of temperatures, relative humidity and THI

Month of the year	2023			2024		
	ºC$_m$	U%	THI	ºC$_m$	U%	THI
January	3.02	87.44	*38.70*	-0.49	79.30	34.06
February	2.32	67.90	*39.72*	6.41	76.31	45.29
March	7.08	51.97	*48.03*	6.88	72.97	46.12
April	8.50	70.53	*48.75*	14.25	63.18	57.36
May	16.13	51.13	*60.14*	16.71	56.01	61.00
June	20.53	52.27	*65.95*	22.83	65.67	70.03
July	23.43	48.74	*69.54*	25.17	58.23	72.39
August	24.83	46.58	*71.04*	24.57	55.97	71.61
September	20.28	51.27	*65.67*	18.90	69.95	64.32
Octomber	14.74	48.90	*58.25*	11.14	83.15	52.61
Noiember	6.98	68.90	*46.53*	3.76	81.12	40.57
December	2.68	82.38	*38.60*	2.19	89.93	37.07

Due to the proven effects that heat stress has on the body of cattle and physiological functions, it is expected to find differences in terms of productive performance and the quality of the milk they produce, especially during the summer months.



	30-56	56-60	60-64	64-68	68-72	≥ 72
MY (kg)	11.514	12.513	13.42	11.369	11.502	9.642
G%	4.173	4.023	4.12	3.938	4.013	4.287
P%	3.579	3.42	3.41	3.41	3.41	3.191
Lact%	4.82	4.819	4.854	4.639	4.885	4.658

MY (kg) G% P% Lact%

MY – milk yield

Figure 1. The influence of heat stress on milk production and composition

As can be seen in the graphical representation of the values in figure 2, under the action of thermal stress, the percentage content of the main components of milk (fat, protein and lactose) have a heterogeneous dynamics once the THI threshold of 64 is crossed. Milk production decreases starting from this threshold and remains somewhat constant, but at THI values higher than 72 it decreases again to 9.642 kg, at which point the quality of milk also changes because the protein and lactose percentages decrease to 3.19% and 4.65% respectively. The fat percentage decreases to 3.938% at THI values equal to 64-68, after which, for the following intervals, it increases to 4.287% when the index has values above 72.

In studies conducted on the influence of heat stress on milk quality, namely the variation in fat and protein content, it was found that these quality traits were generally weakly to moderately negatively correlated with THI, with the strongest correlations being for protein content. [14].

Some studies have shown that the decrease in milk production is due to a 35-50% reduction in feed intake caused by heat stress and that it is also affected by changes that are not associated with energy intake but rather with physiological mechanisms through which a different distribution of nutrients and energy is made in the body to support milk production. [10,15] The reduction in feed intake and implicitly energy intake, causes animals to use fat tissue deposits to ensure the development of metabolic processes, which can cause animals to enter a negative balance. The percentage of protein in milk decreases under stress conditions as a result of a decrease in protein synthesis in the mammary gland and not as a side effect of a general decrease in milk production. [10]

In some studies, heat stress has been associated with a quantitative decrease in milk protein and fat, while other researchers have explained the reduction in the production of these components based on their correlation with milk production. The effects of heat stress on milk fat and protein percentages are inconsistent because data on changes in these parameters as a result of heat stress vary, with authors reporting either a decrease, an increase, or no change. [15]

All these observed differences could be explained by the action of other factors such as differences between lactation or feeding stages, as well as by the different response of breeds to thermal stress. [16]

The mechanisms involved in the reduction of milk protein production due to heat stress remain largely unknown. Cows under heat stress may have an increased use of systemic amino acids in homeostatic physiological processes, coupled with reduced blood flow to the mammary gland, which has negative implications for the synthesis of milk protein components [17].

It is recognized that heat stress has an influence on animal health, affected by the level of cortisol in the blood, the functionality of the mammary gland being sensitive to the action of environmental factors, especially in conditions of imbalance of the immune system.

In vitro studies indicate that epithelial cells in the mammary gland are at increased risk of programmed cell death when exposed to high ambient temperatures, which would explain the decrease in milk production observed in heat-stressed cows. [18, 19]

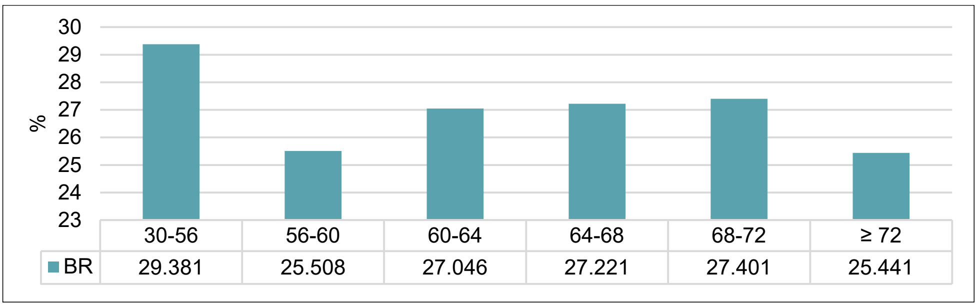


Figure 2 Dynamics of the percentage of casein content in milk for different THI value levels

In figure 2, we can see the variation of the percentage of casein in milk over THI value ranges somewhat similar to that of protein content. In the value range 30-56, the highest values of the percentage of casein are recorded, after which it decreases at THI values equal to 56-60 and increases to values of 27.046 – 27.401 % in the following ranges, so that at THI ≥72 it decreases as it happened with the other components in milk, reaching 25.44%

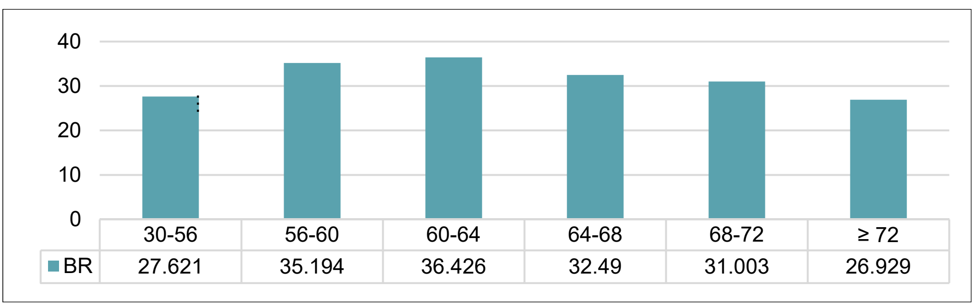


Figure 3. The influence of heat stress on the urea content of milk in the period 2023-2024

In the graphic representation in figure 3, the evolution of the values of the amount of urea in milk for the studied herd can be studied. Although it has very high values in all cases, it begins to decrease continuously with the increase in thermal stress for THI values above 64.

Based on the analyzed data, it can be said that the Romanian spotted cows for which the present study was conducted react to the action of thermal stress and are affected by it mainly for THI values ≥72. Although milk production, the percentage fat content and lactose content are affected by thermal stress from lower thresholds of THI = 64-67. The animals' organisms adapt to unfavorable conditions because milk production increases slightly, as does its quality. Against the background of the decrease in the amount of feed ingested, protein metabolism is affected under stress conditions and from THI=64-68 the urea content in milk decreases. Increases in milk fat percentage at elevated THI values are due to the animals using their own tissue resources to support biological processes.

Table 2 Testing the significance of differences for the main parameters of milk production in the studied herd

Trait/breed		Romanian spotted breed				
	THI	56-60	60-64	64-68	68-72	≥72
% fat	30-56	ns	ns	***	*	ns
	56-60		ns	ns	ns	ns
	60-64			ns	ns	ns
	64-68				ns	**
	68-72					*
% protein	30-56	*	ns	**	***	****
	56-60		ns	ns	ns	ns
	60-64			ns	ns	ns
	64-68				ns	ns
	68-72					ns
% casein	30-56	ns	***	****	****	****
	56-60		ns	ns	ns	****
	60-64			ns	ns	ns
	64-68				ns	ns
	68-72					*
lactose	30-56	****	ns	ns	****	****
	56-60		****	****	***	****
	60-64			ns	****	****
	64-68				****	****
	68-72					****
Milk yield	30-56	ns	*	ns	ns	*
	56-60		ns	ns	ns	***
	60-64			*	*	****
	64-68				ns	ns
	68-72					*

ns - $p>0.05$; * significant - $p<0.05$; ** significant - $p<0.01$; *** high significant - $p<0.001$; **** high significant - $p<0.0001$

Table 2 presents the significance testing of the differences for the analyzed characters at different values of the THI intervals. From the significance analysis of the differences it can be stated that although thermal stress is a factor of influence on the quality of milk for the Romanian spotted breed, the statistically very significant differences ($p<0.0001$) are from THI values equal to 64-68. Thus, the percentage of casein and lactose presents highly significant statistical differences above this threshold for $p<0.0001$.

For values of the temperature-humidity index ≥ 72, milk production and protein percentage show highly significant differences ($p<0.001$; $p<0.0001$) of the mean compared to the other intervals and the fat percentage has significant differences for this threshold ($p<0.01$).

Heat stress is a factor that influences milk production from a quantitative and qualitative point of view, therefore measures must be taken to minimize its effects, especially during the summer. Immediate management measures that can be implemented aim at rigorous monitoring of microclimate indicators in the stable by implementing integrated IoT monitoring systems that automatically activate ventilation and cooling devices for THI thresholds that are identified with the action of heat stress. Also, a recommended solution is to reformulate the rations administered under these conditions to ensure the animals a balanced intake of necessary nutrients, without affecting the functionality of the rumen and which can be consumed in full.

CONCLUSIONS

Heat stress is increasingly felt by animals under the influence of rising temperatures, especially during the summer. Following the analysis carried out in this study, heat stress is clearly felt from THI values ≥ 72 and is a factor of influence for cow production in quantitative and qualitative terms. Based on the values of the estimators calculated for different THI thresholds, it can be concluded:

-for THI ≥ 72, the lowest milk production of 9.642 kg and the lowest percentages of protein and lactose, of 3.191% and 4.658% respectively, are recorded, however, the highest values of fat content of 4.287% are recorded;

- for THI=30-56, 29.38% casein content is recorded, the values being lower in stress conditions (THI > 60) although increasing from one interval to another so that over 72 it is very low 25.44%;

- although the urea content in milk is high in any situation, it decreases when THI equal to 60-64, the quantity being decreasing with the increase in thermal discomfort, which denotes the alteration of protein metabolism if we correlate with the percentage values obtained for them

To summarize, the quantitative changes and of all the components that define the quality of milk are evident for THI≥72, but statistically significant differences ($p<0.0001$) are recorded from index values above 64, as is the case with the percentage of casein and lactose.

The Romanian spotted breed is resistant to heat stress and can adapt to conditions of incipient thermal discomfort.

Considering the influence of heat stress on production quality, the following recommendations can be made:

- reformulating rations during the summer, by production category, in terms of structure, protein content and energy intake during the summer months so that it can be consumed in its entirety and provide the necessary nutrients without affecting the functionality of the rumen;

- management measures aimed at adopting strategies to control environmental parameters by installing an IoT monitoring system that activates ventilation systems based on THI values.

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