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STRESSFUL SEASONAL FACTORS OF INFLUENCE ON MILK PRODUCTIVITY AND QUALITY OF COW'S MILK

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The research is devoted to a topical issue – establishing the influence of seasonal changes on the quality indicators of cow milk in the forest-steppe of Ukraine. Researchers from different countries and climatic regions have proven the impact of seasonal changes on the milk productivity of cows. Studies were conducted on cows of the Ukrainian red-pock dairy breed, in which milk productivity was taken into account by the method of control milking during January-August and the fat and protein content in milk was determined. The experiment was divided into three stages according to the actual ambient temperature: I – from -3 °C to +9 °C, II – from +10 °C to +24 °C, III – from +24.5 °C to +36.4 °C. the actual average air temperature was – +7 °C, +21 °C and 28 °C, respectively.

At the first stage of the experiment, the average daily milk yield of experimental cows was 19.6 kg, during the first – the coldest period of research (from January 2 to March 25) – their productivity increased by 0.2 kg. At the second stage of research, during the spring warming (from March 26 to May 26), the average daily milk yield increased by 0.7 kg. At the end of the hottest third period of the study (from May 27 to August 31), the daily milk yield decreased by 1.1 kg compared to the first period and by 1.8 kg compared to the second period.

Differences between the indicators of fat and protein content in the milk of experimental cows were established. At the first stage of the experiment, the average fat content in the milk of experimental cows was 3.93%, protein – 2.98 %. During the coldest period of the year studied, the fat content in milk increased by 0.14 % ($p<0.01$), protein – by 0.24 % ($p<0.01$). At the end of the second stage of the study, the fat and protein content in milk increased slightly, by 0.05% and 0.02%, respectively. During the hottest period of research, the fat content in the milk of experimental cows increased by 0.14 %. The protein content in milk decreased slightly (by 0.06%) at the end of the third study period.

Thus, it is proved that seasonal changes affect the milk productivity of cows, in particular, the daily milk yield, fat and protein content in milk, which is consistent with studies by other scientists conducted in different countries. Further research should be aimed at finding innovative ways to offset the negative factors of seasonal changes on the productivity of dairy cattle.

Keywords: dairy cattle, milk productivity, daily milk yield, milk fat, milk protein

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СТРЕСОВІ СЕЗОННІ ФАКТОРИ ВПЛИВУ НА МОЛОЧНУ ПРОДУКТИВНІСТЬ І ЯКІСТЬ МОЛОКА КОРІВ

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Дослідження присвячені актуальному питанню – встановленню впливу сезонних змін на показники якості молока корів в умовах Лісостепу України. Дослідниками різних країн і кліматичних регіонів доведено вплив сезонні змін на молочну продуктивність корів. Дослідження проведені на коровах української червоно-рябої молочної породи, в яких обліковували молочну продуктивність методом контрольних доїнь впродовж січня-серпня і визначали вміст жиру і білка у молоці. Дослід було розділено на три етапи за фактичною температурою зовнішнього середовища: I – від -3°C до +9°C, II – від +10°C до +24°C, III – від +24,5°C до +36,4°C. Фактична середня температура повітря становила відповідно – +7°C, +21°C та 28°C.

На першому етапі досліду середній добовий надій молока дослідних корів становив 19,6 кг, за перший – найбільш холодний період досліджень (з 2 січня по 25 березня) – їх продуктивність зросла на 0,2 кг. На другому етапі досліджень впродовж весняного потепління (з 26 березня по 26 травня) середній показник добового надою підвищився на 0,7 кг. Наприкінці найбільш спекотного третього періоду досліджень (з 27 травня по 31 серпня) показник добового надою знизився на 1,1 кг у порівнянні з першим періодом і на 1,8 кг у порівнянні з другим періодом.

Встановлено відмінності між показниками вмісту жиру і білка у молоці дослідних корів. На першому етапі досліду середній вміст жиру у молоці дослідних корів становив 3,93 %, білка – 2,98 %. Впродовж найбільш холодного дослідженого періоду року вміст жиру у молоці підвищився на 0,14 % ($p<0,01$), білка – на 0,24 % ($p<0,01$). Наприкінці другого етапу досліджень вміст жиру і білка у молоці незначно підвищився, відповідно на 0,05 % і 0,02 %. За найбільш спекотний період досліджень вміст жиру у молоці дослідних корів підвищився на 0,14 %. Вміст білка у молоці наприкінці третього дослідного періоду незначно знизився (на 0,06 %).

Таким чином, доведено, що сезонні зміни впливають на молочну продуктивність корів, зокрема – на добовий надій, вміст жиру і білка у молоці, що узгоджується із дослідженнями інших вчених, проведених у різних країнах. Подальші дослідження мають бути спрямовані на пошук інноваційних засобів нівелювання негативних факторів сезонних змін на продуктивність молочної худоби.

Ключові слова: молочна худоба, молочна продуктивність, добовий надій, молочний жир, молочний білок

Introduction. Cow milk production is known to vary with the season and environmental factors (Borshch, 2021; Gauly & Ammer, 2020; Skliarov et al., 2022). Consequently, Picinin and co-authors established a correlation between climatic

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conditions and the physicochemical properties of raw milk, as well as the total volume of milk produced in the conditions of dairy farms in Brazil (Picinin et al., 2019). According to their research, an increase in temperature from 6.2 °C to 31.3 °C led to a significant decrease in the content of milk protein (by 4.09 %), fat (by 5.75 %), also decreased by 1.31% the content of skimmed dry matter (SNF) and by 16.8 % – the content of somatic cells, but the total content of microorganisms in milk increased by 13.7 %. South Korean scientists have studied 1.5 million people. data and established the negative impact of heat stress on the productivity and milk quality of Holstein cows (Lee at al., 2023).

Many scientists prove that the summer season is the most critical for milk production. Experiments on Holstein cows in the conditions of 3,328 dairy farms in the Lombard region of Italy were studied (Bertocchi et al., 2014) results of analysis of 508613 milk samples and established a significant association with seasonal changes in such indicators as the content of dry matter, skimmed milk residue powder, fat and protein in milk. In particular, the most critical season in terms of milk quality was summer, especially July. Tančin and co-authors also on Holstein cows proved the influence of factors of the season of the year on milk quality indicators (Tančin et al., 2020). Parmar and co-authors (Parmar et al., 2020) established the variability of milk density depending on seasonal fluctuations throughout the year. The highest fat and protein content in milk was observed in the autumn-winter period, and the lowest – in the summer. Studies of fat and protein content in cow's milk on large farms under different weather conditions throughout the year have also established seasonal patterns (Feliciano et al., 2023).

It has been proven (Ayemele, 2021) that heat stress causes oxidative stress in the body, resulting in an increase in the content of reactive oxygen species in cells. Significantly higher levels of stress indices catalase, SOD, GSH reductase, and Malone dialaldehyde were found in lactating cows in summer. Increased milk production during this period leads to oxidative tissue damage due to the induction of heat stress. In the work of Rodney J. Feliciano et al. (2020) noted that climate change affects the microbial safety of dairy products. Under conditions of heat stress, the susceptibility of lactating cows to microbial contamination increases, and accordingly, microbial contamination of milk increases. The researchers propose developing models to quantify microbial pollution to evaluate risk reduction strategies, which will be a key step in prioritizing the creation of a climate-resilient dairy industry.

Zazharska et al., 2024) examined the composition of whole milk of cows of different technological groups by season of the year and found that the fat content in the milk of cows of all groups was significantly lower in summer, and the highest in winter. All cows had the lowest content of somatic cells in autumn, and the highest rate – in cows at the beginning of lactation and primiparous – in winter, and in cows of the second lactation – in spring. The lowest urea content in milk in all animal groups was observed in summer. The lowest protein level was observed in autumn (3.27±0.11%), and the highest - in winter (3.39±0.11%) in the volume milk of cows at the beginning of lactation. Sara Pacheco-Pappenheim et al. (2021) link the fatty acid and triacylglycerol composition of cow's milk to seasonal changes. In their research, they associate significant changes in the fatty acid composition of milk with increased intake of C18:3 cis-9,12,15 from grass in spring and summer. The triacylglycerol profile, in turn, depended on the fatty acid composition of the milk. At the same time, low - and medium-molecular groups of the triacylglycerol profile increased in winter and decreased in summer, while high-molecular groups increased in summer and decreased in winter.

They are particularly concerned with the impact of seasonal climate changes on livestock production in countries with arid climates. Thus, studies of the milk quality of Holstein cows in the north-eastern regions of Iran have proven (Toghdory A. at all., 2022)

that livestock productivity is influenced by various factors due to the complex interaction between the animal and the environment. The main factors influencing the quality of milk, these researchers consider the temperature and humidity of the environment. They attribute their conclusions to factors – an increase in temperature from 6.2 to 31.3 °C led to a significant decrease in the content of milk protein (by 4.09 %), fat (by 5.75 %). Depending on the increase in ambient temperature, the content of skimmed dry matter (SNF) decreased by 1.31% and the content of somatic cells (by 16.8 %). But with an increase in ambient temperature, the total content of microorganisms in milk increased by 13.7 %.

At the same time, in different regions of the world, the seasons of the year differ in climatic conditions. Consequently, Iranian scientists prove (Nateghi et al., 2024), in contrast, milk obtained in summer had a significantly higher dry matter content and better microbiological quality compared to milk obtained in winter. Scientists attribute seasonal fluctuations in the composition of cow's milk to differences in diets, because in summer the animals consumed fresh grass on pastures, and in winter – mixtures of dry components. Seasonal changes in milk quality are primarily associated with the feeding diet of cows and other researchers (Magan et al., 2021; Hayes et al., 2023). Insufficient dry matter intake reduces milk synthesis, which is associated with biological changes in the mammary gland (Gao et al., 2019).

Correa-Calderón with co-authors (Correa-Calderón at al., 2022) add that at least a 40% decrease in milk productivity is associated with a decrease in feed dry matter intake, however, the greatest direct impact on overall metabolism and cell thermal resistance. The results of their experiments show that heat stress reduces the transcription of genes associated with metabolism, and, accordingly, increases the concentration of genes associated with inflammation in breast tissues, which leads to a decrease in milk protein synthesis.

Other researchers have shown that in cows exposed to heat or cold stress, body responses included changes in energy balance and nutrient distribution (Razzaghi et al., 2022). The ability of an animal to synthesize milk fat largely depends on the availability of substrates for lipid synthesis from the diet, rumen fermentation, or adipose tissue reserves that can be altered in the face of climate change.

Stojnov et al. (Stojnov et al., 2024) link dairy productivity and milk quality of cows to their calving season in the context of future climate changes in Bulgaria. 199 Holstein cows were examined for 286 lactations. Cows calving in spring had the highest average milk yield (8522.2 kg) and maximum daily milk yield (38 kg), while cows calving in summer had the lowest milk yield (8082.7 kg) and minimum daily milk yield (35.7 kg). In terms of milk composition, fat and protein content, no significant influence of the calving season was found, but there was a tendency to lower the percentage of fat in milk in cows calving in the summer (3.68 %) and higher in cows calving in the spring (3.71 %). As for the percentage of protein in milk, the lowest values were observed in cows calving in autumn (3.19 %) and the highest in cows calving in summer (3.27 %).

Therefore, in conditions of loose keeping, a decrease in fat content was observed during the summer period with the lowest indicator in July and the highest in December. The highest protein content in raw milk was observed from November to January. The average level of somatic cells increased in winter.

Taking into account the relevance of the issue covered in information sources, the aim of the research was to establish the influence of seasonal changes on the quality indicators of cow's milk.

Research materials and methods. The research was conducted in LLC "Pechenezhskoe" Kharkiv region on cows of the Ukrainian red-pock dairy breed. During

2022, control milking of 70 cows was carried out (January-August). The conditions of keeping, feeding, watering and milking regimens during the studies of experimental animals were the same. The experimental cows were clinically healthy, were on 2-4 lactation periods, and their average age was 64.4±3.9 months. The average live weight of the experimental animals was 581±22 kg. Cows were fed with balanced diets. The diet of experimental cows consisted of the following components: corn silage (8.0 kg), triticale haylage+oats (12.0 kg), pea straw (1.0 kg), beer pellets (5 kg), 1.7 kg mixed feed (5.8 kg), sunflower meal (1.6 kg). Control accounting of feed mixture consumption was carried out every 10 days. At the beginning of the experiment, feed samples were selected to determine their chemical composition and nutritional value in the laboratory for assessing the quality of feed and animal products of the Institute of animal husbandry of the National Academy of Sciences. The results of the analysis of the feed mixture of cows in the first half of the transit period are shown in Table 1.

Table 1.

Chemical composition of the feed mixture of experimental cows

Feed mix components, kg	First Transit period	second transit period
Corn silage	8,0	10,0
Haylage triticale+ oats	6,0	9,0
Pea straw	2,0	0,5
Meadow hay	1,0	-
Fresh beer pellets	-	10,0
Sorghum cornage	1,4	2,5
Mixed feed	1,3	2,3
Sunflower meal	1,7	5,0

According to the results of the analysis, the nutritional value of the diet in comparison with the need was established (Table. 2). Consequently, the diet of experimental animals in the first half of the transit period contained 13.04 kg of dry matter, 129.7 MJ of metabolic energy, and 1628 g of crude protein. The level of content per 100 kg of live weight in the first half of the transit period was: Exchange energy – 25.13 MJ, dry matter – 2.24 kg, crude protein – 280.2 g.

Table 2.

Content of metabolic energy and nutrients in the diet of experimental cows during the first transit period

Indicator	content in the diet	need
Exchange energy, MJ	222	250
Dry matter, kg	20,5	20,0
Crude protein, g	3587	3500
Digestible protein, g	2569	2550
Raw fiber, g	19,4	18,0

The daily feed intake of Experimental Animals, based on the control feeding data, was almost complete – residues ranged from 1 to 3% of the set value.

After calving, the cows began the second phase of the transit period, characterized by the formation of colostrum in the udder, and later – intensive milk production. During this period, the feeding ration was adjusted with an advance payment of feed to increase milk production with the introduction of dairy feed – fresh beer pellets and sorghum corsage. The nutritional value of the diet of experimental cows of the second transit period is shown in Table 3.

Consequently, in the second phase of the transit period, cows of the control group received a diet containing 20.5 kg of crude matter, 222 MJ of exchange energy and 3587 g of crude protein, including 2569 g of the rumen-soluble fraction of crude protein and 1018 g of the insoluble protein fraction in the rumen, or 71.62 and 28.4% of the total amount of crude protein, respectively.

The proposed composition and nutritional value of the feed mixture is universal for the total number of cows in a certain transit period, and the satisfaction of the needs of animals with different milk productivity in the required amount of energy and nutrients was carried out by feeding to their heart's content. That is, the feed mixture was in the feeder around the clock and the determining factor was and is the indicator of dry matter consumption in absolute and relative terms.

Control milking was performed twice a day-in the morning and in the evening using portable buckets. Sanitary and hygienic treatment of udders and teats in cows of all groups was carried out in the same way. Samples of milk from each cow were taken using a probe, in proportion to the morning and evening milk yields, when sampling were guided by the European requirements of Codex Alimentarius, Vol. 13 "methods of analysis and sampling" and DSTU ISO 707:2002 "milk and dairy products, instructions for sampling". Samples were delivered to the laboratory with a preservative (broad-spectrum MicroTabs tablets, manufactured in the USA).

The experiment was divided into three stages according to the actual ambient temperature: I – from -3°C to +9°C, II – from +10°C to +24°C, III – from +24.5°C to +36.4°C. the actual average air temperature was – +7°C, +21°C and 28°C, respectively.

Biochemical parameters of milk were determined in a certified laboratory for assessing the quality of livestock products. The mass fraction of protein and protein (casein+whey proteins) was determined by rapid infrared spectrometry (DSTU 8396:2015, 2017). All experimental studies were conducted in accordance with modern methodological approaches, requirements and standards (DSTU ISO/IEC 17025:2019, 2021), directive 2010/63/EC (2010) and the procedure for conducting animal testing in research institutions" (law of Ukraine No. 249, 2012). The experiments were performed in accordance with the provisions of the European Convention for the protection of vertebrates used for experimental and other scientific purposes (European convention, 1986).

Research results. The climatic conditions of the research region are analyzed. LLC "Pechenezhskoe" is located in the North-Eastern District closer to the center of the Kharkiv region within the village of Pechenegi on the southern dam of the Pecheneg reservoir of the Seversky Donets River Basin (Erofeeva & Sashkova, 2011). The village is adjacent to large woodlands and a complex of artificial ponds has been created. The type of climate at the location of the farm is temperate continental, The Zone is forest – steppe. Summers are warm and, due to the proximity of the reservoir, quite humid. Winters are moderately mild with a predominance of cloudy and moderately frosty weather. During the year, the air temperature usually ranges from-8 °C to +27 °C, occasionally it is below-19 °C and above 33 °C. The warm season in the region lasts 3.7

months., usually from May 18 to September 8 with a maximum average daily temperature above 21 °C (July) with a minimum of +17 °C. The cold season lasts 3.9 months. from November 18 to March 13 with a minimum average daily temperature below 4 °C. The coldest month is January with an average temperature maximum of – 7 °C (January) and a minimum of- – 2 °C. The region is characterized by precipitation of 400-650 mm per year, mainly from April to October, in winter the snow cover is maintained for up to 110 days.

Differences in the indicators of daily milk yield of cows at different air temperatures during the year were established (Table. 3).

Table 3.

Dynamics of dairy productivity of cows with seasonal changes

Indicators	Air temperature, °C		
	-3 – +9	**+10 – +24**	**+24,1 – +36,4**
Duration of the period, days	83	60	100
Average daily milk yield at the beginning of the period, kg	19,6±0,56	19,8±0,51	20,5±0,61
Average daily milk yield at the end of the period, kg	19,8±0,51	20,5±0,61	18,7±0,40

At the beginning of the experiment, the average daily milk yield of experimental cows was 19.6 kg, during the first – the coldest period of research (from January 2 to March 25) – their productivity increased by 0.2 kg.

At the second stage of research, during the spring warming (from March 26 to May 26), the average daily milk yield increased by 0.7 kg.

At the end of the hottest third period of the study (from May 27 to August 31), the daily milk yield decreased by 1.1 kg compared to the first period and by 1.8 kg compared to the second period.

Differences between the indicators of fat and protein content in the milk of experimental cows were also established (table. 4).

Table 4.

Dynamics of fat and protein content in cow's milk during seasonal changes

Indicators	Air temperature, °C		
	-3 – +9	**+10 – +24**	**+24,1 – +36,4**
Average mass fraction of fat in milk at the beginning of the period, %	3,93±0,09	4,07±0,06	4,04±0,04
Average mass fraction of fat in milk at the end of the period, %	4,07±0,06	4,12±0,03	4,18±0,01
Average mass fraction of protein in milk at the beginning of the period, %	2,98±0,05	3,22±0,03	3,23±0,01
Average mass fraction of protein in milk at the end of the period, %	3,22±0,03	3,24±0,03	3,17±0,01

Consequently, at the beginning of the studies, the average fat content in the milk of experimental cows was 3.93%, protein – 2.98 %. During the coldest period of the year studied, the fat content in milk increased by 0.14 % ($p<0.01$), protein – by 0.24 % ($p<0.01$).

At the end of the second stage of the study, the fat and protein content in milk increased slightly, by 0.05% and 0.02%, respectively.

During the hottest period of research, the fat content in the milk of experimental cows increased by 0.14 %, which may be associated with a decrease in daily milk yield, because it is known that these signs are negatively related (Alphonsus, 2015; Yoon J. T. et al., 2004). The protein content in milk decreased slightly (by 0.06%) at the end of the third study period.

Discussion. The variability of productivity indicators and the content of fat and protein in cow's milk can be associated with the influence of various factors: climatic parameters, the duration of the World Day, exercise (rehabilitation), and so on. Most researchers believe that milk production varies significantly due to seasonal changes. It is known that milk productivity and milk composition vary depending on environmental conditions, including air temperature. Many studies indicate a negative effect of heat stress on milk production and changes in its composition (Barash et al., 2001; Bouraoui et al., 2002; Bohmanova et al., 2007; West et al., 2003; Schneider Y. et al., 2014). The results of our research are consistent with studies conducted by other domestic scientists (Polupan et al., 2022), that seasonal changes, in particular – air temperature affects milk productivity, fat and protein content in cow's milk in the forest-steppe region of Ukraine. It was found that at the population level, among the mentioned environmental factors, the herd (15-22%), the year of first calving (4.7-12%) and birth (4.2-12%) have the most significant influence on the phenotypic variability of milk productivity of first-born heifers (0.05 - 0.2%) and calving (1.5-2.1%). A number of other researchers report a greater impact of the herd and year and a smaller impact of the calving season and especially birth on the milk productivity of first – born heifers.

So, analyzing the experience of researchers and their own research results, it is planned to further adapt dairy farming in Ukraine to climate change, which requires additional research in determining the degree of vulnerability of livestock industries under the influence of climate change, as well as in finding ways to prevent them. According to climate forecasts of different temperature zones, local and regional strategies for reducing heat stress for dairy cattle should be adjusted to mitigate potential losses of dairy production due to heat stress. Reducing the body temperature of animals during the heat contributes to their consumption of more feed, and the introduction of special feed elements into the diet reduces the release of electrolytes from the body through the skin. In this aspect, the development and use of drugs and probiotics in animal husbandry – anti-stress products of synergistic action, vitagens, immunomodulators, organic acids, mineral compounds-is becoming increasingly relevant. An important direction of leveling heat stress is the development and application of stress-free and adaptive technologies for keeping animals, taking into account actual and possible changes in the environment, the spread of technologies for ecological and organic production of livestock products.

Conclusion. It is proved that seasonal changes affect the milk productivity of cows, in particular, the daily milk yield, fat and protein content in milk. Further research should be aimed at finding innovative ways to offset the negative factors of seasonal changes on the productivity of dairy cattle.

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