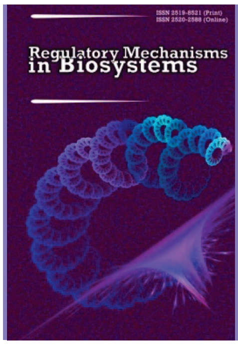

Regulatory Mechanisms in Biosystems

ISSN 2519-8521 (Print)
ISSN 2520-2588 (Online)
Regul. Mech. Biosyst.,
2024, 15(3), 423–428
doi: 10.15421/022459

Influence of the season on the main components of cow milk in Ukraine

N. V. Zazharska, I. A. Biben, N. M. Zazharska

Dnipro State Agrarian and Economic University, Dnipro, Ukraine

Article info

Received 27.04.2024
Received in revised form 08.06.2024
Accepted 21.06.2024

Dnipro State Agrarian and Economic University, Sergiy Efremov st., 25, Dnipro, 49000, Ukraine. Tel.: +38-050-662-90-52. E-mail: zazharskayan@gmail.com

Zazharska, N. V., Biben, I. A., & Zazharska, N. M. (2024). Influence of the season on the main components of cow milk in Ukraine. Regulatory Mechanisms in Biosystems, 15(3), 423–428. doi:10.15421/022459

The quality of dairy products depends on the safety and quality of raw materials, therefore, the analysis of physicochemical and sanitary indicators of raw cow milk is of great importance. The composition of bulk milk of three technological groups of cows: early lactation (5–60 days in milk), primiparous cows and all other cows starting from the second lactation was studied according to seasons. Regardless of the group of animals, the fat content in bulk milk was significantly lower in summer than in other seasons of the year, and the highest in winter. In each group of animals, the lowest somatic cell count was observed in the fall, while the highest indicator of the study of bulk milk of cows in early lactation and primiparous was determined in the winter, and in the spring of cows from the second lactation. The lowest milk urea content in all groups of animals was noted 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 bulk milk of cows in early lactation. The ratio of fat to protein in summer 1.12 ± 0.03 was significantly lower compared to other seasons of the year. The highest level of somatic cells was recorded in this group in winter ($290 \pm 82 * 10^3$ cells/mL), which was twice as much as in autumn ($141 \pm 54 * 10^3$ cells/mL), and by 56.8% more than in summer ($185 \pm 39 * 10^3$ cells/mL). The milk urea content in the summer was 194.0 ± 17.6 mg/kg, which is significantly lower than the indicators in other seasons of the year in the group of early lactation. In the summer period, the lowest protein content (3.23 ± 0.06%) in the bulk milk of primiparous cows was observed compared to other seasons of the year. The winter was characterized by the highest level of somatic cell count in milk ($221 \pm 49 * 10^3$ cells/mL), which was almost twice as high as the autumn period ($116 \pm 31 * 10^3$ cells/mL). The highest urea content in the milk of primiparous cows was found in autumn (228.6 ± 21.9 mg/kg), which exceeded the summer figure by 14.5%. The lowest protein content (3.29 ± 0.06%) and the highest in winter (3.44 ± 0.09%) was observed in the bulk milk of cows of the second lactation and older. The somatic cell count in milk in autumn ($160 \pm 69 * 10^3$ cells/mL) was lower than the winter and spring indicators by 37.5% and 49.3%, respectively. The milk urea content in the summer (198 ± 22 mg/kg) was significantly lower than the autumn and winter indicators. In further studies, to improve the sanitary quality of milk, it is planned to use different hygienic means for processing the udder of cows depending on the season.

Keywords: cow milk; fat; protein; somatic cells; urea; primiparous cows; early lactation.

Introduction

Due to global warming, a significant increase in drought is expected worldwide, which will affect feed and crop production. Heat impairs animal productivity, meat and milk quality, animal reproductive function, metabolic and health status, and immune response. Dairy farms are identified as a major contributor to overall greenhouse gas emissions in the dairy value chain, but also as the most vulnerable. A clear definition of the interaction of the dairy sector and climate change is the starting point to start preparing this sector for the near future under climate change conditions (Nardone et al., 2010; Borovuk & Zazharska, 2022; Guzmán-Luna et al., 2022; Kovalova et al., 2023; Zazharskyi et al., 2023). Milk is a vital source of essential nutrients in the human diet and should be safe for consumption (Nagovska et al., 2018). The analysis of physico-chemical and microbiological indicators of raw cow milk is of crucial importance, since the milk quality significantly affects the final quality of dairy products. The topic of studying the effect of heat stress on the qualitative composition of milk in cows attracts a lot of attention from researchers (Aharoni et al., 2002; Abeni et al., 2007). Kazeminia et al. (2023) evaluated the effect of seasonal variations on the physicochemical and microbiological properties of 60 samples of raw cow's milk collected from 15 milk collection points in Qazvin, Iran. According to the research results, pH, freezing point, solid-not-fat and protein were higher in the warm season, and acidity, lactose and fat indicators were higher in the cold season. The scientists concluded that there is a direct relationship between ambient temperature and solid-not-fat values, and an inverse relationship between pH, acidity, freezing point, lactose, protein and fat values with ambient temperature (Kazeminia et al., 2023). Many scientists study the dynamics of milk composition in connection with changes in the diet, due to the introduction of any additives. An experiment was conducted to evaluate the effect on milk composition of switching from a fresh grass diet on pasture to a mixed grass and corn silage diet during winter. The fatty acid composition of milk from pastured cows was more beneficial to the health of the consumer than that from cows fed silage (Elgersma et al., 2004). In another study, a total mixed diet of grass and corn silage, grains, soybeans and milk concentrates was fed in winter; during the summer months the cows were on pasture. Milk fat produced during the summer contained significantly more short-chain fatty acids than medium-chain fatty acids, indicating that fresh grass can alter the composition of fatty acids produced in the mammary gland (Locke & Garnsworthy, 2003). The composition of milk obtained from seasonal pastures is influenced by the stage of lactation, animal genetics and feeding, which affects the nutritional profile and characteristics of the milk (Hayes et al., 2023; Wang et al., 2024). Calamari et al. (2012) evaluated the effects of three different feeding management schemes on physiological markers of heat stress, milk yield and milk quality in heat. Findings from cow physiology show that cow feeding management better meets cow welfare requirements during the summer season than once-a-day morning feeding (Calamari et al., 2012).

Reducing the incidence of mastitis is one of the primary tasks on dairy farms. Currently, new express diagnostic methods are being introduced, both direct (inoculation on nutrient media) and indirect; these methods serve to determine the number of somatic cells in milk. When comparing three indirect methods (the California test for mastitis, the Porta test for the somatic cell count in milk and the DeLaval cell counter) with the results of a bacteriological examination of milk, it was determined that all these tests can be used for rapid diagnosis of subclinical mastitis, since each test has certain advantages over others (Hisira et al., 2023). Somatic cell count is a standard for measuring the physiological health of dairy cows, the quality and safety of milk, as well as an important indicator of subclinical mastitis (Fotina et al., 2018; Sun et al., 2023). Subclinical mastitis is a common disease that threatens the welfare and health of dairy cows and causes huge economic losses (Sklyarov et al., 2020; Zazharska et al., 2021; Liu et al., 2023). Carmo et al. (2023) evaluated the effect of centrifugation and microfiltration on the number of somatic cells and cheese yield. Milk with a number of somatic cells $\leq 200 * 10^3$ cells/mL has the best characteristics. Although centrifugation and microfiltration affectted milk fat content, solid-not-fat and somatic cell count, they did not affect cheese yield (Carmo et al., 2023). Nahusenay et al. (2023) evaluated changes in microbial contamination of milk between the dry season (January to April) and the wet season (June to August) in Ethiopia.

Ukrainian scientists studied the relationship between weather conditions (air temperature, relative humidity, wind direction, wind strength, insolation) and daily milk yield of Holstein cows, as well as its components (milk fat and protein) (Mylostyvyi et al., 2023); the effectiveness of different breeds for sustainable milk productivity was evaluated (Bashchenko et al., 2023; Krugliak & Krugliak, 2023). The purpose of the study by Brodziak et al. (2012) was to evaluate the effect of breed and feeding system on the content of selective whey proteins in milk collected in the spring-summer and autumn-winter periods from cows of the black-red-spotted breed of the Polish Holstein-Friesian breed and the Simmental and Jersey breeds. Assessment of the simultaneous effects of breed and season on whey protein content showed significant interactions ($P < 0.05$ and $P < 0.01$) for all whey proteins analyzed (Brodziak et al., 2012). Ormston et al. (2023) compared the milk productivity of organic and conventional herds. The milk of cows from conventional herds was characterized by higher milk yield, fat and protein and casein content compared to organic ones. In addition, they more efficiently converted feed into milk, fat and protein. However, organic herds produced more milk, fat and protein per kg of non-pasture and concentrate diets due to a greater reliance on grazing, especially during the outdoor grazing period (Ormston et al., 2023). The purpose of Alrhmoun et al. (2024) was to assess the effect of altitude on milk quality from dairy cows on small farms in alpine areas. 5,680 collected milk samples were taken from 32 farms located at different geographical altitudes. Data (fat, protein, lactose, free fatty acids, casein, milk urea nitrogen, pH value and somatic cell count) were analyzed using a statistical model that considered height category, grazing practice, housing system and season of milk analysis as fixed effects. The results revealed a positive relationship between altitude and milk fat, free fatty acids and somatic cell count. Conversely, lactose content, milk urea nitrogen, and milk pH of cows kept on farms at higher altitudes (>1200 m above sea level) showed a negative relationship with altitude. Farms located at an altitude of more than 1,200 m showed higher fat, protein, urea and somatic cell contents than farms located at lower levels. The results provide new insight into a production effect that has received little attention so far and that should be considered in farm management (e.g. feeding management, breed selection) to ensure animal health and corresponding animal welfare and productivity of dairy cows. on traditional small mountain dairy farms (Alrhmoun et al., 2024). The concentration of urea in milk serves as an indicator of nitrogen excretion in the urine, but with comparable crude protein intake, cows with high and low levels of milk urea excrete the same amount of urea in the urine. Eighteen dairy cows of the Holstein breed with a high level of urea in milk and 18 with a low level of urea were studied. The diet was low and normal in terms of crude protein. Urea concentrations in milk, plasma, and urine were higher with a diet with a normal level of crude protein. Uric acid concentrations in milk and plasma were higher when fed a diet low in crude protein. The ratio of uric acid in milk to urine was higher in cows with high milk urea (Prahl et al., 2023). Scientists from Saudi Arabia evaluated the variability of the productivity of camels and the composition of milk of four Saudi breeds during different seasons. Milk collected in winter was characterized by a significant increase in all milk components and milk pH (El-Hanafy et al., 2023). Yield and compositional characteristics of goat milk had significant correlations with high ambient temperature, while high humidity had little effect on milk composition. Therefore, heat has a significant impact on goat farm profits, and strategies may include improved management as well as heat-resistant animals through genetic selection (Zhu et al., 2020).

So, seasonal fluctuations of the main characteristics of milk are quite often the object of research by scientists, but no literature data was found on seasonal changes in milk parameters between different technological groups of cows (primiparous cows and other cows of older lactations, cows in early lactation). The aim of the study was to identify seasonal changes in the indicators of bulk milk of cows of different technological groups (early lactation (5–60 days in milk), primiparous cows and all other cows starting from the second lactation).

Materials and methods

The research was carried out at the farm "Yekaterinoslavsky", Dnipro city. Today, this enterprise is considered to be the largest in Ukraine in terms of the number of dairy cows of the Brown Swiss breed. In total, 5,600 cattle are kept on the farm, of which 2,200 are dairy herds. Several breeds of cows are raised here: Brown Swiss, Ukrainian black-spotted and red-spotted. Cows of the Brown Swiss breed (of Austrian breeding) predominate – they are considered more resistant to mastitis and problems with hooves. This breed has a calm temperament and a positive reaction to people, but the most important feature is a high percentage of fat and protein in milk. The farm uses the technology of free-stall barn.

After calving, all animals were in the technological group of early lactation (5–60 days in milk) and received the same diet; the colostrum period lasts up to 5 days of lactation. Two months after calving, cows of the first lactation formed a group of primiparous cows, and all other cows from the second lactation were kept and milked separately in the other technological group. Milking took place three times a day in a parallel type milking parlor (De Laval & Sweden, 2015). Each group was milked separately. With the help of means built into the milking system, an average sample of 1 liter was automatically taken from each group. The milk fell into a separate glass for sampling. The sample was analyzed in the laboratory. For statistical processing, average indicators of bulk milk were taken separately by sections of cows per week for two years (2022–2023).

The enterprise "Yekaterinoslavsky" has its own laboratory for milk quality control. The following indicators are usually determined in the laboratory: protein content, fat content, somatic cell count, acidity, urea, pH. The fat content in milk was measured by the acidic method using the Orbita laboratory universal centrifuge (Orbita, Ukraine, 2021), the protein content was determined using the Atago Master Milk refractometer (Atago, Japan, 2022), and the acidity was determined by titrometric method. The ratio coefficient was calculated by dividing the fat index by the protein index. The number of somatic cells in raw milk was determined using the analyzer of somatic cells in milk "DCC" (DeLaval, Sweden, 2018). The essence of the express analyzer's method of operation is the fluorescent illumination of somatic cells and their automated counting using an electronic microscope-sensor. Ulab 101 spectrophotometer (Ulab, China, 2017) was used to determine the milk urea content. Urea, which is present in milk, forms a coloured complex with diacetylmonoxin in the reaction, its colour intensity is proportional to the content of urea.

The data was analyzed by ANOVA using the package Statistica 6.0 (StatSoft Inc., USA). The data in the tables are presented as x ± SD (mean ± standard deviation). Differences between values in the groups were determined using the Tukey test, where the differences were considered significant at $P < 0.05$ (subject to the Bonferroni correctiont).

Results

Changes in milk indicators of cows of different technological groups by season are presented in Tables 1–3. The lowest fat content in the milk of cows in early lactation (Table 1) was observed in the summer, a statistical difference was found compared to other seasons of the year: $P = 2.84*10^{-18}$ (spring); $P = 1.46*10^{-8}$ (autumn); $P = 2.52*10^{-15}$ (winter).

Regarding protein in milk, the lowest indicator was in autumn. The protein content of milk in winter is higher compared to the indicators of summer ($P = 8.02*10^{-4}$) and autumn ($P = 1.94*10^{-4}$). The index of the ratio of fat to milk protein in spring ($P = 1.50*10^{-7}$), autumn ($P = 1.08*10^{-7}$), winter ($P = 6.27*10^{-7}$) is greater than the summer indicator by 7.1%, 11.6%, 8.9%, respectively.

The largest number of somatic cells in milk was noted in winter, which is twice as much as in autumn ($P = 7.42*10^{-4}$). The winter index is 56.8% higher than the summer index ($P = 1.11*10^{-3}$). Regarding the level of urea, a trend similar to the fat content of milk was observed: the lowest indicator was noted in summer, a statistical difference was found relative to other seasons of the year ($P = 2.69*10^{-6}$ (spring), $P = 2.85*10^{-8}$ (autumn), $P = 1.73*10^{-4}$ (winter)). The acidity of the milk of cows in early lactation (5–60 days in milk) is 4.7% lower in autumn compared to the spring indicator ($P = 3.10*10^{-4}$).

The lowest milk fat content of primiparous cows (Table 2) was observed in the summer, a statistical difference was found relative to other seasons of the year ($P = 5.53*10^{-5}$ (spring), $P = 5.87*10^{-8}$ (autumn), $P = 3.14*10^{-12}$ (winter)). Also, the lowest protein content was in summer compared to other seasons of the year ($P = 3.87*10^{-9}$ (spring), $P = 4.31*10^{-8}$ (autumn), $P = 8.58*10^{-13}$ (winter)). The ratio of fat to milk protein in winter is 2.7% higher than in summer ($P = 4.90*10–3$).

In the winter period, the largest number of somatic cells was found in milk, which is almost twice as high as in the autumn period ($P = 1.40*10^{-5}$). Also, the winter index exceeds the summer index by 20.8%. The highest content of urea was noted in autumn, which is 14.5% more than the summer indicator ($P = 1.20*10^{-5}$). Acidity was observed at the same level in summer, autumn and winter. The highest acidity was observed in spring, which may be explained by the more "acidic" silage in this season of the year.

Table 1
Seasonal changes in the composition of bulk milk of cows in early lactation (x ± SD)

Indicator	Spring (n = 20)	Summer (n = 23)	Autumn (n = 26)	Winter (n = 26)
Fat, %	4.053 ± 0.084^{b}	3.711 ± 0.066^{a}	4.088 ± 0.257^{b}	4.147 ± 0.170^{b}
Protein, %	3.331 ± 0.099^{ab}	3.299 ± 0.055^{a}	3.266 ± 0.110^{a}	3.387 ± 0.106^{b}
Somatic cell count, × 10^3 cells/mL	232 ± 89^{ab}	185 ± 39^{a}	141 ± 54^{a}	290 ± 82^{b}
Milk urea content, mg/kg	230.9 ± 26.6^{b}	194.0 ± 17.6^{a}	228.2 ± 18.4^{b}	225.0 ± 32.4^{b}
Acidity, °T	17.03 ± 0.50^{b}	16.65 ± 0.44^{ab}	16.15 ± 0.89^{a}	16.48 ± 0.83^{ab}
Fat / protein	1.203 ± 0.049^{b}	1.123 ± 0.032^{a}	1.254 ± 0.095^{b}	1.222 ± 0.076^{b}

Note: different letters indicate selections that significantly ($P < 0.05$) within the line differ from each other according to the results of the Tukey test, with Bonferroni correction; if there are no letters above the numbers in the line, then no significant difference between any selections is registered.

Table 2
Seasonal changes in the composition of bulk milk of primiparous cows (x ± SD)

Indicator	Spring (n = 20)	Summer (n = 24)	Autumn (n = 26)	Winter (n = 34)
Fat, %	3.737 ± 0.159^{b}	3.573 ± 0.075^{a}	3.828 ± 0.181^{b}	3.839 ± 0.133^{b}
Protein, %	3.365 ± 0.055^{b}	3.234 ± 0.061^{a}	3.408 ± 0.117^{b}	3.413 ± 0.080^{b}
Somatic cell count, × 10^3 cells/mL	206 ± 131^{ab}	183 ± 26^{b}	116 ± 31^{a}	221 ± 49^{b}
Milk urea content, mg/kg	217.2 ± 30.6^{ab}	200.3 ± 20.2^{a}	228.6 ± 21.9^{b}	215.0 ± 37.3^{ab}
Acidity, °T	17.15 ± 0.40	16.83 ± 0.38	16.75 ± 0.70	16.81 ± 0.88
Fat / protein	1.110 ± 0.050^{ab}	1.104 ± 0.009^{a}	1.128 ± 0.055^{ab}	1.125 ± 0.034^{b}

Table 3
Seasonal changes in the composition of bulk milk of cows from the second lactation and older (x ± SD)

Indicator	Spring (n = 60)	Summer (n = 72)	Autumn (n = 79)	Winter (n = 102)
Fat, %	3.788 ± 0.271^{b}	3.665 ± 0.100^{a}	3.832 ± 0.0253^{b}	3.869 ± 0.0201^{b}
Protein, %	3.378 ± 0.114^{b}	3.287 ± 0.059^{a}	3.420 ± 0.098^{bc}	3.441 ± 0.090^{c}
Somatic cell count, × 10^3 cells/mL	239 ± 92^{b}	199 ± 41^{ab}	160 ± 69^{a}	220 ± 61^{b}
Milk urea content, mg/kg	208.8 ± 32.2^{ab}	197.6 ± 22.0^{a}	220.2 ± 33.0^{b}	214.3 ± 36.9^{b}
Acidity, °T	16.87 ± 0.57^{ab}	16.97 ± 0.43^{b}	16.58 ± 0.79^{a}	16.93 ± 0.86^{b}
Fat / protein	1.123 ± 0.078	1.115 ± 0.015	1.120 ± 0.071	1.126 ± 0.049

The lowest fat content of the milk of cows from the second lactation and older (Table 3) was observed in summer, a statistical difference was found relative to other seasons of the year ($P = 4.56*10^{-4}$ (spring), $P = 4.89*10^{-7}$ (autumn), $2.69*10^{-13}$ (winter)). Regarding protein in milk, the lowest value was also noted in summer ($P = 2.57*10^{-8}$ (spring), $P = 3.07*10^{-18}$ (autumn), $P = 1.73*10^{-26}$ (winter)). The ratio of fat to milk protein was higher in winter.

Somatic cell count in milk in spring, winter, summer was greater than the autumn indicator by 49.3% ($P = 9.76*10^{-4}$), 37.5% ($P = 3.08*10^{-4}$), 24.3% respectively. Regarding the level of milk urea content, a trend similar to the fat content of milk was observed: the lowest value was noted in summer, a statistical difference was found relative to autumn ($P = 2.38*10^{-6}$) and winter ($P = 7.44*10^{-4}$). The acidity of the cows' milk was the lowest in autumn, a statistical difference was found relative to summer ($P = 2.66*10^{-4}$) and winter indicators ($P = 5.46*10^{-3}$).

Discussion

According to the somatic cell count, bulk milk of different technological groups meets the requirements of Regulation (EC) No. 853/2004. Cows of all technological groups have statistically lower milk fat content in summer compared to other seasons. Summer heat stress has a negative effect on milk yield and feed consumption by dairy cows (Bernabucci et al., 2015; Könyves et al., 2017; Zazharska et al., 2018). One of the most important components of milk is protein, which directly affects its nutritional value. Another important component of milk is fat. The fat content directly affects not only the nutritional value of the product, but also the sensory properties, such as taste and aroma. In addition, the quality of dairy products such as cheese, butter and cream is highly dependent on the amount and quality of fat contained in the milk. The fat content of raw milk is so important that dairy companies price milk based on its fat content. There are significant seasonal fluctuations in the concentrations of the main components and the fatty acid composition of milk. According to Bernabucci et al. (2015) for all the main components of milk (fat, protein, solids and solid-not-fat), the lowest values were observed in summer, and the highest values were observed in winter. A mild effect of season was observed for milk somatic cell count with higher values in summer than in winter and spring (Bernabucci et al., 2015). The conclusions about the content of fat and protein coincide with our own results: the lowest values were observed in the summer (Table 3). But the number of somatic cells showed a different trend: the highest values were observed in winter and spring, and the lowest values were observed in autumn.

Heck et al. (2009) also noted the lowest protein content of cows' milk in June (3.21 g/100 g), and the highest in December (3.38 g/100 g); the concentration of fat in milk increased from a minimum of 4.10 g/100 g in June to a maximum of 4.57 g/100 g in January. According to our own results, in the milk of cows of the second lactation and older, the lowest protein level is 3.287% in summer, the highest is 3.441%; the lowest fat content is 3.665% in summer, and the highest is 3.869% in winter, which is completely consistent with the data of the above-mentioned scientists. But Leila et al. (2014) reported that the protein content of summer milk was higher than that of winter milk (3.71% and 3.01%, respectively).

Kheowsri et al. (2022) studied changes in milk according to seasons: cold (November to February), hot (March to June) and rainy season (July to October) in Thailand. The hot season turned out to be the most critical season for all studied parameters, showing significantly the lowest values ($P < 0.001$) of fat (3.79 ± 0.27%) and protein (3.02 ± 0.07%), while a significantly higher somatic cell count was obtained in the rainy season ($321.21 \pm 3.93 * 10^3$ cells/mL). These data coincide with our own results regarding the content of protein and fat, but contradict the number of somatic cells: according to the obtained data, the lowest somatic cell count is precisely in autumn. The results of Bokharaeian et al. (2023) in northeastern Iran showed that milk yield, fat and protein content were highest in winter, while somatic cell count was lowest during this season. According to our own results, the highest indicators of the somatic cell count were noted in winter and spring.

Quist et al. (2008) in Canada noted that seasonal differences in fat yield (summer – 1.02 ± 1.05 kg/day; winter – 1.19 ± 1.05 kg/day) and protein yield (summer – 0.85 ± 1.05 kg/day; winter – 0.96 ± 1.05 kg/day) were significant only for the first lactation. According to our own results, the lowest fat index (3.573 ± 0.075%) in the milk of primiparous cows was observed in summer, the highest – 3.839 ± 0.133% in winter ($P = 3.14*10^{-12}$). Also, the lowest protein content was noted in summer (3.234 ± 0.061%) against the highest indicator in winter, 3.413 ± 0.080%, ($P = 8.58*10^{-13}$). According to a retrospective study by Bertocchi et al. (2014) of cow's milk characteristics and the relationship between the temperature and humidity index of the Lombardy region, Italy, the summer season was found to be the most critical. In July, there were the most critical conditions for the content of fat and protein in milk (3.73 ± 0.35% and 3.30 ± 0.15%, respectively), and in August there were higher values of somatic cell count (369 503 ± 228 377 in mL).

Some scientists believe that the protein content of cow's milk can vary from 2.8% to 4.6% depending on four main factors, including management, health, feeding and genetics (Pellegrino et al., 2012; Timlin et al. al., 2021). The content of the investigated milk proteins and the relative content of different caseins in the total casein are significantly influenced by the breed and the month of lactation (Jõudu et al., 2008). The decrease in milk protein content in summer is associated with a decrease in casein content, which is caused by a decrease in α-casein and β-casein content. These changes may explain the change in cheese-making properties of milk commonly observed in summer (Bernabucci et al., 2004). According to our own results, protein in the milk of cows from the second lactation and older was noted in the range of 3.287–3.441%. According to Kazeminia et al. (2023) protein content was measured at 3.06 g/100 g with a range of 2.85% to 3.16%. Milk studies conducted in Romania by Pavel & Gavan (2011) during three seasons of spring, summer and autumn did not reveal any statistically significant differences in protein content. However, a study consistent with our own results found higher protein and fat content in cold season than warm season milk (Chenet al., 2014). Also Gemechu (2016) in Ethiopia and Shokoohmand et al. (2012) in Iran reported higher fat levels in cold seasons than warm seasons. Overall, these results suggest that milk protein content can be influenced by various factors, including season, animal breed, and environmental factors. The positive correlation between the content of protein and fat in milk indicates that the two components may be influenced by similar factors (Kazeminia et al., 2023).

According to Fedorovych et al. (2023) the year of birth and the place of residence of cows had the most significant effect on milk yield and fat content in it, this was especially noticeable in primiparous cows; the highest fat content in milk both during the first and third lactation was also found in cows from the steppe zones — 4.08% and 4.01%, which was significantly ($P < 0.001$) higher than in cows from the forest-steppe zone by 0.48% and 0.44%, and from the Polissia zone by 0.45% and 0.36%. Bernabucci et al. (2014) proved that primiparous cows are less sensitive to heat stress than cows of the second lactation and older when studying the negative effect of temperature and humidity index on the constituent characteristics of milk. The genetic component of heat resistance is important, which indicates the need to include it in the selection of breeding bulls (Bernabucci et al., 2014). It was determined that heat stress had a negative effect on milk yield and fat and protein concentration during lactation. The negative effect of the duration of the daylight hours in the prenatal period and the heat during lactation on these indicators in primiparous cows was especially noted (Aharoni et al., 2002). According to our own results, the fat content of the bulk milk of primiparous cows was determined at the level of 3.573–3.839%, and this indicator in cows of the second lactation and older ranged from 3.665 to 3.869%. Regarding the theory that primiparous cows are less sensitive to heat, we have noted the opposite trend: in primiparous cows the percentage of fat and protein in milk in summer is 0.266% and 0.179% lower, respectively, compared to winter indicators (Table 2). In the milk of cows from the second lactation and older (Table 3), this decrease is not so significant: the percentage of fat and protein in summer is less by 0.204% and 0.154%, respectively, compared to winter indicators.

Milk urea content can potentially serve as a new easily measured indicator of nitrogen excretion by cows. According to our results, the urea content in the milk of primiparous cows was observed at the level of 200.3–228.6 mg/kg, in cows of the second lactation and older – 197.6–220.2 mg/kg. The decrease in this indicator with subsequent lactations is also noted by other scientists: in cows of the first lactation 25.16 mg/kg, in cows of the second lactation – 24.93 mg/kg and in the third lactation 23.75 mg/kg (Jahnel et al., 2023). According to Yoon et al. (2004) increased concentration of urea nitrogen in milk positively correlated with the fat content of Holstein dairy cows. According to our own results, such a trend was not observed. Yoon et al. (2004) notes that with an increase in somatic cell count, the level of urea nitrogen in milk increased; both urea nitrogen concentration and somatic cell count were highest in winter. According to our own data, the maximum number of somatic cells in cows of different technological groups was observed mainly in winter, and the maximum values of milk urea content in milk were observed in autumn. Yoon et al. (2004) stated that the concentration of urea nitrogen in milk produced in summer and autumn was significantly lower ($P < 0.01$) than in spring and winter. The lowest concentration of urea nitrogen in milk in summer coincides with our own results, but in autumn this indicator is significantly higher in all technological groups of cows.

Therefore, the significant influence of the season on the compositional characteristics of cows' milk has been proven.

Conclusion

The fat content in bulk milk of all technological groups of animals (group of early lactation (5–60 days in milk), primiparous cows and all other cows starting from the second lactation) was significantly lower in summer than in other seasons of the year, and the highest rate was noted in winter. The highest content of protein and fat in bulk milk of primiparous cows and other cows from the second lactation was noted in winter, and the lowest in summer. The group of early lactation had the lowest milk fat in summer and the highest in winter, while the protein content was lowest in autumn and highest in winter.

In each group of animals, the lowest number of somatic cells was noted in the autumn, while the highest indicator in bulk milk of the group of early lactation and primiparous cows was determined in the winter, and in other cows from the second lactation and older – in the spring. In the results of a seasonal study of milk urea content in the bulk milk of primiparous cows and other cows from the second lactation, the highest rate was determined in the fall, while the lowest was determined in the summer. In cows of early lactation, the lowest milk urea content was noted in summer, and the highest in spring. The acidity of the milk of cows in early lactation was the lowest in autumn, and the highest in spring. When studying bulk milk in the group of cows of the second lactation and older, acidity in autumn was lower than summer and winter indicators.

The authors do not have any conflict of interest to declare.

References

Abeni, F., Calamari, L., & Stefanini, L. (2007). Metabolic conditions of lactating Friesian cows during the hot season in the Po valley. 1. Blood indicators of heat stress. International Journal of Biometeorology, 52(2), 87–96.

Aharoni, Y., Ravagnolo, O., & Misztal, I. (2002). Comparison of lactational responses of dairy cows in Georgia and Israel to heat load and photoperiod. Animal Science, 75(3), 469–476.

Alrhmoun, M., Zanon, T., Katzenberger, K., Holighaus, L., & Gauly, M. (2024). Exploring the heights: Impact of altitude on dairy milk composition. The Journal of Dairy Science Communications, 5(2), 139–143.

Bashchenko, M. I., Boiko, O. V., & Sotnichenko, Y. M. (2023). Genetic potential for milk and characteristics of lactation activity of cows obtained by purebred breeding and crossing. Animal Breeding and Genetics, 65, 27–37.

Bernabucci, U., Basiricò, L., Morera, P., Dipasquale, D., Vitali, A., Piccioli Cappelli, F., & Calamari, L. (2015). Effect of summer season on milk protein fractions in Holstein cows. Journal of Dairy Science, 98(3), 1815–1827.

Bernabucci, U., Biffani, S., Buggiotti, L., Vitali, A., Lacetera, N., & Nardone, A. (2014). The effects of heat stress in Italian Holstein dairy cattle. Journal of Dairy Science, 97(1), 471–486.

Bernabucci, U., Lacetera, N., Ronchi, B., & Nardone, A. (2002). Effects of the hot season on milk protein fractions in Holstein cows. Animal Research, 51(1), 25–33.

Bertocchi, L., Vitali, A., Lacetera, N., Nardone, A., Varisco, G., & Bernabucci, U. (2014). Seasonal variations in the composition of Holstein cow's milk and temperature – humidity index relationship. Animal, 8(4), 667–674.

Bokharaeian, M., Toghdory, A., Ghoorchi, T., Ghassemi Nejad, J., & Esfahani, I. J. (2023). Quantitative associations between season, month, and temperature-humidity index with milk yield, composition, somatic cell counts, and microbial load: A comprehensive study across ten dairy farms over an annual cycle. Animals, 13(20), 3205.

Borovuk, I., & Zazharska, N. (2022). Evaluation of broiler meat in experimental listeriosis. Journal of Advanced Veterinary and Animal Research, 9(1), 155–165.

Brodziak, A., Barłowska, J., Król, J., & Litwińczuk, Z. (2012). Effect of breed and feeding system on content of selected whey proteins in cow's milk in spring-summer and autumn-winter seasons. Annals of Animal Science, 12(2), 261–269.

Calamari, L., Petrera, F., Stefanini, L., & Abeni, F. (2012). Effects of different feeding time and frequency on metabolic conditions and milk production in heat-stressed dairy cows. International Journal of Biometeorology, 57(5), 785–796.

Carmo, R. M. D., Nascimento, L. E. C. D., Leão, P. V. T., de Paula, G. H., Dias, M. B. D. C., Fernandes, P. B., Mesquita, A. A., Nicolau, E. S., Rezende, M. M. R., Sousa, W. A. D., Silva, E. C. N. M. D., & Silva, M. A. P. D. (2023). Influence of somatic cell removal on milk quality and yield. Beverages, 10(1), 5.

Chen, B., Lewis, M. J., & Grandison, A. S. (2014). Effect of seasonal variation on the composition and properties of raw milk destined for processing in the UK. Food chemistry, 158, 216–223.

Elgersma, A., Ellen, G., van der Horst, H., Boer, H., Dekker, P. R., & Tamminga, S. (2004). Quick changes in milk fat composition from cows after transition from fresh grass to a silage diet. Animal Feed Science and Technology, 117(1–2), 13–27.

El-Hanafy, A. A., Saad, Y. M., Alkarim, S. A., Almehdar, H. A., Alzahrani, F. M., Almatry, M. A., Uversky, V. N., & Redwan, E. M. (2023). Yield and composition variations of the milk from different camel breeds in saudi arabia. Sci, 5(1), 2.

Fedorovych, V. V., Shpyt, I. V., Fedorovych, Y. I., & Supovych, T. M. (2023). The signs of milk productivity of cows bred in different climatic zones depending on the year and season of their birth. The Animal Biology, 25(1), 9–14.

Fotina, T., Fotina, H., Ladyka, V., Ladyka, L., & Zazharska, N. (2018). Monitoring research of somatic cells count in goat milk in the eastern region of Ukraine. Journal of the Hellenic Veterinary Medical Society, 69(3), 1101–1108.

Gemechu, A. T. (2016). Assessment of safety and quality of raw whole cow milk produced and marketed by smallholders in central highlands of Ethiopia. Food Science and Quality Management, 49, 63–71.

Guzmán-Luna, P., Mauricio-Iglesias, M., Flysjö, A., & Hospido, A. (2022). Analysing the interaction between the dairy sector and climate change from a life cycle perspective: A review. Trends in Food Science and Technology, 126, 168–179.

Hayes, E., Wallace, D., O'Donnell, C., Greene, D., Hennessy, D., O'Shea, N., Tobin, J. T., & Fenelon, M. A. (2023). Trend analysis and prediction of seasonal changes in milk composition from a pasture-based dairy research herd. Journal of Dairy Science, 106(4), 2326–2337.

Heck, J. M. L., van Valenberg, H. J. F., Dijkstra, J., & van Hooijdonk, A. C. M. (2009). Seasonal variation in the Dutch bovine raw milk composition. Journal of Dairy Science, 92(10), 4745–4755.

Hisira, V., Zigo, F., Kadaši, M., Klein, R., Farkašová, Z., Vargová, M., & Mudroň, P. (2023). Comparative analysis of methods for somatic cell counting in cow's milk and relationship between somatic cell count and occurrence of intramammary bacteria. Veterinary Sciences, 10(7), 468.

Jahnel, R. E., Blunk, I., Wittenburg, D., & Reinsch, N. (2023). Relationship between milk urea content and important milk traits in Holstein cattle. Animal, 17(5), 100767.

Jõudu, I., Henno, M., Kaart, T., Püssa, T., & Kärt, O. (2008). The effect of milk protein contents on the rennet coagulation properties of milk from individual dairy cows. International Dairy Journal, 18(9), 964–967.

Kazeminia, M., Mahmoudi, R., Mousavi, S., & Mehrabi, A. (2023). Raw cow milk quality: Physicochemical, microbiological, and seasonal variation. Journal of Microbiology, Biotechnology and Food Sciences, 13(3), e10078.

Kheowsri, S., Rojanasthien, S., Semmarath, W., Stott, C. J., Sungkatavat, P., Phetkarl, T., Rueangareerat, P., Suprasert, A., Atthi, R., Chaimongkol, C., Lavilla, C., Singhanetr, S., Yiengvisavakul, V., Pisetpaisan, A., Choongkittaworn, N., Sansamur, C., & Lewchalermvong, K. (2022). Factors affecting milk composition in dairy farms located in Northern Thailand. Veterinary Integrative Sciences, 21(1), 157–173.

Könyves, T., Zlatković, N., Memiši, N., Lukač, D., Puvača, N., Stojšin, M., Halász, A., & Miščević, B. (2017). Relationship of temperature-humidity index with milk production and feed intake of holstein-frisian cows in different year seasons. The Thai Journal of Veterinary Medicine, 47(1), 15–23.

Kovalova, O., Vasylieva, N., Haliasnyi, I., Gavrish, T., Dikhtyar, A., Andrieieva, S., Didukh, N., Balandina, I., Obolentseva, L., & Hirenko, N. (2023). Development of buckwheat groats production technology using plasma-chemically activated aqueous solutions. Eastern-European Journal of Enterprise Technologies, 126, 59–72.

Krugliak, T. O., & Krugliak, A. P. (2023). Milk productivity of cows of the ukrainian red-and-white dairy breed depends on the origin and compatibility of the bulls. Animal Breeding and Genetics, 66, 70–78.

Leila, N., Morvarid, Y., Elham, Z., Mohammad, G., & Mehran, M. (2014). The effect of different seasons on the milk quality. European Journal of Experimental Biology, 4(1), 550–552.

Liu, J., Liu, H., Cao, G., Cui, Y., Wang, H., Chen, X., Xu, F., & Li, X. (2023). Microbiota characterization of the cow mammary gland microenvironment and its association with somatic cell count. Veterinary Sciences, 10(12), 699.

Lock, A. L., & Garnsworthy, P. C. (2003). Seasonal variation in milk conjugated linoleic acid and Δ9-desaturase activity in dairy cows. Livestock Production Science, 79(1), 47–59.

Mylostyvyi, R., Izhboldina, O., Midyk, S., Gutyj, B., Marenkov, O., & Kozyr, V. (2023). The relationship between warm weather and milk yield in Holstein cows. World's Veterinary Journal, 13, 134–143.

Nagovska, V., Hachak, Y., Gutyj, B., Bilyk, O., & Slyvka, N. (2018). Influence of wheat bran on quality indicators of a sour milk beverage. Eastern-European Journal of Enterprise Technologies, 94, 28–35.

Nahusenay, H., Tola, A., Sisay Tessema, T., Vipham, J., & Woldegiorgis, A. Z. (2023). Seasonal comparison of microbial hygiene indicators in raw and pasteurized milk and cottage cheese collected across dairy value chain in three regions of Ethiopia. Foods, 12(24), 4377.

Nardone, A., Ronchi, B., Lacetera, N., Ranieri, M. S., & Bernabucci, U. (2010). Effects of climate changes on animal production and sustainability of livestock systems. Livestock Science, 130(1–3), 57–69.

Ormston, S., Qin, N., Faludi, G., Pitt, J., Gordon, A. W., Theodoridou, K., Yan, T., Huws, S. A., & Stergiadis, S. (2023). Implications of organic dairy management on herd performance and milk fatty acid profiles and interactions with season. Foods, 12(8), 1589.

Pavel, E. R., & Gavan, C. (2011). Seasonal changes in bulk tank milk composition of dairy cows. Scientific Papers Animal Science and Biotechnologies, 44(2), 444–459.

Pellegrino, L., Masotti, F., Cattaneo, S., Hogenboom, J. A., & de Noni, I. (2012). Nutritional quality of milk proteins. In: McSweeney, P. L. H., & Fox, P. F. (Eds.). Advanced dairy chemistry. Springer Science + Business Media, New York. Pp. 515–538.

Prahl, M. C., Müller, C. B. M., Wimmers, K., & Kuhla, B. (2023). Mammary gland, kidney and rumen urea and uric acid transporters of dairy cows differing in milk urea concentration. Scientific Reports, 13(1), 17231.

Quist, M. A., LeBlanc, S. J., Hand, K. J., Lazenby, D., Miglior, F., & Kelton, D. F. (2008). Milking-to-milking variability for milk yield, fat and protein percentage, and somatic cell count. Journal of Dairy Science, 91(9), 3412–3423.

Regulation (EC) No. 853/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules for food of animal origin. Official European Journal Union L139/55, 30.04.2004.

Shokoohmand, M., Mofidi, M., Bitaraf, A., EmamiMeibodi, M., & Saeedabadi, M. (2012). The effect of season and production systems on qualitative and quantitative properties of milk produced in dairy farms of Yazd province. Journal of Occupational Health and Epidemiology, 1(3), 162–170.

Sklyarov, P., Fedorenko, S., & Naumenko, S. (2020). Oxidant/antioxidant balance in cows and sheep in antenatal pathology. Ukrainian Journal of Ecology, 10(5), 26–28.

Sun, X., Zhao, R., Wang, N., Zhang, J., Xiao, B., Huang, F., & Chen, A. (2023). Milk somatic cell count: From conventional microscope method to new biosensor-based method. Trends in Food Science and Technology, 135, 102–114.

Timlin, M., Tobin, J. T., Brodkorb, A., Murphy, E. G., Dillon, P., Hennessy, D., O'Donovan, M., Pierce, K. M., & O'Callaghan, T. F. (2021). The impact of seasonality in pasture-based production systems on milk composition and functionality. Foods, 10(3), 607.

Wang, A., Su, G., Brito, L. F., Zhang, H., Shi, R., Liu, D., Guo, G., & Wang, Y. (2024). Investigating the relationship between fluctuations in daily milk yield as resilience indicators and health traits in Holstein cattle. Journal of Dairy Science, 107(3), 1535–1548.

Yoon, J. T., Lee, J. H., Kim, C. K., Chung, Y. C., & Kim, C. H. (2004). Effects of milk production, season, parity and lactation period on variations of milk urea nitrogen concentration and milk components of Holstein dairy cows. Asian-Australasian Journal of Animal Sciences, 17(4), 479–484.

Zazharska, N., Boyko, O., & Brygadyrenko, V. (2018). Influence of diet on the productivity and characteristics of goat milk. Indian Journal of Animal Research, 52(5), 711–717.

Zazharska, N., Fotina, T., Yatsenko I., Tarasenko, L., Biben, I., Zazharskyi, V., Brygadyrenko, V., & Sklyarov, P. (2021). Comparative analysis of the criteria for goat milk assessment in Ukraine and France. Ukrainian Journal of Ecology, 11(2), 144–148.

Zazharskyi, V. V., Alifonova, K. V., Brygadyrenko, V. V., Zazharska, N. M., Goncharenko, V. P., & Solomon, V. V. (2023). The ability of *Sitophilus oryzae* (Coleoptera, Curculionidae) to transmit *Mycobacterium bovis*: Morphology, cultural biochemical properties of the bacteria. Regulatory Mechanisms in Biosystems, 14(3), 476–486.

Zhu, X., Wen, J., & Wang, J. (2020). Effect of environmental temperature and humidity on milk production and milk composition of Guanzhong dairy goats. Veterinary and Animal Science, 9, 100121.