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THE INFLUENCE OF SEASONAL FACTORS ON DAILY MILK PRODUCTION AND CHEMICAL COMPOSITION OF MILK IN DAIRY COWS

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Abstract: The production characteristics of dairy cows are subject to the influence of numerous environmental and management factors, among which seasonal changes play an important role. The aim of this study was to analyze the influence of the seasons on the amount of milk produced daily and the amount and proportion of milk fat and protein in the milk. Data collected during regular milk control were used, and statistical analysis was performed at the level of more than one million records for each characteristic. The results showed a pronounced seasonal variability of production parameters. The highest daily milk yields were recorded in spring and winter (23.50 kg and 23.00 kg respectively), while these values were lower in summer and autumn. The milk fat and protein content also varied depending on the season - the highest fat and protein contents were recorded in the colder months, while the lowest were recorded during summer, which can be associated with heat stress and reduced feed intake. Seasonal variability in production indicates the need for seasonally adapted herd management strategies, including ration optimization, thermal comfort, and technological adaptation. The research provides an important contribution to understanding the dynamics of production traits throughout the year and provides a basis for further modelling of effective management systems that would enable more sustainable and stable dairy farming under climate change.

Key words: dairy cows, seasonal effect, daily milk yield, milk fat, milk proteins

Introduction

Dairy farming is one of the most important branches of livestock production, with an emphasis on producing high-quality milk while preserving animal and environmental health. Modern trends in agriculture, including the growth of the world population and changes in eating habits, are putting pressure on dairy producers to increase production while reducing negative impacts on the environment (FAO, 2009; Dopelt et al., 2019). Sustainable intensification of milk production is becoming a necessity, and in this context, optimizing the production characteristics of dairy cows is of particular importance.

One of the key factors affecting milk production and its composition is climatic and seasonal conditions. The season in which a cow is during lactation can significantly affect the daily amount of milk produced, the proportion of milk fat and protein, due to changes in ambient temperature, the availability and quality of feed, and the physiological responses of the animal to environmental stresses (Gantner and Barać, 2016; Domaćinović et al., 2015). Heat stress during the summer months reduces feed intake, resulting in lower milk production and changes in its chemical composition (Kirchgessner et al., 1986; Eicher, 2004). In contrast, during colder seasons, production stabilizes and milk quality is often improved.

Milk yield monitoring, as a system for collecting and analyzing data on the milk production parameters of cows, provides valuable information for assessing the impact of various factors on milk production.

In Croatia, it is carried out in accordance with ICAR standards, using AT4/BT4 methods, and the data is processed at the Central Milk Control Laboratory (HAPIH, 2020; ICAR, 2009).

Thanks to the development of precision dairy cattle breeding, it is now possible to systematically monitor production parameters at the individual animal level, which allows for a better assessment of seasonal influences at the farm level and timely management decisions (Gantner, 2020).

The aim of this work was to analyze seasonal variability of daily milk yield, milk fat content and total milk protein content, in order to identify patterns that can serve as a basis for adjusting feeding and housing technology in different seasons. Special emphasis was placed on identifying differences between seasons and on determining the potential for improving production efficiency under climate change conditions.

Materials and Methods

This study was based on a comprehensive database for monitoring the milk yield of Holstein dairy cows, which was collected as part of the official production control in the Republic of Croatia. The database contained a total of 5,691,083 records, collected on the control day in the period from 1 January 2005 to 31 December 2022, thus covering a large period of 18 years. To analyse the seasonal variability of production traits, the part of the database relating to daily milk yield (DMY), daily milk fat yield (DMF), daily protein yield (DMP) and milk fat content (DAMF) and protein content (DAP) was used. All data were collected using methods in accordance with the recommendations of the International Organization for the Control of Livestock Production (ICAR), with the AT4/BT4 method used in Croatia. Milk quantity measurement and sampling were carried out by authorized controllers of the Croatian Agency for Agriculture and Food (HAPIH), and milk composition analysis was performed at the Central Laboratory for Milk Quality Control located in Križevci. In the aforementioned laboratory, analyzes are performed in accordance with accredited laboratory methods, i.e., infrared spectrophotometry is used to determine the proportion of milk fat, protein, lactose and urea, and the fluoro-opto-electronic method is used to count somatic cells. Testing of milk samples in the laboratory is carried out with modern analytical equipment. The chemical quality of milk is tested on four MilkoScan analyzers, two MilkoScan FT 6000 and two MilkoScan 7 RM, which are located in a combi system together with Fossomatic analyzers for determining the number of somatic cells. The results of the quality control analyses of milk samples were downloaded in electronic form. The downloaded data were statistically analyzed at the Faculty of Agrobiotechnical Sciences in Osijek. The data were classified by season: spring, summer, autumn and winter, according to the date of control. Descriptive statistical parameters were calculated for each seasonal period and each observed characteristic: mean value (Mean), standard deviation (SD), coefficient of variability (CV), as well as minimum and maximum value. Statistical processing was performed using the SAS/STAT software package (SAS Institute Inc., 2019), which was used to perform univariate analyses and compare seasonal groups.

Results and Discussion

Due to the sample size, length of the time frame and geographical range of production (different regions and housing conditions), the results have a high level of reliability and representativeness for assessing seasonal variability of production indicators in dairy cattle breeding.

Table 1 shows basic descriptive statistics for the main production traits of Holstein dairy cows, obtained from the official milk control database for the period 2005–2022.

Table 1. Basic statistical parameters of analysed traits

Variable	N	Mean	SD	CV	Min	Max
DMY	5411650	22.76	9.76	42.88	3.00	99.90
DMF	5544603	4.17	0.98	23.44	1.50	9.00
DMP	5579436	3.45	0.47	13.74	1.01	7.00
DAMF	5287610	0.94	0.44	47.24	0.05	7.94
DAP	5319298	0.77	0.31	40.39	0.06	4.97

*DMY – daily milk yield (kg); DMF – daily milk fat (%); DMP – daily milk protein (%); DAMF – daily amount of milk fat (kg); DAP – daily amount of protein (kg); N = absolute number of cows; SD = standard deviation; CV = coefficient of variability; Min = minimum, Max = maximum

The average daily milk yield (DMY) was 22.76 kg, with high variability (CV = 42.88%), with a range of values from 3.00 to as much as 99.90 kg. The milk fat content (DMF) had an average value of 4.17%, while the protein content (DMP) was 3.45%. The absolute amount of milk fat produced (DAMF) was on average 0.94 kg, and the protein (DAP) was 0.77 kg per day. The coefficients of variability for DAMF and DAP were high (47.24% and 40.39%), indicating marked differences between animals and production conditions.

The results of the analysis of the variability of production characteristics, daily milk yield and composition of milk (daily content and daily quantity of milk fat and protein) of dairy cows are divided into 4 tables according to the seasons: spring, summer, autumn and winter and are presented below in Tables 2-5.

Table 2. Basic statistical parameters of daily milk yield characteristics in spring

SPRING						
Variable	**N**	**Mean**	**SD**	**CV**	**Min**	**Max**
DMY	1423248	23.50	10.03	42.66	3.00	99.90
DMF	1471608	4.13	0.96	23.22	1.50	9.00
DMP	1481268	3.42	0.46	13.38	1.06	7.00
DAMF	1396825	0.96	0.45	47.26	0.05	6.47
DAP	1405304	0.79	0.32	40.28	0.07	4.97

*DMY – daily milk yield (kg); DMF – daily milk fat (%); DMP – daily milk protein (%); DAMF – daily amount of milk fat (kg); DAP – daily amount of protein (kg); N = absolute number of cows; SD = standard deviation; CV = coefficient of variability; Min = minimum, Max = maximum

Table 3. Basic statistical parameters of daily milk yield characteristics in summer

SUMMER						
Variable	**N**	**Mean**	**SD**	**CV**	**Min**	**Max**
DMY	1230201	22.64	9.30	41.07	3.00	99.40
DMF	1264659	3.98	0.92	23.04	1.50	9.00
DMP	1273050	3.34	0.44	13.29	1.01	7.00
DAMF	1196292	0.89	0.41	46.08	0.05	7.16
DAP	1203996	0.75	0.29	39.08	0.06	4.44

*DMY – daily milk yield (kg); DMF – daily milk fat (%); DMP – daily milk protein (%); DAMF – daily amount of milk fat (kg); DAP – daily amount of protein (kg); N = absolute number of cows; SD = standard deviation; CV = coefficient of variability; Min = minimum, Max = maximum

Table 4. Basic statistical parameters of daily milk yield characteristics in autumn

AUTUMN						
Variable	**N**	**Mean**	**SD**	**CV**	**Min**	**Max**
DMY	1379755	21.85	9.47	43.33	3.00	99.30
DMF	1406383	4.24	0.99	23.44	1.50	9.00
DMP	1415213	3.52	0.49	13.92	1.03	7.00
DAMF	1349517	0.91	0.43	46.87	0.05	7.94
DAP	1357721	0.76	0.31	40.41	0.06	4.33

*DMY – daily milk yield (kg); DMF – daily milk fat (%); DMP – daily milk protein (%); DAMF – daily amount of milk fat (kg); DAP – daily amount of protein (kg); N = absolute number of cows; SD = standard deviation; CV = coefficient of variability; Min = minimum, Max = maximum

Table 5. Basic statistical parameters of daily milk yield characteristics in winter

WINTER						
Variable	**N**	**Mean**	**SD**	**CV**	**Min**	**Max**
DMY	1378446	23.00	10.09	43.86	3.00	99.50
DMF	1401953	4.32	1.00	23.21	1.50	9.00
DMP	1409905	3.51	0.48	13.63	1.02	7.00
DAMF	1344976	0.98	0.47	47.79	0.05	6.76
DAP	1352277	0.79	0.33	41.09	0.07	4.87

*DMY – daily milk yield (kg); DMF – daily milk fat (%); DMP – daily milk protein (%); DAMF – daily amount of milk fat (kg); DAP – daily amount of protein (kg); N = absolute number of cows; SD = standard deviation; CV = coefficient of variability; Min = minimum, Max = maximum

The results of this study, covering a period of 18 years and more than 5.6 million records, clearly confirm the existence of significant seasonal variability in the production traits of Holstein dairy cows. This long-term time frame allowed a reliable assessment of the effect of seasonal changes on daily milk production and milk chemical composition, independent of annual fluctuations in herd management and environmental conditions.

Daily milk yield (DMY) was highest during spring (23.50 kg) and winter (23.00 kg), while lower values were recorded in summer (21.93 kg) and autumn (21.85 kg). This pattern confirms the findings of previous studies that established a negative effect of heat stress and reduced dry matter intake in the summer months on milk production (Kirchgessner et al., 1986; Eicher et al., 1999; Gantner and Barać, 2016). High temperatures during the summer disrupt the thermoregulation of cows, reduce appetite and nutrient intake, which ultimately results in lower milk yield and changes in milk composition (Domaćinović et al., 2015).

Milk fat content (DMF) and protein content (DMP) also showed a clear seasonal dependence. The highest fat content was recorded in winter (4.32%), while the lowest was in summer (3.98%). Protein content varied in a smaller range (3.34%–3.52%), but was also lowest in the summer period. Similar patterns have been described in the literature, where it is stated that colder seasons result in a higher dry matter content in the ration (due to better feed consumption), which has a positive effect on the synthesis of milk fat and protein (Gross and Bruckmaier, 2019; Gantner, 2020).

It is important to emphasize that the absolute amounts of milk fat (DAMF) and protein (DAP) were highly variable throughout the year (CV about 47%), while the relative values (DMF and DMP) were quite stable (CV about 23% and 13% respectively) (Table 2-5). This confirms that the amount of milk produced has the greatest influence on the absolute amounts of nutrients, while the proportions are more related to the physiological state of the animal, nutritional status and microclimatic conditions (Swenson and Reece, 1993; Gantner and Barać, 2016; Cappellozza, 2024).

Seasonal variability clearly indicates the need to adapt feeding strategies and housing technology throughout the year. During the summer, it is recommended to introduce more energy-rich and digestible rations and ensure thermal comfort in the barns through ventilation, water sprays or shading (FAO, 2009; Gantner, 2020). On the other hand, the winter months can be used to maximize production, with careful monitoring of urea levels and optimization of the protein component of the diet.

Long-term analysis of seasonal production patterns provides the basis for the development of predictive models that can be used for production planning, cost optimization and environmental footprint reduction. Furthermore,

understanding seasonal dynamics is useful for interpreting milk yield monitoring results and for spotting deviations from expected values that may signal problems in feeding or herd management.

Conclusion

The results of this study, conducted on an extensive database collected during 18 years of official control of Holstein cows' milk yield, indicate a pronounced seasonal variability in production traits. The highest daily milk yield, as well as higher milk fat and protein contents, were recorded during the colder months (spring and winter), while the lowest values were determined in summer, confirming the negative effect of heat stress on production results.

These findings clearly indicate the need for a seasonally adapted approach to herd management, with an emphasis on optimizing feeding, improving microclimatic conditions and increased use of precision dairy farming technologies. Such an approach enables more stable and efficient milk production throughout the year and represents an important step towards more economically and environmentally sustainable dairy farming.

The data obtained and the identified patterns can be used as a basis for further modelling and development of practical recommendations for production management in the context of seasonal challenges and climate change.

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