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Study on milk yield in high-producing Holstein cows and its influencing factors

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Abstract

The aim of the study was to examine the milk productivity of 359 Holstein cows reared in two different farms on the territory of Southern Bulgaria. The lactation period covered the years 2019-2023. Considering the conditions in our country, we can assert that the cows exhibited high milk productivity. The average (LS) milk yield per normal (305-day) lactation was 10840 ± 64.29 kg, with milk fat 3.82 ± 0.05 % and protein content of 3.30 ± 0.06 %. The milk yield per full lactation (354 ± 7.3 milking days) was 12158 ± 210.59 kg, with milk fat 3.81 ± 0.05 and protein content of 3.30 ± 0.06 %. The milk yield per normal lactation was significantly influenced (0.001) by the farm, the year of calving, the lactation number, and the sire ($p < 0.01$). The temperament of the cows and the season of calving did not significantly influence any of the examined parameters, whether in relation to full or normal lactation. The daughters of 94% of the bulls produced milk yield exceeding 10 000 kg, while 76% of the bulls had daughters with a yield above 11 000 kg. The milk fat content per normal lactation was significantly influenced ($p < 0.001$) by the lactation number, whereas the protein content ($p < 0.05$) was affected by the farm and the year of calving.

Keywords: Holstein, milk productivity, sire, temperament

INTRODUCTION

New approaches related to the assessment of breeding and genetic improvement of the animals have been introduced in the dairy cattle farming. Most studies on dairy cattle productivity examine the influence of individual animal traits and environmental factors (Hedlund & Løvlie, 2015; Dechow *et al*., 2020; Strabel, 2024). Selection aimed at achiving extremely high milk yield is associated with the earlier culling of breeding animals, as well as digestive, health, reproductive and other issues (Martens, 2023; Schneider *et al*., 2024). Increasing economic emphasis has been placed on longevity, which is linked to a decline in milk yield and improved welfare and more humane treatment of cows (Sdiri *et al*., 2023). The global increase in milk yield among Holstein cattle has led to reduced resistance to various environmental factors, including health challenges and declines in key milk productivity indicators (Ermetin *et al*., 2024). Holstein cattle have the ability to produce milk with a good quality composition, suitable for the production of cheeses with regional, geographical significance (Simoni *et al*., 2024). Several studies confirm the influence of breed, lactation duration, farm conditions, and lactation number on milk productivity parameters. (Genç & Mendes, 2021; Li *et al*., 2022; Sevinç *et al*., 2020.). The sire, on the other hand, has a significant influence ($p < 0.001$) on the lifetime milk productivity parameters of the daughters-lifetime milk yield and lifetime milk fat (Pavlenko & Kompanets, 2024). Bulls from a distinct, productivity-proven lineage with high reliability significantly impact the milk productivity indicators of their daughters (Gorelik *et al*., 2021). In recent years, significant efforts have been made to consolidate specific behavioral traits in Holstein cows and examine their connection to milk productivity, aiming to enhance efficiency and

improve the heritability of a preferred temperament (Adamczyk *et al*., 2013).

The current study aims to analyze the milk productivity of high-producing Holstein cows raised in Southern Bulgaria and the factors influencing it.

MATERIALS AND METHODS

The milk productivity of 359 Holstein cows was analysed. The animals were reared on two farms in Plovdiv province, Southern Bulgaria, under the selection control of the Association of Breeders of Black and White Cattle in Bulgaria, Ruse. The study included cows between their first and fourth lactation, all of which calved between 2019-2023. Milk productivity was monitored in accordance with ICAR-established methods (ICAR, the Global Standard for Livestock data), while milk quality parameters were assessed in an independent dairy laboratory. In addition to analysing the milk productivity, cow temperament during milking was observed between 40 and 160 days after the start of lactation. Behaviour was recorded once during milking using a scoring system from 1 to 5, following the generally accepted parameter evaluation methods in dairy cattle farming established by ICAR and the approved Holstein breeding programs in the country. The behavior scores were interpreted as follows: 1 - Very calm; 2 - Calm; 3 - Moderately calm; 4 - Nervous; 5 - Very nervous.

Data were processed using analysis of variance, applying the following linear model: $Yijklmn = \mu + Fi + YCj + Sk + Tl + Bm + Ln + eijklmn$, where Yijklmn represents the observation vector; μ is the overall mean constant; YC, F, S, T, B, L denote fixed effects for farm (i=2), year of calving (j=5), season of calving (k=4), temperament (1=5), sire (m=17), and lactation number (n=4). Residuals are represented by eijkmn.

Statistical processing of the data was conducted using SPSS, version 21.

RESULTS AND DISCUSSION

The milk yield of the Holstein cows in the current study averaged 10,840 ± 64.29 kg per standard 305-day lactation, with a milk fat content 3.82 ± 0.05% and a protein content of 3.32 ± 0.03 %. The milk yield per full lactation (354 ± 7.3 milking days) was 12158 ± 210.59 kg, with a milk fat content of 3.81 ± 0.05%, and a protein content 3.30 ± 0.06%. For Turkey, Mundan *et al*. (2020) reported a Holstein cow milk yield of 9,356.2 ± 126.1 kg per full lactation, 8,549.2 ± 105.8 kg per normal lactation, with and a lactation period of 315.0 ± 2.3 days. In Moldova, Konstandoglo *et al*. (2023) reported an average Holstein cow milk yield per full lactation of 9,067 ± 95.0 kg, with a milk fat content of 3.92 ± 0.01 %. In the current study, the difference in milk yield (305 days) by year of calving was significant (Table 1). The highest milk yield was recorded in cows that calved in 2023, while the lowest was observed in those that calved in 2020, with the difference of 2.84%.

The largest variation in milk yield was observed in cows that calved in 2022 (SD – 1,376.13 kg), while the lowest variation was recorded in those that calved in 2023 (SD - 546. 08 kg). The milk yield of cows that calved in 2020 was approximately 2.69% lower than that those that calved in 2019. Following this period, an average annual increase of 1% in milk yield was observed.

No significant differences were detected in fat content despite variations in milk yield across different years, with fat content remaining relatively stable throughout the study period. However, a significant difference ($p < 0.05$) in milk protein content was observed within farms and across calving years. The highest milk protein content was recorded in cows that calved in 2023, while the lowest was found in those that calved in 2019, with a difference of 0.05%.

Table 1. Milk productivity of Holstein cows, which calved in different years, per normal lactation.

Year of calving	N	Milk yield, kg		Fat, %		Milk fat, kg		Protein, %		Milk protein, kg	
		LSM ± SE	StDev	LSM ± SE	StDev	LSM ± SE	StDev	LSM ± SE	StDev	LSM ± SE	StDev
2019	33	10984 ± 278	603.423	3.81 ± 0.06	0.032	419.29 ± 10.59	22.93	3.29 ± 0.10	0.021	362.23 ± 9.11	20.50
2020	50	10689 ± 166	863.210	3.83 ± 0.10	0.038	410.52 ± 6.32	32.30	3.30 ± 0.06	0.025	354.07 ± 5.44	28.17
2021	93	10734 ± 140	1277.034	3.82 ± 0.08	0.047	410.85 ± 5.36	48.24	3.31 ± 0.05	0.028	355.93 ± 4.61	42.19
2022	100	10914 ± 164	1376.751	3.81 ± 0.11	0.041	416.99 ± 6.25	51.07	3.32 ± 0.09	0.023	363.24 ± 5.37	45.36
2023	83	11001 ± 221	546.469	3.80 ± 0.13	0.052	419.70 ± 8.41	22.23	3.34 ± 0.08	0.026	368.01 ± 7.23	18.43

The significant difference in protein content between the two farms was 0.04%; in terms of milk yield per normal lactation, the difference was 1,894 kg, and for milk protein, it was 60.3 kg.

Ivancia *et al*. (2023) reported hereditability estimates for Holstein milk yield per lactation (0.15 ± 0.06), fat (0.30 ± 0.12) and protein (0.64 ± 0.23). The Holstein cows in the current study demonstrated high milk productivity and good milk composition quality. Zou *et al*. (2024) found that breed influences milk composition quality. The milk analysed in the current study had a fat-to-protein ratio of 1.15:1, making it suitable for cheese production. Milk fat and protein content showed no significant variation across calving years. In a study by Tirfie (2023), Holstein cows' protein per lactation was reported as 3.14 ± 0.06 %, and the fat content was 3.7 ± 0.03%. The milk yield per normal lactation was significantly influenced ($p < 0.001$) by the farm, year of calving, lactation number, and sire ($p < 0.01$) (Table 2).

Table 2. Influence of major factors on the milk productivity of Holstein cows

Parameters	F – criteria and degree of credibility					
	Farm	Year of calving	Season of calving	Temperament	Sire	Lactation number
Per full lactation						
Lactation period, days	1.752	7.681***	0.561	0.284	0.607	22.749***
Milk yield, kg	28.975***	5.023**	0.474	0.265	0.416	9.609***
Fat, %	7.858**	1.288	2.001	0.675	1.167	10.547***
Protein, %	7.217**	3.726**	0.624	0.658	1.244	1.794
Milk fat, kg	26.970***	5.297***	0.438	0.208	0.422	10.741***
Milk protein, kg	28.290***	4.704**	0.447	0.274	0.429	9.477***
Per normal lactation (305 days)						
Milk yield, kg	222.953***	12.771***	0.656	0.436	9.659**	18.929***
Fat, %	1.202	0.738	0.752	0.969	0.638	7.420***
Protein, %	2.947*	2.880*	0.289	0.057	0.738	1.827
Milk fat, kg	26.571***	0.273	0.204	0.308	0.758	5.099**
Milk protein, kg	26.900***	0.406	0.37	0.302	0.907	7.294***

Legend: ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$

Temperament and season of calving did not significantly influence any of the examined parameters. Akilli *et al*. (2022) determined that season of calving and lactation number are unreliable factors affecting standard milk yield (305 days) in Holstein cows reared in Turkey.

Farm conditions had a significant effect ($p < 0.001$) on both milk fat and protein content in normal and full lactation. Another factor considerably affecting milk productivity parameters was lactation number which significantly influenced almost all parameters examined parameters except protein. Holstein cows achieved high milk productivity as early as their first lactation, with significant increase ($p < 0.001$) observed in subsequent lactations. The largest increase in milk yield per standard lactation was recorded between the first and second lactation, averaging 9.7% (Fig. 1). Between the second and fourth lactation, the annual increase in milk yield was slightly above 1%, a trend observed in milk fat and protein content.

According to Gorelik *et al*. (2021), improving the genetic potential for milk yield can be achieved through selection based on the first lactation. Enhancing milk composition quality, however, requires consideration of the breeding values of the bulls used. In the current study, cows at their third lactation achieved the highest milk yield per normal lactation, averaging 11,246.56 ± 148.36 kg. Abo- Gamil *et al*. (2021) reported that Holstein cows had a milk yield (305 days) of 9,175.83 ± 211.95 at their first lactation, and 8p543.39 ± 259.34 at their fourth lactation. Findings of the current study indicate that the highest fat content (3.87 ± 0.08 %) was observed in cows during their first standard lactation, whereas the highest protein content (3.32%) was recorded in cows during their fourth standard lactation (Fig. 2).

According to Cattaneo *et al*., 2023), cows in their first lactation produce 26% more milk compared to those in their first lactation. Similarly, Rebezov *et al*. (2022) reported that milk yield per second lactation (305 days) was 937 kg, or 14.5% higher than in the first lactation. Foksha *et al*. (2024) observed a positive milk yield correlation (+0.201) between the first and second lactation (305 days), with an average increase of 107 kg in the second lactation. The current study established that milk productivity during the fourth lactation remained very high, suggesting that efforts could be effectively directed toward the prolonged use of cows with marked longevity and high lifetime milk yield. Gorelik et al. (2022) found that Holstein cows reach their highest milk fat and protein content in their second lactation. In the current study, the smallest difference in milk fat content was observed between the first and second lactations, while the largest difference occurred between the first and fourth lactations.

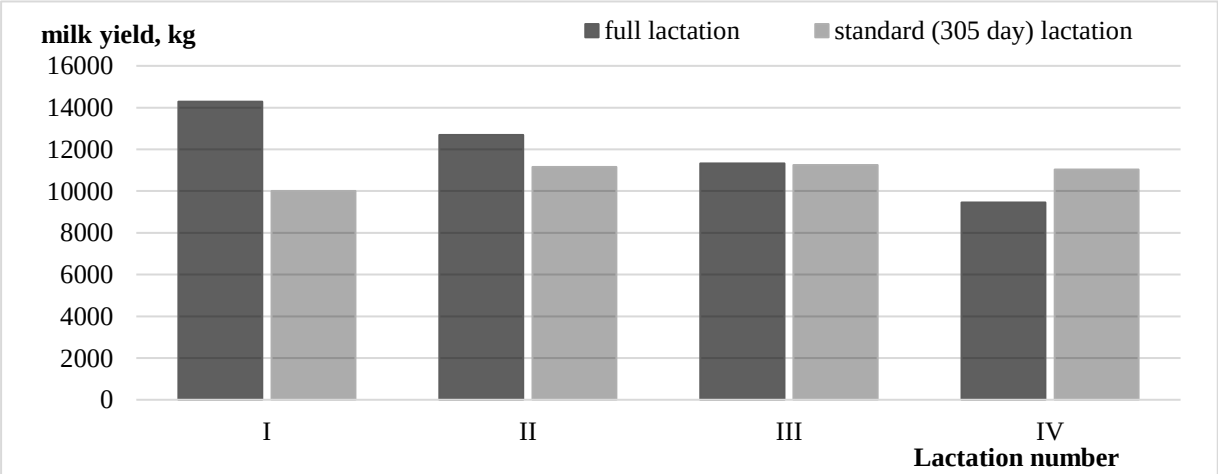

Figure 1. Milk yield of Holstein cows within their lactation number

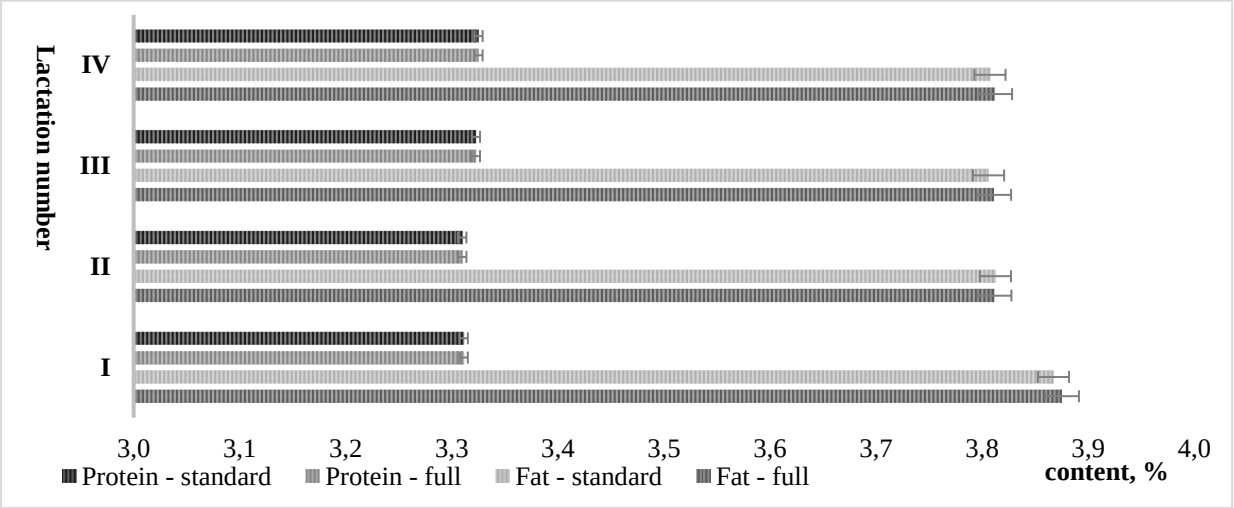

Figure. 2. Qualitative composition of the milk of Holstein cows within the lactation number

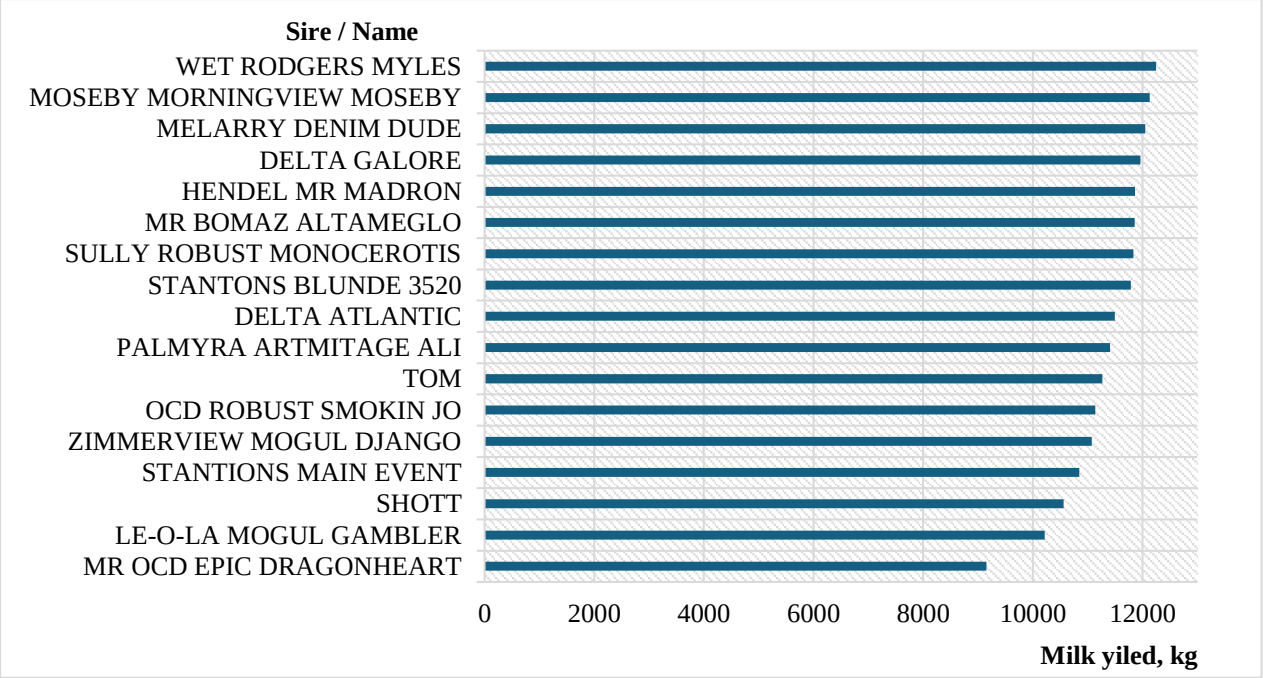

Figure 3. Influence of the sire on the milk yield of Holstein cows per normal lactation

Regarding protein content, the greatest variation by lactation number was observed between the first and third lactations. As milk yield increased from the first to the second lactation, fat content decreased by 0.06%, while protein content declined by 0.02%. One of the factors significantly influencing ($p < 0.01$) milk yield in Holstein cows was the sire (Fig. 3). The results of the current study indicated that 18% of the bulls analyzed had daughters with a milk yield exceeding 12,000 kg per normal lactation.

The daughters of the bull 'WET RODGERS MYLES' achieved a milk yield of 12,252 ± 381.28 kg per normal lactation, demonstrating high productivity under local conditions. Within sire influence, 59% of the bulls had daughters with milk yields between 11,000 and 12,000 kg, while 23% had daughters with yields below 11,000 kg. The lowest recorded milk yield, 9,153 ± 269.6 kg, was observed in daughters of the bull „MR OCD EPIC DRAGONHEART".

Overall, 94% of the bulls had daughters with milk yields exceeding 10,000 kg, and 76% had daughters producing more than 11,000 kg. In a study by Papusha & Muratov (2022), only 26.7% of sires (American Holstein) in Russian conditions successfully expressed their breeding qualities as enhancers.

Lower variation was observed in fat and protein content. The bulls in the current study had daughters with milk fat content ranging from 3.79% to 3.85%, and protein content between 3.29% and 3.34%. Unlike these findings, Palii et al. (2021) reported a significant sire influence ($p > 0.999$) on milk protein content per lactation.

Among the bulls analyzed, 88% had daughters with milk fat content exceeding 3.8%, while 76% had daughters with a protein content above 3.3%. The highest recorded fat content (3.85 ± 0.02%) and protein content (3.34 ± 0.01%) were observed in daughters of the bull 'TOM.' The daughters of all bulls used in the farms demonstrated high milk yield and excellent milk composition quality.

CONCLUSIONS

The Holstein cows achieve high milk productivity. The average (LS) milk yield per standard 305- day lactation was 10,840 ± 64.29 kg, with fat and protein contents of 3.82 ± 0.05% and 3.32 ± 0.03%, respectively The milk yield per full lactation (354 ± 7.3 milking days) was 12,158 ± 210.59 kg, with fat and protein contents of 3.81 ± 0.05 % and 3.30 ± 0.06%, respectively. Milk yield per normal lactation was significantly influenced (p=0.001) by farm, year of calving, lactation number and sire (p<0.01). The temperament and season of calving did not significantly affect any examined parameters in either full or normal lactation. In the current study, 94% of bulls had daughters with milk yields exceeding 10,000 kg, while 76% of bulls had daughters producing over 11,000 kg. Lactation number had a significant effect ($p < 0.001$) on milk fat content per normal lactation, while farm and year of calving significantly influenced protein content ($p < 0.05$)

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