EFFECT OF THE *PERIPARTUM* WEATHER CONDITIONS ON THE PERFORMANCE AND REPRODUCTION OF DAIRY COWS

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Abstract: *The performance of Holstein-Friesian cows calved in winter and summer was compared on two farms. The milk yield in early lactation (in first 100 days) differed; the cows calved in winter produced more milk (0-10%) than the cows calved in summer. The difference is mainly expected for multiparous cows. The maximum daily milk yield and the standard lactation performance (kg/305 days) differed only in the multiparous cows, the production of cows calved in winter was higher. No significant difference in FCM performance (kg/305 days, corrected for 4% fat) was detected. In the first 100 days, the protein content of the milk may also be more favourable after winter calving, but this does not apply to total lactation. No clear difference was found in the somatic cell count of milk. The time of calving (winter or summer) affected also the reproductive performance of the cows, particularly the length of the service period. There were significant differences in the frequency of the service period shorter than 60 days (very good), and longer than 120 days (unfavourable), both in case of primiparous and multiparous cows. After winter calving, the favourable service period and after summer calving, the unfavourable service period occurred in more cows. The results confirm the importance of protecting of dairy cows from summer heat stress, even under the temperate climate.*

Key words: *Holstein-Friesian, heat stress, milk production, reproduction*

INTRODUCTION

The global warming is an increase in the Earth’s average temperature, which also applies to waters and the atmosphere. This mainly due to anthropogenic factors and will continue for at least a few more decades (IPCC, 2001 – http1). The increase in the annual average temperature over the past three and a half decades has been felt in Hungary as well *(Figure 1.).*

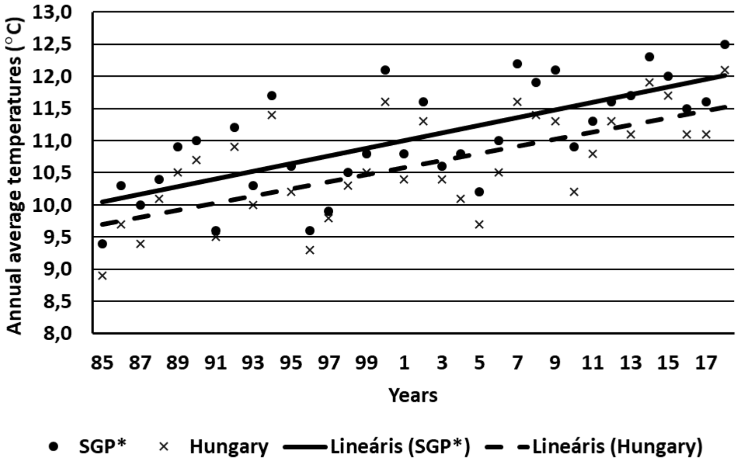

Fig. 1. Trend of annual average temperature between 1985 and 2018
(Based on the data of the KSH (CSO); http2)
* SGP = Southern Great Plain; average of Békéscsaba, Szeged and Kecskemét cities.

The consequence of climate change is the increasingly hot summers, which are placing increasing heat stress on animals. Heat stress occurs when the balance between heat production and heat loss in cows is unhinged, meaning that they are no longer able to compensate for the increase in ambient temperature.

In several countries of the world, including Hungary, the most important breed in milk production is the Holstein-Friesian. These cows are particularly sensitive to the harmful effects of heat stress, precisely because of their high performance (MULLER and BOTHA, 1993). In the case of Holstein-Friesian cows, heat stress can already occur at temperatures above 25-26°C (BERMAN et al., 1985), although the relative humidity of the air is also an important influencing factor (WEST, 2003).

The main effects of heat stress are to increase the body temperature, pulse and respiration of the animals, reduce the daily feed intake, degrade the production and reproduction indicators (BOURAOUI et al. 2002; DAS et al., 2016; PRAGNA et al., 2017). The effect of heat stress on ongoing milk production has been investigated in several studies (INGRAHAM et al., 1979; RAVAGNOLO et al., 2000; ÖTVÖSNÉ, 2011, KOMLÓSI and RIBÁCS, 2020). All mentioned authors experienced a decrease in milk yield under heat stress. The rate of decline was 0-12% under Hungarian conditions (ÖTVÖSNÉ, 2011, KOMLÓSI and RIBÁCS, 2020), which depended on the strength and duration of the heat stress (ÖTVÖSNÉ, 2011). The declining milk production is due to less feed intake on the one hand and hormonal reasons on the other hand (POLSKY and KEYSERLINGK, 2017, PRAGNA et al., 2017). According to some studies, the composition of milk may also change unfavourably (WEST, 2003; DAS et al., 2016; PRAGNA et al., 2017).

The decline in reproductive performance can also be attributed to several reasons. The ability of the *ovum* to fertilization is reduced (KOVÁCS and KOVÁCS, 2012), the temperature of the *uterus* increases and its blood supply decreases (MELLADO et al., 2013), but hormonal causes also play a role (DE RENSIS and SCARAMUZZI, 2003; KADOKAWA et al., 2012).

The heat stress weakens also the general resistance of cows. Therefore, some diseases *(mastitis, ketosis)* may become more common (TÓTH, 2018), which further reduces the profitability of production.

It has long been known that the *peripartum* weather conditions can also significantly determine the milk producing ability of cows (MCDOWELL et al., 1976). Our current research is primarily related to these facts. The heat stress in Hungary is most likely to occur in the summer. It can also occur in late spring or early autumn, but the cows that calve in winter are certainly not exposed to *peripartum* heat stress. Based on this idea, we chose the winter and the opposite season (summer), i.e. when the probability of heat stress is the smallest and the highest. In this study, the milk production, milk quality and reproduction of Holstein-Friesian cows calved in winter and summer were compared under Hungarian (Southern Great Plain) conditions.

MATERIAL AND METHODS

The study was conducted on two farms, both located in Hungary, in the Southern Great Plain. Both farms produce milk with Holstein-Friesian cows. In both cases, the data used for the study were collected from the computerized farm-management system.

The farm “A”, where a preliminary study was conducted, is located in Békés County. The question was whether there could be a detectable difference in milk production of the cows calved in winter and summer. First, 3 age groups were created: 1.) the primiparous cows, 2.) the cows in the 2nd and 3rd lactation, 3.) the older cows that calved at least 4 times. We selected cattle from all three age groups: 1.) the cows calved in winter; they last calved between 1 December 2018 and 28 February 2019, 2.) the cows calved in summer, they last calved between June 1 and August 31, 2019. At the time of the study (autumn 2020), all cows tested had a complete lactation. Within each age group, the following parameters were compared: milk yield in early lactation (in first 100 days), standard lactation performance (kg/305 days), FCM (Fat Corrected Milk) performance (kg/305 days, corrected for 4% fat), maximum daily milk yield and the protein content of milk (percent, the 305-day average). Statistical data processing was performed in Microsoft Excel 2016. The mean values of the cows calved in winter and summer were compared with the Student's t-test or, if the standard deviations were significantly different, with the Welch's t-test. The homogeneity of the standard deviations was checked by F-test.

In the summer of 2021, we conducted further investigations on another farm. The farm "B" is located in Csongrád-Csanád County, 52 km west of farm "A". The cows were classified into 2 age groups: the primiparous and the multiparous cows. The cows calved in summer (between 1 June and 31 August 2020) and winter (between 1 December 2020 and 28 February 2021) were selected from both groups. The multiparous cows were paired according to the following criteria: One cow of each pair calved in the winter and the other in the summer. The number of lactation and performance in the *previous* lactation (corrected for 305 days) by the two cows should be as similar as possible. In this way, we wanted to ensure that there was no significant difference between the milk-producing ability of the studied groups (winter and summer calving), which would distort the results of the investigation. The milk-producing ability of the primiparous cows was not known, they did not have production data yet, so it was not possible to arrange them in pairs. All those who calved during that period were included in the study. From the available data, taking into account the preliminary study also, the following parameters were examined: milk yield in early lactation (in first 100 days), maximum daily milk yield, milk protein percentage and production (kg/100 days), and the somatic cell count of milk. On this farm, the reproductive performance of the groups was also compared, such as the time of first insemination after the calving and the length of the service period. The statistical data processing was performed using similar methods as on farm "A". In some cases – e.g. incomplete data set, very large standard deviation – cows were categorized instead of calculating the average. In this case, the proportion of cows calved in winter and summer in each category was compared using Fisher's test.

RESULTS AND DISCUSSIONS

Results on the farm "A" (as a preliminary study)

The *Tables 1-3.* contain these results.

The milk yield in early lactation (in first 100 days): From a statistical point of view, there are the most obvious differences in this parameter. The cows calved in summer produced 6.5-9.5% less milk than the cows calved in winter. The difference is significant at the 5% error level for all three age groups.

Standard lactation performance (corrected for 305 days): The performance of cows calved in the summer was 4.3-8.5% less. The difference is clear only in the 2nd and 3rd lactation at the 5% error level, but it can also be detected in the other two age groups at 10% error level.

FCM-performance (Fat Corrected Milk): The results corrected for 305 days are further corrected for 4% fat as well. For this, the Gaines formula is used:

$$FCM = 0.4 \times \textit{milk yield [kg/305 days]} + 15 \times \textit{milk fat production [kg/305 days]}$$

Thus, the FCM-performance also depends on the fat content of the milk produced. As the fat content of Holstein-Friesian milk is usually less than 4.0%, its performance in FCM is lower than that the standard – corrected only for 305 days – performance. For the primiparous cows, as well as in the 2nd and 3rd lactation no significant difference can be detected between the FCM-performance of cows calved in winter and summer.

Table 1.

Results of the primiparous cows

	WINTER n = 78	SUMMER n = 39	Differences	
Milk production (kg/100 days)	3 668 ± 484	3 431 ± 392	*	-6.5%
Standard lactation performance (kg/305 days)	10 306 ± 1 296	9 865 ± 1 226	+	-4.3%
FCM performance (kg/305 days, 4% fat)	9 360 ± 1 239	9 247 ± 1 151	NS	
Maximum milk yield (kg/day)	43.4 ± 5.6	43.5 ± 5.9	NS	
Milk protein content (%) (305-days average)	3.38 ± 0.16	3.44 ± 0.18	+	+0.06 % (abs.)

* The difference between the two groups is significant at the 5% error level ($p \leq 0.05$)
+ The difference between the two groups is significant only at the 10% error level ($0.05 < p \leq 0.1$)
NS: The difference between the two groups is not significant ($p > 0.1$)

Table 2.

Results of cows in the 2nd and 3rd lactation

	WINTER n = 49	SUMMER n = 80	Differences	
Milk production (kg/100 days)	4 468 ± 578	4 127 ± 569	*	-7.6%
Standard lactation performance (kg/305 days)	11 647 ± 1 257	10 697 ± 1 478	*	-8.2%
FCM performance (kg/305 days, 4% fat)	10 231 ± 1 050	10 069 ± 1 393	NS	
Maximum milk yield (kg/day)	51.0 ± 5.0	48.8 ± 6.7	*	-4.3%
Milk protein content (%) (305-days average)	3.37 ± 0.16	3.54 ± 0.16	*	+0.17% (abs.)

* The difference between the two groups is significant at the 5% error level ($p \leq 0.05$)
NS: The difference between the two groups is not significant ($p > 0.1$)

Table 3.

Results of cows calved at least 4 times

	WINTER n = 23	SUMMER n = 22	Differences	
Milk production (kg/100 days)	4 558 ± 689	4 127 ± 613	*	-9.5%
Standard lactation performance (kg/305 days)	11 657 ± 1 943	10 669 ± 1 663	+	-8.5%
FCM performance (kg/305 days, 4% fat)	10 820 ± 2 115	9 734 ± 1 618	+	-10.0%
Maximum milk yield (kg/day)	50.4 ± 7.6	49.7 ± 7.9	NS	
Milk protein content (%) (305-days average)	3.37 ± 0.18	3.41 ± 0.17	NS	

* The difference between the two groups is significant at the 5% error level ($p \leq 0.05$)
+ The difference between the two groups is significant only at the 10% error level ($0.05 < p \leq 0.1$)
NS: The difference between the two groups is not significant ($p > 0.1$)

For the older cows (at least 4 times calved), FCM-performance was 10% lower after summer calving, but this was detectable only at 10% error level.

Maximum milk yield (kg/day): Differences were observed only in the 2nd and 3rd lactations. In this age group, the milk yield of cows calved in summer was 4.3% lower.

Milk protein content (305-days average): For the dairy industry, the most valuable component in milk is protein. For the *complete* lactation, the cows calved in summer did not have a lower percentage of milk protein, and may even have a higher percentage than after calving in winter. The early lactation could not be studied because data for the first 100 days were not available separately.

Results on the farm "B"

The results of the multiparous cows

The study groups were designed so that the age (number of lactations) and milk-producing ability of the cows were almost the same *(Table 4.).*

Table 4.

Characteristics of the studied groups

	WINTER n = 60	SUMMER n = 60
Number of calving	2.75 ± 0.75	2.68 ± 1.00
Milk production in the previous lactation (kg/305 days)	10 191 ± 1 464	10 182 ± 1 459

Note: There are no significant differences ($p > 0.05$)

The effect of calving time on milk quantity and quality is illustrated in *Table 5.*

Table 5.

Effect of calving time on milk quantity and quality

	WINTER n = 60	SUMMER n = 60
Milk production in early lactation (kg/100 days)	4 558 ± 629	4 290* ± 656
Maximum milk yield (kg/day)	50.2 ± 6.6	47.3* ± 7.1
Milk protein content (100-days average, %)	3.35 ± 0.28	3.24* ± 0.21
Milk protein production (kg/100 days)	151.9 ± 17.9	138.6* ± 20.4
Somatic cell count (× 1 000/ml) – for complete lactation	670 ± 775	726 ± 596

* The difference between the two groups is significant at the 5% error level ($p \leq 0.05$)

The milk yield (kg/100 days), maximum daily milk production (kg/day), milk protein percentage, and milk protein production (kg/100 days) in early lactation after summer calving were significantly lower than after winter calving.

The somatic cell count of the milk produced is also an important parameter, as it determines the quality or even the consumability of the milk. An increase in somatic cell count is typical of the *mastitis.* A very large standard deviation was observed for this parameter (CV = 115.6% for winter group, and 82.2% for summer group). Therefore, instead of comparing the means, we categorized the cows and then compared the frequencies in each category (Fisher's test) *(Table 6.).* From a statistical point of view, no differences can be detected between the winter and summer groups. So, neither category has significantly more cows calved in winter than cows calved in summer (or inversely). The evaluation is complicated by the fact that the available data apply to the *complete* lactation, and not just to the *early* lactation. Thus, it is difficult to draw a reliable conclusion about the effect of calving time.

Table 6.

Analysis of somatic cell count in milk with Fisher's test

Somatic cell count categories (× 1 000/ml)		WINTER	SUMMER	Fisher-test value	Result
		Number of the cows			
Up to 400	Normal	30 (50.00%)	26 (43.34%)	0.5832	NS
401-700	Increased	13 (21.67%)	11 (18.33%)	0.8199	NS
701-1 000	High	3 (5.00%)	8 (13.33%)	0.2043	NS
More than 1 000	Very high	14 (23.33%)	15 (25.00%)	1	NS

NS: The difference in frequency between the two groups at 5% error level is not significant.

In the winter group, calving could take place on 28 February 2021 at the latest. Therefore, at the time of the study (end of July 2021), more than 140 days had elapsed in the winter group since the last calving. The same period for the summer group is more than 320 days, because calving could take place on 31 August 2020 at the latest. The proportion of cows not inseminated since calving in the winter group is 1 in 60 cows (1.67%). The same proportion in the summer group is 5 out of 58 cows (8.62%). (In the meantime, 2 cows from the summer group were culled, so the new data number (60-2) is 58.) The result of Fisher's test: 0.1109; which is not significant at the 5% error level. Therefore, no difference can be detected in the proportion of cows not inseminated since calving.

The first insemination in the winter group (n = 59) was 55 ± 15 days after calving. The same period in the summer group (n = 53) was 56 ± 14 days. There is obviously no difference between the two groups in this parameter. This is probably due to the fact that every cow on this farm receives hormone treatment 35 days after calving, which promotes the *oestrus.*

Many cows in the winter group did not become pregnant by the time of the study, which in principle causes a loss of data, but the categorization method (Fisher's test, *Table 7.*) still allows for statistical evaluation. According to BÁDER (2001) the length of the service period: within 60 days is very good, within 90 days is good, within 120 days is satisfactory, and beyond 120 days is unfavourable. The winter period under study ended on 28 February 2021 and more than 120 days have passed since then. Therefore, the cows that have not yet become pregnant can be classified in the 120+ category, so they can also be considered. Data from 60 cows in the winter group and 58 cows in the summer group were processed. The *very good* and *good* service periods were significantly more common after winter calving. However, the *unfavourable* service period was significantly more common after summer calving. There is no detectable difference in the frequency of the *satisfactory length* of service period between the groups.

Table 7.

Analysis of the length of the service period with Fisher's test

Service period categories (days)		WINTER	SUMMER	Fisher-test value	Result
		Number of the cows			
Shorter than 60	Very good	11 (18.33%)	2 (3.45%)	0.016	*
61-90	Good	15 (25.00%)	3 (5.17%)	0.0039	*
91-120	Satisfactory	7 (11.67%)	11 (18.97%)	0.3132	NS
Longer than 120	Unfavourable	27 (45.00%)	42 (72.41%)	0.0029	*

* The difference in frequency between the two groups at 5% error level is significant.
NS: The difference in frequency between the two groups at 5% error level is not significant.

The results of the primiparous cows

The milk production and milk quality of the study groups are shown in *Table 8.* In contrast to multiparous cows, there is no significant difference in milk yield (kg/100 days) and maximum daily milk production (kg/day) between the groups. However, it should be noted that the investigation may be disturbed by some circumstances. The milk-producing ability of the groups may not be similar. As these are primiparous cows, no previous production data were available for them. Therefore, the animals could not be arranged in pairs, which method would have reduced this error. As winter group, 41 cows were available for the study, leading to few data numbers.

Table 8.

Effect of calving time on milk quantity and quality

	WINTER n = 41	SUMMER n = 66
Milk production in early lactation (kg/100 days)	3 535 ± 579	3 554 ± 501
Maximum milk yield (kg/day)	40.8 ± 5.8	39.8 ± 5.2
Milk protein content (100-days average, %)	3.29 ± 0.16	3.16* ± 0.18
Milk protein production (kg/100 days)	116.0 ± 17.9	111.9 ± 14.4
Somatic cell count (× 1 000/ml) – for complete lactation	262 ± 482	259 ± 232

* The difference between the two groups is significant at the 5% error level ($p \leq 0.05$)

On farm “A”, the primiparous cows of the winter group produced 6.5% more milk in early lactation (kg/100 days), although the number of samples was not abundant there either.

Similar to multiparous cows, the percentage of milk protein is lower after summer calving. However, there is no a detectable difference in milk protein production (kg/100 days). This can be explained by the fact that the milk yield (kg/100 days) of the groups did not differ significantly either.

In terms of somatic cell count, the standard deviations are similarly large as in the multiparous cows (CV = 184.3% for winter group, and 89.4% for summer group). Therefore, the statistical evaluation was performed using the same method (Fisher’s test, *Table 9.*)

Table 9.

Analysis of somatic cell count in milk with Fisher's test

Somatic cell count categories (× 1 000/ml)		WINTER	SUMMER	Fisher-test value	Result
		Number of the cows			
Up to 400	Normal	36 (87.80%)	52 (78.78%)	0.3025	NS
401-700	Increased	1 (2.44%)	11 (16.67%)	0.0273	*
701-1 000	High	1 (2.44%)	2 (3.03%)	1	NS
More than 1 000	Very high	3 (7.32%)	1 (1.52%)	0.156	NS

* The difference in frequency between the two groups at 5% error level is significant.
NS: The difference in frequency between the two groups at 5% error level is not significant.

In the summer group, there were more cows with increased (401-700 thousand/ml) somatic cell counts. A mild form of *mastitis* was probably more common, although we do not have exact data on this. In the other categories, there is no significant difference in the proportion of “winter-summer” cows. As in the multiparous cows, the somatic cell count data refer to *complete* lactation, making the evaluation uncertain. In the case of the multiparous cows, no differences were found in either category; however, their somatic cell counts were significantly higher. This is true for the both groups and can be demonstrated despite the extremely large standard deviations *(Table 10.).*

In the winter group (41 cows), one cow was not inseminated by the time of the study. Excluding this cow (n = 40), the longest time between calving and first insemination was 83 days. In the summer group, all cows were inseminated (n = 66). In the case of 3 cows, the first insemination took place after 100 days (128; 132 and 170 days). However, based on the Dixon test, these do not qualify as outstanding values and were therefore not excluded from the evaluation. The first insemination in the winter group (n = 40) was 54 ± 14 days after calving. In the summer group (n = 66), the same period was 63 ± 23 days. The difference is significant at the 5% error level. For the multiparous cows, no difference was found in this parameter. For the primiparous cows, the result of the winter group is the same as for the multiparous cows. However, the cows in the summer group became *oestrous* on average 9 days later. Some cows may have had *metritis* after calving (not confirmed). It is a well-known fact that heat stress on the one hand reduces the general resistance (thereby increasing the risk of infection) and on the other hand has a direct detrimental effect on reproductive results (AHMADI and MIRZAEI, 2006; AHMED et al., 2015; DAS et al., 2016; PRAGNA et al., 2017).

Table 10.

Somatic cell count averages (× 1 000/ml)

Groups	Primiparous cows	Multiparous cows
WINTER	262 ± 482 n = 41	670* ± 755 n = 60
SUMMER	259 ± 232 n = 66	726* ± 596 n = 60

* Within the rows, the difference is significant at the 5% error level ($p \leq 0.05$)

The effect of calving time on the length of the service period was analysed in the same way as for the multiparous cows (Fisher's test). All cows that have not become pregnant since the calving were classified in the 120+ category. From the winter group, all the cows were included (n = 41). From the summer group, meanwhile, 3 cows were culled and one cow died, so (66-4) 62 cows were categorized *(Table 11.).*

Table 11.

Analysis of the length of the service period with Fisher's test

Service period categories (days)		WINTER	SUMMER	Fisher-test value	Result
		Number of the cows			
Shorter than 60	Very good	12 (29.27%)	2 (3.23%)	0.0002	*
61-90	Good	9 (21.95%)	9 (14.52%)	0.4279	NS
91-120	Satisfactory	6 (14.63%)	14 (22.58%)	0.4463	NS
Longer than 120	Unfavourable	14 (34.15%)	37 (59.67%)	0.0156	*

* The difference in frequency between the two groups at 5% error level is significant.
NS: The difference in frequency between the two groups at 5% error level is not significant.

Significant differences were found between the groups in two categories, only in the extreme categories: The frequency of the *very good* service period was higher in the winter group, while the frequency of the *unfavourable* service period was higher in the summer group. The same differences could be demonstrated also for the multiparous cows.

There were 3 abortions in the summer group (if one cow culled is also considered), while no abortions in the winter group. The abortion could only occur in *pregnant* cows. They became pregnant by the time of the study: 29 cows in the winter group and none had aborted (0%); 59 cows in the summer group and 3 cows of them had aborted (5.08%). The result of Fisher's test: 0.1109; which is not significant at the 5% error level. So, the data did not prove that the abortions are more common after summer calving.

Discussion

Our results are similar to TÓTH'S (2018) studies in Hungary (Fejér County). In cows calved during the heat stress period, she also observed a decrease in milk production at the beginning of lactation. McDowell's et al. (1976) research over several years has also shown that the milk-producing ability of the cows calving in winter months may be significantly higher, but the difference is particularly spectacular in the first 60 days. Ríos-Utrera et al. (2013) also discovered a relationship between the *peripartum* weather and milk production; the performance of cows calved during cool period was higher.

Tóth (2018) also recorded a decrease in milk protein percentage at the beginning of lactation. This is also confirmed by the results of Bernabucci et al. (2002) and Bouraoui et al. (2002). The latter authors found significant differences also in milk fat percentage and somatic cell count due to *peripartum* heat stress. McDowell et al. (1976) also observed a higher milk fat content in cows calved in winter. We consider the milk fat data to be less reliable, because they are highly dependent on feeding (Schmidt, 2015), especially comparing different experiments. In terms of somatic cell count, Tóth (2018) did not find a significant difference, but the *mastitis* was significantly more common in cows calved during the heat stress period. The same did not apply to *metritis.* The standard deviation of somatic cell count data proved to be very large (CV = 163.6-265.9%), similar to our studies.

According to McDowell et al. (1976) and Faust et al. (1988), the *peripartum* weather affects also the reproductive performance. The service period for cows calved in summer was longer and fewer cows became pregnant for the first insemination, than for cows calved in winter. The studies of Ahmadi and Mirzaei (2006) were performed involving more than 500 Holstein-Friesian cows. The authors experienced significantly more placenta-retention after the summer calving, which is a common cause of the *metritis.* However, the studies of Tóth (2018) did not confirm this; she found no significant increase in the incidence of either placenta-retention or *metritis* in cows calved during the heat stress period.

CONCLUSIONS

Our results confirm the previous experience that the *peripartum* weather may determine the performance and reproduction of dairy cows for a longer time. This also applies to Hungarian conditions, where the climate is temperate. After summer calving, the milk yield and milk protein percentage of Holstein-Friesian cows – *in early lactation* – may be lower than after winter calving. The exact results may vary from herd to herd (within a breed also). The time of calving (winter or summer) affected also the length of the service period, both in case of primiparous and multiparous cows. After summer calving, the proportion of cows that are empty beyond 120 days may be significantly higher. In summer, especially during the *peripartum* period, the dairy cows should be protected from heat stress.

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