THE RELATIONSHIPS BETWEEN MILK PRODUCTION AND REPRODUCTION IN A HIGH-PERFORMANCE HOLSTEIN-FRIESIAN HERD

Adrienn Zsanett KRAJCSOVICS, A. RIBÁCS

Hungarian University of Agriculture and Life Sciences
Corresponding author: Ribacs.Attila@uni-mate.hu

Abstract: *The authors studied the relationships between the milk production and reproduction in a high performance Holstein-Friesian herd in Hungary (Békés County). The corrected lactation performance (calculated for 305 days) was above 10 thousand kg in the first lactation and later above 11 thousand kg. From the 2nd lactation, the FCM performance (calculated for 305 days and 4% fat) also exceeded 10 thousand kg. The effect of milk production (total lactation, corrected for 305 days, FCM) as well as the production of milk components (fat, protein) on the length of the service period and the fertility index was examined. The studied parameters influenced the length of the service period mainly in young (the first and second lactation) and older (the fourth and fifth lactation) cows, while there was less correlation in the third lactation cows. The strongest correlation was found with the length of lactation (r = 0.82-0.89) and the total lactation performance (r = 0.57-0.80). There was also a significant correlation with the ratio (%) of the performance in the first 100 days / total lactation (r = (-0.59)-(-0.78)). In young age, the milk protein production (r = 0.42-0.47), while in older cows the milk fat production (r = 0.47-0.59) had a stronger effect on the length of the service period. The fertility index was also most related to the length of lactation (r = 0.63-0.76) and the total lactation performance (r = 0.40-0.70).*

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

INTRODUCTION

In recent years, there has been a significant increase in milk production from cow herds. This is the result of several processes such as genetic management (selection), physical environment (husbandry technology, animal welfare) and the development of feeding methods (WHITFILD, 2020). There is an apparent conflict between the increased milk yield and cow's reproductive performance; an increase in milk production is usually accompanied by a decrease in reproductive performance (DHALIWAL et al. 1996; BÁDER et al. 2006; HATVANI, 2012; ALBARRÁN-PORTILLO and POLLOTT, 2013).

The fertility of dairy cows fundamentally determines the genetic progress in the herd and also the economics of production. If the pregnancy is delayed, the problem of reproduction causes a reduction in milk production in the given farm. However, fertility is difficult to improve by genetic methods because it is very weakly inherited. The non-pregnant cows are usually culled from the herd (ÓZSVÁRI, 2004; MULLER et al. 2018). In dairy farms, the rate of culling due to infertility is usually above 20-30%, but in extreme cases it can reach up to 50% (BÁDER et al. 2004).

The negative correlation between milk production and fertility is usually attributed to two reasons; on the one hand to the competition between the physiological needs of the two processes and on the other hand to the selection on the milk yield (LEBLANC, 2003).

According to KÁTAI et al. (2003) and BÁDER et al. (2004), the feeding of high performance dairy cows has a complex effect on reproduction. In more experiments, the increasing of the energy supply (feeding of concentrate or protected fat products) improved the reproductive results (GARG és METHA, 1998; HUSZENICA és SCHMIDT, 1998; MULLER et al. 2018). MIKÓNÉ (2007) and ŘEHÁK et al. (2012) emphasize the importance of a proper condition. However, BERRY et al. (2016) studies show that the decrease in reproductive results at the beginning of lactation is largely not caused by a negative energy balance. The feeding methods for restoring of energy balance did not significantly improve reproductive performance. Similarly, SON et al. (2000), supplementing the feed ration with fat did not significantly increase reproductive performance. FAHEY et al. (2002) found a beneficial effect of the fat supplementation only in the first lactation.

LEBLANC (2013) concluded that there is no obligatory conflict between milk production and reproduction. The experimental results can vary greatly from herd to herd and even within herds to cows. MIKÓNÉ (2007) also found in case of Holstein-Friesian herds in Hungary that even the reproductive results of the same production groups can differ significantly.

There are several suggestions in the literature for improving reproductive performance in high performance dairy cows:

- The good farming management (condition, oestrus detection, insemination) (MIKÓNÉ, 2007; LEBLANC, 2013)
- Selection (persistence, reproductive results) (ALBARRÁN-PORTILLO and POLLOTT, 2013; MULLER et al, 2018)
- Feeding methods (improving energy supply) (MULLER et al. 2018)
- Crossing with a dual-purpose breed (MULLER et al. 2018)

MATERIAL AND METHOD

The analysis was performed in Hungary, in Békés County, with 469 cows. The examined herd was Holstein-Friesian with excellent milk-producing ability. This is confirmed by the fact that even the first-calf cows produced over 10 thousand kg on average, the older ones over 11 thousand kg, calculated for 305 days. From the 2nd lactation, their FCM production also exceeded 10 thousand kg *(Table 1.)*

Table 1.

Milk-producing ability of the examined herd

		The number of the lactation				
		1.	2.	3.	4.	5.
The number of the cows		224	126	62	41	16
Standard lactation (305 days)	Average, kg	10159 ± 1273	11013 ± 1521	11302 ± 1374	11210 ± 1489	11497 ± 1814
	CV%	12.5	13.8	12.2	13.3	15.8
FCM (305 days, 4% milk fat)	Average, kg	9331 ± 1172	10122 ± 1356	10203 ± 1239	10463 ± 1619	10535 ± 1811
	CV%	12.6	13.4	12.1	15.5	17.2

The effect of the following production parameters on the reproductive capacity of cows was investigated:

- Length of the lactation (days)
- Total lactation performance (kg)
- Standard lactation performance (305 days, kg)
- Proportion of 100 days performance / total lactation performance (%)
- Persistence* (%)
- FCM performance (305 days, 4% fat, kg)
- Milk fat yield (305 days, kg)
- Milk protein yield (305 days, kg)

- Milk fat + milk protein yield (305 days, kg)
- Rate of milk fat / milk protein

*Persistence: average / maximal daily milk production (%)
100 * (total lactation performance [kg] / lactation length [days]) / maximal daily milk production [kg/day]

The reproductive capacity of cows was expressed in two ways; on the one hand, with the length of the service period, on the other hand, with the fertility index. Service period: the number of days from the calving to the next successful insemination. Fertility index: the number of the inseminations required for pregnancy.

The cows were grouped according to the number of the complete lactation and the analysis was performed separately for each group. The effect of milk production on the reproductive capacity was examined in two ways:

1. The average of the groups in a given production parameter was calculated. The cows were then divided into two classes within the group: below-average and average performance (1); and above-average performance (2). The mean performances of the two classes 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.
2. The correlation between the parameters of milk production and fertility was determined also using the following formula:

$$r = \sum(x-\bar{x})*(y-\bar{y}) / \sqrt{[\sum(x-\bar{x})^2*\sum(y-\bar{y})^2]}$$

In which:

$\bar{x}$ and $\bar{y}$ = the average value of the data arrays

Statistical data processing was performed in Microsoft Excel 2016.

RESULTS AND DISCUSSION

The reproductive indices of below-average and above-average cows are shown in *Tables 2-5.* The detectable linear correlations of the length of service period involves *Table 6.*, while of the fertility index involved *Table 7.*

In terms of total lactation performance, the average milk yield per cow was around 12 thousand kg. The service period of below-average cows was 90-100 days, while of above-average cows was 160-190 days, and even exceeded 200 days in the first lactation. According to BÁDER (2011), a very good result is the average length of the service period in a herd is 80-90 days. Within the examined herd, this was approached only by below-average cows.

The studies of DHALIWAL et al. (1996) also proved, that the high performance dairy cows fertilize later, and require more insemination, than at lower performance. A strong correlation between the fertility and total lactation performance was observed by ALBARRÁN-PORTILLO and POLLOTT (2013), and a close correlation was found also with the daily production of milk components. They also emphasize the importance of good persistence in selection. In the case of a well-persistent cow, a lower daily milk production is sufficient to have a high total lactation performance. Thus, as the body will be less overloaded, more favourable reproductive results are expected. This assumption is confirmed also by our own results, although we found only a weak correlation between persistence and the length of the service period. However, the ratio (%) of the performance in the first 100 days / total lactation, practically also expresses the persistence. With this method, a strong correlation can be detected in the first two lactations and a moderate correlation in the third and fourth lactations.

Table 2.

The reproductive indices of below-average and above-average cows **in the 1st lactation**

		Service period (days)		Fertility index	
	Mean	≤ Mean	> Mean	≤ Mean	> Mean
Length of the lactation	352 ± 77 days n = 224	89 (a) ± 34 n = 141	234 (b) ± 100 n = 83	1,5 (a) ± 0,7 n = 141	3,6 (b) ± 1,9 n = 83
Total lactation performance	11461 ± 2754 kg n = 224	93 (a) ± 43 n = 132	216 (b) ± 106 n = 92	1,6 (a) ± 0,8 n = 132	3,3 (b) ± 1,9 n = 92
Corrected lactation performance (305 d.)	10159 ± 1276 kg n = 224	112 (a) ± 66 n = 111	174 (b) ± 113 n = 113	1,9 (a) ± 1,1 n = 111	2,7 (b) ± 1,9 n = 113
100 days / total lactation performance	33 ± 6% n = 224	202 (a) ± 101 n = 114	82 (b) ± 32 n = 110	3,1 (a) ± 1,8 n = 114	1,5 (b) ± 0,7 n = 110
Persistence	75 ± 7% n = 224	161 (a) ± 107 n = 102	128 (b) ± 84 n = 122	2,5 (a) ± 1,7 n = 102	2,2 (a) ± 1,6 n = 122
FCM performance (305 days, 4% fat)	9331 ± 1172 kg n = 224	110 (a) ± 64 n = 113	176 (b) ± 112 n = 111	1,8 (a) ± 1,1 n = 113	2,8 (b) ± 1,9 n = 111
Milk fat production (305 days)	351 ± 54 kg n = 224	121 (a) ± 77 n = 118	168 (b) ± 110 n = 106	1,9 (a) ± 1,2 n = 118	2,7 (b) ± 1,9 n = 106
Milk protein production (305 days)	344 ± 41 kg n = 224	107 (a) ± 74 n = 108	177 (b) ± 103 n = 116	1,7 (a) ± 0,9 n = 108	2,9 (b) ± 0,9 n = 116
Milk fat + milk protein production (305 days)	695 ± 86 kg n = 224	111 (a) ± 67 n = 114	177 (b) ± 110 n = 110	1,8 (a) ± 1,1 n = 114	2,8 (b) ± 1,9 n = 110
Ratio of milk fat / protein	1,03 ± 0,13 n = 224	148 (a) ± 86 n = 112	139 (a) ± 106 n = 112	2,4 (a) ± 1,5 n = 112	2,3 (a) ± 1,7 n = 112

(a), (b): The values marked with different letters in the rows significantly differ from each other (p ≤ 0.05).

Table 3.

Reproductive indices of below-average and above-average cows **in the 2nd lactation**

		Service period (days)		Fertility index	
	Mean	≤ Mean	> Mean	≤ Mean	> Mean
Length of the lactation	347 ± 59 days n = 126	95 (a) ± 38 n = 69	197 (b) ± 57 n = 57	1,8 (a) ± 1,1 n = 69	3,1 (b) ± 1,4 n = 57
Total lactation performance	12054 ± 2511 kg n = 126	99 (a) ± 42 n = 65	186 (b) ± 66 n = 61	1,8 (a) ± 1,0 n = 65	3,0 (b) ± 1,5 n = 61
Corrected lactation performance (305 d.)	11013 ± 1521 kg n = 126	117 (a) ± 65 n = 62	165 (b) ± 66 n = 64	2,0 (a) ± 1,2 n = 62	2,8 (b) ± 1,4 n = 64
100 days / total lactation performance	36 ± 6% n = 126	184 (a) ± 61 n = 66	95 (b) ± 44 n = 60	3,0 (a) ± 1,5 n = 66	1,7 (b) ± 0,9 n = 60
Persistence	71 ± 7% n = 126	153 (a) ± 75 n = 60	131 (a) ± 63 n = 66	2,4 (a) ± 1,3 n = 60	2,4 (a) ± 1,5 n = 66
FCM performance (305 days, 4% fat)	10122 ± 1356 kg n = 126	119 (a) ± 64 n = 65	166 (b) ± 68 n = 61	2,0 (a) ± 1,3 n = 65	2,8 (b) ± 1,4 n = 61
Milk fat production (305 days)	381 ± 62 kg n = 126	124 (a) ± 69 n = 62	158 (b) ± 67 n = 64	2,1 (a) ± 1,4 n = 62	2,6 (b) ± 1,4 n = 64
Milk protein production (305 days)	385 ± 49 kg n = 126	111 (a) ± 58 n = 60	169 (b) ± 68 n = 66	1,9 (a) ± 1,3 n = 60	2,8 (b) ± 1,4 n = 66
Milk fat + milk protein production (305 days)	766 ± 99 kg n = 126	118 (a) ± 64 n = 64	166 (b) ± 68 n = 62	2,0 (a) ± 1,3 n = 64	2,8 (b) ± 1,4 n = 62
Ratio of milk fat / protein	0,99 ± 0,13 n = 126	146 (a) ± 75 n = 59	138 (a) ± 65 n = 67	2,6 (a) ± 1,6 n = 59	2,2 (a) ± 1,1 n = 67

(a), (b): The values marked with different letters in the rows significantly differ from each other (p ≤ 0.05).

Table 4.

Reproductive indices of below-average and above-average cows **in 3rd lactation**

		Service period (days)		Fertility index	
	Mean	≤ Mean	> Mean	≤ Mean	> Mean
Length of the lactation	339 ± 62 days n = 62	84 (a) ± 38 n = 34	195 (b) ± 70 n = 28	1,7 (a) ± 0,9 n = 34	3,5 (b) ± 1,8 n = 28
Total lactation performance	12075 ± 2023 kg n = 62	94 (a) ± 48 n = 31	174 (b) ± 82 n = 31	1,9 (a) ± 1,1 n = 31	3,1 (b) ± 1,9 n = 31
Corrected lactation performance (305 d.)	11302 ± 1374 kg n = 62	128 (a) ± 89 n = 27	140 (a) ± 69 n = 35	2,3 (a) ± 1,3 n = 27	2,7 (a) ± 1,9 n = 35
100 days / total lactation performance	37 ± 5% n = 62	189 (a) ± 79 n = 26	95 (b) ± 48 n = 36	3,4 (a) ± 1,9 n = 26	1,9 (b) ± 1,1 n = 36
Persistence	71 ± 8% n = 62	161 (a) ± 82 n = 35	99 (b) ± 56 n = 27	2,9 (a) ± 1,8 n = 35	2,0 (b) ± 1,2 n = 27
FCM performance (305 days, 4% fat)	10203 ± 1239 kg n = 62	128 (a) ± 91 n = 30	140 (a) ± 64 n = 32	2,2 (a) ± 1,3 n = 30	2,8 (a) ± 1,9 n = 32
Milk fat production (305 days)	379 ± 58 kg n = 62	125 (a) ± 85 n = 35	146 (a) ± 68 n = 27	2,2 (a) ± 1,2 n = 35	2,9 (a) ± 2,0 n = 27
Milk protein production (305 days)	380 ± 42 kg n = 62	130 (a) ± 96 n = 25	137 (a) ± 64 n = 37	2,2 (a) ± 1,5 n = 25	2,7 (a) ± 1,7 n = 37
Milk fat + milk protein production (305 days)	759 ± 91 kg n = 62	131 (a) ± 90 n = 32	138 (a) ± 64 n = 30	2,3 (a) ± 1,3 n = 32	2,8 (a) ± 1,9 n = 30
Ratio of milk fat / protein	1,00 ± 0,12 n = 62	134 (a) ± 75 n = 31	134 (a) ± 82 n = 32	2,5 (a) ± 1,3 n = 31	2,5 (a) ± 2,0 n = 31

(a), (b): The values marked with different letters in the rows significantly differ from each other ($p \leq 0.05$).

Table 5.

Reproductive indices of below-average and above-average cows **in 4-5th lactation**

		Service period (days)		Fertility index	
	Mean	≤ Mean	> Mean	≤ Mean	> Mean
Length of the lactation	341 ± 58 days n = 57	94 (a) ± 37 n = 33	188 (b) ± 46 n = 24	1,8 (a) ± 1,0 n = 33	3,3 (b) ± 1,3 n = 24
Total lactation performance	12078 ± 2173 kg n = 57	102 (a) ± 48 n = 27	162 (b) ± 60 n = 30	1,9 (a) ± 1,2 n = 27	2,9 (b) ± 1,3 n = 30
Corrected lactation performance (305 d.)	11290 ± 1576 kg n = 57	123 (a) ± 60 n = 26	143 (a) ± 63 n = 31	2,2 (a) ± 1,3 n = 26	2,6 (a) ± 1,4 n = 31
100 days / total lactation performance	38 ± 5% n = 57	163 (a) ± 58 n = 32	96 (b) ± 44 n = 25	2,9 (a) ± 1,4 n = 32	1,8 (b) ± 1,0 n = 25
Persistence	69 ± 8% n = 57	151 (a) ± 66 n = 31	114 (b) ± 51 n = 26	2,7 (a) ± 1,3 n = 31	2,0 (b) ± 1,2 n = 26
FCM performance (305 days, 4% fat)	10483 ± 1659 kg n = 57	116 (a) ± 53 n = 30	154 (b) ± 66 n = 27	2,2 (a) ± 1,3 n = 30	2,7 (a) ± 1,3 n = 27
Milk fat production (305 days)	398 ± 77 kg n = 57	113 (a) ± 52 n = 31	158 (b) ± 65 n = 26	2,2 (a) ± 1,3 n = 31	2,7 (a) ± 1,3 n = 26
Milk protein production (305 days)	382 ± 48 kg n = 57	114 (a) ± 54 n = 26	150 (b) ± 64 n = 31	2,1 (a) ± 1,3 n = 26	2,7 (a) ± 1,4 n = 31
Milk fat + milk protein production (305 days)	780 ± 117 kg n = 57	113 (a) ± 55 n = 30	156 (b) ± 63 n = 27	2,2 (a) ± 1,3 n = 30	2,7 (a) ± 1,3 n = 27
Ratio of milk fat / protein	1,04 ± 0,14 n = 57	106 (a) ± 49 n = 26	157 (b) ± 63 n = 31	2,1 (a) ± 1,3 n = 26	2,7 (a) ± 1,4 n = 31

(a), (b): The values marked with different letters in the rows significantly differ from each other ($p \leq 0.05$).

Table 6.

The detectable linear correlations (p ≤ 0.05) of the length of service period (days)

With the…	The number of the lactation				
	1. (n = 224)	**2.** (n = 126)	**3.** (n = 62)	**4.** (n = 41)	**5.** (n = 16)
	correlation coefficient (r)				
Length of the lactation (days)	**0,89**	**0,89**	**0,84**	**0,89**	**0,82**
Total lactation performance (kg)	**0,80**	**0,76**	0,60	0,57	0,65
Corrected lactation performance (305 days)	0,38	0,45	NS	NS	NS
100 days / total lactation performance (%)	**-0,78**	**-0,75**	-0,69	-0,59	NS
Persistence (%)	-0,31	-0,20	-0,39	-0,35	NS
FCM performance (305 days, 4% fat)	0,41	0,42	NS	0,42	0,51
Milk fat production (305 days, kg)	0,35	0,31	NS	0,47	0,59
Milk protein production (305 days, kg)	0,42	0,47	NS	NS	NS
Milk fat + protein prod. (305 days, kg)	0,42	0,43	NS	0,44	0,53
Ratio of milk fat / protein	NS	NS	NS	0,40	0,62

NS: There is no significant correlation.
Bold numbers: considerable relationship (|r| ≥ 0.70)

Table 7.

The detectable linear correlations (p ≤ 0.05) of the fertility index

With the…	The number of the lactation				
	1. (n = 224)	**2.** (n = 126)	**3.** (n = 62)	**4.** (n = 41)	**5.** (n = 16)
	correlation coefficient (r)				
Length of the lactation (days)	**0,76**	0,63	0,64	0,63	**0,70**
Total lactation performance (kg)	**0,70**	0,55	0,52	0,40	NS
Corrected lactation performance (305 days)	0,32	0,33	NS	NS	NS
100 days / total lactation performance (%)	-0,66	-0,55	-0,52	-0,37	NS
Persistence (%)	-0,18	NS	-0,26	NS	NS
FCM performance (305 days, 4% fat)	0,39	0,29	NS	NS	NS
Milk fat production (305 days, kg)	0,35	0,21	NS	0,31	NS
Milk protein production (305 days, kg)	0,39	0,35	NS	NS	NS
Milk fat + protein prod. (305 days, kg)	0,41	0,30	NS	NS	NS
Ratio of milk fat / protein	NS	NS	NS	NS	0,58

NS: There is no significant correlation.
Bold numbers: considerable relationship (|r| ≥ 0.70)

The length of the service period is also influenced by human factors, such as unrecognized oestrus or insemination at the wrong time. If the fertilization is missed for any reason during an oestrus, it extends the service period by 21 days. According to BÁDER'S (2011) studies in Hungary, an average of 42 days elapse between two inseminations. In practice, this means that the fertilization is missed every second oestrus. Thus, if a cow became pregnant for 3 insemination, her service period is already 42 days longer than would be justified. Improving of the reproductive results does not require costly investments, only more attention.

It is advisable to fertilize of the genetically valuable cows with excellent bulls, and the semen of excellent bulls is very expensive. Therefore, an appropriate fertility index is important for practice. According to BÁDER (2011), for heifers a value of 1.5–1.8; while for cows a value of 2.0-2.5 is desirable. In the examined herd, the fertilization index of below-average cows was favourable, but that of above-average cows was between 2.5 and 3.0. However, the difference is not significant in many cases, and there is a high standard deviation between the cows, even at the same performance. The lactation length, total lactation performance, and the ratio (%) of the performance in the first 100 days / total lactation had the greatest effect on the fertility index. For these parameters, the fertility index of above-average cows reached or exceeded the value of 3.

CONCLUSIONS

The studied parameters influenced the length of the service period mainly in young (the first and second lactation) and older (the fourth and fifth lactation) cows, while there was less correlation in the third lactation cows.

The length of the service period was mostly influenced by the length of lactation and the total lactation performance. The effect of total lactation performance is clearer at a younger age; probably because then the animals are still growing, so the milk production puts more strain on their bodies.

In terms of milk components, the protein production (kg/305 days) had a stronger effect on the length of the service period in younger cows, while the fat production (kg/305 days) and the ratio of produced fat to protein had a stronger effect in older cows. This can presumably be explained by the fact that until the growth is completed, the animals incorporate protein also into the muscles, while at the same time accumulating less body fat (sebum).

The service period of well-persistent cows was somewhat shorter, although the correlation between the two traits proved to be weak. The calculating the ratio (%) of the performance in the first 100 days / total lactation seems more appropriate than classical persistence, i.e. the ratio of average to maximum daily milk production. The former indicator was more closely related to the length of the service period.

The studied production parameters had less an effect on the fertility index than on the length of the service period. The fertility index was also most closely related to length of the lactation and total lactation performance, but there was a weaker correlation than in case of the service period.

BIBLIOGRAPHY

ALBARRÁN-PORTILLO, B. – POLLOTT, G. E. (2013): The relationship between fertility and lactation characteristics in Holstein cows on United Kingdom commercial dairy farms. J. Dairy Sci. 96: 635-646.

BÁDER E. – GERGÁCZ Z. – GYÖKÖS I. – BÁDER P. – KOVÁCS A. – GYŐRFFY E. – BOROS N. (2004): Az első termékenyítés idejének alakulása magas holstein-fríz vérhányadú tejelő állományokban. Holstein-magazin. 12:27-29.

BÁDER E. – GERGÁCZ Z. – MUZSEK A. – KOVÁCS A. – GYÖRKÖS I. – BÁDER P. (2006): Termékenység alakulása tejelő tehénállományokban. Állattenyésztés és Takarmányozás. 55:31-32.

BÁDER (2011): Termékenység, szaporaság. Agro Napló 2011/7 63. p.

BERRY, D. P. – FRIGGENS, N. C. – LUCY, M. – ROCHE, J. R. (2016): Milk production and fertility in cattle. Annu. Rev. Anim. Biosci. 4:269-290.

DHALIWAL, G. S. – MURRAY, R. D. – DOBSON, H. (1996): Effects of milk yield, and calving to first service interval, in determining herd fertility in dairy cows. Anim. Reproduction Sci. 41: 109-117.

FAHEY, J. – MEE, J. F. – O'CALLANGHAN, D. – MURPHY, J. J. (2002): Effect of calcium salts of fatty acids calcium salts of methionine hidroxy analogue on reproductive responens and milk production in Holstein Friesian cows. J. anim. Sci. 74:145-154.

GARG, M. R. – METHA, A. K. (1998): Effect of feeding bypass fat on feed intake, milk production and body condition of Holstein Friesian cows. Indian J. Anim. Nutr. 15:242-245.

HATVANI CS. (2012): Petefészek rendellenességek előfordulásának gyakorisága, hatása a szaporodásra és kezelésének lehetőségei nagyüzemi tehenészetben. Doktori (PhD) értekezés, Kaposvári Egyetem, Állattudományi Kar.

HUSZENICA GY. – SCHMIDT J. (1998): Védett zsír/fehérje készítmény szarvasmarháknak. OMFB zárójelentés.

KÁTAI L. – KULCSÁR M. G. – HUSZENICZA GY. (2003): A nagy tejtermelésű tehén takarmányozásának, tejtermelésének és szaporodóképességének kapcsolata. Irodalmi áttekintés 3. Az újravemhesülés zavarai. Magyar Állatorvosok Lapja. 125:143-145.

LEBLANC, S. J. (2003): Is a high level of milk production compatible with good reproductive performance in dairy cows? Animal Frontiers 3:84–91.

MIKÓ J-NÉ J. E. (2007): A hazai holstein-fríz állományok tenyésztésének kiemelt területei – I. Szaporasági mutatók elemzése. Agrár- és Vidékfejlesztési Szemle. 2:11-16.

MULLER, C. J. C. – CLOETE, S. W. P. – BOTHA, J. A. (2018): Fertility in dairy cows and ways to improve it. South African J. Anim. Sci. 48:858-868.

ÓZSVÁRI, L. (2004): Állategészségügyi döntéselemzés a tejtermelő gazdaságokban. Doktori (PhD) értekezés, Szent István Egyetem, Gazdálkodás és Szervezéstudományok Doktori Iskola, Gödöllő.

ŘEHÁK, D. – VOLEK, J. – BARTOŇ, L. – VODKOVÁ, Z. – KUBEŠOVÁ, M. – RAJMON, R. (2012): Relationships among milk yield, body weight, and reproduction in Holstein and Czech Fleckvieh cows. Czech J. Anim. Sci. 57:274-282.

SON, J. – LARSON, L. L. – GRANT, R. J. (2000): Effect of time of initialling dietary fat supplementation on performance and reproduction of early lactation dairy cows. Asian-Australasian J. Anim. Sci. 13:182-187.

WHITFILD, L. (2020): Milk production, fertility and the modern dairy cow. Livestock Vol. 25. https://www.magonlinelibrary.com/doi/abs/10.12968/live.2020.25.2.72