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Study on the milkability of cows of the Bulgarian Rhodope cattle breed

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Abstract

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The milkability of 18 cows on the 30th day after calving was examined based on 178 individual measurements performed over 5 consecutive days. The cows subject to the study were form the local mountain Bulgarian Rhodope cattle breed. The average daily milk yield of the cows was 16.5 ± 0.12 kg. The milkability was relatively low – 1.197±0.016 kg/min which did not differ significantly ($P > 0.05$) during the morning (1.232±0.022 kg/min) and the evening (1.161±0.024) milking. The reason for the low milkability was the long decreasing phase of the lactation curve after reaching the peak of the milk flow, which started from the third minute and took up more than ¾ of the total milking time. The milk flow peak was achieved at the first minute during the evening and at 1min and 30 s during morning milking. The peak values were retained for 1 min and 30 s with 10% of the total milk quantity being milked every 30 s (30% per 1.5 min). 38.6% of the total milk quantity per milking was removed during the first 2 min, 57.7% – during the first three min, and 90.01% – for 6 min. The milkability was significantly affected by the milking interval ($P < 0.001$) and the milking time ($P < 0.001$). The milkability (kg/min) was more considerably dependent on the milking time ($Rp = -0.693$; $P < 0.001$) and less on the milk yield ($Rp = +0.563$; $P < 0.001$).

Keywords: milkability; workability; milk cow; Bulgarian Rhodope cattle

Introduction

Not only technological but also selection solutions are sought for the purpose of increasing the dairy cattle breeding production efficiency, optimizing the operating process, decreasing the costs and improving the milk quality. They are also related to the optimization of the functional features such as milkability, udder conformation, somatic cell total count et al. The milking-related activities take up more than 50% of the working hours in the dairy cattle farms, and the larger the herd, the greater the time expenditure. Bosselli et al. (2020) consider that the milkability optimization contributes to the reduction of the working time and increase in the milk yield and the farmers earnings.

The milkability is an aggregate value connected to the ability of the animals to fully, quickly and evenly eject milk when appropriate milking equipment is used. Milkability evaluation is performed with the use of a set of indicators – average and maximum milk flow rate (respectively average and maximum milk production per minute, kg/min) (Duda, 1996; Gäde et al., 2006; Lee & Choudhary, 2006; Zucali et al., 2009), percentage of milk obtained during the first three minutes of milking (%), length of the ascending and decreasing part of the milk flow curve (Samoré et al., 2011), trapping the maximum rate ('lactation plateau'), interruption of the milk flow (bi- or polimodality) (Sandrucci et al., 2005; Samoré et al., 2011; Tamburini et al., 2010).

A number of studies point to the interrelation between the milkability, milk productivity and the udder health condition (Zucali et al., 2009; Samoré et al., 2010; Prendiville et al., 2010; Tamburini et al., 2010). Zucali et al. (2009) have ascertained a close relationship between the maximum milk flow rate, the length of the lactation plateau phase and the somatic cell count in the milk of the first-calf heifers at the beginning of the lactation. Samoré et al. (2010) report an unfavorable relationship between the total somatic cell count, the milk productivity and the longevity. The authors suggest that the somatic cell count and the average milking time be included as selection criteria despite their low genetic diversity, $h^2 = 0.14$ and 0.33 respectively.

Lee & Choudhary (2006) establish that there are significant correlations between the milk yield and the maximum ($r = 0.30$) and the average ($r = 0.41$) milk production time with reference to Holstein cows with the two times highly correlating with one another – $r = 0.85$. The authors have also ascertained that there is a substantial link between the milk yield and the maximum quantity of milk obtained per minute ($r = 0.48$) and the milking time ($r = 0.47$). High correlations between the average and the maximum milk flow rate during evening and morning milking – respectively $r^2 = 0.92$ and 0.90 have been reported by Duda (1996).

There are divergent opinions regarding the milkability optimization by means of selection. Gäde et al. (2006) have ascertained that the average and the maximum milk flow rates are with a heritability of 0,55, and the milking time – 0.39. Gray et al. (2011) report considerably lower values for the average and the maximum milk flow rate – $h^2 = 0.27$ and $h^2 = 0.40$ respectively, and for the milking time – $h^2 = 0.11$. Samoré et al. (2011) calculate a heritability coefficient of 0.10 regarding the ascending milk flow curve, 0.41 for the maximum milkability and 0.06 for the decreasing phase of the milkability curve.

The milk production needs to be even and fast, and each milk flow interruption might be a signal for a disorder in the milk gland functional status. High frequency of bimodality is observed in animals with clinical and subclinical mastitis, and the bimodality percentage increases along with the advancement of the lactation period (Tamburini et al., 2010). Other studies, however, do not support the thesis above (Samoré et al., 2011) and consider that the modality is a result of overmilking. Tancin et al. (2001), on the other hand, do not find any relationship between the 'blind milking' and the total somatic cell count in the milk but agree that the overmilking has a negative effect on the teats ends and the blood circulation in them. Other studies prove that the insufficient preparation before milking is a reason for bimodality (Sandrucci et al., 2005). Nevertheless, all studies and authors are unanimous with reference to the standpoint that the interrupted milk curve has a negative influence on the efficiency, milking duration and the quantity of the milk obtained.

This comes to prove the necessity to examine the milkability, establish the milk curve indicators and their relationship with the milk productivity, the length of use of the animals and their health condition, and in particular – the health of the udder. No such studies have been performed for the Bulgarian Rhodope cattle. The aim of the present study is to examine the milkability of the breed. The results may be used as selection criteria for the breed in view of the milking time optimization.

Materials and Methods

The study was carried out in the farm of Research Center for Stockbreeding and Agriculture – Smolyan (RCSA). The animals in the farm are tie-stall, barn-pasture reared in accordance with the climatic conditions. In the winter period the ration includes concentrated feed (0.7 kg/l), lucerne hay (2-3 kg), maize silage (20-25 kg), beet slices (2 kg) which are alternated with sunflower oil meal (1.5 kg) every other day. During the spring the animals are taken out to pasture and no maize silage is fed. The concentrated feed quantity is 0.5 kg/l, lucerne hay – 7-8 kg, and they are again alternated with beet slices and sunflower oil meal.

The milking in the farm is performed twice a day by means of a central milk line. The morning milking starts at 6:00 am and the evening one in 5:00 pm.

The milkability of 18 cows of the Bulgarian Rhodope cattle (BRC) breed was examined on the 30th day after calving in March and May 2021. The observations were performed in 5 consecutive days and each cow was subject to 8 to 10 controls. The total number of registrations was 178. The quantity of milk collected was measured with a lactometer, and the data were recorded every 30 seconds. The milkability was examined during the machine milking from attaching the teat cups of the milking device until its removal.

Data were processed statistically by SPSS 21, IBM. A linear model with the following statistical expression was used for the calculation of the means of the milk yield per control period, milking time and milkability:

$$Yijkl = m+Ii+Mj+Dk+IMij+IDik+MDjk+IMDijk+eijkl,$$

where *I, M, D* are fixed effects of respectively the i-th individual ($n = 18$), j-th milker ($n = 3$) and the k-th control period ($n = 2$ – morning, evening), *IM, ID, MD, IMD* – are random effects of one factor within another, *eijkl* – residuals.

The effect of the individual, milk yield, milking time and milking interval on the milkability at the control interval (calculated as a relative proportion of the milk yield during the interval in relation with the total milk yield during a control milking) was ascertained following the respective linear model:

$$Yijkl = m+In+MAi+TMj+MPk+MATMij+MAMPik+ \\ +TMMPjk+MATMMPijk+eijkl,$$

where *In* – a random effect of the n^{-th} individual (n = 18), *MA*, *TM*, *MP* are fixed effects of respectively i^{-th} milk yield per control milking (n = 7, from 5 kg, every other 1 kg), j^{-th} duration of a control milking (n = 12, from 3.5 min every other 1 min), k^{-th} milking interval (n = 35, from 0.5 every 0.5 min), *MAMP*, *TMMP*, *MATMMP* – are random effects of one factor within another, *eijkl* – residuals.

The total milkability for the time intervals was calculated as a relative share of the total quantity of milk collected during the respective interval, at all controls, in relation to the total milk collected quantity due to the different milking time and the different milk yield of the separate cows as well as of one and the same animal during the different controls.

Results and Discussion

The results of our readings (n = 178) are displayed in Table 1. The average milk yield of the cows per control milking was 8.4 kg (from 3.5 to 15.2 kg, P < 0.001). The milk production during the morning milking was significant more than that received during the evening one (P < 0.001). The mean individual milk yield variation was within 12.4%, and the variation during the evening (CV = 14.5%) was higher than that during the morning milking (CV = 10.4%).

The average daily milk yield of the cows included in the observation 16.5±0.12 kg varied from 8.3 kg to 26.8 kg. The Bulgarian Rhodope cattle is a mountain breed. It has been created through the crossbreeding of the local Rhodope Shorthorn cattle with other breeds – the Danish Jersey was the major one (Markovska, 2010; Nikolov, 2012). Taking into account the fact that RCSA is located at an altitude of 1070 m, and that the average milk yield for normal lactation (305 days) for the cows of the breed under selection control in the last three years has been varying from 3081 kg to 3562 (Nikolov et al., 2021), the milk yield observed during our experiment was relatively high. The data regarding the milk yield per control milking were close to those reported by Bobic et al. (2020) with reference to the Jersey cattle breed in Macedonia – 9.72 kg (from 5.0 kg to 1589 kg) on average.

The cows included in the experiment were milked for 7.6 min on average but there was a wide variation – from 3.7 to 17.7 min (P < 0.001) ascertained during the evening milking. The average individual variation during the morning and the evening milking was very close – CV = 17.8% and 18% respectively, and the milk yield did not correspond linearly with the milking time. The difference between the milk yield during the morning and the evening milking was +10.6% (P < 0.001), and between the milking time – +2.6% (P > 0.05). This also led to lower and insignificant differences between the morning and the evening milkability of the cows – 6.11 % (P > 0.05).

The average milk flow rate of the cows of the Bulgarian Rhodope cattle breed included in the experiment was 1.2 kg/min with values from 0.4 to 2.8 kg/min (P < 0.001). This speed was considerably lower than the maximum values recommended by Göft et al. (1994) – from 3.0 to 4.5 kg/min even though the milking time of the BRC cows was relatively close to that recommended by the authors – 6 min. The values recommended by Göft et al. (1994) may be considered as indicative due to the fact that both the milkability and the milking time are largely dependent on the breed. Samoré et al. (2011) have ascertained milkability close to that recommended by Göft et al. (1994) – between 3.7 and 4.1 kg/min in Holstein cows, however, the total milking time was longer – 7.52 min. During a comparative analysis of the milkability of the Holstein and the Simental cattle breeds, Bobić et al. (2014) have ascertained that it is 2.56 kg/min with reference to the Simental, and 3.6 kg/min with reference to the Holstein, and the milking time is respectively 7.96 and 7.26 min.

Table 1. Milk yield per control milking, milking duration and milkability of cows of the Bulgarian Rhodope cattle breed

	N	LS	±SE	Std. Dev.	Min.	Max.
Morning						
Milk yield per control milking, kg	89	8.797*	0.097	0.912	3.5	14.1
Milking duration, min	89	7.701	0.145	1.369	3.9	14.8
Milkability, kg/min	89	1.232	0.022	0.206	0.442	2.208
Evening						
Milk yield per control milking, kg	89	7.954*	0.123	1.157	4.2	15.2
Milking duration, min	89	7.504	0.144	1.354	3.7	17.7
Milkability, kg/min	89	1.161	0.024	0.222	0.395	2.677
Average						
Milk yield per control milking, kg	178	8.375	0.078	1.042	3.5	15.2
Milking duration, min	178	7.603	0.102	1.361	3.7	17.7
Milkability, kg/min	178	1.197	0.016	0.214	0.395	2.677

*P < 0.001

The data regarding the BRC obtained by us were closer to those regarding the Jersey cattle breed in the study of Bobić et al. (2020) cited above – the average milkability of the cows was 1.66 kg/min, and the maximum one – 2.49 kg/min.

Along with the individual differences, the milkability was significantly affected by the milker ($P < 0.05$). The accumulation of the different effects (milk yield, milker, milking time) led to the elimination of the significant effects which came to prove that the influence of the factors examined was diverging. Obviously, the BRC milkability increase selection activities must be aimed at different aspects such as milking time, temperament et al, which need to be examined in more detail.

Probably, the milkability increase through selection, which is possible when considering the maximum values (2.7 kg/min) and the relatively high variation coefficient (17.9%), might lead to decrease in the milking time, which in turn would lead to reduction in the labour, electricity as well as other indirect costs. The potential positive economic efficiency (Boselli et al., 2020), however, should be carefully analyzed in view of the possible negative effects. Zucali et al. (2009) for example, have ascertained a high correlation between the maximum milkability of 3.71 kg/min and the total somatic cell count in the milk ≤ 200 000 cells per milliliter. A study carried out by Tamburini et al. (2010) establishes that the high milkability animals have worse udder health condition. The condition of the cows which have poor health indicators during the first

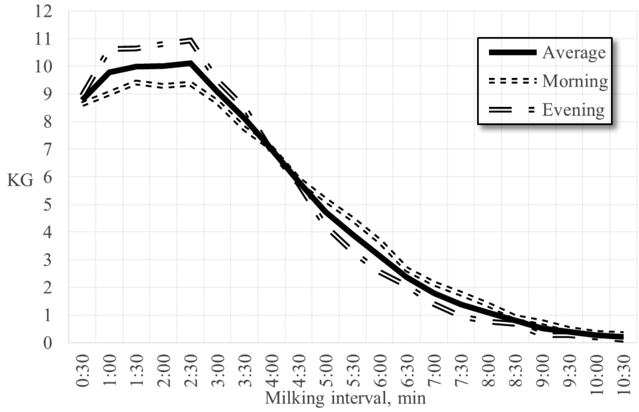

Fig. 1. Milk flow curves during morning and evening milking and a control period average, % of the total for the respective control

Table 2. Milking time and milk received percentage of the total quantity obtained

Time since the start of milking, min	Morning		Evening		Average	
	%	%, accumulation	%	%, accumulation	%	%, accumulation
0:30	8.62		8.95		8.78	
1:00	9.02	17.65	10.62	19.57	9.78	18.55
1:30	9.41	27.06	10.65	30.22	10.00	28.55
2:00	9.28	36.34	10.81	41.03	10.00	38.55
2:30	9.37	45.71	10.94	51.97	10.11	48.66
3:00	8.71	54.43	9.49	61.46	9.08	57.74
3:30	7.75	62.18	8.51	69.97	8.11	65.85
4:00	7.04	69.21	6.94	76.91	6.99	72.84
4:30	5.92	75.13	5.77	82.67	5.85	78.69
5:00	5.17	80.30	4.22	86.89	4.72	83.41
5:30	4.46	84.76	3.29	90.19	3.91	87.32
6:00	3.66	88.42	2.54	92.73	3.13	90.45
6:30	2.66	91.08	2.05	94.78	2.37	92.83
7:00	2.14	93.22	1.40	96.18	1.79	94.62
7:30	1.77	94.99	0.94	97.12	1.38	95.99
8:00	1.38	96.36	0.77	97.89	1.09	97.08
8:30	0.93	97.29	0.68	98.57	0.81	97.89
9:00	0.75	98.04	0.27	98.84	0.52	98.42
9:30	0.50	98.54	0.27	99.12	0.40	98.81
10:00	0.36	98.90	0.19	99.31	0.28	99.09
10:30	0.31	99.21	0.12	99.42	0.22	99.31
11:00	0.22	99.43	0.10	99.52	0.16	99.48
11:30	0.21	99.64	0.09	99.61	0.15	99.63

three months of their lactation continues to deteriorate with its progress. According to the authors this is due to the wider teat canals which facilitate the higher milkability but also ease the introduction of pathogens in the gland.

Arguably, the first steps to be taken must be aimed at shortening the decreasing phase of the BRC milk flow curve which has a considerable length (Figure 1). The amount of milk removed within the 6 minutes recommended by Göft et al. (1994) was 90.5% (Table 2), 38.6% of the total milk was obtained during the first two minutes of the milking, and until the end of the third minute, the quantity received was more than the half – 57.7%. 20 % of the total milk quantity was received within the second minute alone. These values are close to those reported for the Holstein cows – respectively 42% obtained during the first two minutes and 62% – during the first three minutes of milking (Lee & Choudhary, 2006).

As a whole, the ascending phase was relatively short – it was reached at the first minute during the evening milking and at 1.5 min during the morning one. During the evening milking, the lactation plateau remained steady within 1.5 min with a slight increase of 3% from the first to 2.5 min. During the morning milking, the maximum milk yield was reached 30 s later, stood for a shorter period – 1 min and slightly decreased with 1.4% in the middle of the plateau. The plateau remained steady for 1.5 min and the milk received every 30 s was 10% of the total milk quantity. Overall, 30% of the total milk quantity was milked for 1.5 min upon maximum milk flow rate. The time necessary for the BRC to reach the lactation plateau was similar to that ascertained by Lee & Choudhary (2006) – 1.08 min for the Holstein cattle breed, however, here the plateau length is considerably longer – 2.97 min and the lactation curve decreasing phase is shorter – 2.67 min.

In our study, the decreasing phase during both milking procedures began from the third minute and took up more than ¾ of the total milking time. The decrease was more noticeable up to the 6th minute – more than 30%. 3% of the milk per day was milked after the 8th minute.

The higher relative proportion of the milk received during the decreasing phase was the reason for the lower relative milkability in the morning against the higher milk yield (Figure 1). As a whole, during the evening milking, the milk flow intensity was higher (Figure 2) and the milking time – shorter but due to the lower milk yield, the milkability reported as kg/min was lower. The milkability during the evening milking was higher up to 3.30th minute until which 66% of the milk per day was received.

Unlike the average milk flow curve, the individual ones were too different. Figure 3 displays the milk flow curves of

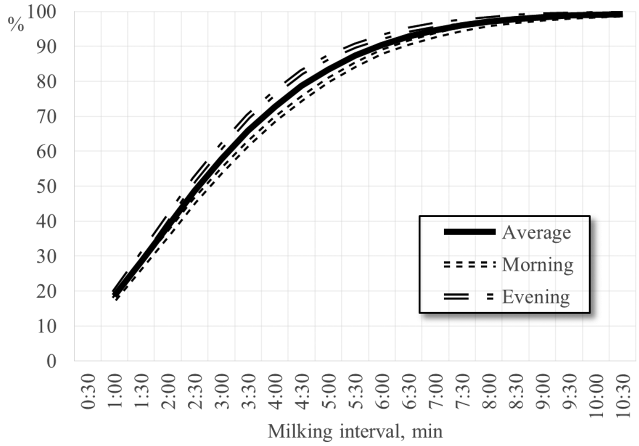

Fig. 2. Milk flow curves during morning and evening milking and average per control period, % of the total for the respective control, with accumulation towards the end of the milking

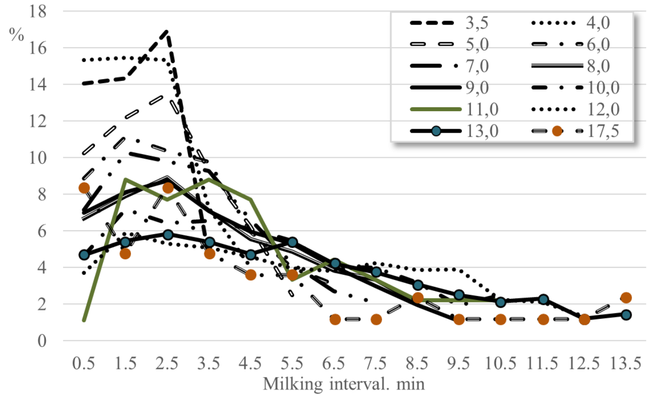

Fig. 3. Milkability per different milking time, % of the total for the respective time

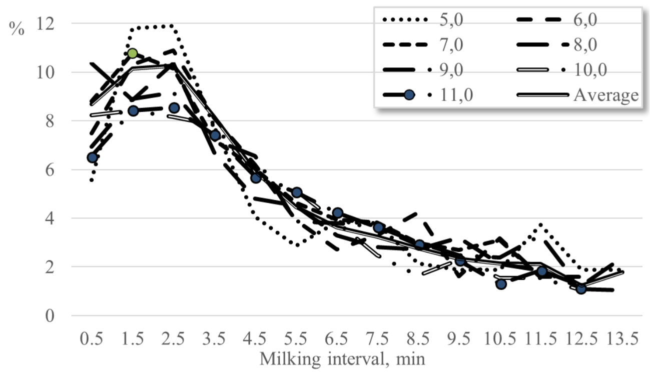

Fig. 4. Milkability of cows with different milk yield per control milking, % of the total for the respective groups cows

cows with different milking time, and Figure 4 – with different milk yield per control milking.

Figure 3 exhibits the logical pattern – when the milking time is shorter, a bigger quantity of milk is received during the initial minutes. 63.3% of the milk was removed during the first two minutes, and 95.4% – within three minutes when the cows were milked for 3.5 min. Those cows which were milked for 5 minutes ejected 44.84% of the milk during the first two minutes of milking, and at the end of the third minute, the quantity was 70.09%. Those cows which had milking time of 8 min ejected 37.73% and 57.42% respectively for the first two and three minutes with the percentages being lower than the average. The values were even lower with reference to the cows which had milking time of 10 min – 26.58% during the first two minutes and 38.3% for the first three minutes. Overall, the milk flow of the BRC was fluctuating. The curve of the cows with an average milking time of 6 min was the steadiest and the closest to the average one.

Similar irregularity was also observed in the cows with different milk yield (Figure 4). The percentage of the milk received from the cows with an average daily milk yield of 5 kg was 39.88% during the first two minutes, and the milk obtained for three minutes was 63.95%. Similar percentage of milk received during the first two minutes was reported for the cows with a milk yield of 7 kg – 39.93%, they, however, reduced their milkability afterwards and the quantity obtained for three minutes was 58.17%. The two values decreased in parallel with the increase of the milk yield. Thus, the quantity of milk obtained form cows with a milk yield of 9 and 11 kg during the first two minutes was respectively 33.62% and 30.99 % of the total milk, and the milk removed within three minutes was 50.61% and 46.79%.

Table 3 shows that the cows milk yield, distributed in the intervals specified in materials and methods, had practically no effect on the milk flow rate. However, the interval and milk yield per interval correlation was high for all groups. The correlation regarding the average milk yield per milking of 7 kg and above 9 kg was almost linear. The milk yield during the different intervals determined the milkability and therefore, the effect of the interval on the milkability was predictably strong and significant ($P < 0.001$). Probably, the milk yield was also the reason for the ascertained highly significant influence of the individual ($P < 0.001$), which, when set as a factor in the middle of the milking interval, was not a significant source of variation (Table 3).

Table 3. Influence of the individual, daily milk yield, milking time and milking interval on the milkability in the control interval

Factor	F	Sig.
Individual	0.023	0.879
Milking interval (every 0.5 min)	14.594	0.000
Milking time, min	23.106	0.000
Milk yield, kg	0.191	0.979
Interval * Duration	2.511	0.000
Interval * Milk yield	0.833	0.925
Duration * Milk yield	0.082	1.000
Interval * Duration * Milk yield	0.892	0.950

The total milking time also had a significant influence ($P < 0.001$) on the milkability. Petkov (2009) has also established a strong correlation between the milkability and the milking time with reference to cows of the Black and White cattle breed at different lactation stages during the different lactation months.

The factors 'milk yield per milking', 'milking time' and 'milking interval' had a divergent influence on the milkability. Therefore, upon their joint study, their effect on the milkability was eliminated (Table 3).

The milkability is a resultant value (proportion) of the milk yield and the milking time, and is more dependent on the latter. The phenotype correlation (Rp) between the milkabilty and the milking time was 0.693 ($P < 0.001$), and between the milkability and the milk yield + 0.563 ($P < 0.001$). Similar correlation values regarding the milkability and the milk yield are ascertained by Duda (1996) during the evening and morning milking, respectively $r^2 = 0.46$ and $r^2 = 0.38$ ($r = 0.678$ and $r = 0.616$)

The milk yield and the milking time do not significantly correlate with each other (Rp = 0.109, $P > 0.05$).

Conclusion

The Bulgarian Rhodope cattle has a relatively low milkability – 1.197±0. 016 kg/min which does not differ significantly ($P > 0,05$) during morning (1.232±0.022 kg/min) and evening (1.161±0.024) milking.

The reason for the low milkability is the long decreasing phase of the lactation curve after reaching the milk flow peak. It starts at the third minute and takes up more than ¾ of the total milking time. The milk flow peak is reached at the first minute during the evening and at 1min 30 s during the morning milking. The peak values are retained for 1 min 30 s with 10% of the total milk quantity being received every 30 s (30% for 1.5min).

38.6% of the total quantity of milk per milking is removed during the first 2 minutes, 57.7% during the first 3 min, and the quantity of milk removed for 6 min is 90.1%.

The milking interval ($P < 0.001$) and the milking time ($P < 0.001$) have a significant effect on the milkability.

The milkability (kg/min) is more considerably dependent on the milking time (Rp = -0.693; P < 0.001) and to a lesser extent on the milk yield (Rp = +0.563; P < 0.001).

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