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Milk production during the colostral period is not related to the later lactational performance in dairy cows

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ABSTRACT

In dairy cows, milk yield increases rapidly after parturition until a peak at around wk 6 of lactation. However, the description of the shape of the lactation curve is commonly based on weekly average milk yields. For a more detailed analysis of the milk production curve from the very beginning of lactation including the colostral period and the effect of colostrum yield on further lactational performance, the first 10 milkings after parturition, daily milk yields from d 1 to 28 of lactation, and the cumulative milk production on d 100 to 305 of lactation were investigated in 17 primiparous and 39 multiparous cows milked twice daily. Milk yield at the first milking after parturition (colostrum) ranged from 1.3 to 20.7 kg (Δ = 19.4 kg) in multiparous and from 1.8 to 10.9 kg in primiparous animals (Δ = 9.1 kg). At the tenth milking, milk production ranged from 9.2 to 21.5 kg (Δ = 12.3 kg) in multiparous and from 7.0 to 15.2 kg (Δ = 8.2 kg) in primiparous animals. Immediately after parturition, daily milk production increased rapidly, but after approximately 1 wk in lactation, the slope of the daily milk production curve flattened and continued more linear. A nonlinear regression equation was used to determine this timely change, which occurred earlier in primiparous (d 6.9 ± 0.3) than in multiparous cows (d 8.2 ± 0.2). The correlation between the amount of first colostrum and milk production during further lactation decreased already from 0.47 on d 5 to 0.32 on d 14. In multiparous cows, the correlation between total milk production of the previous 305 d standard lactation and the amount of first colostrum was not significant (correlation = 0.29), whereas the correlation with the daily production increased from 0.45 on d 5 to 0.69 on d 14. However, in primiparous animals, correlations between first-colostrum yield and daily milk yields up to d 28 of lactation were not significant, possibly due to the smaller sample size compared with multiparous animals. First-colostrum yield and cumulative milk production of 100, 200, and 305 lactation days were not significantly correlated in multiparous and primiparous cows. In conclusion, the milk production during the first few milkings is widely independent from the overall production level of a cow. Potentially, genetic selection toward lower milk yield during the very first days after parturition at a simultaneously high lactational performance may be a tool to ensure sufficient colostrum quality and to reduce the metabolic load around parturition.

Key words: colostrum, lactation curve, milk yield, dairy cow

INTRODUCTION

Since the beginning of the last century, the lactation curve of dairy cows has been repeatedly investigated (Brody et al., 1923; Gaines, 1926) but is still the subject of current research (Macciotta et al., 2005; Madouasse et al., 2012). The description of the shape of the lactation curve is commonly based on daily (after the colostral period) or weekly average milk production, whereas the milk production of individual milkings immediately after parturition has not yet been investigated in terms of effects on later lactation performance. The lack of information may be due to the fact that during the colostral period, milk cannot be delivered and, consequently, milk yield is not automatically recorded during the first few days of lactation.

Nevertheless, parturition and the onset of lactation impose great physiological changes in dairy cows (Goff and Horst, 1997). To meet the demands of the mammary gland at the beginning of abundant milk production, tremendous homeorhetic changes take place during the peripartal period (Bauman and Currie, 1980). Thus, the transition period is crucial for the development of metabolic disorders such as hypocalcemia and is associated with peak incidence of production diseases (Mulligan and Doherty, 2008). Besides, these metabolic disorders have effects on health and productivity far into the following lactation. Moreover, optimal health status of the periparturient cow is also crucial for high colostrum quality (Dardillat et al., 1978). Ingvartsen et al. (2003) and Hansen et al. (2006) pointed out the accelerating pattern in milk yield after parturition and its relation to the occurrence of health disorders following

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metabolic stress. Because of the potential advantage of moderate milk production during the very first milkings for optimal colostrum quality and reduced risk of metabolic disturbances, the aim of this study was to investigate the variation in colostrum yield and milk production during the first days of lactation and their correlation with the overall production level based on individual milkings at the onset of lactation and thereafter, on the basis of daily milk yields.

MATERIALS AND METHODS

Animals and Milk Recording

Seventeen primiparous and 39 multiparous (2.9 ± 0.2 parities; mean ± SEM) Holstein dairy cows, housed at the Agroscope Liebefeld-Posieux Research Station ALP-Haras (Posieux, Switzerland), were followed during the entire lactation. The milk yield of the previous standard lactations (305 d) of the multiparous cows was 8,137 ± 232 kg.

Cows were fed according to their energy and nutrient requirements. Until parturition, animals received hay for ad libitum intake, plus 1 kg of cereal-based concentrate and 0.5 kg of mineral supplement for dry cows. After parturition, the amount of concentrate was increased and after the peak of lactation amounts were adjusted weekly according the current milk production. No samples were taken from the diets.

Multiparous cows were milked for the first time 2 h and 15 min ± 15 min (range: 30 min to 5 h and 15 min) and primiparous cows 4 h and 50 min ± 26 min (range: 2 h and 30 min to 9 h and 45 min) after parturition. The time interval between the first and the second milking after parturition averaged 10 h and 35 min ± 29 min (range: 3 h and 30 min to 19 h and 30 min). From the second milking after parturition onwards, cows were milked twice daily at the scheduled milking times around 0500 and 1600 h in the milking parlor. Milk yields of individual a.m. and p.m. milkings as well as daily milk yield were recorded electronically.

Data Analysis

Data presented are means ± standard error of the mean. The development of milk yield during the first 10 milkings after parturition and 28 d of lactation between multiparous and primiparous cows was compared by using the MIXED procedure of SAS (version 9.2; SAS Institute Inc., Cary, NC). The model included group (primiparous or multiparous) as fixed effect and *P*-values <0.05 were considered to be significant.

A nonlinear regression (Equation [1]) was used for the characterization of the lactation curve up to d 28 and its coefficients were calculated individually for each cow with SigmaPlot 11 (Systat Software Inc., San José, CA):

$$f(x) = [A \times x]/[B + x], \quad [1]$$

where x = day of lactation, f(x) = milk yield at day x, A = maximum milk yield in lactation, and B = day of lactation with 50% of maximum milk yield. The time point when the lactation curve passed from a steep to a steady linear slope was determined with the first derivative of Equation [1]:

$$f'(x) = (A \times B)/(B + x)^2. \quad [2]$$

The slope threshold was defined as the first day with $f'(x)$ <1 kg/d. The mean values for multiparous cows (and primiparous cows) were A = 42.76 (29.29) and B = 2.34 (2.22).

Hourly milk production was calculated as milk yield divided by the interval since the last milking. Pearson correlation coefficients between the amount of colostrum and milk yields at different time points, time spans in between the first 3 milkings, and milk yield in the previous lactation were evaluated using the CORR procedure of SAS.

RESULTS

Multiparous cows showed a wide range of milk yields at the first milking (Δ = 19.4 kg; Figure 1). At the tenth milking, an obvious range (Δ = 12.3 kg) was still present, but considerably decreased compared with the first milking. In primiparous cows, the variation between the milk yields at the first (Δ = 9.1 kg) and tenth milking (Δ = 8.2 kg) was also huge, but decreased less compared with multiparous cows (Figure 1).

Table 1. Pearson correlation coefficients between milk yield of the first 3 milkings and time since the respective previous milking

	Multiparous cows			Primiparous cows		
Item	r	*P*-value	n[1]	r	*P*-value	n
First milking/time between parturition and first milking		NS	39		NS	17
Second milking/time between first and second milking	0.77	<0.01	39	0.44	0.08	17
Third milking/time between second and third milking		NS	39		NS	17

[1]n = number of animals/observations.

Table 2. Hourly milk production (kg/h) since the last milking in multiparous and primiparous dairy cows

	Multiparous cows		Primiparous cows	
Milking	Mean	SEM	Mean	SEM
2	0.59	0.03	0.48	0.07
3	0.79	0.04	0.62	0.06
4	0.98	0.04	0.76	0.04
5	1.08	0.03	0.76	0.05
6	1.11	0.04	0.79	0.04
7	1.18	0.04	0.83	0.05
8	1.26	0.04	0.85	0.05
9	1.25	0.04	0.86	0.05
10	1.34	0.04	0.88	0.05

The amount of colostrum in primiparous and multiparous cows was not related to the time between calving and time of first milking (Table 1). In contrast, the milk yield at the second milking was correlated with the interval between the time of the first and second milking in multiparous cows ($P < 0.01$) and not in primiparous cows ($P = 0.08$; Table 1). When cows were subjected to the twice-daily milking rhythm, the time interval between the preceding 2 milkings did not affect milk yield anymore in both primiparous and multiparous cows, as shown for the third milking on Table 1.

Milk yield increased steeply from the second to the fourth individual milking in multiparous and primiparous cows (Figure 2). Thereafter, the rate of increase in milk yield was reduced. Milk yields were always higher in multiparous cows compared with primiparous cows ($P < 0.05$), except for the second milking.

The hourly milk production increased steeply by almost 60% from the second to the fourth milking in primiparous and multiparous cows (Table 2). From the fifth milking on, the increase in hourly milk production slowed down.

The 28-d lactation curve increased steeply at the onset of lactation until d 6.9 ± 0.3 in primiparous and d 8.2 ± 0.2 in multiparous cows ($P < 0.01$; Figure 3). Thereafter, the curve of the daily milk production flattened and continued more linearly, but still increased toward the peak of lactation. Multiparous cows showed higher milk yields than primiparous cows over the entire first month of lactation ($P < 0.05$).

In multiparous cows, the correlation of first-colostrum yield with daily milk yield decreased markedly from d 5 to 14 (Table 3). Subsequently, in wk 3 and 4 of lactation, the correlations were not significant. The

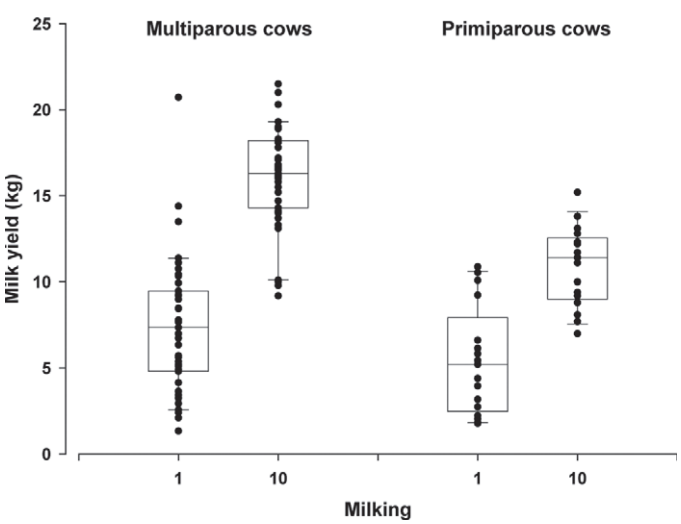

Figure 1. Range of the milk yields at the first and tenth milkings in multiparous and primiparous cows. Each circle represents data of individual animals. The box gives the 25th to 75th quartile, whereas the whiskers show the 5th to 95th percentile distribution of the data. The line within the box represents the median of the data.

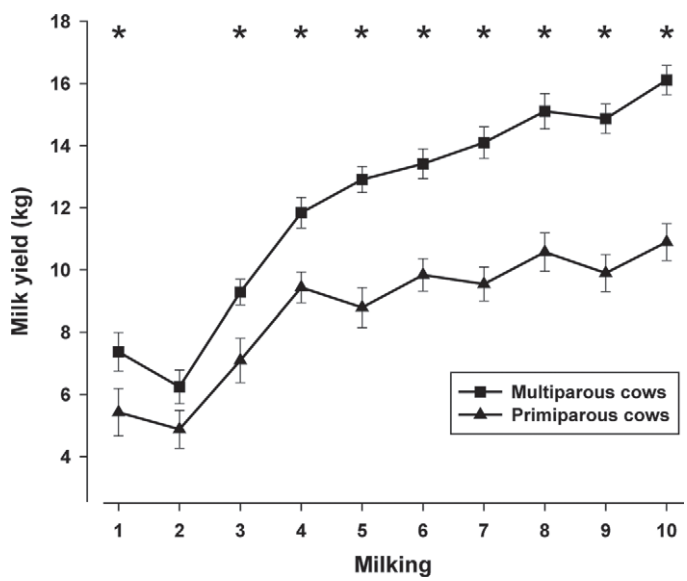

Figure 2. Development of the milk yield of the first 10 individual milkings after parturition in multiparous and primiparous cows. Data are given as mean values ± SEM. Differences between multiparous and primiparous cows within milking are indicated by * ($P < 0.05$).

Table 3. Coefficient of variation in milk yield and Pearson correlation coefficients between first colostrum yield and daily milk yield until d 28 of lactation and cumulative milk production until 305 d of lactation

Milk production	Multiparous cows				Primiparous cows		
	n[1]	CV	r	*P*-value	n	CV	r
d 5	38	0.23	0.47	<0.01	17	0.22	NS
d 8	39	0.17	0.37	<0.05	16	0.16	NS
d 14	39	0.14	0.32	<0.05	16	0.13	NS
d 21	39	0.13		NS	16	0.23	NS
d 28	39	0.14		NS	15	0.16	NS
100 d	36	0.13		NS	15	0.15	NS
150 d	31	0.12		NS	15	0.16	NS
200 d	29	0.12		NS	14	0.15	NS
250 d	29	0.12		NS	14	0.15	NS
305 d	29	0.13		NS	14	0.16	NS

[1]n = number of animals/observations.

amount of first colostrum in multiparous cows was not related to the cumulative milk production on d 100, 150, 200, 250, and 305 (Table 3; Figures 4 and 5). For multiparous cows, the coefficient of variation in milk yield decreased distinctly from d 5 to 14 and stayed thereafter in wk 3 and 4 on a similar level as the coefficient of variation for cumulative milk production on d 100, 150, 200, 250, and 305 (Table 3).

Primiparous cows showed neither significant correlations between their amount of first colostrum and daily milk yield during the first month of lactation, nor between first-colostrum yield and cumulative milk production later in lactation (Table 3; Figures 4 and 5). The coefficient of variation of milk yield in primiparous cows was inconsistent during the first month of lactation, but constant for the cumulative milk production on d 100, 150, 200, 250, and 305 of lactation.

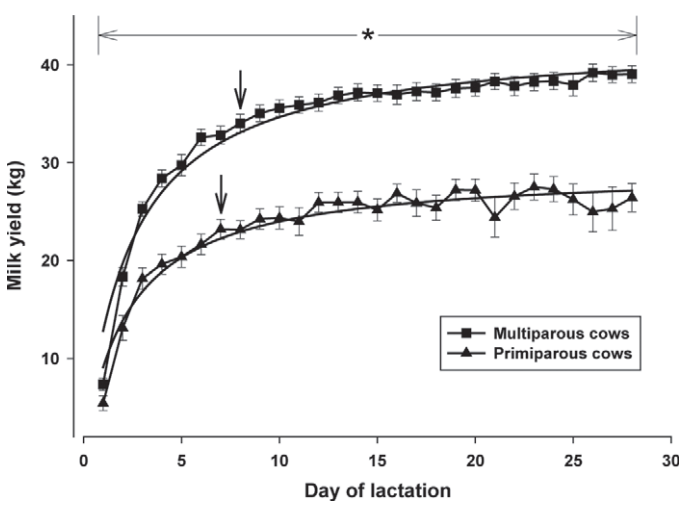

Figure 3. Development of the milk yield over the first 28 d of lactation in multiparous and primiparous cows. Data are given as mean values ± SEM. Differences between multiparous and primiparous cows within day of lactation are indicated by * ($P < 0.05$). A smoothed nonlinear regression equation characterizes the change from a steep curvilinear to a steady linear slope (marked with arrows) for multiparous and primiparous cows.

In multiparous cows, first-colostrum yield was only partly correlated with the precedent 305-d standard lactation yield (Table 4). The correlation between the daily milk yields of the current lactation and the performance of the previous 305-d lactation increased distinctly from d 5 to 14 (Table 4). Thereafter, in wk 3 and 4, the correlations were consistent. Cumulative milk production on d 100 to 305 was highly correlated with the previous lactational performance.

DISCUSSION

The time span between parturition and first milking showed a wide range (30 min to 9 h and 45 min) and might be supposed to affect colostrum yield. However, and in agreement with Pritchett et al. (1991), this time interval did not affect the amount of first colostrum in the present study. The amount of first colostrum showed wide variation in both multiparous and primiparous cows, although the range was larger in multiparous cows (1.3 to 20.7 kg) than in primiparous cows (1.8 to 10.9 kg). These results are consistent with the findings on colostrum yields reported by Morin et al. (2010). The average of first-colostrum yield differed also between multiparous and primiparous cows. A lower colostrum volume in first-lactation cows compared with multiparous cows was also found previously (Devery-Pocius and Larson, 1983), which was suggested to be the result of less mammary gland development in first-lactation cows. One might assume that variation in first-colostrum yield could be due to incomplete milk removal. After the second milking following parturition, milking times were scheduled uniformly and, thus, the time span between first and second milking varied widely. If first colostrum was not harvested completely, remaining milk along with newly secreted milk would

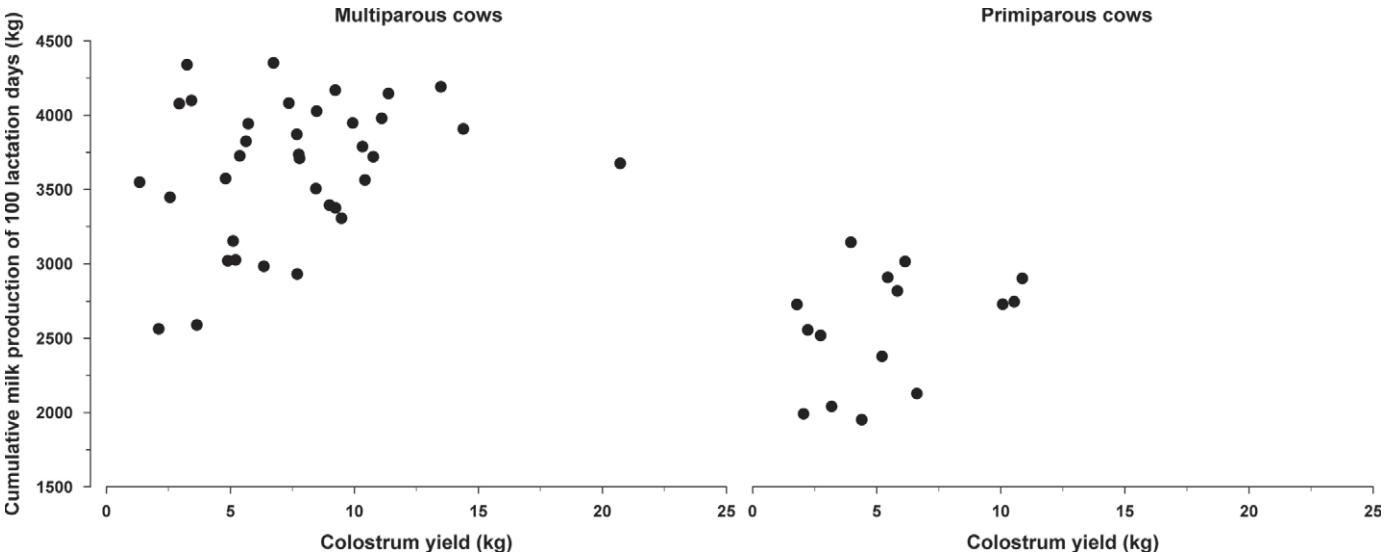

Figure 4. First-colostrum yield versus cumulative milk production of 100 lactation days in multiparous and primiparous cows.

accumulate in the udder and would be available at the next milking. However, milk yields at the second milking after parturition were dependent only on the time interval since the first milking, indicating the initiation of copious milk secretion after the first milk removal. Therefore, the decrease in milk yield at the second milking shown in Figure 2 was due to the shorter average time between the first and second milking compared with the interval between twice-daily milkings. Lower colostrum yields were not followed by a higher milk yield at the second milking and vice versa.

In the present study, milk yield and the hourly milk production increased steeply from the second to the fourth milking, which might be explained by rapid addition of lactose into the milk secreted (Madsen et al., 2004; Baumrucker et al., 2010). Around parturition, tight junctions start closing (McFadden et al., 1987) and lactose, which is the main osmole in milk (Linzell, 1972), remains in the mammary gland. Thus, water enters the secretory vesicles (Linzell, 1972) and influences the milk yield (Nickerson and Akers, 1984).

At the onset of lactation, immature alveoli and milk epithelial cells are still present in the mammary gland, suggesting that secretory activation and lactogenesis are not completed before parturition (Annen et al., 2007). Furthermore, Annen et al. (2007) showed that the increase in milk yield during early lactation up to d 7 is not only the result of an increased secretory capacity of milk epithelial cells, but also due to increasing numbers of alveoli completing activation and contributing to milk synthesis. In agreement with these findings, the steep increase in milk yield during the first week of lactation suggests that milk epithelial cells need at least the first week of lactation to get fully activated and ready for continuous milk secretion thereafter. For primiparous cows, a lower amount of alveoli together with a minor secretory capacity might explain the slightly earlier flattening in daily milk production.

According to previous studies, factors such as the length of the dry period or continuous milking affect the milk yield of the subsequent lactation (Annen et al., 2007; Bernier-Dodier et al., 2011). However, to our knowledge, the effect of colostrum yield on subsequent milk production has not been previously reported. Interestingly, first-colostrum yield did not influence the

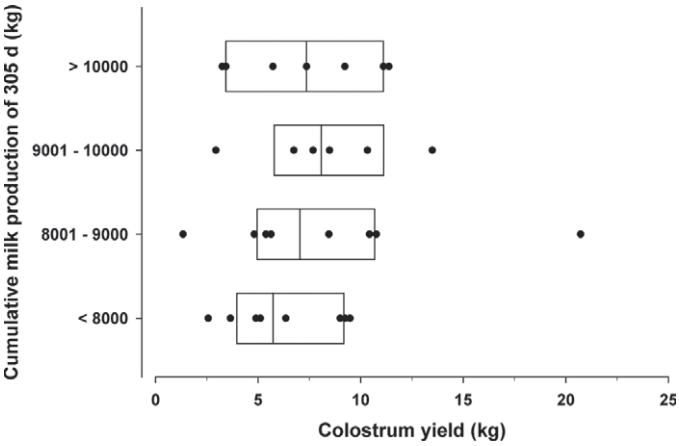

Figure 5. First-colostrum yield versus cumulative milk production of the current 305-d standard lactation in multiparous cows grouped according to their production level. Each circle represents data of individual animals. The box gives the 25th to 75th percentile distribution of the data. The line within the box represents the median of the data.

Table 4. Pearson correlation coefficients between milk yield of the previous standard lactation yield (305 d) and daily milk yield until d 28 of lactation and cumulative milk production until 305 d of lactation

	Multiparous cows		
Day	r	*P*-value	n[1]
Colostrum	0.29	0.07	39
d 5	0.45	<0.01	38
d 8	0.47	<0.01	39
d 14	0.69	<0.01	39
d 21	0.73	<0.01	39
d 28	0.71	<0.01	39
100 d	0.71	<0.01	36
150 d	0.74	<0.01	31
200 d	0.79	<0.01	29
250 d	0.81	<0.01	29
305 d	0.83	<0.01	29

[1]Number of animals/observations.

further lactation potential in multiparous and primiparous cows. The influence of the amount of first milk on daily milk production decreased within the first 14 d of lactation, whereas concomitantly, the influence of the previous lactation yield increased in multiparous cows. Further, first-colostrum yield was only partially dependent on the previous lactation performance in contrast to the later milk production. The results of the present study, which indicate that the amount of colostrum does not affect the further lactational performance in cows (expressed as cumulative milk production of 100, 200, and 305 d in lactation), raise the relevance of 2 prominent aspects in dairy research: metabolic load after parturition and colostrum quality.

First, lower milk production at the onset of lactation without adverse effects on the performance level might be of interest in terms of reduced risk for metabolic diseases during the periparturient period. It is widely accepted that the transition period is critical for health disorders and that high milk yield can be responsible for higher disease susceptibility (Bertoni et al., 2009). Uribe et al. (1995) demonstrated a high and inverse correlation between milk yield and hypocalcaemia. Thus, lower milk yields at the first milkings after parturition could possibly reduce the incidence of milk fever. Additionally, the level of milk production contributes significantly to the extent of the negative energy balance directly after parturition (Harrison et al., 1990). Although not taking the first-colostrum yield into account, it was pointed out that the accelerating pattern in milk yield after parturition has clear effects on the occurrence of health disorders following metabolic stress (Ingvartsen et al., 2003; Hansen et al., 2006). Interestingly, in the study of Hansen et al. (2006), cows had only a small milk yield at calving but had variable lactation performance, followed by different incidence rates for metabolic diseases between high- and low-yielding cows. Despite this finding, moderate milk production during the onset of lactation decreases the metabolic load, which, in turn, can decrease the risk for subsequent diagnosis of other diseases such as clinical ketosis, metritis, and lameness (Duffield et al., 2009; Roberts et al., 2012).

Not of minor importance, the effect of colostrum yield on its quality should be mentioned. In cattle, the placenta is impermeable for antibodies and calves are born without IgG antibodies. Thus, the neonate depends on the passive transfer of immunity by the ingestion of colostrum of sufficient quality. The IgG concentration in the colostrum of beef cows is more than twice as high as in dairy cows such as Holstein-Friesians (Norman and Hohenboken, 1981; Baumrucker et al., 2010). Guy et al. (1994) explained the difference in colostral IgG concentrations between dairy and beef cows by a greater dilution effect. Thus, a smaller colostrum volume in dairy cows could possibly compensate for this dilution effect and increase the IgG concentration in colostrum.

CONCLUSIONS

The first-colostrum yield varied widely in both multiparous and primiparous cows, although the variance of ongoing milk yields decreased more distinctly in multiparous than in primiparous cows. Further, first-colostrum yield was not influenced by the time interval between calving and first milking and was only partially dependent on the previous lactational performance. The milk yield at the onset of lactation was not related to subsequent milk production. Considering a simultaneously lower metabolic load in cows giving less milk at the very beginning of lactation and possibly improved colostrum quality, this attribute might gain importance as a breeding objective.

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