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ASSESSMENT OF THE QUALITY AND YIELD OF COW COLOSTRUM OBTAINED IN THE FIRST 24 HOURS AFTER CALVING

Salamończyk Ewa#, Krysiak Grzegorz

University of Siedlce, Faculty of Agricultural Sciences, Institute of Animal Science and Fisheries, Prusa 14 St, 08-110 Siedlce, Poland

SUMMARY

The aim of the study was to assess the quality of colostrum of Polish Holstein-Friesian cows on the first day after calving, by measuring the refractive index on the Brix scale with an electronic refractometer, as well as the colostrum yield. The influence of the following factors on these colostrum characteristics was analysed: time after calving, herd, lactation number, and length of the dry period before parturition. In total, colostrum from 21 cows (7 from each herd) was assessed. Yield was assessed, and antibody content on the Brix scale was determined using an electronic refractometer up to 2 hours after calving and at the time of subsequent milking on the farms (between 3 and 12 hours and between 13 and 24 hours after calving). Time after calving was shown to significantly affect the quality and yield of colostrum ($P < 0.05$). The immunological value of colostrum assessed on the Brix scale decreased at successive milking times after calving, amounting to 22.7%, 19.2% and 16.4%. However, the average colostrum yield increased with time (from an average of 6.5 kg in the first colostrum collection to 9.4 kg in the period between 13 and 24 hours after calving). The length of the dry period and the age of the cow were particularly important factors for the high value of the first colostrum. The best colostrum was produced by cows with a longer dry period, lasting from 46 to 59 days (23.4% Brix) and by older cows in lactations from 4 to 7 (24.2% Brix). The correlation and regression coefficients calculated in the study indicate that the increase in the yield of colostrum obtained up to 2 hours after calving is associated with a decrease in its quality. Extension of the dry period before parturition is accompanied by an increase in antibody content assessed on the Brix scale. Despite the fact that routine assessment of colostrum quality using an electronic refractometer is known to have tangible benefits, it is still not widely conducted.

KEY WORDS: dairy cows, colostrum quality, colostrum yield, electronic refractometer

Corresponding author e-mail: ewa.salamonczyk@uws.edu.pl
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INTRODUCTION

Colostrum is the first and an extremely important food for a newborn calf. This specific secretion of the mammary gland of cows, produced in the last few weeks of pregnancy, contains over 250 chemical compounds with an almost 40-fold increased share of biologically active ingredients (such as hormones, enzymes, amino acid derivatives and others) compared to milk. It also contains bacteriostatic substances, including immunoglobulins, lactoperoxidase, lactoferrin, lysozyme and leukocytes. Compared to milk, colostrum has an increased share of components transferred directly from the mother's blood and approximately 60% protein in dry matter, of which 80% is whey protein and 20% is casein (Szulc and Zachweja, 1998; Szulc, 2012). Due to the structure of the placenta, the foetus in the uterus does not receive antibodies from its mother, and therefore newborn calves are exposed to all pathogens present in the environment. Only effective delivery of colostrum from the mother ensures activation of the calf's immune system and provides adequate energy and protein to control body temperature and initiate metabolism (Lombard et al., 2007; Runnels et al., 1986; Reisdorffer and Besnier, 2019).

It is crucial to provide an adequate amount (four litres) of high-quality colostrum (over 100 g/l of antibodies) within two hours after birth. Such colostrum will ensure immunity, and in the future will result in the animal's high growth, high productivity and good health. Faber et al. (2005) indicate that calves that received more colostrum on the first day of life (4 l vs. 2 l) produced approximately 10% more milk in the first lactation and 15% more milk in the second lactation. The authors estimated that this resulted in 550 kg more actual milk produced per cow during the first two lactations. Results published by Soberon and Van Amburgh (2011) showed that calves which drank four litres of colostrum later consumed 8.5% more starter feed and achieved 18% greater daily gains than calves that drank only two litres of colostrum.

Therefore, an essential element of successful rearing is to quickly ascertain the content of antibodies in the colostrum, so that only colostrum with the highest content of immunoglobulins will be used to feed newborn calves. In field practice, a colostrum meter (colostometer, aerometer) or an electronic refractometer can be used to estimate the level of antibodies in cow colostrum. The first works by assessing the density of the fluid. The results are not highly accurate, in part due to the influence of temperature. The colostrum meter is also quite difficult to use, because it is a fragile glass device and a relatively large amount of colostrum must be poured into the cylinder (Fig. 1). An electronic refractometer is a small optical device used to assess the properties of a fluid (e.g. colostrum or serum) by measuring the refractive index on the Brix scale. Testing the sample involves dripping colostrum into the measuring chamber; after a few seconds, the result is visible on the screen (Fig. 2). The refractometer automatically converts the value of the refractive index into the desired concentration unit. Quigley et al. (2013) and Bartens et al. (2016) reported that electronic refractometers provided the most accurate assessment of colostrum quality and demonstrated excellent repeatability precision. Brix refractometry is inexpensive, readily available, and less sensitive to variability in colostrum temperature, season, and other factors.

The immunological value of colostrum to be administered to a newborn calf should be quickly ascertained in order to protect the calf with passive immunity and thus reduce disease and mortality. It should also be remembered that the transfer of antibodies from the colostrum to the bloodstream is most rapid and efficient up to the 2nd hour of life; thereafter the rate of transfer decreases with each hour. These considerations suggest that the immunological value of colostrum, especially on the first day after calving, should be assessed in every herd. Therefore, the aim of the study was to determine the yield of colostrum obtained from Polish Holstein-Friesian cows on the first day after calving and assess its quality on the Brix scale (%) using an electronic refractometer.

Figure 1. Colostrometer (Phot. E. Salamończyk)

Figure 2. Electronic refractometer (Phot. E. Salamończyk)

MATERIAL AND METHODS

The research was carried out in three herds of Polish Holstein-Friesian dairy cows located in the Masovian Voivodeship. The first herd consisted of 19 cows, the second comprised 40 cows, and the third 35 cows. The average milk yield in the three herds was 8579 kg, 12,700 kg, and 9900 kg, respectively. Colostrum quality was assessed in the period from October 2021 to April 2022. In total, colostrum from 21 cows (7 from each farm) was assessed. All first colostrum quality tests were performed no later than two hours after calving. Subsequent tests of antibody content on the Brix scale, using the Milwaukee MA871 electronic refractometer, were performed on samples from subsequent milking on the farms (between 3 and 12 hours after calving and between 13 and 24 hours after calving). The total number of colostrum samples assessed was 63.

The following scale was used to interpret the results (Rząsa et al., 2019):

≥22% (Brix) – Ig concentration >100 g/l,
16–21% (Brix) – Ig concentration 60–80 g/l,
14–15% (Brix) – Ig concentration 40–60 g/l,
≤13% (Brix) – Ig concentration <40 g/l.

After milking, the colostrum was weighed in a bucket, after taring the electronic scale.

The influence of the following factors on the yield and quality of colostrum at each sampling time was analysed:

- time of sampling and weighing milked colostrum after calving (up to 2 hours; between 3 and 12 hours; between 13 and 24 hours),
- herd in which the cows were kept (3 herds),
- lactation number: cows in lactation 1; in lactations 2 and 3; in lactations 4 to 7,
- dry period length in cows, from the second lactation (35–45 days; 46–59 days).

Statistical analysis of the results was then performed using Statistica software according to the following linear model:

$$Y_{ijk} = \mu + a_i + b_j + ab_{ij} + e_{ijk},$$

where:

μ – average trait value (% Brix; colostrum yield),
a_i – fixed effect of time after calving (i = 1, 2, 3),
b_j – fixed effect of herd (j = 1, 2, 3), lactation number (j = 1, 2, 3) or dry period length (j = 1, 2),
ab_{ij} – interaction (time after calving x herd; time after calving x lactation; time after calving x dry period length),
e_{ijk}– sampling error.

One-way and two-way analysis of variance with interaction, using Duncan's test, were used to assess the effect of the factors. The significance of differences between means was assessed at $P < 0.05$. Results are presented as mean values and standard deviation (SD).

Correlation and regression coefficients were calculated between the quality of colostrum obtained within the first two hours after calving (the most important for the newborn calf) and the colostrum yield in the first milking and the length of the dry period. The significance of the correlation coefficients was determined at $P < 0.05$. In the regression analysis, the dependent variable byx was the quality of colostrum (% Brix) obtained in the first two hours after calving. Regression coefficients were calculated using the least squares method, checking the significance of the linear effect.

RESULTS

Table 1 presents the results obtained for colostrum quality assessed with an electronic refractometer on the Brix scale. Colostrum obtained up to two hours after delivery had an average Brix value of 22.7% (for the herd and lactation factors) and 23.1% Brix (for the dry period factor), which indicates an antibody content of >100 g/l. Therefore, this result can be interpreted as very good colostrum. The highest colostrum quality in the first two hours after calving (>22%) was found in 13 cows (Table 2). In subsequent samples, the average levels of immune proteins were as follows: 19.2% (herd and lactation) and 20.5% (dry period length) between 3 and 12 hours after birth; 16.4% Brix (herd and lactation) and 17.7% (dry period length) between 13 and 24 hours after calving (Table 1). This indicates a very rapid deterioration in colostrum quality at successive sampling times. In addition, when the results of primiparous cow colostrum quality tests were discarded (to assess the influence of dry period length), the average antibody content on the Brix scale was higher than the average for the entire population, by 0.4 p.p. up to 2 hours after calving; 1.3 p.p. between 3 and 12 hours after calving; and 1.3 p.p. between 13 and 24 hours after calving.

Table 1.

Colostrum quality on the Brix scale (%) at different times after calving, depending on the herd in which the cows were kept, lactation number, and the length of the dry period in older cows

Factor	**Number of observations**	**Colostrum sampling time after calving, hours**					
		≤ 2		**3–12**		**13–24**	
		Mean SD	**Min. Max.**	**Mean SD**	**Min. Max.**	**Mean SD**	**Min. Max.**
Herd							
1	**21**	22.7	20.5	18.3 ^{B}	15.8	15.8 ^{AB}	13.4
		1.36	24.2	2.80	23.8	3.32	22.4
2	**21**	23.2	20.0	21.2 ^{A}	18.2	18.6 ^{A}	14.2
		1.79	25.0	2.37	23.7	3.03	22.5
3	**21**	22.1	20.4	18.0 ^{B}	16.4	14.7 ^{B}	14.3
		1.56	24.3	1.85	22.2	1.59	19.3
Total	**63**	22.7 ^{1}	20.0	19.2 ^{2}	15.8	16.4 ^{3}	13.4
		1.57	25.0	2.72	23.8	3.08	22.5
Lactation							
1	**21**	21.9 ^{B}	20.0	16.7 ^{C}	15.8	13.7 ^{C}	13.4
		1.46	24.2	1.31	20.1	1.00	17.4
2–3	**18**	21.6 ^{B}	20.5	18.7 ^{B}	16.4	15.6 ^{B}	15.8
		0.95	23.0	2.22	22.7	2.47	20.6
4–7	**24**	24.2 ^{A}	23.5	21.8 ^{A}	20.5	19.3 ^{A}	18.6
		0.47	25.0	1.41	23.8	2.22	22.5
Total	**63**	22.7 ^{1}	20.0	19.2 ^{2}	15.8	16.4 ^{3}	13.4
		1.57	25.0	2.72	23.8	3.08	22.5
Dry period length, days							
35–45	**18**	22.2 ^{B}	20.5	19.4	16.1	16.2	14.3
		1.63	24.2	2.37	22.5	1.93	19.0
46–59	**24**	23.7 ^{A}	21.4	21.2	17.4	18.8	12.7
		1.13	25.0	2.02	23.1	3.13	21.3
Total	**42**	23.1 ^{1}	20.5	20.5 ^{2}	16.1	17.7 ^{3}	12.7
		1.57	25.0	2.28	23.1	2.94	21.3

Means in columns marked with different letters, within the same sampling time, differ significantly at $P < 0.05$.
Means in rows marked with different numbers, between different sampling times, differ significantly at $P < 0.05$.

Table 2.
Frequency of colostrum samples (%) with a specific Ig content assessed on the Brix scale, at different sampling times

Ig concentration on the Brix scale, %	Colostrum sampling time after calving, hours		
	≤ 2	3–12	13–24
	%	%	%
≥ 22	61.9	33.3	14.3
16–21	38.1	66.7	57.1
14–15	-	-	23.8
≤ 13	-	-	4.8
Total, %	100.0	100.0	100.0

Table 3 presents data on the yield of colostrum obtained from the cows. The average colostrum yield at successive milking times was as follows: 6.5 kg (herd and lactation) and 6.4 kg (length of the drying period); 8.0 kg (herd and lactation) and 7.8 kg (length of the drying period); 9.4 kg (herd and lactation) and 9.2 kg (length of the drying period). Therefore, it can be concluded that colostrum yield increased with each subsequent milking time ($P < 0.05$). The impact of the herd on colostrum yield was significant only at later milking times, i.e. between 3 and 12 hours and between 13 and 24 hours after calving. Colostrum yield at the second milking time (between 3 and 12 hours) was higher in herds 1 and 2 than in herd 3. The highest yield at the third milking time after calving was achieved by cows in herd 1. It should be noted that colostrum yield increased with each successive milking on the first day after calving, in all lactation groups and groups of cows with different dry period lengths. However, these differences were not statistically significant.

The correlation coefficient between the quality (on the Brix scale) of colostrum obtained in the first two hours after calving and the colostrum yield obtained in the same period was negative and amounted to −0.26 (Table 4), while the correlation coefficient between colostrum quality and dry period length was 0.59. Therefore, the quality of colostrum in the first two hours after calving was shown to be significantly determined by its yield and the length of the dry period before calving. The regression coefficients (b) shown in Table 4 indicate that the increase in colostrum yield was accompanied by a decrease in colostrum quality. However, extending the dry period has a positive effect on the antibody content in the colostrum ingested by the calf up to 2 hours after birth.

Table 3.
Colostrum yield from one milking session (kg) at each milking time after calving, depending on herd and lactation number and on dry period length in older cows

Factors	Number of observations	Colostrum milking time after calving, hours					
		≤ 2		3–12		13–24	
		Mean	SD	Mean	SD	Mean	SD
Herd							
1	**21**	6.9	0.76	8.3^{A}	0.80	10.0^{A}	1.29
2	**21**	6.3	0.91	8.2^{A}	0.97	9.4^{AB}	1.02
3	**21**	6.4	0.69	7.4^{B}	0.84	8.7^{B}	0.96
Total	**63**	6.5^{3}	0.80	8.0^{2}	0.92	9.4^{1}	1.18
Lactation							
1	**21**	6.8	0.73	8.2	0.91	9.7	1.50
2–3	**18**	6.3	0.96	8.1	1.00	9.8	0.61
4–7	**24**	6.4	0.74	7.7	0.88	8.8	1.03
Total	**63**	6.5^{3}	0.80	8.0^{2}	0.92	9.4^{1}	1.18
Dry period length, days							
35–45	**18**	6.5	0.92	7.9	0.85	9.3	0.82
46–59	**24**	6.3	0.76	7.8	0.45	9.1	1.15
Total	**42**	6.4^{3}	0.81	7.8^{2}	0.63	9.2^{1}	0.99

Means in columns marked with different letters, within the same sampling time, differ significantly at P < 0.05. Means in rows marked with different numbers, for colostrum weighing times after calving, are significantly different at P < 0.05.

Table 4.
Correlation coefficients and regression equations between analysed traits

Traits	% Brix in colostrum obtained in the first 2 hours after calving	
	Correlations (r_{xy})	Regression equations Y=a+bx
Milk yield up to 2 hours after calving	−0.26 *	y = 26.13 – 0.48x
Dry period length	0.59 *	y = 14.81 + 0.18x

* Correlation coefficient significant at P < 0.05

DISCUSSION

The results of many studies indicate high variability of antibody content in cow colostrum, especially from the first milking after parturition (Guliński et al., 2006; Hostetler et al., 2003; Tyler et al., 1999; Quigley et al., 1994). The high variability of the colostrum composition of dairy cows within a herd and between herds is significantly influenced by housing conditions and diet, including the use of feed additives for cows before calving (Kehoe et al., 2007; Zachwieja, 1995; Zachwieja et al., 1997). Cows fed incorrectly in the most critical perinatal period produce colostrum and then milk with a poorer chemical composition and thus lower biological value. Król et al. (2010) showed that milk produced by cows fed green fodder (on pastures) was richer in calcium, magnesium, iron and copper. Kuczyńska (2014) reported that the addition of fish oil and flax seeds to the diet of dry cows had a significant impact on colostrum quality and increased the number of beneficial lactic acid bacteria.

Other factors having a significant impact on the composition of colostrum include breed, colostrum yield, the cow's age, dry period length, past diseases, and individual characteristics (Guliński and Gago, 2019; Silva-del-Rio et al., 2017; Buczinski and Vandeweerd, 2016; Robinson et al., 2009; Gulliksen et al., 2008; Guliński and Giersz, 2006; Szulc and Zachwieja, 1998). In recent years, a deterioration in the qualitative composition of colostrum and milk has been observed due to the strong intensification of milk production aimed at maximizing milk yield.

In order for the calf to fully benefit from the antibodies contained in colostrum, attention should be paid to factors such as the concentration and amount of colostrum administered, the time passed since birth (due to the decrease in antibody levels and the capacity for absorption by the intestinal epithelium), and microbiological quality (Puppel et al., 2019). Very high-quality colostrum contains at least 50 g/l of immunoglobulins (Buczinski and Vandeweerd, 2016; Godden, 2008), which is ≥21% on the Brix scale (Quigley et al., 2013). As shown in our study, colostrum of very high quality is produced by the cow only on the first day after calving.

Testing of the quality of colostrum obtained on the first day after calving using an electronic refractometer enabled rapid identification of samples with the required (preferably high) immunoglobulin content. Assessment of colostrum quality on the Brix scale is currently a highly recommended method for estimating the amount of antibodies, due to advantages such as lower sensitivity to changes in colostrum temperature or season and the low cost and availability of the device (Zobel et al., 2020; Silva-del- Rio et al., 2017; Bartens et al., 2016; Quigley et al., 2013; Bielmann et al., 2010). Our own work revealed high content of antibodies in the colostrum of cows in the first two hours after calving in all three herds assessed (average Brix value 22.7% ranging from 22.1% to 23.2%). These values indicate that colostrum produced by domestic cattle of the Polish Holstein-Friesian breed is of very good quality. In a study by Silva-del-Rio et al. (2017), the IgG concentration in colostrum from the first milking averaged 83.8 g/l (range: 23.7 to 172.9 g/l). The authors also found that the vast majority of colostrum samples (90.4%) met the standards for IgG concentration (>50 g/l).

However, not all herds achieve such good colostrum composition results. In a study by Morrill et al. (2012) conducted in 67 herds located in 12 US states, almost 30% of bovine colostrum did not achieve IgG concentrations above 50 g/l. The authors also found regional differences in colostrum quality.

The results obtained in our research indicating better quality of colostrum from older cows correspond to findings reported by Morrill et al. (2012), Silva-del-Rio et al. (2017), Dunn et al. (2017) and Devery-Pocius and Larson (1983). Morrill et al. (2012) reported that the IgG concentration increased with parity (42.4, 68.6 and 95.9 mg/ml in the first, second, third and later lactations, respectively). Silva-del-Rio et al. (2017) found that the mean IgG concentration in colostrum from the first milking was similar in cows in the second (77.3 g/l) and third lactation (74.9 g/l), but lower ($P < 0.01$) than in cows in the fourth lactation and later (98.4 g/l). Earlier research by Donovan et al. (1986) suggested that this is linked to increased exposure to antigens in older cows, resulting in a larger set of antibodies being transferred from the mother's serum to the colostrum.

Mammary gland development may also play a role: younger cows may not be fully developed, and IgG transport to the mammary gland may be lower (Devery-Pocius and Larson, 1983).

According to Kessler et al. (2020), the relationship between the length of the dry period and the concentration of IgG in colostrum is controversial. Some studies have found no relationship between dry period length and IgG content in colostrum (Shoshani et al., 2014; Mayasari et al., 2015; Dunn et al., 2017; Kessler et al., 2020). However, in line with our current results, other authors have also described a positive effect of a dry period of at least four weeks on the concentration of immunoglobulins in cow colostrum (Watters et al., 2008). According to Mansfeld et al. (2012), if drying does not occur before the next lactation, the colostrum will be diluted.

CONCLUSION

The quality and quantity of the first colostrum given to a newborn calf is extremely important for its future health, productivity and longevity. The acquisition of passive immunity minimizes the incidence of digestive and respiratory diseases and deaths in the first months of life. The present study found that the immunological value of colostrum assessed on the Brix scale decreased at subsequent milking times after calving, amounting to 22.7%, 19.2% and 16.4%. However, the average colostrum yield increased over time (from an average of 6.5 kg in the first colostrum collection to 9.4 kg in the period between 13 and 24 hours after calving). The length of the dry period and the age of the cow were particularly important factors for high value of first colostrum. The best colostrum, i.e. > 100 g/l Ig, was produced by cows with a longer dry period, i.e. lasting from 46 to 59 days (23.4% Brix), and by older cows in lactations from 4 to 7 (24.2% Brix). Therefore, in order to adequately protect newborn calves with antibodies for the first weeks of life without their own immunity, only the best colostrum in terms of immunoglobulin content should be given – as soon as possible. The use of an electronic refractometer in everyday breeding practice will help to make early and quick decisions about feeding (or finding a substitute for) the first food.

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