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COW FEEDING SYSTEM VS. QUALITY OF MILK USED FOR ACID-CURD CHEESE (TVAROG) PRODUCTION

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ABSTRACT

The study focused on processing quality of milk used for acid-curd cheese (tvarog) production, obtained from Polish Holstein-Friesian cows (Black-and-White variety) either fed a total mixed ration (TMR) or conventional feeds. Milk for analyses was collected six times per year, in about two months' intervals. The milk was analysed for density, acidity, and the content of fat, protein, and lactose. Fat dry matter content, non fat dry matter content, and protein:fat ratio were calculated. Thermal stability of milk was evaluated using alcohol (ethanol) tests. Titratable acidity, pH, hardness, and drip loss were measured in ready tvarog products. The cheese was also subjected to sensory evaluation. A marked effect of the feeding system on the composition and physico-chemical properties of milk was observed. Milk of cows fed conventional feeds contained more fat and dry matter, whereas that obtained from cows fed a TMR usually contained more crude protein, casein, and fat-less dry matter; it was also of higher density. Acid-curd cheeses produced from milk of a TMR-fed cows had a slightly better flavour, and also contained more water. Tvarogs made from milk of conventionally fed cows, on the other hand, contained more fat. The latter product was usually harder in texture. No direct linkage was found between acidity of tvarog or a drip loss thereof and the feeding system of cows.
Key words: cow feeding, milk, acid-curd cheese (tvarog)

INTRODUCTION

Tvarogs represent a group of highly valued food products that supply much proteins, minerals, organic acids, and vitamins to a human diet. The quality of raw material is a key factor underlying the quality and shell life of the resulting tvarog.

Whether a high milk yield resulting from the genetic predisposition of the cow can be attained without compromising the processing quality of milk, heavily depends on the proper feeding that would satisfy the nutritional requirements of the animal. Feeding is a factor by which the composition and yield of milk can easily be altered, although the linkage between the composition of feed and the composition of milk is extremely complex rather than straightforward [9, 12]. A total mixed ration (TMR), the system that radically changed dairy cow feeding doctrine, has been in use in Poland since 1996. In the TMR system, all the ration components are fed to cows following mixing in appropriate proportions, depending on the feeding requirements of the animals [8]. Feeding represents one of the ways of adjusting milk composition to changing requirements of the market, i.e. primarily the expectations of the consumers and the dairy industry [11].

The aim of the presented studies was to determine the effects of dairy cow feeding system on physico-chemical properties of milk and its processing quality in terms of acid-curd cheese (tvarog) production.

MATERIAL AND METHODS

The analyses were carried out using acid tvarog produced in a traditional way (Procedure Manual CZSM 342/88) [6] in a laboratory of the Department of Milk Technology. The feeding system of cows from which milk had been taken represented the treatment differentiating the samples. Raw milk was obtained from two dairy farms located in the West Pomeranian province. Polish Holstein-Friesian cows (Black-and-White variety) were fed using either a conventional or TMR feeding system. Milk was collected six times, approx. every two months, on the following dates: November, January, March, May, June, and September. However, comparative analyses of acid-curd cheeses were only performed for November, January, and September, since in the other months it was impossible to make tvarog from milk obtained from cows fed a conventional feed (milk acidity merely about pH 5.0). In those remaining months only tvarog produced from milk of a TMR-fed cows was evaluated.

Farm A managed a stock of 12 cows of the earlier mentioned breed, each producing 7000 kg of milk per year on average. During the spring and summer, the feeding of the cows was based on pasture forage supplemented with concentrates. In the autumn and winter, on the other hand, the diet was composed on grass haylage, sugar-beet pulp silage, crushed maize, and supplemented with feed concentrates. Farm B had 700 cows with an average yield of 9300 kg milk. Feeding on this farm was based on a TMR, adjusted to daily yield and the physiological state of the cow. The ration was composed of maize silage, sugar-beet pulp silage, alfalfa silage, grass haylage, brewer's grains, and a mineral-vitamin supplement. Milk for analyses was collected from the morning milking, transported to the lab within 2 h from the moment of milking, where it was subjected to sensory and physico-chemical evaluation. All the studied milk samples were visually sound, free of any visible contaminants, nearly white to ecru (if containing more fat) in colour, with a characteristic aroma. The only exception was the September sample from farm A which had an odour and taste of a barn and feed.

Following pasteurization (75°C/15s), the milk was cooled to 23°C and inoculated with 5% starter prepared from CHOOZIT TP 03 lyophilised culture for direct inoculation (Danisco Biolacta). Milk coagulation was continued until pH 4.6 was reached (approx. 10 h). Tvarog wedges were vacuum-packed using 80 µm thick PE/PA film with EVOH (a copolymer of ethylene vinyl alcohol). The vacuum packing took 2.5 s at 15 mbar, with the “soft air” option of 400 mbar. The cheese was placed for storage at 5°C±1°C. Samples in the form of a cheese wedge per batch were taken for analysis after 1, 3, 7, 14, and 21 days of storage.

Methods

The following parameters were determined in raw milk used for acid-crud cheese (tvarog) production (according to the Standard PN-68/A-8612)[15]: fat content, by the Gerber method, protein content, by the Walker method, areometric density, using a lacto-densitometer, titratable (potential) acidity in °SH, active acidity (pH), and lactose content, by the Bertrand method [4]. Also single and double alcohol tests were done [4], dry matter and fat-less dry matter content were calculated using the Fleischmann formula [15], and protein:fat ratio was determined.

The acid-curd cheese samples were analysed for the following parameters:
- titratable acidity, in °SH, according to [16]
- active acidity (pH), using the IQ 150 pH-meter, according to [16]
- hardness, using a special template assuring replicability of measurements, with double compression test (TPA) by means of the TA.XT plus (UK) texture analyser. Hardness was measured penetrometrically using an aluminium pin with a diameter of 6 mm (part. Code P/6, Batch No 10763). Penetrated depth was 20 mm, the speed of the mandrel approaching the surface of a sample was 1 mm · s^{-1}, and the speed of submerging and emerging mandrel was 5 mm · s^{-1}. The applied force of pressure was 1 G.

Whey leakage was determined by weight and expressed as a percentage of the cheese weight.

Analysed tvarog samples were every time subjected to a panel sensory assessment with use of a 5-point scale [18, 19]. The assessment involved structure, texture, colour, and flavour of the sample.

Additionally, after 1 and 21 days of storage, the cheese was measured for water content, by drying at 130°C for 30 min (technical method according to [16], as well as fat content by Gerber's method according to [16].

The presented results are the arithmetic means of 3 or, as in the case of hardness, 9 parallel replications. Resulting data were statistically processed by two-way ANOVA and significance of differences between two means was tested for related samples, using the Microsoft Excel 2000 spreadsheet. All the test were carried out assuming the level of significance at $\alpha = 0.05$.

RESULTS AND DISCUSSION

As a result of the analyses, it was observed that the feeding system, either conventional (farm A) or a TMR feeding (farm B), had an effect on the physical and chemical properties of milk (Table 1).

Milk from farm A contained more dry matter and fat, which was observed over the entire time of the studies (1 year), whereas milk produced on farm B contained more fat-less dry matter (except for June) and, in a majority of cases, more protein and casein. Lactose content in milk of both farms was similar in November, January, and March (autumn-winter season), whereas in May, June, and September (spring-summer season) the differences in the content of this sugar were higher and usually the milk from farm B contained more lactose. The milk from farm A sampled in September, when it exhibited atypical odour and taste, was of particularly low lactose concentration.

Table 1. Composition and physicochemical properties of milk obtained from cows kept on traditional (farm A or TMR (farm B) feeding regimes

Month	November		January		March		May		June		September	
Farm	farm A	farm B	farm A	farm B	farm A	farm B	farm A	farm B	farm A	farm B	farm A	farm B
Dry matter [%]	12.4^{A}	11.73^{A}	12.72^{A}	11.9^{A}	12.47^{A}	11.68^{A}	14.27^{A}	11.86^{A}	12.66^{A}	11.61^{A}	13.11^{A}	11.96^{A}
Solids-not-Fat (SNF)	8.12^{A}	8.30^{A}	8.25^{A}	8.53^{A}	8.17^{A}	8.41^{A}	8.22^{A}	8.53^{A}	8.66^{A}	8.44^{A}	8.11^{A}	8.46^{A}
Crude protein [%]	3.06^{A}	3.36^{A}	3.01^{A}	2.94^{A}	2.90	2.86	3.23^{A}	3.46^{A}	2.88^{A}	3.30^{A}	2.96^{A}	3.14^{A}
Casein [%]	2.34^{A}	2.57^{A}	2.31^{A}	2.25^{A}	2.22	2.19	2.47^{A}	2.65^{A}	2.21^{A}	2.53^{A}	2.26^{A}	2.41^{A}
Fat [%]	4.28^{A}	3.43^{A}	4.47^{A}	3.37^{A}	4.3^{A}	3.27^{A}	6.05^{A}	3.33^{A}	4.00^{A}	3.17^{A}	5.00^{A}	3.50^{A}
Lactose [%]	4.49	4.45	4.47	4.42	4.51	4.56	5.38^{A}	5.18^{A}	4.27^{A}	4.75^{A}	3.75^{A}	4.45^{A}
Density [g/cm^{3}]	1.028	1.0294	1.0284	1.0304	1.0282	1.030	1.0270	1.0304	1.0304	1.0302	1.0274	1.0300
Acidity [°SH]	6.00	6.00	7.75^{A}	7.20^{A}	6.93^{A}	6.60^{A}	6.53^{A}	7.20^{A}	7.40^{A}	6.90^{A}	7.80^{A}	7.20^{A}
pH	6.73	6.77	6.68	6.77	6.74	6.74	6.76	6.78	6.68	6.70	6.44	6.37
Single alcohol test	–	–	–	–	–	–	–	–	–	–	–	–
Double alcohol test	–	–	–	–	–	–	–	–	–	–	–	–
Protein/fat ratio	0.71^{A}	0.98^{A}	0.67^{A}	0.87^{A}	0.67^{A}	0.87^{A}	0.53^{A}	1.04^{A}	0.72^{A}	1.04^{A}	0.59^{A}	0.90^{A}

Alcohol test (–) – milk is not coagulate.
Statistically significant differences for mean values of analyzed features in the month ($p \leq 0.05$).

If we look at the basic components of milk, fat content is the easiest parameter to manipulate through feeding modifications. The bulky feeds, their structure and energy content per unit of dry matter, are the primary factors of fat content in milk [10]. The conventional feeding system applied on farm A involved more bulky feeds, hence the milk produced there was richer in fat. An influence of cow feeding system on milk content of protein is much weaker in relation to fat. Protein content in milk is not a direct consequence of a protein level in the ration or feeding protein concentrates to cows; opposite, protein content in milk is strongly correlated with provision of high energy feeds. The low protein content in milk observed during summer is mainly due to energy deficiencies in the diet [7, 10]. In 4 out of 6 analyses, farm B milk contained more protein, which may imply that TMR feeds are better balanced both in terms of composition and energy. Lactose content, on the other hand, does not usually depend on the diet [12]. A low level of this sugar in farm A milk may have been a result of mastitis.

Also Reklewska et al. [20] found that Black-and-White cows managed in an extensive feeding system, grazing on ecologically sound pastures, produced considerably less milk though of higher fat content and richer in a number of biologically important components, as compared with cows managed without pasture and fed a balanced diet.

Milk density met the requirements of the standard [17], so it did not fall below 1.028 g/cm^{3}, except for milk produced on farm A in September, 1.027 g/cm^{3} (Table 1). Milk of cows fed a conventional feed was generally of lower density, since it contained more fat, which results in lower density.

Titratable acidity of the studied milk did not match the requirements of the standard (17 only in two cases: samples from farm A in January and September). Active acidity (pH) in September was too high in relation to the requirements of the cited Standard in the milk from both A and B farm (Table 1).

Protein:fat ratio was distinctly higher in the milk of farm B (0.87–1.04) compared with that of farm A (0.59–0.72) over the entire period of observations. An improvement of protein:fat ratio is at the moment one of the most important goals of dairy cattle breeding in all the leading milk-producing countries.

Over the entire period of the studies (1 year), the analysed milk exhibited appropriate thermal stability as determined using the ethanol tests – single and double alcohol test. It was also found that the milk obtained from cows fed on a conventional system (farm A) had a similar dry matter and fat content in November, January, and March, whereas larger fluctuations of these two components were observed in May, June, and September, i.e. during the grazing season. On the other hand, milk dry matter and fat content in cows fed a TMR (farm B) was similar over the entire period of the analysis.

No significant effect of the season was found in relation to milk crude protein and casein concentrations (Table 1). Milk from farm B had the lowest and very similar concentrations of these components in January and March. The milk obtained from farm A and B was used to produce acid-curd cheese.

The sensory analysis revealed that tvarog produced from milk of cows managed on two feeding systems, conventional and TMR, differed mainly in flavour (Table 2). In November and January, tvarog produced from milk of TMR-fed cows attained a very high score, whereas tvarog from milk of conventionally fed cows was slightly worse as regards flavour. Tvarog produced in September received lower scores compared to two previous batches, mainly due to flavour. Tvarog produced from milk of TMR fed cows achieved much higher scores for this as compared with conventional feeding. It should be stressed that milk from conventionally fed cows was of a lower quality in September, which was in consequence reflected in tvarog produced thereof.

The presented results show a higher water content in tvarog produced from milk of TMR-fed cows (farm B), both after 1 and 21 days of storage (Fig. 1). If we look at the season of milking, the highest water content in tvarog obtained from farm A milk was found in January, whereas tvarog from farm B milk contained most water in November. On the whole, the difference in water content between 1 and 21 days of storage was lower for tvarog produced from milk of TMR-fed cows as compared to conventional feeding.

On the other hand, tvarog produced from milk of conventionally fed cows contained more fat (Fig. 2) as compared with that of TMR-fed cows milk. A higher fat content was noted during November–January rather than in September. These differences were more pronounced for the cheeses made of milk of conventionally fed cows. After 21 days of storage, fat content in the analysed tvarog decreased, except for tvarog made of farm B milk, in which fat content increased about 1%.

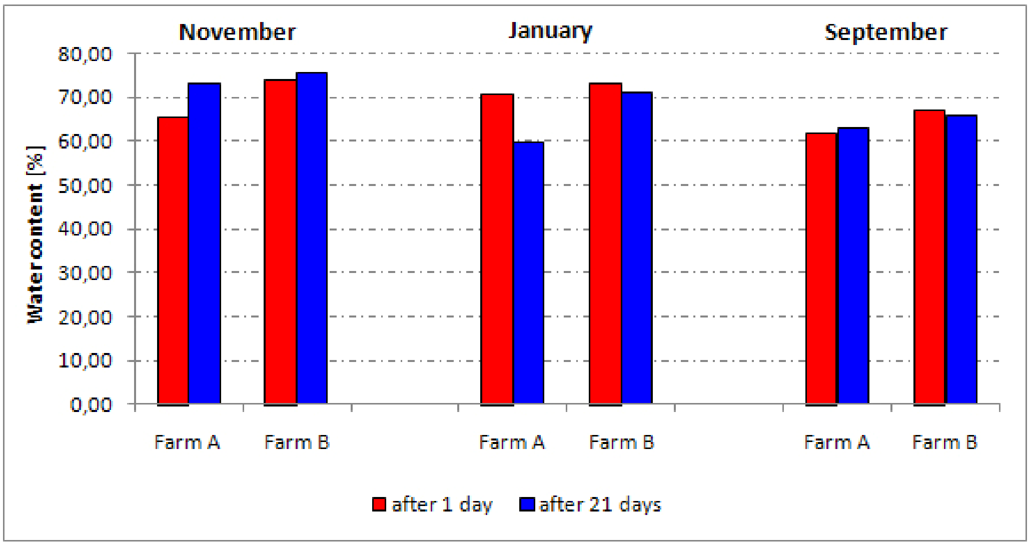

Fig. 1. Content of water in acid-curd cheese (tvarog) made from milk obtained from cows kept on traditional (farm A) or TMR (farm B) feeding regimes after 1 and 21 days cold storage

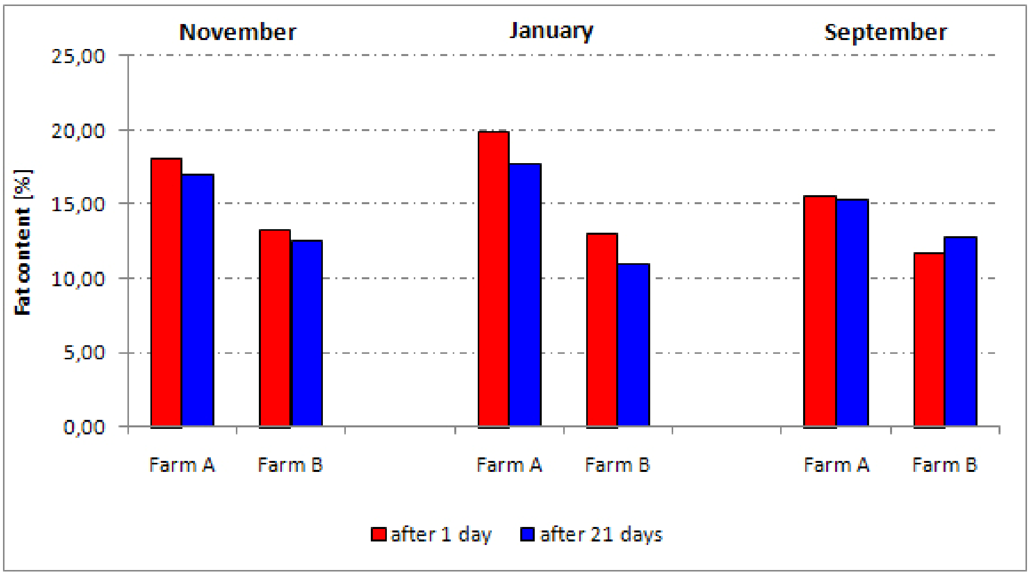

Fig.2. Content of fat in acid-curd cheese (tvarog) made from milk obtained from cows kept on traditional (farm A) or TMR (farm B) feeding regimes after 1 and 21 days cold storage

Table 2. Scores awarded during sensory evaluation of acid-curd cheese (tvarog) made from milk obtained from cows kept on traditional or TMR feeding regimes and stored cold (1–5 scale)

Month / Organoleptic feature	**November**										**January**										**March**				
	tvarog B					tvarog A					tvarog B					tvarog A					tvarog B				
	storage time (day)										storage time (day)										storage time (day)				
	1	**3**	**7**	**14**	**21**	**1**	**3**	**7**	**14**	**21**	**1**	**3**	**7**	**14**	**21**	**1**	**3**	**7**	**14**	**21**	**1**	**3**	**7**	**14**	**21**
Colour	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Taste	5.0	5.0	5.0	5.0	4.5	4.0	4.0	4.3	4.0	3.5	5.0	5.0	5.0	5.0	4.5	4.0	4.0	4.3	4.5	4.0	5.0	5.0	5.0	4.5	4.0
Aroma	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.5	4.5	5.0	5.0	5.0	5.0	4.5	5.0	5.0	5.0	4.0	4.0	5.0	5.0	5.0	4.5	4.5
Structure and consistency	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0

Month / Organoleptic feature	**May**					**June**					**September**									
	tvarog B					tvarog B					tvarog B					tvarog A				
	storage time (day)										storage time (day)									
	1	**3**	**7**	**14**	**21**	**1**	**3**	**7**	**14**	**21**	**1**	**3**	**7**	**14**	**21**	**1**	**3**	**7**	**14**	**21**
Colour	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.5	4.5	5.0	5.0	5.0
Taste	5.0	4.0	5.0	4.5	3.5	5.0	4.5	4.3	4.5	3.5	4.5	4.8	4.5	3.3	3.5	3.0	3.5	3.0	2.5	2.5
Aroma	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.5	4.5	5.0	4.8	4.0	3.8	4.0	4.0	4.0	4.0	3.0	3.0
Structure and consistency	5.0	5.0	5.0	5.0	5.0	5.0	4.3	4.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	4.5	4.5	5.0	5.0

Table 3. Results of statistical analysis of relative mean values (t-Student's test)

	November				**January**				**March**		**May**		**June**		**September**			
	tvarog A		tvarog B		tvarog A		tvarog B		tvarog B		tvarog B		tvarog B		tvarog A		tvarog B	
	t	t_α	t	t_α	t	t_α	t	t_α	t	t_α	t	t_α	t	t_α	t	t_α	t	t_α
Water content [%]	1.905	2.447	0.520	2.447	1.905	2.447	1.150	2.447	1.452	2.447	1.692	2.447	0.520	2.447	3.811	2.447	1.800	2.447
Fat kontent [%]	1.605	2.447	1.350	2.447	0.652	2.447	1.800	2.447	1.524	2.447	1.960	2.447	1.964	2.447	1.964	2.447	1.452	2.447
pH	5.058	3.182*	7.141	3.182*	1.527	3.182	5.422	3.182*	1.789	3.182	14.346	3.182*	0.829	3.182	0.330	3.182	0.071	3.182
Titratable acidity	2.164	3.182	1.353	3.182	7.000	3.182*	8.521	3.182*	2.182	3.182	8.385	3.182*	1.464	1.382*	1.515	3.182	8.677	3.182*
Hardness	0.740	2.306	7.814	2.306*	2.514	2.306*	11.088	2.306*	3.181	2.306*	2.287	2.306	2.287	2.306	6.540	2.306*	11.946	2.306*

Comparative analyses of acid-curd cheeses were only performed for November. January. and September. since in the other months it was impossible to make tvarog from milk obtained from cows fed a conventional feed (milk acidity merely about pH 5.0).

* – statistically significant differences at $p \leq 0.05$.

t – value of t-Student's test.

t_α – critical value.

Tvarog A – Farm A.

Tvarog B – Farm B.

The differences in water and fat content between 1 and 21 days of storage in all analysed samples were statistically non-significant (Table 3).

Higher fat content in tvarog made from milk of conventionally fed cows results from a higher content of fat in milk, since raw milk used for tvarog production had not been normalized.

On the other hand, Pluta et al. [14] observed only a decrease in water content in tvarog packaged in PE/PA laminate bags during 21 days of storage. The drop in water content resulted from whey leakage into the packaging. Similarly, Dmytrów et al. [2] noted a drop in water content in acid-crud cheese vacuum-packed in 80 µm thick PE/PA film with EVOH during 21 days of storage at 5°C. Also Śmietana et al. [21] reported a slight decrease in water content and a slight increase in fat content after 15 days of 8–10^{o}C storage of semi-fat and fat tvarog obtained from commercial production using own modern technology.

Another analysed parameter was titratable acidity. During the analyses (21 days), we did not find a direct relationship between cow feeding system and titratable acidity of tvarog (Fig. 3). In January, tvarog produced from milk of cows fed a TMR had a higher acidity, whereas in September – that made of milk of cows fed in a conventional way. In November, however, we observed fluctuations in this parameter in tvarogs produced from milk of both cows in farm A and those farm B. On the whole, a decreasing trend in acidity could be observed during the time of storage. After 21 days of storage, the parameter was 5.75°SH lower in relation to the initial value in tvarog of milk form farm A in November and September, whereas in January it was 10°SH higher. On the other hand, after 21 days of storage of farm B tvarog, acidity was lower by 4.5°SH in November, by 11.33°SH in January, and by 10.75°SH in September.

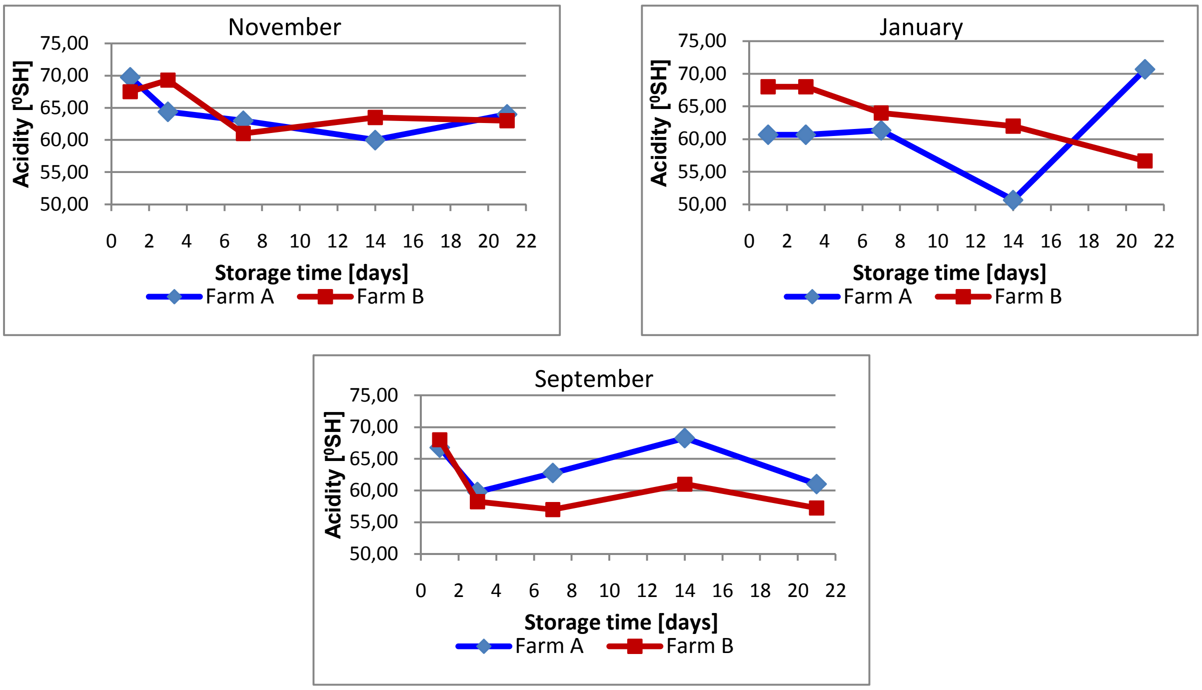

Fig. 3. Changes in titratable acidity of acid-curd cheese (tvarog) made from milk obtained from cows kept on traditional (farm A) or TMR (farm B) feeding regimes during cold storage

Tvarog made of milk of TMR-fed cows had a higher active acidity (lower pH) in January and September, whereas in November we observed fluctuations in pH of tvarog from farm A and a gradual increase in pH during the storage of tvarog produced from farm B milk (Fig. 4). After 1 day of storage, pH of tvarog from milk of TMR-fed cows was 0.1 lower jun January and 0.06 lower in September, as compared with pH of tvarog made of milk from conventionally fed cows, while in November it was virtually the same.

The differences in titratable acidity between 1 and 21 days of storage were statistically significant as regards tvarog of both batches produced in January, and that from farm B milk produced in September. In terms of active acidity, on the other hand, the differences were significant in November and, in farm B cheese, in January (Table 3).

Also Molska et al. [13] observed an increase in both titratable acidity and pH of tvarog during storage. The authors claim that this increase may result from, among other factors, proteolysis and ionized groups arising thereof. In turn, a decrease in titratable acidity of tvarog, according to Gertner et al. [5] results from suppression of lactic streptococci or even their gradual killing as a result of cold storage. Pluta et al. [14] observed a systematic increase in titratable acidity and pH of tvarog stored at 10°C, irrespective of the packaging system. Dmytrów et al. [2] reported an increase in titratable acidity of tvarog packed in the same way as the analysed cheese, after 21 days of storage at 5°C. Śmietana et al. [21], on the other hand, observed a gradual increase in pH of tvarog stored at 8–10°C for 15 days.

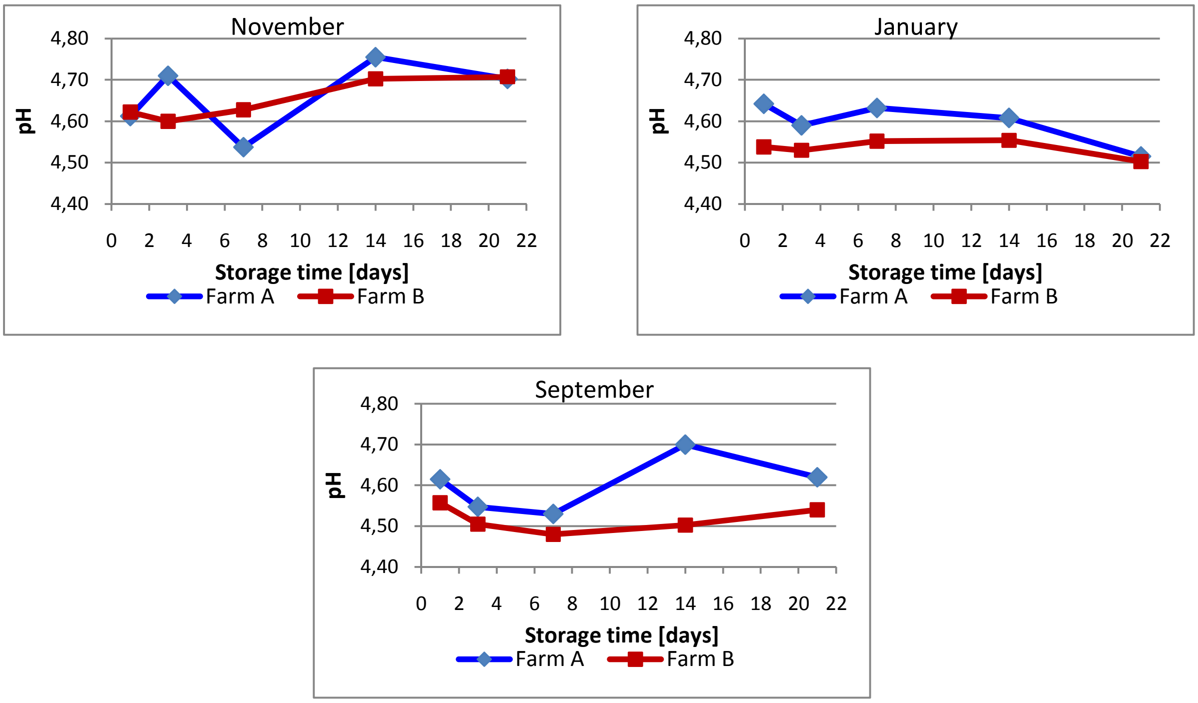

Fig. 4. Changes in pH of acid-curd cheese (tvarog) made from milk obtained from cows kept on traditional (farm A) or TMR (farm B) feeding regimes during cold storage

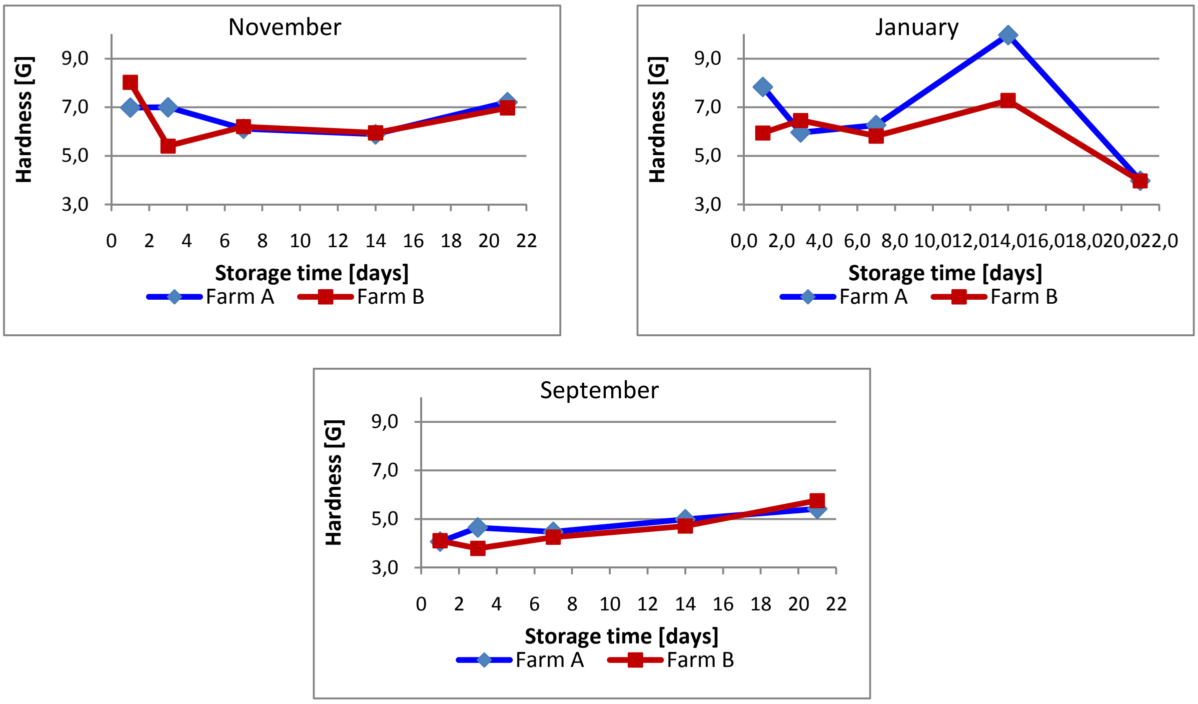

Fig. 5. Changes in hardness of acid-curd cheese (tvarog) made from milk obtained from cows kept on traditional (farm A) or TMR (farm B) feeding regimes during cold storage

Tvarog samples produced from milk of cows fed in a conventional way were generally harder in January and September (Fig. 5). In November, on the other hand, differences in the hardness of the experimental cheeses were evident during the first week of storage; over the following two weeks, however, the samples became very similar in hardness. Changes in hardness depended on the season of milking; in November and September the trend was increasing, while in January – decreasing.

The differences in the hardness of tvarog between 1 and 21 days of storage were statistically significant in January and September, whereas in November it was significant for tvarog made from milk from farm B (Table 3).

With an increase in water content, tvarog looses its hardness [2, 3]. This pattern was reflected in our studies, since tvarogs made from milk of TMR-fed cows contained more water and were of lower hardness. Fat also reduces the hardness of a acid-curd cheese. Śmietana et al. [21] stated that semi-fatty tvarog, as compared with a full-fat product, had a more compact texture. As regards fatty curd cheeses, no distinct changes in texture were found. This implies a stabilising role of fat in terms of rheological characteristics of an acid curd cheese during storage.

Whey leakage was another evaluated factor. We did not see a direct relationship between a feeding system and whey leakage from tvarog (Fig. 6). In November, tvarog made of milk from conventionally fed cows (farm A) exhibited a higher level ofwhey leakage. The mean for the entire period of studies for this farm was 3.48%, whereas for the TMR system it was 2.69%. In September, on the other hand, tvarog of milk from farm B showed morewhey leakage, 5.3%, as compared with farm A, 4.43%. In January, however, whey leakage observed during the first week was at a similar level in both analysed products, whereas in the second and third weeks of storage, the whey leakage was considerably higher in tvarog produced from farm B milk. The mean whey leakage measured for the entire period of studies for farm B was 4.03%, while that for farm A was 3.13%.

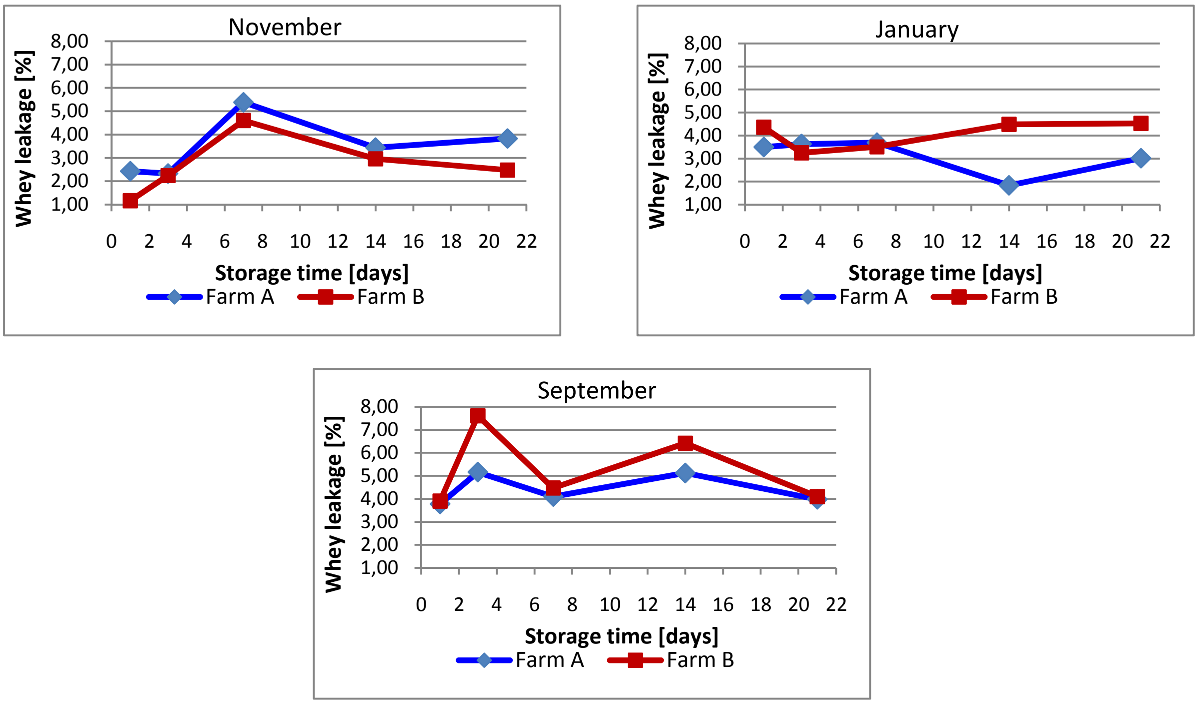

Fig. 6. Changes in whey leakage of acid-curd cheese (tvarog) made from milk obtain from cows kept on traditional (farm A) or TMR (farm B) feeding regimes during cold storage

An increase in the amount of whey leakage from vacuum-packed tvarog during storage time was found by Pluta et al. [14].

As it has been previously mentioned, we failed to produce tvarog from milk of cows fed in a conventional way (farm A) three times, in March, May, and June. Therefore for this period the analysis involved acid-curd cheese produced from milk of TMR-fed cows (farm B) only.

Sensory evaluation of curd cheeses produced only from milk of TMR-fed cows demonstrated that tvarog in March and May were evaluated at a very high level, with scores for flavour slightly lower in relation to the remaining characteristics (Table 2). In June, however, tvarogs achieved lower scores for flavour, but also for structure and texture. In the case of nearly all samples, a decrease in scores for taste mainly was observed with the elapsed time of storage.

Water content in tvarogs depended on the season of milk collection. The highest water content was measured in March, 68.54%, whereas in May and June it was about 1% and 5% lower, respectively (Fig. 7). We also found differences in tvarog water content between 1 and 21 days of storage. Water content in tvarog produced in March and June decreased after 21 days, whereas in May in increased during the same storage time.

Tvarog fat content in March and May was similar, 18.0% and 15.33%, respectively, while in May it was lowest, 6.17% (Fig. 8). Like for water content, fat in tvarog decreased in March and, to some extent, in June, whereas in May it increased in relation to the level observed after 1 day of analysis.Observed differences in water and fat content, however, between 1 and 21 days of storage were non-significant in any of three months (Table 3).

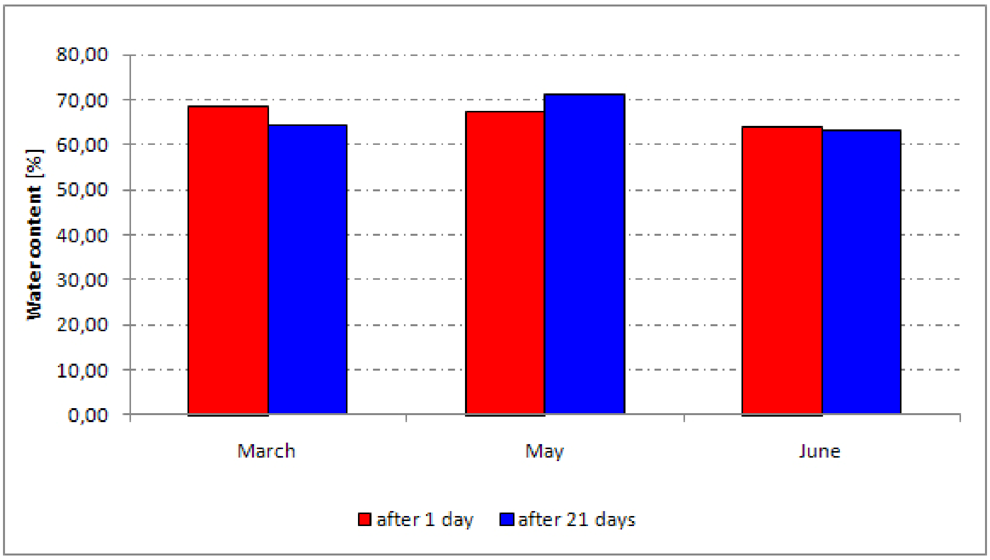

Fig. 7. Content of water in acid-curd cheese (tvarog) made from milk obtained from cows kept TMR (farm B) feeding regimes after 1 and 21 days cold storage

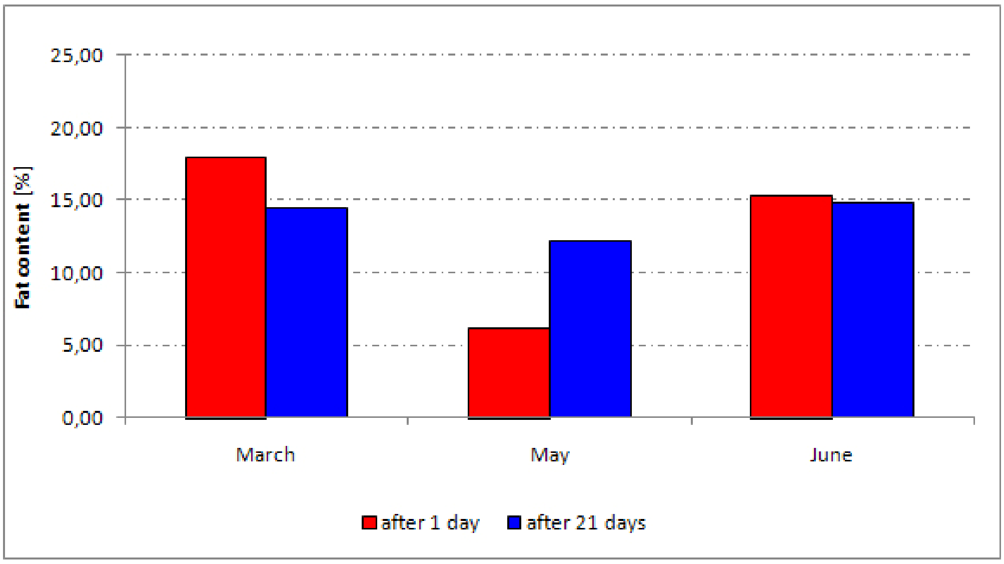

Fig. 8. Content of fat in acid-curd cheese (tvarog) made from milk obtained from cows kept TMR (farm B) feeding regimes after 1 and 21 days cold storage

The highest titratable acidity was found in acid-curd cheese produced from milk obtained in June 61.5–64°SH, (Fig. 9). Titratable acidity of tvarog produced in March and May were similar, and only after 1 day of storage did acid-curd cheese produced in March have the parameter higher by as much as 16.3°SH, as compared with that in May. On the whole, tvarog acidity changed very little during storage.

Tvarogs produced in May and June gad a similar active (pH) acidity (Fig. 10). The peak pH in these cheeses was noted after 7 days of storage, followed by a decrease observed over the remaining storage time. pH of tvarog produced in March, however, was highest after one day of storage. After 7 days of storage, the minimum pH was reached, which again was followed by a gradual increase.

Differences between 1 and 21 days of storage for titratable acidity were significant in May and June, whereas for active acidity only in May (Table 3).

Hardness represented another evaluated characteristic. We found a considerable effect of the season of milking as regards hardness of tvarog. The highest hardness in tvarog was noted in June, the lowest in May (Fig. 11). Fluctuations in this parameter during storage were observed in all the analysed samples. Differences between 1 and 21 days of storage in terms of tvarog hardness were significant in March (Table 3).

The season of milk collection did not have a direct effect on drip loss (Fig. 12). The mean drip low for the entire period of storage was highest for tvarog produced in May, 4.93%, followed by that from June, 4.35%, with the lowest drip observed in March, 4.16%. During storage of tvarog produced in March, we observed an increase in drip loss over the first seven days; for the acid-curd cheese produced in May, the increase was observed between 4 and 21 days, whereas for that in June between 4 and 14 days of storage.

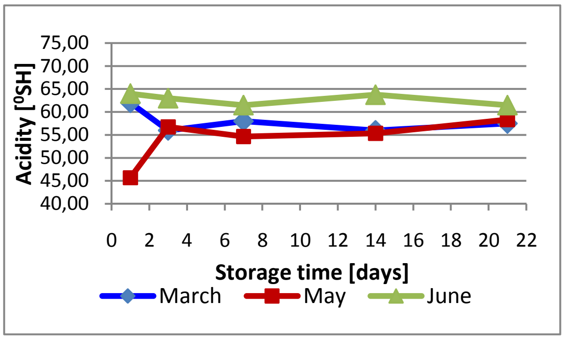

Fig. 9. Changes in titratable acidity of acid-curd cheese (tvarog) made from milk obtained from cows kept TMR (farm B) feeding regimes during cold storage

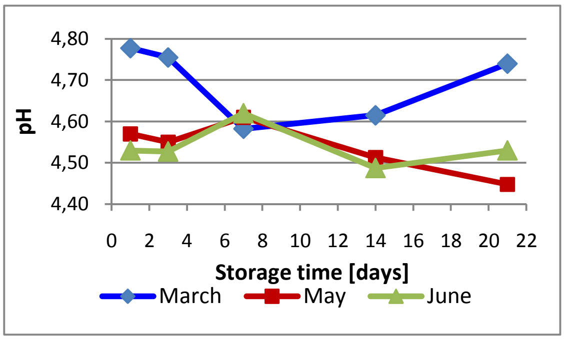

Fig. 10. Changes in pH of acid-curd cheese (tvarog) made from milk obtained from cows kept TMR (farm B) feeding regimes during cold storage

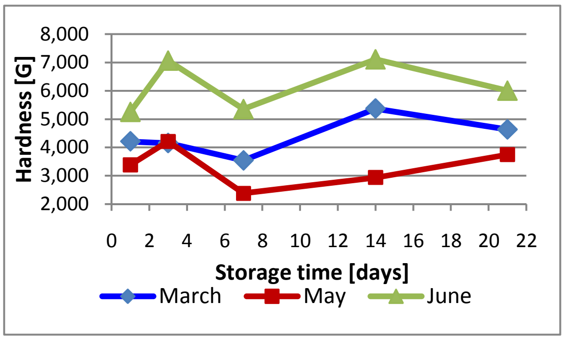

Fig. 11. Changes in hardness of acid-curd cheese (tvarog) made from milk obtained from cows kept TMR (farm B) feeding regimes during cold storage

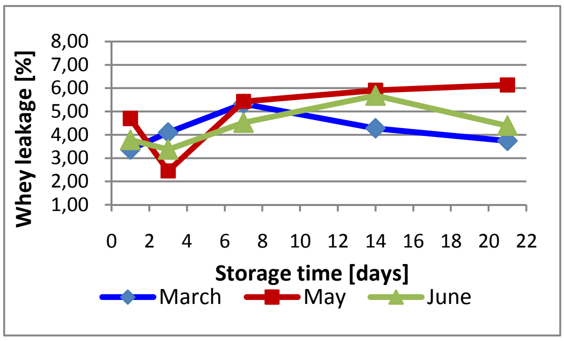

Fig. 12. Changes in whey leakage of acid-curd cheese (tvarog) made from milk obtained from cows kept TMR (farm B) feeding regimes during cold storage

The differences in the composition and physico-chemical properties between milk and the resulting acid-curd cheese produced thereof, as regards the TMR feeding system, imply that there are factors influencing these parameters other than feeding. Also Bogdanowicz-Zazula et al. [1] demonstrated that, despite identical feeding with a basic TMR, there were significant differences in composition and processing parameters of cow milk in relation to season of the year, lactation stage, yield of the cow, and subsequent lactation. A varying degree in which nutritional requirements of cows of various yields are met results in varied supply of components for milk production.

Statistical analysis of all the resulting data allowed concluding that both feeding system and season of milk production significantly influenced the content of water, titratable acidity, pH, as well as hardness (Table 4) of the evaluated acid-curd cheese.

Table 4. Results of bifactor variance of physicochemical indicators of acid-curd cheese[1]

		F	p	Test F
Water content	test period	7.386	0.0032*	3.403
	method of feeding	185.945	9.588E-17*	3.009
	interactions	0.109	0.995	2.508
Fat content	test period	0.188	0.0830*	3.403
	method of feeding	58.906	3.246E-11*	3.009
	interactions	3.240	0.018*	2.508
pH	test period	13.578	1.98E-06*	2.69
	method of feeding	23.396	3.69E-05*	4.171
	interactions	1.702	0.1757	2.689
Titratable acidity	test period	65.015	2.4E-14*	2.690
	method of feeding	18.862	0.000148*	4.171
	interactions	8.633	9.24E-05*	2.690
Hardness	test period	188.854	9.9E-32*	2.748
	method of feeding	4.918	0.03014*	3.991
	interactions	25.229	6.8E-11*	2.748

[1] – The presented results concern to whole analysed period (1 year).
[*] –statistically significant differences at $p \leq 0.05$.
F – testing value of ANOVA.
p – empirical significance level.
Test F – critical value.

CONCLUSIONS

1. Milk obtained from cows fed a TMR did not differ sensorically from milk of cows fed in a conventional system.
2. Milk of cows fed a TMR contained less dry matter and fat, but more fat-less dry matter and, in most cases, protein and casein, as compared with milk of cows fed in a conventional feeding system.
3. Protein:fat ratio was higher for milk of cows fed a TMR than that of cows fed conventionally.
4. Curd cheese produced from milk of TMR-fed cows had a slightly better flavour compared with tvarog from milk of conventionally fed cows.
5. Curd cheeses of cows fed a TMR contained more water, whereas tvarog from milk of cows fed in a conventional system exhibited a higher fat content.
6. No direct association was found of cow feeding system with titratable acidity, active acidity (pH), or drip loss from tvarog.
7. Curd cheeses produced from milk of cows fed a TMR in March, May, and June varied in sensory characteristics and physico-chemical properties.
8. Chemical composition and physico-chemical properties of curd cheese were significantly influenced by the feeding system of cows and the season of milk sampling.

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