ASSESSMENT OF SELECTED MILK PERFORMANCE TRAITS AND METABOLIC STATUS INDICATORS OF COWS IN HERDS UTILIZING DIFFERENT FEEDING TECHNOLOGIES

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Abstract

The study analyzed the impact of feeding technology on selected dairy production traits and metabolic status indicators in cows. Two feeding systems were considered: the partly mixed ration (PMR) technology and the traditional three-component feeding system, where individual types of feed were provided separately in the rations. It was shown that the type of feeding technology had a significant effect on daily milk yield (FCM). In the population of cows fed in the PMR system, the average daily milk yield in lactation was 31.9 kg, while in the population fed with the traditional system, the average daily milk yield was 27.8 kg. Furthermore, it was found that milk produced according to the PMR feeding system contained more fat, protein, lactose, and dry matter compared to milk produced using the traditional feeding system, with increases of 0.31%, 0.28%, 0.14%, and 0.52%, respectively. Regarding selected metabolic status indicators, the average urea concentration in milk from the PMR system was 223 mg/L, while in the traditionally fed population, it was 251 mg/L. The study also evaluated the significance of the feeding system on the percentage of milk samples indicating typical metabolic diseases. In assessing the impact of the feeding system on the percentage of milk samples with a specific fat-to-protein ratio (FPR), it was shown that cows fed in the PMR system had a higher percentage of samples indicating acidosis (9% vs 6%) and a lower percentage of milk samples indicating optimal energy balance and ketosis (42% vs 55% and 3% vs 8%, respectively) compared to those fed traditionally. The study also evaluated the impact of factors such as lactation period, cow age (lactation number), and production level, and it was found that they significantly influenced most of the analyzed traits. In conclusion, it was stated that in the production conditions of eastern Mazovia, the feeding system had a significant impact on the level of analyzed dairy performance traits and the size of the assessed metabolic status indicators. The use of the PMR feeding system resulted in increased FCM milk yield and improved its chemical and cytological quality. An important advantage of this system was also the high proportion of milk samples with low urea content (<250 mg/L). In light of the results obtained, PMR feeding was also associated with a lower percentage of milk samples in the first 100 days of lactation indicating acidosis (6% vs 10%).

Keywords: feeding technologies, dairy cows, FCM milk yield, chemical composition

Introduction

Proper nutrition of dairy cows is one of the key factors determining the profitability of milk production. The choice of feeding technology is one of the most important practical decisions made in herds specializing in dairy cattle breeding. Currently, three basic feeding technologies (feeding systems) are used for dairy cows in Poland. These are: the traditional three-component system, the partly mixed ration (PMR) system, and the total mixed ration (TMR) system. The introduction of a particular system into practice depends on the economic possibilities of the farm, the organizational and technical conditions, herd size, and the milk production efficiency of the cows. The traditional three-component feeding system is labor-intensive. It involves the separate feeding of concentrate and roughage feeds. This allows selective feeding in appropriate amounts but also facilitates cows' preference for tastier feeds, which increases the likelihood of metabolic diseases due to the excessive intake of easily digestible carbohydrates. In this traditional system, the feed ration lacks a uniform structure, and its feeding is usually carried out without specialized equipment. Therefore, this system is time-consuming and requires significant labor input (Litwińczuk et al., 1994; Podkówka et al., 1999). In this system, both roughage and concentrate feeds are given three times a day, meaning cows do not have continuous access to them. This reduces the possibility for cows to consume the proper amount of feed (Lach and Podkówka, 2000; Podkówka and Podkówka, 2004). According to Kański and Wandzel (2009), a disadvantage of this system is the great difficulty in optimizing feed intake by animals. Usually, the amount of feed is insufficient to meet the milk production requirements, or farmers overfeed the cows, leading to obesity. The total mixed ration (TMR) system is used worldwide and is the main feeding system in large dairy farms that house cows in loose housing systems (Schingoethe, 2017). It involves feeding cattle a mixed, chopped, complete feed that consists of roughage, concentrate feeds, and mineral-vitamin additives. Typically, the feed is divided into several nutritional groups, each receiving an appropriate amount of feed depending on the lactation period. Poor preparation of the TMR mix can lead to undesirable animal behaviors and various metabolic issues, such as ruminal acidosis. One of the best methods of preventing ruminal acidosis, characterized by a pH of the rumen content dropping below 5.8 for at least 3 hours a day, is providing a well-balanced ration. The ration should meet nutritional requirements and have a proper physical structure that significantly affects the chewing time. For dairy cows, chewing time should be maximized because it results in the production of large amounts of saliva, which naturally buffers the acidity of the rumen content. According to Jiang et al. (2017), high-producing cows can produce up to 250 liters of saliva per day. In roughage feeds, the physical structure is provided by haylage or grass silage. If the feed is poorly mixed, cows may start sorting their feed. To ensure that animals correctly utilize all components of the TMR, the length of fibrous components should not exceed 3 cm. The finer the feed is chopped, the shorter the chewing time for cows. The degree of chopping has a significant impact on the proper functioning of the rumen, its buffering with saliva, and swallowing. During pasture feeding, cows swallow many times, whereas with finely chopped feed, they only swallow a few times. All of this affects the frequency of metabolic diseases such as acidosis, ruminal bloating, or displacement of the abomasum. The order of adding components depends on the physical structure of the feed, i.e., how finely the feed was chopped before ensiling. Corn silage and young grass haylage are usually finely chopped, while silage made from later grasses has a higher amount of hard structural components. Often, finely chopped silages need to be supplemented with straw to create a proper structure. Feed mixer manufacturers recommend adding the finest components (such as meal and grains) and mineral-vitamin additives and rumen-buffering additives at the beginning of mixing, with silages and straw added at the end. In practice, the order of adding individual TMR components varies, as it largely depends on the degree of chopping of structural feeds at a given farm. The partly mixed ration (PMR) system involves feeding semicomplete rations, with a complete TMR given to all cows adapted to a cow producing 25 kg of milk daily. Cows producing more milk are additionally fed with concentrate feeds, which in tie-stall barns are provided by suspended feed carts, allowing different amounts for each cow, or by hand. In loose housing systems, feed is provided from feeding stations. The basis of the PMR system consists of roughage, some concentrate feeds, and protein components. High-yielding cows are usually fed three types of concentrate feeds. In the PMR system, there is no need to separate cows into different feeding groups, as is the case of TMR feeding (Humer et al., 2018). Minakowski (2008) states that cows can be fed in two ways: with 50% or 60% roughage in the ration. In the first case, the proportion of concentrate feeds increases, allowing for the production of 1400–1800 kg of milk per 100 kg of cow body weight. In this case, concentrate feed consumption is 0.2–0.3 kg per kg of milk. Cichocki et al. (2007) and Kruczyńska et al. (2006) indicate that the proportion of concentrate feed in the ration should not exceed 50%, and no more than 3 kg of this feed should be given per feeding. Concentrate feeds are best fed together with roughage. This option is provided by TMR. The concentrate feeds can also be divided into several feedings, for example, by using feeding stations, which is possible with the PMR system. Van Soest (2023) emphasizes that the PMR feeding system is the basic feeding system in barns using automatic milking machines.

The aim of the study was to compare two feeding systems for dairy cows in farms located in the eastern part of the country in terms of their impact on selected milk yield and quality traits as well as metabolic status indicators.

Material and methods

In the population of cows fed according to the PMR system, feeding was carried out using a feed wagon and a feeding station. The animals were housed in a free-stall system with a communal lying area. The farm area was approximately 70 hectares, of which 25 hectares were used for maize cultivation, 25 hectares for grassland, and 15 hectares for cereal cultivation. Milk was obtained in a 2 × 12 side-by-side milking parlor. The components fed by the feed wagon were as follows: maize silage – 26 kg, first-cut grass silage – 12 kg, barley straw – 0.7 kg, 22% distiller's grain – 5 kg, rapeseed expeller meal – 2 kg, grain mixture – 1 kg, soybean expeller meal – 0.5 kg, vitamins – 0.2 kg, feeding lime – 0.1 kg. The components fed by the feeding station were provided in the following amounts: energy mix – 2 kg and complete feed – 4 kg per cow.

In the second subpopulation of cows, feeding was carried out using the traditional three-component system. This means that roughage, concentrate feeds, and mineral-vitamin additives were fed separately. The animals in this group were housed in a tie-stall system. The farm area was approximately 25 hectares, with around 10 hectares allocated to cereals, 10 hectares to grassland, and 5 hectares to maize cultivation. Milk was obtained using a mechanical milker with pipes leading to a cooling tank. The daily feed ration for a cow consisted of the following components: grass silage (1st and 2nd cuts) – 20 kg, maize silage – 25 kg, oat straw – 1 kg, rapeseed expeller meal – 3 kg, grain mixture – 1.5 kg, vitamins – 0.1 kg, lime – 0.1 kg, buffer – 0.1 kg, yeast – 0.1 kg, crushed maize grain – 3 kg, energy mix – 2 kg, complete feed – 5 kg. In total, the study analyzed the characteristics of 73 cows that completed 68 whole lactations. Of these, 23 cows that completed 30 whole lactations were fed using the traditional system, and 50 cows that completed 38 whole lactations were fed using the PMR system. All cows were of the Polish Holstein-Friesian (PHF) breed, of the Black-and-White variety.

The study focused on the impact of the feeding system on the following production traits of the cows: daily milk yield (FCM, kg) and the percentage content of fat, protein, dry matter, and lactose. Additionally, the following milk biomarkers were assessed: urea concentration (mg/L), and the fat-to-protein ratio (FPR). Data on the milk performance of the cows were taken from the test milking reports based on the AT-4 method conducted by the Polish Federation of Cattle Breeders and Dairy Producers. In total, 939 milk samples were evaluated, originating from PHF cows, including 471 from cows fed PMR and 468 from cows fed traditionally. The daily milk yield was adjusted to 4% fat milk (FCM) using the formula: FCM = 0.4 × milk yield (kg) + 15 × fat yield (kg).

To assess the occurrence of metabolic diseases in the herds, the following indicators were used: the fat-to-protein ratio, urea levels in milk (mg/L), and protein concentration in milk (%). The following classifications were used for these factors: FPR was divided into four groups: 1. ≤1.0 – indicating acidosis; 2. 1.01 to ≤1.2 – indicating subclinical acidosis; 3. 1.21 to ≤1.5 – optimal; 4. >1.5 – indicating ketosis; urea content was classified into three groups: <150 mg/L, 150–250 mg/L, and >250 mg/L; protein content was divided into three groups: <3.2%, 3.2–3.6%, and >3.6%.

The study identified the following variability factors compared in terms of milk production traits: 6 lactation periods (months: 1–2, 3–4, 5–6, 7–8, 9–10, 11–17), 3 age groups (lactations: 1, 2, 3–6), and 4 production groups (daily milk yield (kg): ≤20, 20.1–30, 30.1–35, >35). A linear model including fixed effects of lactation periods, cow age, production level, lactation trimester, and farm number was used for statistical calculations. The results were statistically processed using multivariate analysis of variance by the least squares method. Statistical procedures GLM and FREQ from the SAS statistical package (2008) were used in the calculations.

Results

Milk Yield

Table 1 presents data on the daily milk yield of the analyzed cow population. The influence of the feeding system, lactation month, cow age (lactation number), and production level was taken into account. The data showed that the average daily milk yield (FCM) in 939 observations was 29.8 kg, ranging from 4.6 kg to 73.1 kg. When evaluating the influence of the feeding system, it was found that the average daily milk yields (FCM) for cows fed according to the PMR system and the traditional system were 31.9 kg and 27.8 kg, respectively. The difference of 3.1 kg in favor of cows fed the PMR was statistically significant at P≤0.05 (Figure 1).

Upon analyzing the effects of the other factors defined in the methodology, it was confirmed that the lactation month, cow age, and production level significantly influenced the daily milk yield (FCM). The highest daily milk yields (FCM) were observed in cows in the first two months of lactation, cows in their second lactation, and cows in the highest production level group. The average daily milk yields (FCM) in these groups of cows were as follows: 34.6, 31.0, and 41.0 kg, respectively.

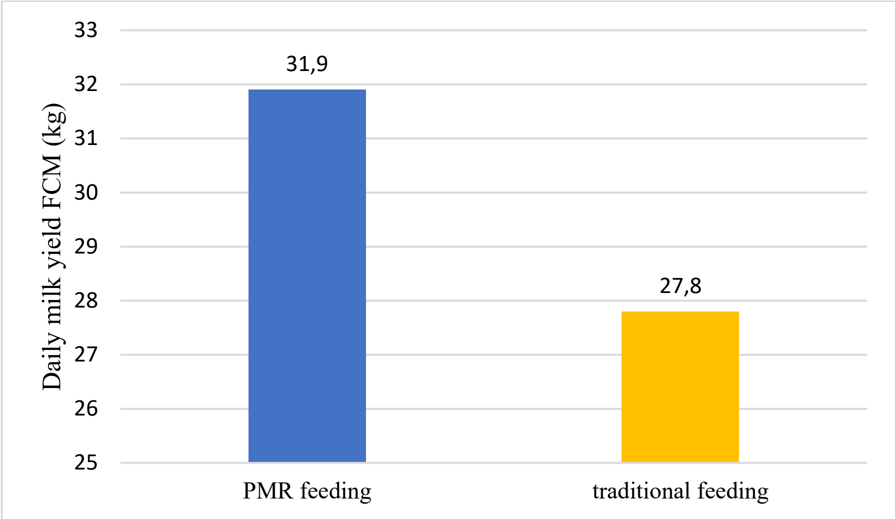

Figure 1. Daily FCM milk production (kg) in herds with different feeding systems

Chemical Composition of Milk

Table 2 presents information on the influence of the feeding system, lactation period, cow age, and production level on the percentage content of fat, protein, lactose, and dry matter in milk. The data shows that the average fat content in the assessed population was as follows: 4.24%, 3.47%, 4.74%, and 13.15%. The concentration of individual milk components varied widely: fat ranged from 1.8% to 6.7%, protein from 2.6% to 7.0%, lactose from 2.8% to 5.3%, and dry matter from 4.6% to 17.2%.

When evaluating the impact of lactation month, it was observed that as lactation progressed, the percentage content of fat, protein, and dry matter in milk increased. The lowest fat, protein, and dry matter contents were found in milk obtained during the first two months of lactation, with values of 3.93%, 3.16%, and 12.55%, respectively. The highest fat, protein, and dry matter contents were found in milk from the last period of lactation (months 11–17), with values of 4.64%, 3.47%, and 13.82%. Statistical analysis confirmed the significance of these differences at $P \leq 0.05$. Similarly, significant differences in average fat, protein, and dry matter content were observed in milk from cows at different production levels. The concentration of fat, protein, and dry matter systematically decreased as milk yield increased. The highest content of fat, protein, and dry matter was observed in milk from the lowest production level (≤20 kg/day), with values of 4.49%, 3.59%, and 13.43%, respectively. The lowest levels of these components were found in milk produced by the highest-producing cows (>35 kg/day), with values of 4.05%, 3.31%, and 12.75%.

The data in Table 2 also indicates that the average lactose level in 939 milk samples was 4.74%. The lactose content showed the least variability compared to fat, protein, and dry matter. The coefficient of variation for lactose was 5.1%, while for fat, protein, and dry matter, it was 16.0%, 12.4%, and 8.5%, respectively. Regarding the impact of various factors on lactose concentration, it was found that the highest lactose levels were observed in milk obtained in the first 100 days of lactation, from cows in their first lactation, and from cows with the highest production level. The lactose concentration in these groups of cows was 4.80%, 4.78%, and 4.80%, respectively.

Table 1. Impact of the feeding system on daily FCM milk yield (kg), considering the identified factors

Factor		Feeding system								Total/average			
		PMR Partly Mixed Ration				Traditional – three component							
		n	x̄ ±SD	Min	Max	n	x̄ ±SD	Min	Max	N	x̄ ±SD	Min	Max
Lactation month	1–2	94	$34.7^{1}\pm7.4$	17.6	51.0	98	$34.5^{1}\pm8.8$	13.4	73.1	192	$34.6^{A}\pm8.1$	13.4	73.1
	3–4	93	$33.9^{1}\pm4.8$	23.3	46.2	91	$32.3^{1}\pm7.1$	15.8	48.8	184	$33.1^{A}\pm6.1$	15.8	48.8
	5–6	89	$32.3^{1}\pm4.9$	20.5	46.7	81	$29.0^{2}\pm7.0$	13.8	48.9	170	$30.8^{B}\pm6.2$	13.8	48.9
	7–8	87	$29.9^{1}\pm5.3$	15.8	40.2	77	$24.8^{2}\pm7.8$	8.1	51.9	164	$27.5^{C}\pm7.1$	8.1	51.9
	9–10	63	$28.5^{1}\pm12.4$	17.6	44.7	67	$22.1^{2}\pm7.1$	9.1	43.3	130	$25.2^{D}\pm10.5$	9.1	44.7
	11–17	45	$29.6^{1}\pm33.8$	15.1	48.2	54	$17.0^{2}\pm7.0$	4.9	31.2	99	$22.8^{E}\pm24.1$	4.9	48.2
Lactation (number)	1	165	$31.0^{1}\pm6.1$	15.1	49.7	227	$26.2^{2}\pm9.2$	4.9	47.4	392	$28.3^{B}\pm8.4$	4.9	49.7
	2	247	$32.5^{1}\pm16.1$	16.3	48.2	190	$29.0^{2}\pm9.9$	7.4	73.1	437	$31.0^{A}\pm13.9$	7.4	73.1
	3–6	59	$31.4^{1}\pm7.4$	16.5	49.1	51	$29.6^{2}\pm8.1$	13.8	47.7	110	$30.6^{A}\pm7.8$	13.8	49.1
Production level (kg)	<=20	23	$17.8^{1}\pm1.3$	15.1	19.3	97	$14.6^{2}\pm3.7$	4.9	20.0	120	$15.3^{D}\pm3.7$	4.9	20.0
	20.1–30	176	$26.1^{1}\pm2.7$	20.0	29.9	170	$24.9^{2}\pm2.8$	20.1	29.9	346	$25.6^{C}\pm2.8$	20.0	29.9
	30.1–35	142	$32.5^{1}\pm1.3$	30.2	34.9	97	$32.1^{1}\pm1.4$	30.0	35.0	239	$32.4^{B}\pm1.4$	30.0	35.0
	>35	130	$41.4^{1}\pm19.7$	35.1	48.2	104	$40.4^{1}\pm5.0$	35.2	73.1	234	$41.0^{A}\pm15.1$	35.1	73.1
Total/average		471	$31.9^{1}\pm12.6$	15.1	48.2	468	$27.8^{2}\pm9.5$	4.9	73.1	939	29.8 ± 11.3	4.9	73.1

The means in the columns, within factors, marked with different letters, differ significantly at $P\leq0.05$.
The means in the rows, marked with different numbers, differ significantly at $P\leq0.05$.

The analysis of the feeding system showed a high and statistically significant effect of the feeding technology on the evaluated chemical quality traits of milk. It was found that in the milk of cows fed PMR, the average concentrations of fat, protein, lactose, and dry matter were 4.29%, 3.61%, 4.81%, and 13.41%, respectively, while cows fed traditionally produced milk with average concentrations of fat, protein, lactose, and dry matter of 4.18%, 3.33%, 4.67%, and 12.89%, respectively (Figure 2). The difference in fat, protein, lactose, and dry matter concentrations between milk produced using the two feeding systems was +0.11% (fat), +0.28% (protein), +0.14% (lactose), and +0.52% (dry matter) in favor of cows fed PMR. Statistical analysis confirmed the significance of these differences at P≤0.05, except for lactose, where no statistically significant difference in concentration was found between milk from cows fed PMR and those fed traditionally.

When comparing the content of fat, protein, and dry matter in milk from the two feeding systems, it was observed that, except for two subgroups of factors, milk from cows fed PMR had a higher concentration of these components. Statistical analysis confirmed the significance of these differences at P≤0.05.

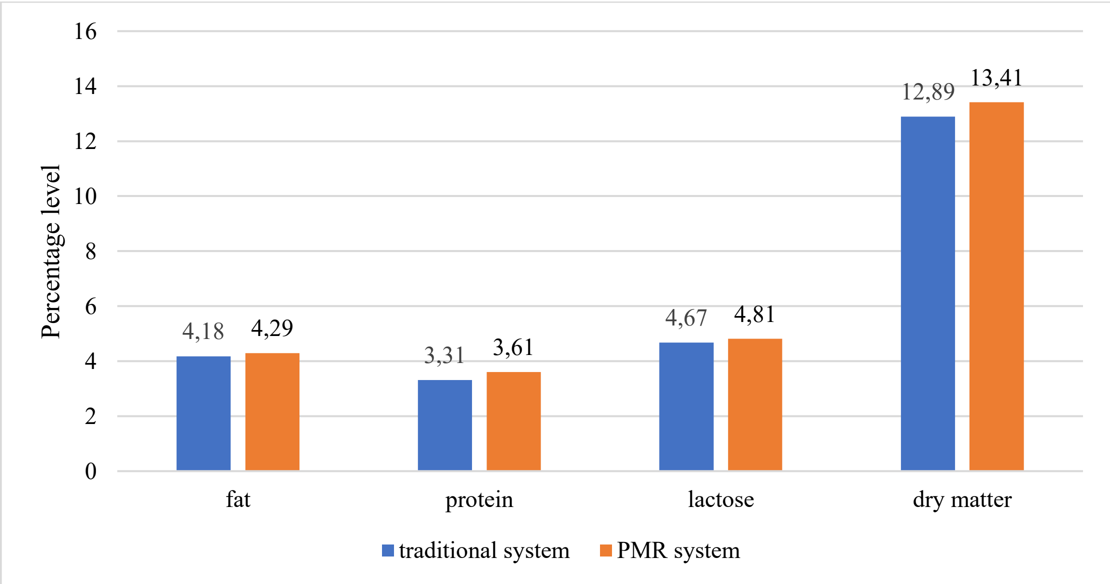

Figure 2. Chemical composition of milk produced in herds with different feeding systems

Metabolic Indicators/Indices

Table 3 presents information on the urea concentration in milk. The average urea content in 939 observations was 237 mg/L of milk, with a wide range from 1 mg/L to 577 mg/L. The analysis of the influence of lactation month, cow age, and production level showed that these factors caused slight variations in urea concentration across the entire population. The observed differences, although statistically significant in some cases (specifically for lactation month and production level), were small. They ranged for lactation month, cow age, and production level at 35 mg/L, 12 mg/L, and 16 mg/L, respectively.

The data in Table 3, however, indicates a strong influence of the feeding system on urea levels in milk. Milk from cows fed PMR contained 223 mg/L of urea, while milk from traditionally fed cows contained 251 mg/L of urea. This difference was statistically significant at P≤0.05. A similarly high impact of the feeding system was observed across different factors. The greatest differences in urea content between milk produced in the PMR and traditional systems were noted in milk produced in months 11–17 of lactation, from cows in their second lactation, and from cows in the lowest production level. These differences were 64, 55, and 55 mg/L, respectively.

Fat-to-Protein Ratio

Tables 4 and 5 present the impact of the feeding system on the proportion of milk samples indicating the presence of metabolic diseases. For this purpose, the FPR (fat-to-protein ratio) in milk was evaluated. The proportion of milk samples showing a certain FPR value was assessed to determine the effect of the feeding system.

The results presented in Table 4 show that the proportion of milk samples indicating optimal energy balance for the entire population was 49%. 47% of the milk samples indicated the presence of ruminal acidosis, and 6% indicated subclinical and clinical ketosis. When evaluating the impact of the feeding system on the proportion of milk samples with a specific FPR value, it was found that cows fed in the PMR system had a higher proportion of milk samples indicating acidosis compared to those fed traditionally (9% vs. 6%), as well as a lower proportion of milk samples indicating optimal energy balance and ketosis. The percentage distribution of milk samples was as follows: 42% vs. 55% for optimal energy balance and 3% vs. 8% for ketosis.

Data presented in Table 6 regarding FPR in milk obtained during the first 100 days of lactation showed that in the PMR system, the proportion of milk samples indicating acidosis was lower compared to the traditional feeding system (6% vs. 10%).

Energy-Protein Balance Assessment of the Ration

Table 6 presents an assessment of the balance between protein and energy needs in the rations fed to the analyzed population of cows. The analysis takes into account the feeding systems used. Overall, the data in the table show that in the PMR and traditional feeding systems, complete energy and protein balance in the rations was achieved in 20% and 17% of the samples, respectively. The percentage of samples indicating acidosis was 10% for the PMR system and 11% for the traditional system.

Furthermore, it was observed that the PMR feeding system was associated with a higher proportion of samples showing a full energy balance compared to the traditional system. This proportion was 59% for PMR vs. 41% for traditional feeding. The PMR system also showed a lower percentage of samples with excessively high energy content (31% vs. 48%) and a higher percentage of samples with excessively high protein content (47% vs. 20%).

Table 2. Impact of the herd feeding system on the percentage content of fat, protein, lactose, and dry matter in milk, considering the identified factors

Factor		Feeding system								Total/average			
		PMR Partly Mixed Ration				Traditional – three component							
		N	$\bar{x} \pm SD$	Min	Max	n	$\bar{x} \pm SD$	Min	Max	N	$\bar{x} \pm SD$	Min	Max
Fat (%)													
Lactation month	1–2	94	$4.05^{1} \pm 0.65$	2.5	5.8	98	$3.80^{2} \pm 0.64$	1.8	5.3	192	$3.93^{C} \pm 0.66$	1.8	5.8
	3–4	93	$3.97^{1} \pm 0.51$	2.9	5.3	91	$3.92^{1} \pm 0.60$	2.6	5.5	184	$3.95^{C} \pm 0.56$	2.6	5.5
	5–6	89	$4.21^{1} \pm 0.68$	3.0	6.5	81	$4.31^{2} \pm 0.62$	2.6	6.5	170	$4.26^{B} \pm 0.65$	2.6	6.5
	7–8	87	$4.36^{1} \pm 0.63$	3.3	5.8	77	$4.35^{1} \pm 0.51$	3.1	5.7	164	$4.36^{B} \pm 0.58$	3.1	5.8
	9–10	63	$4.69^{1} \pm 0.71$	2.6	6.5	67	$4.50^{2} \pm 0.55$	3.4	6.7	130	$4.60^{A} \pm 0.64$	2.6	6.7
	11–17	45	$4.87^{1} \pm 0.73$	2.2	6.3	54	$4.44^{2} \pm 0.58$	3.2	5.6	99	$4.64^{A} \pm 0.69$	2.2	6.3
Lactation (number)	1	165	$4.31^{1} \pm 0.67$	3.0	6.5	227	$4.21^{2} \pm 0.61$	1.8	5.7	392	$4.26^{A} \pm 0.64$	1.8	6.5
	2	247	$4.26^{1} \pm 0.73$	2.2	6.5	190	$4.14^{2} \pm 0.67$	2.6	6.7	437	$4.21^{A} \pm 0.71$	2.2	6.7
	3–6	59	$4.36^{1} \pm 0.68$	2.5	5.7	51	$4.15^{2} \pm 0.68$	2.3	5.3	110	$4.26^{A} \pm 0.69$	2.3	5.7
Production level (kg)	<=20	23	$4.64^{1} \pm 0.83$	3.1	6.3	97	$4.45^{2} \pm 0.71$	1.8	6.7	120	$4.49^{A} \pm 0.74$	1.8	6.7
	20.1–30	176	$4.37^{1} \pm 0.78$	2.6	6.5	170	$4.25^{2} \pm 0.67$	2.3	6.5	346	$4.32^{B} \pm 0.73$	2.3	6.5
	30.1–35	142	$4.28^{1} \pm 0.67$	2.5	6.3	97	$4.01^{2} \pm 0.57$	2.6	5.5	239	$4.18^{C} \pm 0.65$	2.5	6.3
	>35	130	$4.11^{1} \pm 0.55$	2.2	5.8	104	$3.95^{2} \pm 0.47$	2.6	5.1	234	$4.05^{D} \pm 0.53$	2.2	5.8
Total/average		471	$4.29^{1} \pm 0.71$	2.2	6.5	468	$4.18^{2} \pm 0.65$	1.8	6.7	939	4.24±0.68	1.8	6.7
Protein (%)													
Lactation month	1–2	94	$3.22^{1} \pm 0.33$	2.6	4.3	98	$3.09^{2} \pm 0.31$	2.6	4.0	192	$3.16^{F} \pm 0.33$	2.6	4.3
	3–4	93	$3.39^{1} \pm 0.29$	2.7	4.3	91	$3.19^{2} \pm 0.24$	2.7	3.8	184	$3.30^{E} \pm 0.29$	2.7	4.3
	5–6	89	$3.59^{1} \pm 0.28$	3.1	4.5	81	$3.33^{2} \pm 0.28$	2.8	4.1	170	$3.47^{D} \pm 0.31$	2.8	4.5
	7–8	87	$3.73^{1} \pm 0.29$	3.2	4.6	77	$3.39^{2} \pm 0.27$	2.9	4.4	164	$3.58^{C} \pm 0.33$	2.9	4.6
	9–10	63	$3.95^{1} \pm 0.43$	3.1	5.8	67	$3.52^{2} \pm 0.35$	3.0	4.9	130	$3.73^{B} \pm 0.45$	3.0	5.8
	11–17	45	$4.13^{1} \pm 0.57$	3.2	7.0	54	$3.61^{2} \pm 0.33$	3.0	4.7	99	$3.85^{A} \pm 0.53$	3.0	7.0
Lactation (number)	1	165	$3.54^{1} \pm 0.38$	2.8	4.8	227	$3.31^{2} \pm 0.32$	2.6	4.2	392	$3.41^{B} \pm 0.37$	2.6	4.8
	2	247	$3.66^{1} \pm 0.51$	2.6	7.0	190	$3.33^{2} \pm 0.35$	2.6	4.9	437	$3.52^{A} \pm 0.48$	2.6	7.0

	3–6	59	$3.54^{1}\pm0.37$	2.8	4.3	51	$3.38^{2}\pm0.41$	2.7	4.4	110	$3.47^{A}\pm0.40$	2.7	4.4
Production level (kg)	<=20	23	$3.89^{1}\pm0.57$	2.8	4.7	97	$3.51^{2}\pm0.39$	2.9	4.9	120	$3.59^{A}\pm0.46$	2.8	4.9
	20.1–30	176	$3.70^{1}\pm0.40$	2.8	4.8	170	$3.38^{2}\pm0.30$	2.6	4.2	346	$3.55^{A}\pm0.40$	2.6	4.8
	30.1 –35	142	$3.58^{1}\pm0.37$	2.8	4.6	97	$3.24^{2}\pm0.28$	2.7	4.0	239	$3.45^{B}\pm0.38$	2.7	4.6
	>35	130	$3.45^{1}\pm0.52$	2.6	7.0	104	$3.13^{2}\pm0.28$	2.6	4.0	234	$3.31^{C}\pm0.46$	2.6	7.0
Total/average		471	3.61 ± 0.46^{1}	2.6	7.0	468	3.33 ± 0.35^{2}	2.6	4.9	939	3.47 ± 0.43	2.6	7.0
Lactose (%)													
Lactation month	1–2	94	$4.85^{1}\pm0.16$	4.3	5.3	98	$4.73^{1}\pm0.34$	2.8	5.2	192	$4.79^{AB}\pm0.28$	2.8	5.3
	3–4	93	$4.88^{1}\pm0.13$	4.3	5.1	91	$4.73^{2}\pm0.16$	4.4	5.1	184	$4.81^{A}\pm0.17$	4.3	5.1
	5–6	89	$4.83^{1}\pm0.17$	4.0	5.1	81	$4.67^{2}\pm0.17$	4.2	5.0	170	$4.76^{BC}\pm0.19$	4.0	5.1
	7–8	87	$4.79^{1}\pm0.16$	4.1	5.1	77	$4.62^{2}\pm0.21$	4.0	5.1	164	$4.72^{C}\pm0.21$	4.0	5.1
	9–10	63	$4.71^{1}\pm0.33$	3.2	5.1	67	$4.61^{1}\pm0.19$	4.2	5.1	130	$4.66^{D}\pm0.27$	3.2	5.1
	11–17	45	$4.63^{1}\pm0.27$	3.7	5.0	54	$4.55^{1}\pm0.22$	4.0	5.1	99	$4.59^{E}\pm0.25$	3.7	5.1
Lactation (number)	1	165	$4.87^{1}\pm0.16$	4.3	5.3	227	$4.70^{2}\pm0.20$	4.1	5.1	392	$4.78^{A}\pm0.21$	4.1	5.3
	2	247	$4.79^{1}\pm0.23$	3.2	5.1	190	$4.61^{2}\pm0.27$	2.8	5.1	437	$4.72^{B}\pm0.27$	2.8	5.1
	3–6	59	$4.65^{1}\pm0.20$	4.0	4.9	51	$4.72^{1}\pm0.20$	4.2	5.2	110	$4.68^{B}\pm0.21$	4.0	5.2
Production level (kg)	<=20	23	$4.62^{1}\pm0.27$	4.1	5.1	97	$4.83^{2}\pm0.26$	4.0	5.1	120	$4.57^{C}\pm0.24$	4.0	5.1
	20.1–30	176	$4.77^{1}\pm0.20$	4.0	5.3	170	$4.64^{1}\pm0.24$	2.8	5.2	346	$4.72^{B}\pm0.24$	2.8	5.3
	30.1–35	142	$4.84^{1}\pm0.14$	4.4	5.1	97	$4.71^{1}\pm0.18$	4.3	5.1	239	$4.79^{A}\pm0.17$	4.3	5.1
	>35	130	$4.83^{1}\pm0.26$	3.2	5.2	104	$4.75^{1}\pm0.24$	2.8	5.1	234	$4.80^{A}\pm0.26$	2.8	5.2
Total/average		471	$4.81^{1}\pm0.22$	3.2	5.3	468	$4.67^{1}\pm0.24$	2.8	5.2	939	4.74 ± 0.24	2.8	5.3
Dry matter (%)													
Lactation month	1–2	94	$12.82^{1}\pm0.79$	11.0	15.0	98	$12.29^{2}\pm1.08$	4.7	14.0	192	$12.55^{D}\pm0.99$	4.7	15.0
	3–4	93	$12.94^{1}\pm0.69$	11.4	14.5	91	$12.56^{2}\pm0.76$	11.0	14.5	184	$12.75^{D}\pm0.75$	11.0	14.5
	5–6	89	$13.37^{1}\pm0.84$	12.0	16.7	81	$13.02^{2}\pm0.77$	10.8	14.7	170	$13.21^{C}\pm0.83$	10.8	16.7
	7–8	87	$13.74^{1}\pm0.82$	12.1	15.9	77	$13.09^{2}\pm0.70$	11.3	15.4	164	$13.43^{B}\pm0.84$	11.3	15.9
	9–10	63	$13.94^{1}\pm1.87$	4.6	16.2	67	$13.39^{2}\pm0.84$	11.7	17.2	130	$13.66^{AB}\pm1.46$	4.6	17.2
	11–17	45	$14.30^{1}\pm1.75$	4.8	16.5	54	$13.41^{2}\pm0.79$	11.9	15.1	99	$13.82^{A}\pm1.39$	4.8	16.5
Lactation (number)	1	165	$13.47^{1}\pm0.94$	12.0	16.7	227	$12.90^{2}\pm0.78$	10.9	14.8	392	$13.15^{A}\pm0.90$	10.9	16.7

	2	247	13.40^{1}±1.43	4.6	16.5	190	12.83^{2}±1.08	4.7	17.2	437	13.15^{A}±1.32	4.6	17.2
	3–6	59	13.30^{1}±0.86	11.0	15.3	51	13.03^{2}±1.00	10.7	15.4	110	13.18^{A}±0.93	10.7	15.4
Production level (kg)	<=20	23	14.04^{1}±1.29	11.5	16.5	97	13.29^{2}±0.96	11.0	17.2	120	13.43^{A}±1.07	11.0	17.2
	20.1–30	176	13.64^{1}±1.07	11.1	16.7	170	13.01^{2}±0.87	10.7	14.8	346	13.33^{AB}±1.03	10.7	16.7
	30.1–35	142	13.45^{1}±0.96	11.0	15.9	97	12.68^{2}±0.75	10.8	14.6	239	13.14^{B}±0.96	10.8	15.9
	>35	130	12.94^{1}±1.46	4.6	15.0	104	12.50^{2}±1.00	4.7	14.0	234	12.75^{C}±1.29	4.6	15.0
Total/average		471	13.41^{1}±1.22	4.6	16.7	468	12.89^{1}±0.94	4.7	17.2	939	13.15±1.12	4.6	17.2

The means in the columns, within factors, marked with different letters, differ significantly at P≤0.05
The means in the rows, marked with different numbers, differ significantly at P≤0.05

Table 3. Urea concentration in milk (mg/L) considering the feeding system and other factors

Factor		Feeding system								Total/average			
		PMR Partly Mixed Ration				Traditional – three component							
		N	$\bar{x} \pm SD$	Min	Max	n	$\bar{x} \pm SD$	Min	Max	n	$\bar{x} \pm SD$	Min	Max
Urea (mg/L)													
Lactation month	1–2	94	$221^{1}\pm47$	115	347	98	$213^{1}\pm72$	13	370	192	$217^{B}\pm61$	13	370
	3–4	93	$243^{1}\pm51$	129	346	91	$263^{2}\pm90$	100	505	184	$253^{A}\pm73$	100	505
	5–6	89	$228^{1}\pm48$	123	332	81	$264^{2}\pm82$	100	455	170	$245^{A}\pm69$	100	455
	7–8	87	$231^{1}\pm63$	1	361	77	$263^{2}\pm72$	119	481	164	$246^{A}\pm69$	1	481
	9–10	63	$210^{1}\pm67$	15	361	67	$265^{2}\pm76$	111	577	130	$238^{A}\pm77$	15	577
	11–17	45	$183^{1}\pm65$	16	291	54	$247^{2}\pm63$	100	424	99	$218^{B}\pm71$	16	424
Lactation (number)	1	165	$230^{1}\pm56$	100	361	227	$231^{1}\pm72$	100	478	392	$231^{A}\pm66$	100	478
	2	247	$219^{1}\pm61$	1	357	190	$274^{2}\pm74$	13	505	437	$243^{A}\pm72$	1	505
	3–6	59	$221^{1}\pm54$	100	346	51	$256^{2}\pm104$	100	577	110	$237^{A}\pm82$	100	577
Production level (kg)	<=20	23	$184^{1}\pm63$	92	320	97	$239^{2}\pm80$	100	577	120	$229^{B}\pm80$	92	577
	20.1–30	176	$224^{1}\pm58$	16	361	170	$253^{2}\pm76$	100	481	346	$238^{AB}\pm69$	16	481
	30.1–35	142	$236^{1}\pm53$	105	346	97	$259^{2}\pm86$	100	505	239	$245^{A}\pm69$	100	505
	>35	130	$216^{1}\pm59$	1	330	104	$251^{2}\pm78$	13	478	234	$232^{AB}\pm70$	1	478
Total/average		471	$223^{1}\pm58$	1	361	468	$251^{2}\pm80$	13	577	939	237 ± 71	1	577

The means in the columns, within factors, marked with different letters, differ significantly at $P\leq0.05$.
The means in the rows, marked with different numbers, differ significantly at $P\leq0.05$.

Table 4. Impact of the cow feeding system on the proportion of milk samples indicating the occurrence of metabolic diseases (for the whole lactation)

FPR value	Metabolic status	Feeding system				Total/average	
		PMR Partly Mixed Ration		Traditional – three component			
		n	%	n	%	N	%
≤1.0	Acute acidosis	40	9	26	6	66	7
1.01 to ≤1.2	Subacute acidosis	217	46	145	31	362	38
1.21 to ≤1.5	Optimal	198	42	259	55	457	49
>1.5	Ketosis	16	3	38	8	54	6
Total		471	100	468	100	939	100

Chi-square test value = 34.4

Table 5. Impact of the cow feeding system on the proportion of milk samples indicating the occurrence of metabolic diseases (for the first 100 days of lactation)

FPR value	Metabolic status	Feeding system				Total/average	
		PMR Partly Mixed Ration		Traditional – three component			
		n	%	n	%	N	%
≤1.0	Acute acidosis	9	6	14	10	23	8
1.01 to ≤1.2	Subacute acidosis	59	42	50	34	109	38
1.21 to ≤1.5	Optimal	64	46	71	49	135	47
>1.5	Ketosis	9	6	10	7	19	7
Total		141	100	145	100	286	100

Chi-square test value = 2.2

Table 6. Impact of the cow feeding system on the proportion of milk samples with varying urea and protein content

Protein	Feeding system	Urea						Total	
		<150 mg/L		150–250 mg/L		>250 mg/L			
		n	%	N	%	n	%	n	%
<3.2%	Partly Mixed Ration	7	2	15	3	26	6	48	10
	Traditional	18	4	23	5	10	2	51	11
3.2–3.6%	Partly Mixed Ration	63	13	94	20	122	26	279	59
	Traditional	71	15	81	17	40	9	192	41
>3.6%	Partly Mixed Ration	18	4	52	11	74	16	144	31
	Traditional	97	21	82	17	46	10	225	48
Total	Partly Mixed Ration	88	19	162	34	222	47	471	100
	Traditional	186	40	186	40	96	20	468	100

PMR feeding – $\chi2$ test value = 7.7
Traditional feeding – $\chi2$ test value = 2.7

Discussion

The increase in milk yield and optimization of its chemical composition are among the primary goals of dairy cattle improvement programs in market-oriented economies (Miglior et al., 2005; PFCBMP, 2016). The amount of milk production and its technological suitability are key factors determining the profitability of milk production. Therefore, identifying factors that contribute to improving these aspects is considered one of the most important objectives of scientific research in this area.

In this study, a significant and noteworthy influence of cow age and lactation month on the daily milk yield (FCM) was demonstrated. The results obtained in this part of the work align with the findings of several other studies: Bogucki et al. (2009), Czerniawska-Piątkowska et al. (2007), Gierdziewicz et al. (2009), Górska et al. (2006), Guliński and Salamończyk (2007), Kuczaj et al. (2008), Król et al. (2009), Miciński (2007), Pilarska (2014), Sawa et al. (2007), and Winnicki et al. (2016). The cited studies indicated significant variability both in milk yield across different months of the production cycle and between successive lactations. Assessing the effect of the traditional and TMR feeding systems on the chemical composition of milk, Barłowska et al. (2012) showed a lower fat and protein level in the milk of cows fed traditionally compared to the milk of cows fed TMR in the two analyzed production seasons (summer and winter). These differences for fat were: 3.93 and 4.59% and 4.17 and 4.32%, respectively, and for protein: 3.48 and 3.67% and 3.41 and 3.61%, respectively.

The higher milk yield observed in cows fed PMR compared to those fed traditionally was confirmed by numerous scientific studies. Kruczyńska et al. (2006), Łuczak et al. (2009), Mäntyssari et al. (2004), and Podkówka and Podkówka (2004) noted that feeding PMR or TMR resulted in higher milk yields compared to traditional feeding systems. In the study by Golder et al. (2014), cows fed PMR produced higher daily milk yields and had a greater fat percentage, by 0.1 kg and 0.24%, respectively, compared to the control group. Sobotka et al. (2017) compared the milk performance of cows in herds using three feeding systems: TMR, PMR and traditional (TR). They showed that the highest daily milk yield was observed in cows fed in the TMR system. Average daily yield of cows during summer and winter feeding was as follows: PMR – 21.5 kg, TMR – 23.7 kg of milk and for TR – 23.3 kg. Assessing the effect of the feeding system on the chemical quality of milk, they found that in summer time the highest protein and fat level was achieved in the herd fed the TMR (3.39% and 4.14%). In winter time, however, the highest content of protein and fat was achieved by using the PMR system (3.4% and 4.39%).

In the work of Barłowska et al. (2012) the daily milk yield of cows in two production seasons (summer and winter) fed according to the TMR and traditional systems was compared. It was shown that feeding the TMR was associated with higher daily milk yield compared to the traditional system, regardless of the production season. The average daily milk yield for TMR and traditional systems during the summer and winter seasons was respectively: 27 vs. 18.7 kg and 28.1 vs. 15 kg.

The results of this study regarding the impact of lactation month and production level on the concentrations of fat, protein, and dry matter should be considered typical for dairy cattle populations. The reduction in the concentration of these components as milk yield increases is a well-documented relationship in scientific research. This finding was supported by studies such as those by Brzozowski and Zdziarski (2006), Guliński and Kłopotowska (2019), Guliński (2023), Gnyp (2012), Januś et al. (2013), and Miciński and Klupczyński (2006). Sobotka et al. (2011) showed that cows fed the TMR system consumed 10 kg more feed per day compared to cows fed the traditional system. This had a positive effect in higher milk yield (daily and lactation) and in a more favorable chemical composition of milk.

According to Oetzel (2007), the normal fat percentage in milk for Holstein herds in the USA ranges from about 3.4% to 4.0%, and fat depression begins when it falls below 3.2%. Very low fat content in milk (<2.5% for Holstein cows) was observed in no more than 10% of cows in a single herd, and typically for milk produced between the 30th and 70th days of lactation (Oetzel, 2007). According to Salamończyk and Guliński (2023), a typical chemical composition for a breed can only be discussed in the case of cows fed fully balanced rations. For cows in varied feeding conditions, the basic chemical composition is most strongly dependent on milk yield. According to Guliński and Kłopotowska (2019), in a population of unlimited Polish Holstein-Friesian cows, an increase in daily milk yield by 10 kg was associated with a decrease in the fat, protein, and dry matter percentages by 0.3%, 0.3%, and 0.5%, respectively.

Urea is one of the most important biomarkers in milk. Knowledge of its concentration in milk is widely used in modern zootechnical research. According to Guliński et al. (2016), information about its concentration can be used in cattle breeding to assess the balance of energy and protein in diets, evaluate reproductive efficiency, and prevent excessive nitrogen emissions from dairy farms. The data presented in this study indicate that the feeding system significantly influenced its concentration in milk. The studies demonstrated that in the PMR system, the urea level was lower compared to traditional feeding. According to Guliński et al. (2016), the primary cause of excessive urea levels in milk is an excess of protein in the diet or an imbalance between energy and protein levels. The results of the influence of lactation period on urea content in milk were confirmed by studies by other authors. For example, Bogucki et al. (2009) found the highest urea concentration in milk during the fifth month of lactation. Higher urea levels in the milk of primiparous cows compared to multiparous cows were also observed in the study by Bogucki et al. (2009). Pilarska (2014) and Pytlewski et al. (2011) observed similar urea levels in different lactations. The increase in urea content in milk with higher production levels, as seen in this study, was also confirmed by Satoła and Ptak (2016).

FPR in milk is widely recognized as an indicator of energy deficit (Buttchereit et al., 2010) or subclinical ketosis (Jenkins et al., 2015). Studies by Villot et al. (2018) and Li et al. (2012) provided evidence of a high correlation between FPR and rumen pH. Enemark et al. (2002) set the threshold for clinical ruminal acidosis at FPR <1.0. Similarly, Zschiesche et al. (2020) found significant correlations between FPR in milk and rumen pH. Using FPR as the sole indicator of average daily rumen pH, the length of time the pH was below 5.8, and the pH range yielded determination coefficients of 0.30, 0.32, and 0.17, respectively. According to Guliński et al. (2018), there are three main reasons for the importance of FPR in dairy cattle breeding: FPR is universally recognized as an accurate indicator of energy balance; protein, as part of its structure in milk payment systems, has about twice the economic value due to its higher usefulness in milk processing; in breeding practice, cows with higher FPR ratios in their milk are classified as high-performing (Guliński et al., 2018). Currently, the average FPR value in milk for Polish Holstein-Friesian cows in lactation is considered to be 1.23 (Guliński et al., 2018). Barłowska et al. (2006) marked the lowest FPR value of 1.25 in Simmental and Jersey breeds, and the highest in Red-and-White cows at 1.29. In other populations of Simmental cows analyzed by Barłowska et al. (2005), this coefficient was even lower (1.11). Litwińczuk et al. (2006) obtained a similar average FPR value of around 1.20 for Polish Holstein-Friesian cows of the Black-and-White variety.

Rational feeding of cattle is one of the key factors influencing their milk production efficiency (Guliński, 2017). Important elements of feeding in modern high-yielding dairy herds that affect the chemical composition of milk include: the proportion of concentrate feed in the diets (an excess of concentrate feed in the diet for cows can lead to a decrease of 1% or more in fat content, while increasing protein levels in milk by 0.2–0.3%), excessive grinding of feeds (which can reduce fat concentration and even cause the so-called fat depression syndrome, i.e., a drop in fat content in milk below 3%), and the fiber level (if the dietary fiber level is below the recommended minimum levels (NDF 26% of the total dry matter of the diet), cows are at increased risk of acidosis) (Guliński et al., 2018).

Ketosis is a disease that most often occurs as a result of energy deficiencies, or a negative energy balance. The development of energy deficiencies leading to ketosis is usually caused by: high energy requirements necessary for milk production, reduced appetite in cows shortly after calving, the use of unbalanced diets, and excessive body condition of cows at the time of calving. Data on the incidence of subclinical ketosis are generally very varied, depending on the source. The problem mainly occurs in poorly fed animals with high milk production potential. Among cows evaluated for β-hydroxybutyrate, a level exceeding 1.4 mmol/L was found in at least 10% of animals in Poland. According to Guliński (2017), the percentage of cows affected by ketosis in Poland was 20%, 16%, and 23% in the first, second, and the third and subsequent lactation, respectively. According to Duffield (2013), the incidence of subclinical ketosis in herds located in North America ranged from 30% to 50%. The incidence of subclinical and clinical ketosis in cows in early lactation across 12 different countries worldwide was assessed by Brunner et al. (2019). The percentage of cows found to have subclinical ketosis averaged 24.1%, ranging from 8.3% to 40.1%. In the study by Buttchereit et al. (2012), involving 1,693 Holstein-Friesian cows, the frequency of metabolic disorders related to ketosis was

9.7%. In light of the data presented, the average percentage of cows (7%) indicating the occurrence of ketosis in our own study can be considered low. According to Martins et al. (2022), the basic element in preventing ketosis is their appropriate condition during the transition period. According to these authors, in cows with a condition score of > +3.75 points on the Wildman scale, the risk of ketosis is 4.3 times higher compared to cows with optimal condition. Kang et al. (2025) report that cows with a negative energy balance have an increased level of β-hydroxybutyric acid (BHBA), which is accompanied by a decrease in the concentration of calcium and phosphorus in the cows' blood.

Acidosis is a metabolic disorder that most often results from excessive intake of easily fermentable carbohydrates. Factors that increase the risk of acidosis include: the content of neutral detergent fiber (NDF) in the diet, the particle size of the fed feeds, heat stress, excessive animal density in the barn leading to increased competition for access to feed, and separate feeding of different types of feeds. The pH of ruminal fluid is one of the basic indicators of fermentation processes in the rumen. The optimal pH values range from 6.3 to 6.7, which guarantees maximum synthesis of microbial protein and high cellulolytic activity. A decrease in ruminal pH below 6.3 is usually the result of feeding excessive amounts of non-structural carbohydrates, mainly starch. According to Bilik et al. (2012), the main reason for the decrease in pH of the rumen content of cows is the increased share of concentrates in the diet and the reduced share of bulk feed. According to Włodarczyk and Budvytis (2011), two feeding technologies enable safe feeding of large doses of concentrates from the point of view of preventing the occurrence of ruminal acidosis, i.e. feeding stations dosing small single doses of concentrates and TMR. Oetzel (2007), based on 766 Holstein cows maintained in 61 herds in Wisconsin, USA, estimated the average incidence of acidosis (pH <5.5) to be 21% of the total observations. Kleen et al. (2009) assessed the incidence of subacute ruminal acidosis (SARA) in 197 dairy cows in 18 herds in the Dutch province of Friesland. The average frequency of ruminal acidosis was 13.8%, ranging from 0% to 38%. Morgante et al. (2007) studied SARA in 10 Italian herds and found three herds where more than 33% of the individuals had pH <5.5 or lower. Stefańska et al. (2017) studied Polish Holstein-Friesian cows in a population of 213 cows, classifying 14% (30) of cows as acidotic (pH <5.6), 13% (29) as risky (pH 5.6–5.8), and 73% (154) as healthy (pH >5.8). Kleen et al. (2013) in studies involving 315 German Holstein cows in Germany, diagnosed clinical acidosis (pH <5.5) in 20% of the cows. In practical conditions, acidosis problems in cattle are prevented by adding buffer supplements to the rumen content (sodium bicarbonate, potassium bicarbonate, magnesium oxide, bentonite). A typical feed buffer supplement added to the diets of high-yielding cows is sodium bicarbonate. In scientific experiments, sodium bicarbonate added to diets dominated by maize silage, hay, and grass silage, and alfalfa silage, increased the average rumen pH of cows by 0.10 to 0.25 units (Paton et al., 2004; Bach et al., 2018).

Summary

The study demonstrated that the feeding system had a significant impact on the daily milk yield. In the subpopulation of cows fed in the PMR feeding system, the average daily milk yield during lactation was 31.9 kg, while in the subpopulation of cows fed traditionally, the average daily milk yield was 27.8 kg. The study also showed that milk produced according to the PMR feeding system contained, on average, more fat, protein, lactose, and dry matter compared to milk produced using the traditional feeding system, with increases of 0.31%, 0.28%, 0.14%, and 0.52%, respectively. In the analyzed population, differences in the urea level in milk were also observed between cows fed different feeding technologies. The average urea concentration in the milk of cows fed PMR was 223 mg/L, while in the milk of cows fed traditionally, it was around 251 mg/L. The study also examined the impact of the feeding system on the proportion of milk samples indicating the presence of metabolic diseases. It was found that 48% of cows fed the PMR had a low FPR in their milk, while only 44% of cows fed traditionally showed similar results. When assessing the impact of other factors, such as lactation period, age of cows (lactation number), and production level, it was found that these factors significantly influenced the formation of most of the analyzed traits. In conclusion, the research indicated that in the production conditions of Eastern Mazovia, the feeding system has a significant effect on daily milk yield, fat content, protein content, dry matter content in milk, and urea levels. The use of the PMR feeding system led to increased milk yield and improved its chemical quality. An important advantage was also the higher proportion of milk samples with low urea content (<250 mg/L). Based on the results of the study, feeding the PMR was also associated with a lower percentage of milk samples in the first 100 days of lactation indicating acidosis (6% vs 10%).

References

Bach A., Guasch I., Elcoso G., Duclos J., Khelil-Arfa H. (2018). Modulation of rumen pH by sodium bicarbonate and a blend of different sources of magnesium oxide in lactating dairy cows submitted to a concentrate challenge. J. Dairy Sci., 101(11): 9777–9788.

Barłowska J., Litwińczuk Z., Topyła B. (2005). Parametry fizykochemiczne tłuszczu mleka krów różnych ras z okresu żywienia wiosenno-letniego. Med. Weter., 61 (8): 937–939.

Barłowska J., Litwińczuk Z., Król J., Topyła B. (2006). Technological usefulness of milk of cows of six breeds maintained in Poland relative to a lactation phase. Pol. J. Food Nutr. Sci., 15/56, SI 1: 17–22.

Barłowska J., Litwińczuk Z., Brodziak A., Chabuz W. (2012). Effect of the production season on nutritional value and technological suitability of milk obtained from intensive (TMR) and traditional feeding system of cows. J. Microbiol., Biotechnol. Food Sci., 1(5): 1205–1220.

Bilik K., Łopuszańska-Rusek M., Furgał-Dierżuk I. (2012). Kwasica żwacza u krów mlecznych. Rocz. Nauk. Zoot., 39(2): 157–170.

Bogucki M., Sawa A., Neja W., Bembnista M. (2009). Użytkowość mleczna krów rasy holsztyńsko-fryzyjskiej pochodzenia krajowego i zagranicznego. Rocz. Nauk. PTZ, 5, 4: 21–31.

Brunner N., Groeger S., Raposo J.C., Bruckmaier R.M., Gross J.J. (2019). Prevalence of subclinical ketosis and production diseases in dairy cows in Central and South America, Africa, Asia, Australia, New Zealand, and Eastern Europe. Transl. Anim. Sci., 3(1): 84–92.

Brzozowski P., Zdziarski K. (2006). Wpływ genotypu, wieku, stadium laktacji i wydajności mlecznej krów czarno-białych na punkt zamarzania mleka. Med. Wet., 62, 1: 93–95.

Buttchereit N., Stamer E., Junge W., Thaller G. (2010). Evaluation of five lactation curve models fitted for fat:protein ratio of milk and daily energy balance. J. Dairy Sci., 93: 1702–1712.

Buttchereit N., Stamer E., Junge W., Thaller G. (2012). Genetic parameters for energy balance, fat/protein ratio, body condition score and disease traits in German Holstein cows. J. Anim. Breed. Gen., 129: 280–288.

Cichocki M., Wroński M., Szydłowski R. (2007). Użytkowość mleczna krów żywionych z zastosowaniem systemu TMR lub PMR. Acta Sci. Pol. Zoot., 6, 2: 15–20.

Czerniawska-Piątkowska E., Szewczuk M., Kamieniecki H., Adamski M, Bruś A., Falta D. (2007). The comparison of dairy performance and some reproductive parameters of Holstein cows imported from Sweden and their Polish age mates. Acta Univ. Agric. Silvic. Mendelianae Brun., 55, 1: 39–44.

Duffield T. (2013). Wpływ podklinicznej ketozy na zdrowie, mleczność, wyniki rozrodu oraz ryzyko brakowania krów. XVI Międzynarodowa Sesja Naukowa, Zaburzenia w Rozrodzie i Produkcyjności Bydła". Polanica Zdrój 20‒22.06.2013.

Enemark J., Jorgensen R., Enemark P. (2002). Rumen acidosis with special emphasis on diagnostic aspects of subclinical rumen acidosis: A review. Vet. Zoot., 20: 16–29.

Gierdziewicz M., Otwinowska-Mindur A., Ptak E. (2009). Wpływ wielkości stada i dziennej wydajności mlecznej na zawartość komórek somatycznych w mleku krów rasy polskiej holsztyńsko-fryzyjskiej odmiany czarno-białej. Rocz. Nauk. PTZ, 5, 2: 65‒74.

Gnyp J. (2012). Wpływ kraju pochodzenia na produkcyjność krów i relacje pomiędzy zawartością tłuszczu i białka w mleku. Rocz. Nauk. PTZ, 8, 4, 19‒26.

Golder H.M., Denman S.E., McSweeney C., Wales W.J., Auldist M.J., Wright M.M., Marett L.C., Greenwood J.S., Hannah M.C., Celi P., Bramley E., I.J. Lean I.J. (2014). Effects of partial mixed rations and supplement amounts on milk production and composition, ruminal fermentation, bacterial communities, and ruminal acidosis. J. Dairy Sci., 97(9): 5763‒5785.

Górska A., Mróz B., Rymuza K., Dębska M. (2006). Zmiany w zawartości białka i tłuszczu w mleku krów czarno-białych i czerwono-białym w zależności od stadium laktacji i pory roku. Rocz. Nauk. Pol. Tow. Zoot., 2, 1: 113‒118.

Guliński P. (2017). Bydło domowe hodowla i użytkowanie. Wyd. Nauk. PWN Warszawa.

Guliński P. (2023). The effect of different content of protein and urea in milk, as biomarkers of energy-protein balance of food rations, on the level of selected milk performance characteristics of Polish Holstein-Friesian cows. Acta Sci. Pol. Zoot., 22(2): 17–30.

Guliński P., Kłopotowska A. (2019). Próba opracowania metody określania typowego składu chemicznego mleka polskich krów rasy holsztyńsko-fryzyjskiej – propozycja. Rocz. Nauk. PTZ 15, 3: 9–21.

Guliński P., Salamończyk E. (2007). Ocena wybranych wskaźników użytkowości mlecznej, długości laktacji i stanu zdrowotnego wymion wysoko wydajnych krów rasy polskiej holsztyńsko-fryzyjskiej odmiany czarno-białej. Rocz. Nauk. PTZ, 3,1: 29–36.

Guliński P., Salamończyk E., Młynek K. (2016). Improving nitrogen use efficiency of dairy cows in relation to urea in milk – A review. Anim. Sci. Pap. Rep., 34(1): 5‒24.

Guliński P., Salamończyk E., Młynek K. (2018). Możliwości modyfikacji składu chemicznego mleka krów. Wyd. Uniwersytetu Przyrodniczo-Humanistycznego w Siedlcach.

Humer E., Petri R.M., Aschenbach J.R., Bradford B.J., Penner G.B., Tafaj M., Südekum K.-H., Q. Zebeli Q. (2018). Invited review: Practical feeding management recommendations to mitigate the risk of subacute ruminal acidosis in dairy cattle. J. Dairy Sci., 101 (2): 872‒888.

Januś E., Borkowska D., Piątek D. (2013). Ocena wpływu wybranych czynników na skład chemiczny mleka wysoko wydajnych krów rasy polskiej holsztyńsko-fryzyjskiej i montbeliarde. Med. Weter., 69, 6: 378‒382.

Jenkins N.T.. Peña G., Risco C., Barbosa C.C., Vieira-Neto A., Galvão K.N. (2015). Utility of inline milk fat and protein ratio to diagnose subclinical ketosis and to assign propylene glycol treatment in lactating dairy cows. Can. Vet. J. Rev. Vet. Can., 56: 850–854.

Jiang F.G., Lin X.Y., Yan Z.G., Hu Z.Y., Liu G.M., Sun Y.D., Liu X. W., Z.H. Wang Z.H. (2017). Effect of dietary roughage level on chewing activity, ruminal pH, and saliva secretion in lactating Holstein cows. J. Dairy Sci., 100: 2660‒2671.

Kang D., Lungu S.E., Danso F., Dzou C.F., Chen Y., Zheng X., Nie F., Lin H., Chen J., Zhou G. (2025). Animal health and nutrition: metabolic disorders in cattle and improvement strategies. Front.Vet. Sci., 25(12) :1470391.

Kański J., Wandzel K. (2009). Najczęściej popełniane błędy w żywieniu krów. Hod. Byd., 4, 6–11.

Kleen J.L., Hooijer G.A., Rehage J., Noordhuizen J.P.T.M. (2009). Subacute ruminal acidosis in Dutch dairy herds. Vet. Rec., 164: 682–685.

Kleen J.L., Upgang L., Rehage J. (2013). Prevalence and consequences of subacute ruminal acidosis in German dairy herds. Acta Vet. Scand., 55: 48.

Król J., Litwińczuk A., Brodziak A., Topyła B. (2009). Jakość mleka trzech ras krów w kolejnych latach użytkowania. Rocz. Nauk. PTZ, 5, 4: 181−188.

Kruczyńska H., Mitke A., Tylkowska E., Kozłowska-Hałas J. (2006). Wydajność i skład mleka wysokowydajnych krów żywionych dawkami pełnoporcjowymi – TMR. Prac. Mat. Zoot., 63: 49−57.

Kuczaj M., Kupczyński R., Zielak A., Blicharski P., Klucznik J. (2008). Zmiany wartości cech produkcyjnych krów rasy holsztyńsko-fryzyjskiej odmiany czarno- i czerwono-białej w pierwszych 5 laktacjach. Rocz. Nauk. PTZ, 4, 2: 9−17.

Lach Z., Podkówka W. (2000). Wydajność i skład chemiczny mleka krów żywionych w systemie PMR. Zesz. Nauk. Prz. Hod., 51: 109−118.

Li S., Gozho G.N., Gakhar N., Khafipour E., Krause D.O., Plaizier J.C. (2012). Evaluation of diagnostic measures for subacute ruminal acidosis in dairy cows. Can. J. Anim. Sci., 92: 353–364.

Litwińczuk Z., Borkowska D., Zając B. (1994). Produkcyjność bydła w gospodarstwach indywidualnych z uwzględnieniem wartości pokarmowej skarmianych pasz objętościowych. An. UMCS, sec. EE, 12: 25–31.

Litwińczuk Z., Teter U., Teter W., Sianek P., Chabuz W. (2006). Ocena wpływu niektórych czynników na wydajność i jakość mleka krów utrzymywanych w gospodarstwach farmerskich. Rocz. Nauk. PTZ, 2 (1): 133−140.

Łuczak W., Skurczyńska K., Kuczaj M. (2009). Systemy żywienia krów wysoko wydajnych łączące pastwisko i TMR. Prz. Hod., 2: 9–3.

Martins L.F., Wasson D.E., Hristov A.N. (2022). Feeding dairy cows for improved metabolism and health. Anim. Front., 12(5): 29−36.

Mäntyssari P., Huhtanem P., Nousiainen J., Virkki M. (2004). The effect of concentrate crude protein content and feeding strategy of total mixed ration on performance of primiparous dairy cows. Livest. Prod. Sci., 85: 223–233.

Miciński J. (2007). Ważniejsze wskaźniki użytkowości krów w kolejnych laktacjach w zależności od ich najwyższej wydajności dobowej. Acta Sci. Pol. Zoot., 6, 3: 33–42.

Miciński J., Klupczyński J. (2006). Correlations between polymorphic variants of milk proteins and milk yield and chemical composition in Black-and-White and Jersey cows. J. Food Nutr. Sci., 15/56, 1: 137−143.

Miglior F., Muir B.L., Van Doormaal B.J. (2005). Selection indices in Holstein cattle of various countries. J. Dairy Sci., 88: 1255–1263.

Minakowski D. (2008). Pasze przemysłowe – znaczenie w żywieniu bydła. Hod. Byd., 2: 6−11.

Morgante M., Stelletta C., Berzaghi P., Gianesella M., Andrighetto I. (2007). Subacute rumen acidosis in lactating cows: an investigation in intensive Italian dairy herds. J. Anim. Physiol. Anim. Nutr., 91: 226–234.

Oetzel G.R. (2007). Subacute ruminal acidosis in dairy herds: Physiology, pathophysiology, milk fat responses, and nutritional management. Dairy Herd Problem Investigation Strategies, Proceedings of the 40th Annual Conference, Vancouver, Canada, 17 September 2007. Available online: https://www.vetmed.wisc.edu/fapm/wp-content/uploads/2020/01/sara1aabp.pdf (accessed on 30 September 2020).

Paton L.J., Beauchemin K.A., Veira D.M., von Keyserlingk M.A.G. (2004). Effects of sodium bicarbonate on ruminal pH and feed intake in feedlot cattle. J. Anim. Sci., 82: 39–40.

Pilarska M. (2014). Wpływ pory roku i kolejnej laktacji na wydajność krów i parametry fizykochemiczne mleka. Wiad. Zoot., 52, 2: 3–12.
Podkówka W., Podkówka Z. (2004). Żywienie wysoko wydajnych krów w systemie TMR. Zesz. Nauk. Prz. Hod., 74: 9–23.
Podkówka Z., Podkówka L., Jermak B., Podkówka W. (1999). Wpływ żywienia krów systemem PMR na zawartość białka, tłuszczu i kwasów tłuszczowych w mleku. Anim. Sci., 36: 15–24.
Polish Federation of Cattle Breeders and Dairy Farmers (PFCBMP), National Research Institute of Animal Production. Assessment of the Breeding Value of PHF Bulls of the Black-and-White and Red-and-White Varieties. 2016. Available online: www.wycena.izoo.krakow.pl (accessed on 25 January 2025).
Pytlewski J., Antkowiak I., Skrzypek R. (2011). The effect of some non-nutritional factors on urea level in milk of Polish Holstein-Friesian cows. Nauka Przyr. Tech., 5, 3: 1–11.
SAS Institute Inc. (2008). Statistical Analysis System User's Guide. Version 9.1. SAS Institute, Cary.
Salamończyk E., Guliński P. (2023). Ocena zmienności wydajności i podstawowych składników mleka krów rasy polskiej holsztyńsko-fryzyjskiej. Rocz. Nauk. Zoot., 50(2): 179–196.
Satoła A., Ptak E. (2016). Wpływ wybranych czynników na zawartość mocznika w mleku krów rasy polskiej holsztyńsko-fryzyjskiej. Rocz. Nauk. Pol. Tow. Zoot., 12, 3: 21–32.
Sawa A., Neja W., Bogucki M., Paczos A. (2007). Wpływ wybranych czynników poza genetycznych na związek między wydajnością mleka w pierwszym próbnym doju a wydajnością w poszczególnych okresach laktacji. Rocz. Nauk. Pol. Tow. Zoot., 3, 1: 57–62.
Schingoethe D.J. (2017). A 100-year review: Total mixed ration feeding of dairy cows. J. Dairy Sci., 100(12): 10143–10150.
Sobotka W., Miciński J., Wróblewski P., Zwierchowski G. (2011). Wpływ systemu żywienia tradycyjnego i TMR na pobranie paszy przez krowy, ich wydajność, skład mleka i jego jakość higieniczną. Rocz. Nauk. Zoot., 7(4), 87–96.
Sobotka W., Gołaś B.I., Miciński J. (2017). The impact of feeding system on performance and chemical composition of cows. Rolnictwo - problemy i perspektywy: zbiór prac naukowych / Ministerstwo Rolnictwa i Żywności Republiki Białoruś. Państwowy Uniwersytet Rolniczy w Grodnie, Zootechnika, 37: 379–396.
Stefańska B., Nowak W., Komisarek J., Taciak M., Barszcz M., Skomiał J. (2017). Prevalence and consequence of subacute ruminal acidosis in Polish dairy herds. J. Anim. Physiol. Anim. Nutr., 101: 694–702.
Van Soest B.J. (2023). Management and nutritional factors associated with metabolic health and production in dairy cows milked with automated milking systems. A doctor thesis presented to the University of Guelph. Guelph, Ontario, Canada, 265 pp.
Villot C., Meunier B., Bodin J., Martin C, Silberberg M. (2018). Relative reticulo-rumen pH indicators for subacute ruminal acidosis detection in dairy cows. Animal, 12: 481–490.
Winnicki S., Jugowar J. L., Sobek Z., Nienartowicz-Zdrojewska A., Różańska-Zawieja J. (2016). Analiza cech użytkowości mlecznej krów w zależności od organizacji i poziomu ich żywienia w stadzie o wysokiej wydajności. Rocz. Nauk. PTZ, 12, 4: 59–70.
Włodarczyk R., Budvytis M. (2011). Właściwe żywienie krów wysoko wydajnych – jak w pełni wykorzystać ich potencjał produkcyjny. Życie Wet., 86(10): 771–776.
Zschiesche M., Mensching, A., Sharifi, A. R., Hummel J. (2020). The milk fat-to-protein ratio as indicator for ruminal pH parameters in dairy cows: A Meta-Analysis. Dairy, 1(3): 259–268.

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OCENA WYBRANYCH CECH UŻYTKOWOŚCI MLECZNEJ I WSKAŹNIKÓW STATUSU METABOLICZNEGO KRÓW W STADACH WYKORZYSTUJĄCYCH RÓŻNE TECHNOLOGIE ŻYWIENIA

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STRESZCZENIE

W pracy analizowano wpływ rodzaju technologii żywienia na wybrane cechy użytkowości mlecznej i wskaźniki statusu metabolicznego krów. Uwzględniono dwa systemy żywienia: technologię częściowo wymieszanych dawek pokarmowych (ang. Partly Mixed Ration – PMR) i tradycyjnej trójczłonowej technologii żywienia, w której poszczególne rodzaje pasz w dawkach pokarmowych podawane były odrębnie. Wykazano, że typ technologii żywienia miał duży wpływ na dobową wydajność mleka FCM. W populacji krów, w której stosowano system żywienia PMR, dobowa wydajność mleka w laktacji wynosiła przeciętnie 31,9 kg mleka, podczas gdy w populacji, w której stosowano żywienie tradycyjne, średnia dobowa wydajność mleka wynosiła 27,8 kg mleka. Stwierdzono ponadto, że mleko produkowane z wykorzystaniem systemu żywienia PMR w porównaniu z mlekiem wyprodukowanym z wykorzystaniem tradycyjnego systemu żywienia zawierało więcej tłuszczu, białka, laktozy i suchej masy odpowiednio o: 0,31%, 0,28%, 0,14% i 0,52%. Oceniając poziom wybranych wskaźników statusu metabolicznego, stwierdzono, że średnia koncentracja mocznika w mleku z systemem PMR wynosiła 223 mg/L mleka, a w populacji żywionej tradycyjnie ukształtowała się na przeciętnym poziomie 251 mg/L mleka. W badaniach oceniono ponadto znaczenie systemu żywienia krów na udział prób mleka wskazujących na występowanie typowych chorób metabolicznych. Oceniając wpływ systemu żywienia na udział prób mleka z określoną wartością STB wykazano, że krowy żywione w systemie PMR charakteryzowały się wyższym w porównaniu do systemu tradycyjnego udziałem prób wskazujących na kwasicę 9% vs 6% oraz niższym udziałem prób mleka wskazujących na optymalne zbilansowanie potrzeb energetycznych i na występowanie ketozy. Procentowe udziały prób mleka wyniosły odpowiednio: 42% vs 55 i 3% vs 8%. Oceniając wpływ wyznaczonych w metodyce pracy czynników, tj. okresu laktacji, wieku krów (numeru laktacji) i poziomu produkcyjnego, stwierdzono istotny ich wpływ na kształtowanie się większości analizowanych cech. W podsumowaniu stwierdzono, że w warunkach produkcyjnych wschodniego Mazowsza system żywienia miał bardzo duży wpływ na poziom analizowanych cech użytkowości mlecznej i wielkość ocenionych wskaźników statusu metabolicznego. Stosowanie systemu żywienia PMR prowadziło do zwiększania wydajności mleka FCM i poprawy jego jakości chemicznej i cytologicznej. Istotną jego zaletą był także wykazany wysoki udział prób mleka z niską zawartością mocznika w mleku (<250 mg/L). W świetle wyników uzyskanych w pracy żywienie PMR wiązało się także z niższym odsetkiem prób mleka w okresie pierwszych 100 laktacji, wskazujących na występowanie kwasicy (6% vs 10%).

Słowa kluczowe: technologie żywienia, krowy mleczne, wydajność mleka FCM, skład chemiczny