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Effects of the automatic feeding with dynamic feed delivery time on milk yield and composition in commercial dairy cow herd

Wpływ automatycznego żywienia z dynamicznym czasem podawania paszy na wydajność i skład mleka w stadzie krów mlecznego

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ABSTRACT

The quantity and composition of milk are strongly influenced by the way cows are fed. This study was carried out using data from a commercial dairy farm, where the conventional way of feeding was replaced by an automatic feeding system (AFS) characterised by dynamic feed delivery time. The effect of changing the method of TMR delivery to cows on their yield and milk composition (DM, Protein, Fat, Caseine, Lactose, F:P Ratio, SCC, MUN) in individual months (VI – XI) under observation was evaluated considering the stages of lactation (5-30, 31-60, 61-100, 101-200, 201-369 DIM) of Polish Holstein-Friesian cows. The results of the statistical analysis indicate that the change in the method of supplying feed to the feed table did not significantly affect the cows' daily milk yield but had a significant effect on changes in milk composition. The introduction of AFS contributed to an increase in the protein and fat content of milk at each stage of lactation, except for fat during the 31 – 60 DIM period. Furthermore, the lactation stage (milking day) was proven to be a stronger determinant of milk quantity and composition than the method of feed delivery analysed.

Keywords: automatic feeding, dairy cattle, milk production, feeding frequency, lactation stage

STRESZCZENIE

Ilość i skład mleka są silnie uzależnione od sposobu żywienia krów. Badanie przeprowadzono na podstawie danych pochodzących z komercyjnego gospodarstwa mlecznego, w którym konwencjonalny sposób zadawania pasz zastąpiono systemem automatycznego zadawania pasz (AFS) cechującym się dynamicznym czasem jej dostarczania. Wpływ zmiany sposobu podawania TMR krowom na ich wydajność i skład mleka (DM, Białko, Tłuszcz, Kazeina, Laktoza, Stosunek F:P, LKS, MUN) w poszczególnych miesiącach (VI-XI) objętych obserwacją oceniono, biorąc pod uwagę etapy laktacji (5-30, 31-60, 61-100, 101-200, 201-369 DIM) krów rasy polskiej holsztyńsko-fryzyjskiej. Wyniki przeprowadzonej analizy statystycznej wskazują, że zamiana sposobu dostarczania karmy na stół paszowy nie wpłynęła istotnie na wydajność dobową mleka krów, wpłynęła jednak istotnie na zmiany składu mleka. Wprowadzenie AFS przyczyniło się do zwiększenia zawartości białka i tłuszczu w mleku w poszczególnych fazach laktacji, z wyjątkiem tłuszczu w okresie 31 – 60 DIM. Ponadto dowiedziono, że faza laktacji (dzień doju) jest czynnikiem silniej determinującym ilość i skład mleka niż poddany analizie sposób dostarczania paszy.

Słowa kluczowe: krowy mleczne, automatyczne żywienie, dynamiczne zadawanie pasz, wydajność mleczna, skład mleka

INTRODUCTION

The basic components of cow's milk, from the perspective of diet and technological suitability, are dry matter (approximately 87.7%), fat (3.4%), protein (3.3%), carbohydrates (including lactose, 4.9%), mineral salts (0.7%) and vitamins (Rezaei et al., 2016). According to Guliński (2019), the price of milk protein has doubled in payment schemes around the world due to the increasing suitability of this ingredient for milk processing, and also as a result of changes in the diet of consumers who prefer foods with lower fat content. Milk yield and composition depend on many factors, among which are breed, lactation stage, age, nutrition and herd management (Johnstone and DeVries, 2018; Garamu, 2019). In addition, attention is paid to cow behaviour, in particular resting, rumination or feed intake (DeVries and von Keyserlingk, 2009; Bisaglia et al., 2010; Johnstone and DeVries, 2018).

Proper feeding practices on dairy farms, leading to optimal rumen function and adequate dry matter and nutrient intake, determine the production of high-quality milk with optimal composition (Tyasi et al., 2015; Da Borso et al., 2017; Tangorra and Calcante, 2018). Dry matter intake depends on, for example, the size of individual meals, the frequency and duration of the meals, and the time of feeding (Johnstone and DeVries, 2018). Dry matter and nutrient intake are also influenced by factors such as cow stocking density in relation to the length of the feed table, the age structure of the cows (especially when the barn area is almost fully utilised) (Tyasi et al., 2015).

In order to provide cows with the balanced nutrition necessary to ensure stable and efficient rumen function, Total Mixed Ration (TMR) is quite commonly used (Miller-Cushon and DeVries, 2017a). Cow feeding strategies on modern dairy farms are important from an economic as well as a technological point of view, especially given the need to provide high-yielding cows with large amounts of feed. The way feed is delivered plays an important role in stimulating cows to eat (Bisaglia et al., 2010; Mattachini et al., 2015). The classical approach to feeding is to feed them twice a day; however, due to cost concerns, feeding is often limited to only one per day. According to Tyasi et al. (2015), feed should be available to cows for 20 hours a day. This is possible due to the development of automatic feeding systems, providing cows with feed at a higher frequency with less effort (Mattachini et al., 2015).

The introduction of automatic feeding systems took place at the turn of the 21st century and made it possible to reduce workload and improve working time flexibility. Currently, 24 manufacturers of this type of equipment are listed in the literature, and the number of farms in the world using them is estimated at more than 1,250 (Romano et al., 2023). Most studies on automated feeding systems for cattle have focused on the analysis of energy consumption, labour input and economic effects (Grothmann et al., 2010a and 2010b; Oberschätzlatzl et al., 2015; Pezzuolo et al., 2016; Da Borso et al., 2017; Kaczor, 2017; Tangorra and Calcante, 2018; Vaculik and Smjetkova 2019), the impact of this feeding strategy on cow behaviour (Grothmann et al., 2014; Oberschätzl-Kopp et al., 2016a and 2016b; Tangorra and Calcante, 2023) or greenhouse gas emissions (Siatka, 2022; Bragaglio et al., 2023). However, there is a lack of studies on the impact of automatic feeding on the effectiveness of milk production in cows.

The present study aimed to compare the yield and milk quality of cows before and after the change from conventional feeding (TMR twice a day, using a mixer feeder and tractor) to feeding using an automatic system, based on irregular delivery of TMR according to the cows' rate of feed intake, under commercial commodity production conditions, taking into account the lactation stages.

MATERIALS AND METHODS

The study was conducted on a commercial dairy farm located in Poland, in the Warmińsko-Mazurskie Voivodeship, which kept an average of 110 milking cows during the analyzed period. The controlled Polish Holstein-Friesian cows were included in the assessment of cattle performance value (AT4 method) conducted by the Polish Federation of Cattle Breeders and Dairy Farmers. In the year 2019 (January-November), the herd had an average 305-day milk production of 8,175 kg. The results of 520 trial milkings of cows from June to November 2019 were used in the statistical calculations. The following indicators were evaluated:

- Daily productivity of cows (kg) – MILK
- Days in milk [days] – DIM
- Milk fat content [%] – %FAT
- Milk protein content [%] – %PROT
- Milk casein content [%] – %CAS
- Milk lactose content [%] – %LAC
- Milk dry matter content [%] – %DM
- Milk urea level [mg/L] – MU
- Number of somatic cells in milk [pcs. x 1000/mL] – SCC
- Somatic cell score – SCS
- Milk fat/protein ratio – F:P Ratio

Feed rations for lactating cows (two technological groups) were developed by a nutritional advisor (feed supplier), according to the DLG system. The TMR consisted of corn silage, grass silage, straw, purchased complete feed, buffer as well as mineral and vitamin feed additives. In the period from June to August, the feed was administered using a tractor and mixer feeder (CFS), and from September to November using an automated feeding system (AFS) (Lely Vector, Lely Holding, Maassluis, the Netherlands) (Table 1).

The automatic feeding system used in the study, which operates continuously throughout the day, is unique on the market. It dispenses fresh feed at irregular intervals, depending on the animals' rate of intake. Successive portions of feed are delivered to the appropriate sections of the feed table (for a technological group) when the minimum preset level is reached. The mixing feeding wagon (MFR) measures the amount of feed on the table using a laser sensor each time it passes through the feed table (Lely, 2018).

Data on SCC were subjected to logarithmic transformation to obtain the somatic cell score (SCS):

$$SCS = log_2 (SCC / 100\ 000) + 3,\ \text{(IZ-PIB, 2021)}$$

where *SCS* was somatic cell score (log), and *SCC* was somatic cell count (thousand/ml).

A multifactor analysis of variance was performed to confirm factors statistically affecting milk yield, milk composition and SCS (SAS Institute Inc., 2014). The data analyzed in both periods came from the same cows. The following linear model was used:

$$Y_{ijklm} = \mu + a_i + b_j + c_k(a_j) + (ab)_{ij} + e_{ijklm},$$

where:

- Y_{ijklm} – phenotypic value of studied trait,
- μ – mean,
- a_i – fixed effect of ith feeding system (CFS, AFS),
- b_j – fixed effect of jth stage of lactation, DIM (5-30, 31-60, 61-100, 101-200, 201-369),
- $c_k(a_j)$ – fixed effect of the month (June, August, September, October, November) nested in the feeding system,
- $(ab)_{ij}$ – feeding system × stage of lactation interaction,
- e_{ijklm} – random error.

Table 1. Characteristics of the barn before and after the change of the feeding method

Items	Barn	
	Before robotization (CFS)	With mixing-feeding robot (AFS)
Housing system	Approx. 110 milking cows, free-stall barn	
Milking system	2 × 5 herringbone milking parlour, twice-daily milking	
Feeding system	TMR	TMR
Feeding frequency	1.5 times a day	12 times a day
Feed pushing	Manually, 3 times a day	Each time the robot provides feed

Statistical analysis of the investigated traits was performed using the PROC GLM procedure in the SAS 9.4 software (SAS Institute Inc., 2020). Groups of animals that were identified with the means of the classification model were compared based on least squares means using the Scheffé test.

RESULTS

Analysis based on the total milk samples (Table 2) showed that daily milk yields were stable in the following months and, after the introduction of automatic feeding, remained at a similar level to that during the period when cows were fed traditionally with a tractor and mixer feeder. A statistically confirmed difference ($P≤0.01$) was found only between June and August (26.8 vs 23.5 kg). In the case of fat, protein and casein contents (components important for milk and dairy producers), there was an increasing trend in the following months, especially after the change in the feeding method, but the differences found ($P≤0.05$) occurred only for fat between its content in the June (3.85%) and November (4.21%) samples, for protein between its content in August (3.29%) and September (3.51%), while for casein between its content in the August (2.57%), September and November samples (2.77% and 2.76%). The effect of the change in the feeding method on other milk parameters was not statistically confirmed.

The results presented in Table 3 indicate that changes in milk yield and composition were significantly greater due to the lactation stage than to the method of feeding. The daily yield of cows between the 5th and 200th day of lactation in the group of cows fed with CFS did not differ significantly and decreased from 30.0 to 25.6 kg, and was significantly higher than the yield of cows between the 201st and 369th day of milking (21.6 kg). For cows fed with AFS, there was no significant difference between the 5th and 100th day of lactation (decrease from 30.2 to 28.7 kg). Statistically confirmed differences ($P≤0.01$ and $P≤0.05$) occurred between the yields of cows at 5 – 30 days of milking and those at 101 – 200 and 201 – 369 days of milking (30.2 vs 24.5 and 19.4 kg, respectively). In contrast, there was no effect (P>0.05) of the feeding method on the obtained yields in the different lactation periods. In the early lactation period (day 5 – 60), cows fed with AFS showed a tendency towards slightly higher milk yield (no statistical confirmation) than those fed with CFS.

Table 2. Least-squares means (LSM) for milk yield and milk component content during the study period

Month	n	Milk yield	DIM [days]	Fat [%]	Protein [%]	Casein [%]	Lactose [%]	Dry Matter [%]	MU [mg/L]	SCC [×1000/mL]	SCS	F:P Ratio
[kg]	93	26.8^{a}	189	3.85^{A}	3.31	2.61	4.72	12.69	183.7^{ABCD}	492.4	4.81	1.12
August	104	23.5a	177	4.01	3.29^{A}	2.57^{AB}	4.74	12.92	223.7^{A}	292.3	4.47	1.23
CFS total	**197**	**25.0**	**183**	**3.94^{B}**	**3.30^{B}**	**2.59^{C}**	**4.73^{a}**	**12.81**	**204.8^{E}**	**386.7**	**4.63**	**1.12**
September	106	24.1	177	4.09	3.51^{A}	2.77^{A}	4.72	12.97	232.2^{B}	205.9	4.57	1.17
October	109	24.5	168	4.16	3.45	2.73	4.66	12.94	214.9^{C}	250.7	4.54	1.21
November	108	24.8	184	4.21^{A}	3.47	2.76^{B}	4.66	13.00	224.6^{D}	336.6	4.45	1.21
AFS total	**323**	**24.5**	**177**	**4.15^{B}**	**3.48^{B}**	**2.75^{C}**	**4.68^{a}**	**12.97**	**223.8^{E}**	**264.7**	**4.52**	**1.12**

Results in columns marked with the same letters are statistically significantly different at: AA $P≤0.01$; aa $P≤0.05$

Table 3. Least-squares means (LSM) for milk yield and component percentages obtained by the herd before and after the introduction of automatic feeding by lactation stage

Benchmark	Feeding method	Stage of lactation [days]				
		5-30 (n = 20;32)	31-60 (n = 19;30)	61-100 (n = 26;52)	101-200 (n = 47;88)	201-369 (n = 85;122)
DIM [days]	CFS	16^{aABCD}	42^{JKLM}	80^{bRSTU}	$153^{AFJNRVZA'}$	$302^{CHLPTXZB'}$
	AFS	14^{bEFGHI}	43^{NOPQ}	80^{aEVWXY}	$149^{BGKOSWB'C'}$	$312^{DIMQUYA'C'}$
Milk yield [kg]	CFS	30.0^{AB}	28.7^{EF}	$28.8J^{K}$	25.6^{N}	21.6^{ACEHJL}
	AFS	30.2^{aCD}	31.6^{GHI}	28.7^{LM}	24.5^{aGO}	$19.4^{BDFIKMNO}$
Dry matter [%]	CFS	12.56	12.39^{ab}	12.03^{CD}	12.46^{GH}	13.39^{aACEG}
	AFS	12.97	12.28^{AB}	12.56^{EF}	12.85^{c}	13.40^{bcBDFH}
Fat [%]	CFS	3.94	3.81	3.46^{AB}	3.73^{C}	4.22^{A}
	AFS	4.29	3.74^{a}	3.90	4.07	4.38^{aBC}
Protein [%]	CFS	3.07^{AB}	2.92^{DEF}	2.94^{IJK}	3.17^{NO}	$3.62^{aAEGJLN}$
	AFS	3.28^{aC}	3.05^{bGH}	3.22^{LM}	3.41^{bDIP}	$3.79^{BCFHKOMP}$
Casein [%]	CFS	2.38^{aAB}	2.28^{DEF}	2.30^{JKL}	2.49^{OP}	$2.86^{bAEHKMO}$
	AFS	2.56^{bC}	2.40^{GHI}	2.54^{MN}	2.70^{aDGJQ}	$3.01^{BCDILNP}$
Lactose [%]	CFS	4.75	4.86^{A}	4.85^{C}	4.74^{a}	4.66
	AFS	4.76	4.84^{B}	4.78^{D}	4.72^{b}	4.55^{abABCD}
MU [mg/L]	CFS	164.3^{aAB}	191.6	194.7	224.5^{a}	209.5
	AFS	200.5	189.6^{b}	219.9	229.0^{A}	236.1^{bB}
SCC [×1000/mL]	CFS	1118.4	349.4	301.9	425.0	227.8
	AFS	257.8	65.7	159.3	317.5	322.4
SCS	CFS	4.82	4.45	4.36	4.67	4.69
	AFS	4.17	3.83^{a}	4.12^{b}	4.43	5.02^{ab}
F:P Ratio	CFS	1.29	1.31	1.19	1.18	1.17
	AFS	1.32^{a}	1.23	1.22	1.20	1.15^{a}

Scores within an indicator marked with the same letters are statistically significantly different at: AA $P \leq 0.01$; aa $P \leq 0.05$; (n = n for CFS; n for AFS); CFS – conventional feeding system, AFS – automatic feeding system

There was no statistical evidence of an effect of the feeding method on the dry matter content of milk during the different lactation periods, although a slightly higher dry matter content was observed in the milk of cows fed with AFS (Table 3; Figure 1).

The highest dry matter content, regardless of the method of feeding, was found in milk from cows at 201 – 369 days of milking (13.39% and 13.40%). The lowest milk dry matter content (12.03%) was recorded at 61 – 100 days of milking in cows fed with CFS.

The fat content of milk, depending on the method of feeding and stage of lactation, was 3.46 – 4.38% (Table 3). The method of feeding did not significantly differentiate the fat content between lactation periods.

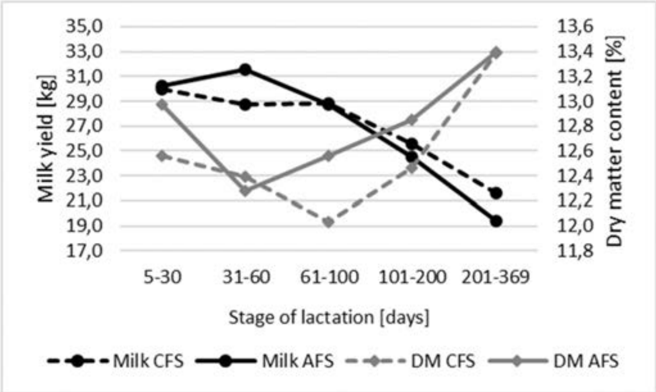

Figure 1. Changes in milk yield (Milk) and percentage dry matter (DM) in relation to feeding method (CFS – conventional feeding; AFS – automatic feeding) and stage of lactation

During most of its periods (except for the 31st – 60th day of milking), cows fed with AFS tended to produce milk with a slightly higher fat content. For cows fed with AFS, the decrease in fat content over the course of lactation was shorter (31-60 days of lactation), compared to those fed conventionally (31-100 days of lactation) (Table 3 and Figure 2). The highest fat content (4.22% – CFS and 4.38% – AFS) was observed in the milk of cows at 201 – 369 days of milking.

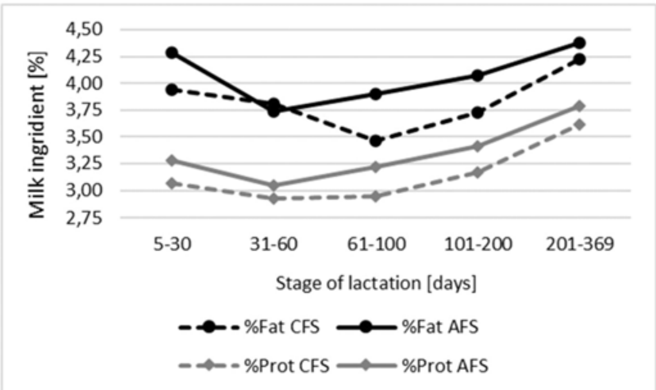

Figure 2. Changes in fat (%Fat) and protein (%Prot) contents depending on the feeding method (CFS – conventional feeding; AFS – automatic feeding) and stage of lactation

Depending on the feeding system and stage of lactation, the milk protein content was 2.92 – 3.79%, while casein content was 2.28 – 3.01% (Table 3; Figure 2). The milk of cows fed with AFS, irrespective of the lactation period, contained more protein and casein, with a statistically confirmed difference occurring only for the protein content between 61 and 100 days of lactation. As in the case of fat content, protein and casein contents depended ($P≤0.05$; $P≤0.01$) on the impact of the interaction between feeding regime and lactation stage.

The feeding regime did not statistically affect the lactose content of the milk (Table 3). The lowest values were recorded between 201 and 369 days of milking (4.55% for AFS and 4.66% for CFS), and the highest between 31 and 60 days of milking (4.84% and 4.86% for AFS and CFS). The trends of changes in milk lactose content for both feeding systems took the same direction (Figure 3).

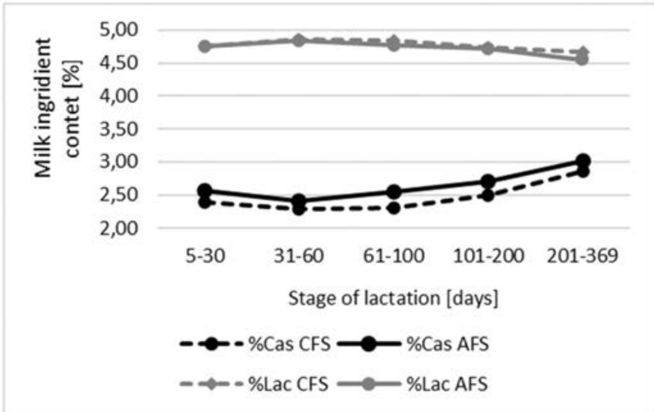

Figure 3. Changes in casein (%Cas) and lactose (%Lac) contents depending on the feeding method (CFS – conventional feeding; AFS – automatic feeding) and stage of lactation

The feeding method did not significantly affect the fat/protein ratio in milk during the different lactation periods. Statistically confirmed differences were found only for cows fed with AFS in the first and last lactation periods (Table 3).

There was no significant impact of the feeding method on the urea level in milk in the different lactation periods, although a slightly lower level was observed in cows fed with CFS (Table 3; Figure 4) than those fed with AFS. For cows fed with CFS, statistically confirmed differences ($P≤0.05$) in urea levels in milk occurred between the first month of lactation (164.3 mg/L) and 101 – 200 days of milking (224.5 mg/L), while for cattle fed with AFS, statistically confirmed differences were observed for 31 – 60 and 201 – 369 days of milking, for which urea contents of 189.6 and 236.1 mg/L were recorded, respectively.

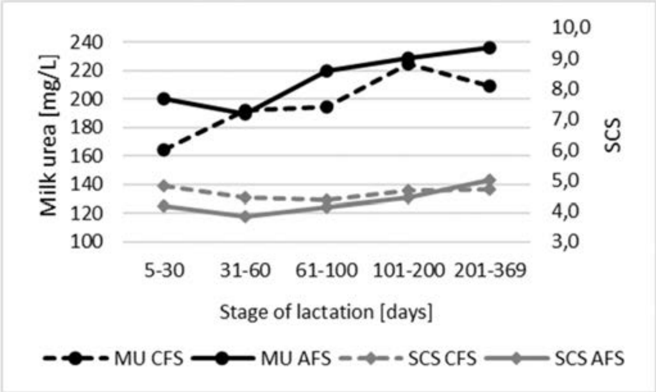

Figure 4. Changes in urea content (MU) and somatic cell count (SCS) depending on the feeding method (CFS – conventional feeding; AFS – automatic feeding) and stage of lactation

The hygienic quality of milk as determined by SCC and SCS during the different lactation periods (except 201 – 369 days) was better for cows fed with AFS than with CFS (Table 3; Figure 4), but the differences were not statistically confirmed. Statistically significant changes in somatic cell content in milk were only recorded for AFS between SCS at 31 – 100 days of milking and 201 – 369 days of milking.

DISCUSSION

Dairy producers focused on achieving optimal results are taking an increasing interest in ensuring the highest level of cow welfare. Through, for example, the robotization of feeding, they ensure that the animals are fed regularly, in an optimised and properly timed manner. As mentioned in the methodology, the Lely Vector automatic feeding system allows precise and, at the same time, flexible and regular distribution of fresh feed to the cows with minimal effort. Research results obtained by a number of authors (Johnstone and DeVries, 2018; Garamu, 2019) indicate that milk yield and milk composition are closely linked to the amount of nutrients consumed by the cows, and that ensuring the optimal amount of nutrients is directly related to the amount of dry matter taken up by the animals from the feed table. Efficient conversion of nutrients into milk components is essential for production profitability (Sova et al., 2013). Factors influencing feed intake include the eating behaviour of cows, including the size of individual meals and their frequency, and the timing of feeding. Feed intake behaviour has an impact on the rumen environment, which in turn translates into milk fat content or the risk of developing diseases such as SARA, in particular (Sova et al., 2013; Miller-Cushon and DeVries, 2017b; Johnstone and DeVries, 2018).

In our study, the use of AFS did not result in an increase in milk yield of cows compared to CFS (Table 2). In the first 60 days of lactation, cows fed with AFS had a higher yield than those fed with CFS, but the difference was not statistically significant. In subsequent lactation periods, the amount of milk from cows receiving feed more frequently due to the automation of this process was lower than that of cows fed with CFS (the differences were not statistically significant (Table 3, Figure 1). It is difficult to compare the results obtained with those of other authors, as the actual frequency of approaching the feed table and time spent eating were not measured in our study. The lack of a significant impact of feeding frequency on the performance of robot-fed cows is in line with the results presented by Oberschatzl-Kopp et al. (2016b), who compared this effect when feeding cows six and two times per day. Similarly, an earlier study by Mäntysaari et al. (2006) showed that increasing the number of feedings from 1 to 5 did not affect the milk quantity and composition of Finnish Ayrshire cows, although it did result in a statistically significant improvement in nutrient utilisation (dry matter, metabolic energy and feed protein) for ECM milk production. The lack of impact of the number of feedings on the amount of milk produced was also shown by Hart et al. (2014). Comparing the performance of cows fed 1, 2 or 3 times per day, they reported no significant effect on actual milk yield, ECM milk yield and 3.5%FCM. In contrast to those mentioned above, Macmillan et al. (2017) obtained results indicating a significant increase in 3.5%FCM milk yield for cows fed three times per day compared to those fed once/day.

In contrast, Johnston and DeVries (2018), who evaluated the effect of eating behaviour on milk production, showed that more time spent eating promoted greater dry matter intake. Each additional hour spent eating resulted in an increase in dry matter intake of 0.96 kg per day, while the increase in dry matter intake per additional meal was 0.19 kg/day. The authors explain that high-yielding cows need to approach the feed table more often in order to take in sufficient nutrients, rather than compensating for the necessary dry matter intake by increasing single meals. In this regard, it is worth noting the results presented by Tangorra and Calcante (2023), who showed an increase in the number of cows present at the feed table after a fresh feed was distributed than after it was pushed. These authors analysed the behaviour of cows in a facility that worked with the system evaluated in this paper.

A study by Jonhston and DeVries (2018) found associations between time spent eating and a trend towards such associations between frequency of feed intake and milk yield of cows. Each additional hour cows spent eating per day represented an expected increase in yield of 1.74 kg per day. For each additional meal, such an increase was estimated at 0.3 kg milk/day. The positive effect of increased feed intake frequency on milk yield was also confirmed in a study by Sova et al. (2013). On the other hand, Bava et al. (2012) showed that cows that were fed more frequently in a day (2 vs. 1 and 3 vs. 2 times per day) did not consume more dry matter, but produced significantly more milk, supporting the theory that more frequent feeding promotes improved feed utilisation.

The higher total and, for most of the lactation periods, fat content of the milk produced by the robot-fed cows recorded in our study (Tables 2 and 3) is probably due to the higher feed accessibility resulting from more frequent feed delivery. More frequent feeding in smaller quantities generally reduces the possibility of feed sorting, thus influencing better feed utilisation. The positive effect of reduced feed sorting is confirmed by the results obtained by Miller-Cushon and DeVries (2017b), as they showed a decrease in protein content by 0.04% and fat content by 0.10% for every 10% increase in the level of feed sorting. Concurrently, the frequency of its pushing did not affect the amount of milk produced or its composition. In contrast, Sova et al. (2013) proved that each additional 10 cm of space per cow at the feed table contributes to a 0.06 percentage point increase in milk fat percentage. Also, Harvatine (2012) indicated that a change in feeding from feeding once a day to evenly spaced meals throughout the day (every six hours) contributed to a reduction in the daily amplitude of fluctuations in milk fat content by approximately 50% and an increase in daily milk yield by 8.3% (P<0.001), which the authors explained by the beneficial effect of more frequent feeding on stabilising rumen fermentation and lowering bioactive fatty acids. The increase in milk fat content observed in our study from day 60 of lactation onwards in the case of cows fed with CFS and AFS can be attributed to the effect of decreasing dilution due to decreasing milk production and the concomitant increase in milk dry matter content observed (Table 3; Figs. 1, 2).

Although the dry matter intake of cows was not assessed in our study, it can be assumed that the increased accessibility of feed throughout the day favourably influenced feed intake and this in turn influenced the observed higher protein content in milk (in each lactation period, with a statistically confirmed difference (P≤0.01) between 60 and 100 days) in the group of cows fed with AFS (Tables 2 and 3; Figure 2). This is supported by reports indicating that freshly delivered feed is the factor that most stimulates cows to intake the feed (Harvatine, 2012; Sova et al., 2013; Oberschätzl-Kopp et al., 2016a), and in our study, in the case of robot feeding, it was delivered up to 12 times per day compared to 1.5 times in the case of conventional feeding (Table 1). The available studies indicate that an increase in dry matter intake can contribute to an increase in protein content of 0.2 – 0.3 percentage units (Tyasi et al., 2015). This finding is in agreement with the results presented by Hart et al. (2014), indicating that more frequent feeding resulted in higher dry matter intake and percentage of protein in milk.

In contrast, according to Mäntysaari et al. (2006), there was no increase in the content of components such as fat, protein, lactose or urea in milk after increasing the number of feedings from 1 to 5. A study by Macmillan et al. (2017) also showed no effect of the frequency of feeding (1 vs. 3) on the proportion of protein, lactose and urea content in milk, although it did show an effect on increasing the amount of fat in milk and a tendency to increase the percentage of fat in milk.

The changes in the protein content of milk over the course of lactation (Table 3) were in line with those available in the literature (Garamu, 2019), indicating the lowest content of the mentioned components between the 25th and 50th day of lactation, and the highest around the 250th day of milking (when the amount of milk produced starts to decrease). Furthermore, Čobanović et al. (2021) found a systematic increase in the percentage of fat and protein in milk over successive lactation periods, with the maximum values falling above day 300, when the lowest average daily yields were recorded, which is also consistent with the reports of Senbet et al. (2021). Johnston and DeVries (2018) obtained statistically significant linear regression coefficients for DIM and milk yield (-0.053), as well as fat content (0.0022) and protein content (0.0021). Similarly, Deming et al. (2013) indicate a negative association between day of lactation and cow performance; the linear regression coefficient estimated by this team was -0.06. In contrast, Miller-Cushon and DeVries (2017b) report a regression coefficient for DIM and milk protein content of 0.0024. In contrast, the regression coefficients obtained by Sova et al. (2013) for DIM and percentage of milk fat and milk protein were 0.003 and 0.0016, respectively.

It should be emphasized that the results obtained from a single herd, over a short period of time, and without the possibility of detailed analysis of feed intake, have limitations. However, they provide insight into some potential benefits of practical use of feeding robots by dairy producers, which requires further expansion of the research undertaken in this study to provide strong recommendations.

CONCLUSIONS

The statistical analyses carried out showed that the change in the feeding method on the selected farm did not significantly affect the daily yield of cows, but contributed significantly to the change in milk composition. The increase in protein and fat content in milk observed after switching to an automatic feeding system are positive effect expected by commercial milk producers. In addition, it was proven that the lactation phase (milking day) was a factor that determines the quantity and composition of milk more strongly than the analyzed method of feed delivery. This should be considered when assessing the efficiency of feeding using automatic feed distribution systems. A potential explanation for the observed changes, in the context of the knowledge gathered so far, may be the lack of possibility of sorting feed by cows due to the frequent distribution of small amounts; however, their detailed determination requires further research.

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