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EFFECT OF TYPE OF ROUGHAGE ON CHEMICAL COMPOSITION AND TECHNOLOGICAL VALUE OF MILK FROM COWS FED TMR DIETS*

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Abstract

An experiment was conducted to determine the degree to which feeding Polish Black-and-White Holstein-Friesian cows with total mixed rations (TMR) differing in the type of "energy" roughages (whole-crop maize silage, MS; winter barley silage, BS) and their proportion (70% or 50% in DM) relative to wilted meadow grass silage (GS) will affect the yield, chemical composition, fatty acid profile and technological suitability of milk, the quality traits and organoleptic score of some milk products (curd cheese, soft rennet cheese, creamery butter), and the fatty acid profile of butter fat. The study was carried out during the second trimester of lactation using 36 cows assigned to four analogous groups with 9 animals per group. It was found that replacing maize silage with barley silage in TMR diets had no significant effect on the yield, chemical composition, fatty acid content and technological suitability of milk, or on the content of major protein fractions and protein substances. Curd cheese and rennet cheese from the milk of cows fed diets with barley and wilted grass silages (groups BS/GS-I and BS/GS-II) and creamery butter from the milk of cows fed diets with a lower (50% DM) proportion of "energy" silages (MS/GS-II and BS/GS-II) were characterized by a higher ($P \leq 0.01$) content of solids and fat compared to analogous products from the milk of cows in the other groups (MS/GS-I and BS/GS-I). Butter from the milk of MS/GS-I and MS/GS-II cows had a significantly higher content of PUFA (including C18:2 *n-6*, C18:3 *n-6*, C18:3 *n-3* and CLA), and a lower content of SFA (from C-4 to C-16) compared to BS/GS-I and BS/GS-II cows. Regardless of the type of total mixed ration fed in the second trimester of lactation, the milk and milk products had desirable functional and technological properties.

Key words: dairy cows, TMR, milk yield and composition, quality of milk products

In recent years, researchers have paid more and more attention to the health aspects of different types of fats, proteins and biologically active components found in milk and milk products, and to the possibility of modifying their composition

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using different methods (Couvreur et al., 2006; Litwińczuk et al., 2011). Among the dietary factors, the composition of daily ration and the amount and type of fat were found to have a significant influence on the content of essential unsaturated fatty acids (EUFA) and other functional milk components (Kliem et al., 2008). Most studies made with dairy cows use feeds rich in unsaturated fatty acids, including oilseeds (Kenelly and Glimm, 1996). However, long-term feeding of cows with high-fat diets reduces their milk yield and milk protein content, due to a permanent reduction in the number of ruminal microorganisms (Benchaar et al., 2007). One of the natural ways of elevating the EUFA and CLA content of milk is to increase the dietary proportion of roughages rich in *n-3* PUFA precursors, in particular grasses and legumes found in pasture sward (Kelly et al., 1998). It was found (Couvrer et al., 2006), however, that feeding of cows based on these diets may reduce milk protein content and the size of milk fat globules and result in casein micelles being mineralized by calcium, thus decreasing the technological suitability of milk. Similar results were reported when feeding cows based on one type of silage or hay (Amenu et al., 2006).

The current trend toward feeding cows in dairy farms with total (TMR) or partly mixed rations (PMR), in which whole-crop maize silage is the basal roughage, has almost completely eliminated the pasture feeding of cows. Due to the current harvesting technology, maize silage is a feed with little structural fibre, which, together with a high contribution of concentrates used in the feeding of high-producing cows, negatively affects physical structure of the diet (Al Zahal et al., 2009) and increases the risk of rumen acidosis (Brzóska and Śliwiński, 2011). Adequate levels of physically effective fibre (peNDF) in TMR diets not only contributes to maintenance of ruminal pH at physiological level and ruminal digestive activity, but may also affect the fatty acid profile of milk (Al Zahal et al., 2009). In this context, wilted grass or legume silages not only are a source of protein but also help to maintain adequate physical structure of the diet (Oetzel, 2007). The recently increasing incidence of fungal diseases and maize pests as well as the growing biofuel production sector may limit the cultivation of maize for feed. In these cases, cereal whole-crop silages (GPS) or mixed cereal-legume silages may serve as an alternative roughage, instead of maize silage, for dairy cattle during the total period of lactation in many regions of Poland.

In animal science literature, there is no conclusive and exhaustive evidence to determine the possibility of modifying the content of functional components and the technological value of milk from cows fed total mixed rations (TMR) differing in the type and ratio of energy and protein wet roughages.

The objective of the study was to determine the degree to which feeding Polish Black-and-White Holstein-Friesian cows with TMR differing in the type of "energy" roughages (whole-crop maize silage, winter barley silage) and their proportion relative to "protein" roughages (wilted grass silage) will affect the yield, chemical composition, fatty acid content and technological suitability of milk, the quality traits and organoleptic score of some milk products (curd cheese, soft rennet cheese, creamery butter), and the fatty acid profile of butter.

Material and methods

Experimental design, animal feeding and housing

The feeding trial was performed in 2009–2010 at the Chorzelów Experimental Station Ltd. of the National Research Institute of Animal Production with 36 multiparous mid-lactation cows of the Black-and-White Polish Holstein-Friesian breed (from the second technological group). The experiment was divided into two stages (1 and 2) differing in the type of high-energy silages (from maize, stage 1; or from whole-crop cereals, stage 2) and in their proportion (70:30% or 50:50% in DM) relative to wilted meadow grass silage (Table 1). In each stage, two feeding groups were formed that were analogous in terms of milk yield, genotype and lactation number (9 animals per group). Cows assigned to each group were chosen in parallel; they were of the same lactation number (2 to 4) and during the same period of lactation (from days 91 to 180). Experimental animals were chosen from a herd of about 260 lactating cows with a yield of about 7800 kg milk for a 305-day lactation, which contained 3.86% fat and 3.44% protein. The rations and concentrate mixtures (Table 1) were formulated according to IZ PIB-INRA system (2009) using INRAtion PrévAlin software (ver.4.05, 2009). Body weight, milk yield, and milk fat and protein content were accounted for when formulating the rations (Table 1). The percentage ratio of roughages to concentrates in TMR diets used in different groups was approximately 70:30 in DM. Cows were group fed twice daily. They were kept in a free-stall barn with separate straw-bedded lying boxes and a central feeding passage. The barn was equipped with automatic drinkers, and a herringbone milking parlour with 2 × 10 places.

Measurements, chemical analyses and statistical calculations

During the experiment, measurements were made of chemical composition and intake of feeds, physical structure of TMR diets, milk yield and chemical composition, and fatty acid profile of milk fat. Milk samples, taken during the last week of the analysed lactation period from randomly selected cows (5 from each feeding group) were analysed for technological suitability, and milk products (curd cheese, soft rennet cheese, creamery butter) were analysed for quality traits, organoleptic characteristics and fatty acid profile of butter fat.

The basic chemical composition of the feeds was determined using standard procedures (AOAC, 2005), and NDF in silages according to Goering and Van Soest (1970) method. Determination of volatile fatty acids (VFA) in the silage was performed by gas chromatography, and lactic acid by high performance liquid chromatography (HPCL), after centrifugation of aqueous filtrates with 24% meta-phosphoric acid (filtrate/acid=5/l, v/v). VFA analysis was performed on VARIAN 3400 gas chromatograph, ZB-WAX, 30 m, 0.53 mm, 1.0 µm column using the autosampler 8200CX and Star Chromatography Workstation software (Varian Star 4.5). Lactic acid was determined on a Shimadzu chromatograph, using a column Nucleosil 250/4-C 18 (mobile phase flow rate of 1 ml/min), UV-VIS detector SPD-6AV and autosampler SIL-10 AX, and pH using an Elwro N 5170 pH meter. The physical structure of TMR was determined using the Penn State Particle Separator with three sieve sizes. Feed intake by the cows was evaluated based on daily weighing (over 3 successive days of weeks 1–2, 5–6 and 12–13) of total feed ration offered to a given feeding group and the amount of feed refusals.

Table 1. Composition of daily TMR rations for cows[1]

Feeds	Groups [2]							
	MS/GS-I (TMR-1)		MS/GS-II (TMR-2)		BS/GS-I (TMR-3)		BS/GS-II (TMR-4)	
	Amount of feed (kg/day)							
	total	DM	total	DM	total	DM	total	DM
Whole-crop maize silage	24.4	8.5	18.2	6.3				
Winter barley silage					27.3	9.50	17.5	6.10
Wilted grass silage	10.2	3.6	18.2	6.4	11.5	4.00	17.5	6.10
Fresh brewers' grains	8.1	1.91	8.1	1.91	8.1	1.91	8.1	1.91
Meadow hay	0.5	0.4	0.5	0.4	0.6	0.50	0.6	0.50
Concentrate mixture no. 1[3]	5.6	4.90			5.0	4.38		
Concentrate mixture no. 2[3]			5.0	4.37			6.0	5.25
Rapeseed meal	0.6	0.54	1.0	0.90	1.0	0.90	1.2	1.08
Soybean meal	0.6	0.54	0.6	0.54	0.63	0.57	0.6	0.54
Ground maize	1.0	0.86	2.0	1.72	1.1	0.95	1.8	1.55
Premix (Biomix Premium)[4]	0.15	0.144	0.15	0.144	0.15	0.144	0.15	0.144
Ground limestone	0.05	0.047	0.05	0.047	0.05	0.047	0.05	0.047
Sodium bicarbonate	0.10	0.090	0.10	0.090	0.10	0.090	0.10	0.090
Total (kg)	51.3	21.53	53.9	22.82	55.5	22.99	53.6	23.31
Content of DM in TMR (%)	42.0		42.0		41.4		41.7	

[1] Multiparous cows, body weight 650 kg, yield 30 kg milk with 4.2% fat and 3.3% protein (acc. to INRAtion, PrévAlin 4.05, 2009).

[2] Proportion (in % dry matter – DM): of whole-crop maize silage (MS) or winter barley silage (BS) in relation to wilted grass silage (GS) in groups: MS/GS-I= 70%, MS/GS-II= 50%, BS/GS-I=70%, BS/GS-II=50%.

[3] Composition of concentrate mixtures: mixture no. 1: ground barley 6%, ground maize 25%, rapeseed meal 12%, soybean meal 16%, ground triticale 15%, ground wheat 6%, wheat bran 10%, ground oats 6%, ground limestone 1.7%, Blatin M92 ADE 2[4], fodder salt 0.3; mixture no. 2: ground barley 18%, ground maize 25%, rapeseed meal 12%, soybean meal 6%, ground triticale 15%, ground wheat 6%, wheat bran 6%, ground oats 8%, ground limestone 1.7%, Blatin M92 ADE 2[4], fodder salt 0.3%. Nutritive value of concentrate mixtures (Table 2).

[4] Manufacturer: Blattin-Mineralfutterwerk Seitschen GmbH, 02633 Seitschen, distributed in Poland by Blattin Polska Ltd. 46-040 Ozimek.

Body weight was determined by weighing the cows each day before morning feeding.

Cows were milked in a milking parlour twice daily, and the amount of milk drawn from each cow was determined in 2-week periods using Tru-Test milk meters. Milk samples were preserved with Gropol, chilled and stored frozen (–20ºC) for about two weeks until analysis. The content of fat, total protein, casein, lactose, solids and urea in milk was determined three times during the experiment (1–2, 5–6 and 12–13 weeks of the analysed lactation) with MilkoScan FT 120 (Foss Electric). Fatty acids were analysed as methyl esters by gas chromatography. Samples were extracted with the chloroform/methanol mixture (2:1 v/v) as described by Folch et al. (1957). Fatty acids were saponified using 0.5 N NaOH in methanol and next converted to methyl esters by esterification with boron trifluoride/methanol (ISO 12966-2:2011; Loor and Herbein, 2001). Methyl esters were extracted with hexane and separated on the Rtx 2330, 105 m, 0.32 mm, 0.2 µm column using Varian 3400 gas chromatograph with a flame ionization detector (FID, helium 6 ml/min) and Varian 8200 CX autosampler. The results were recalculated using the Star Chromatography Workstation software (Varian Star 4.5).

Major fractions of milk proteins and protein substances (total nitrogen, total protein, total caseins, total albumins, total globulins, proteoses and peptones, non-protein nitrogen) were determined by the Kjeldahl method. The pH of milk was determined with a digital pH meter (CP215) using an ERH-111 electrode (Hydromet), active acidity with a digital pH meter (N 517), and titratable acidity (ºSH) using the PN-68/a-86122 procedure. The fermentation and rennet fermentation tests were performed according to Budsławski (1971), and rennet-induced coagulation was tested using the method of Schern (Budsławski, 1971). The quality characteristics of milk products (content of water, solids, fat and solids not fat) were evaluated according to AOAC (2005) procedures. Cream with 36% fat was obtained from the acidified and centrifuged cream of bulk milk from cows selected from each feeding group, from which unsalted butter was made with a laboratory method using a home butter churn. Butter was compressed to an appropriate level of water distribution (using water dispersion control), followed by formation into balls weighing 535.5 g. From bulk samples of milk (5 l/cow), soft rennet cheese was made in the form of 8 loaves each weighing 133–157 g and 3250 ml of whey (pH 4.67, fat 0.2%). The following procedure was used for cheese production: heating (72ºC), rapid cooling to 33ºC, addition of 2% starter (Fromase 2200 cultures, 1.5 h). After forming and pressing (24 h) the cheese was placed in brine (about 20% salt, pH 5.1–5.2, temp. 16–18ºC). The following procedure was used for curd cheese production: pasteurization (72ºC), cooling to 33ºC, adding CHN-19 starter, acidification, clot heating and cutting, transfer to a sieve, weighing down, and leaving to drip. Until chemical analyses and organoleptic evaluation, the products were protected and cold stored at 4ºC. To determine the fatty acid profile of butter fat, samples were heated (55ºC), centrifuged and filtered through a filter paper filled with anhydrous sodium sulfate. Clear fat was collected into tubes, saponified and esterified using the method described by De Mann (1964). The methyl esters of fatty acids were determined chromatographically using TRACE GC ULTRA gas chromatograph (Thermo Electron Corp.) with column SUPELCOWAX 10 (30 m × 0.25 mm × 0.25 μm) and a flame ionization detector (FID). Organoleptic evaluation of the milk products (aroma, colour, taste, consistency during cutting and consistency in mouth) on a 5-point hedonic scale (Kurpisz, 1984), taking account of the quality characteristics and the severity coefficient (5 – very good, 1 – very poor) was performed using the standard method (PN-65-86155) by a consumer sensory panel of 4 members.

Statistical calculations of the results concerning milk yield, the content of milk components, the fatty acid profile of milk and butter, traits of technological suitability of milk (except clot form and type of clotting) and quality traits of milk products were made by analysis of variance using the ANOVA procedure of the SAS package (1999/2001). Significant differences between the groups were determined using Duncan's test. The other results (feed intake by the cows due to loose housing, and organoleptic evaluation of some milk products) were not analysed statistically. Therefore, these results should be considered as estimates because they only show the means calculated by dividing these values by the number of animals from a given feeding group.

Table 2. Chemical composition and nutritive value of feeds and TMR

Feeds	Dry matter (%)	Content in DM (%)						Content in 1 kg DM of feed			
		crude protein	ether extract	crude fibre	N-free extractives	ash	NDF	UFL	PDIN (g)	PDIE (g)	UEV
Maize silage	34.9	8.3	3.40	17.80	66.51	3.99	40.1	0.96	51	72	0.99
Barley silage	35.0	8.1	3.70	26.70	55.60	5.90	48.5	0.71	50	60	1.06
Grass silage	35.0	13.3	2.60	26.60	50.50	7.00	56.1	0.82	77	67	1.07
Fresh brewers' grains	23.6	27.8	3.80	16.1	48.05	4.25	43.5	0.83	206	179	
Meadow hay	87.8	15.4	2.80	34.0	40.27	7.53	59.6	0.72	96	90	0.99
Concentrate mixture no. 1[1]	87.3	19.6	2.75	5.35	68.60	3.70		1.07	141	128	
Concentrate mixture no. 2[1]	87.8	16.0	2.67	6.43	67.58	7.32		1.06	111	106	
Rapeseed meal	90.0	35.7	4.15	13.0	39.63	7.52		0.97	232	150	
Soybean meal	89.5	48.3	2.17	3.90	38.63	7.00		1.22	352	250	
Ground maize	86.0	9.97	4.50	2.30	81.73	1.50		1.22	78	100	
TMR 1[2]	42.0	15.4	4.35	14.98	57.58	7.69	37.0	0.89	101	99	0.81
TMR 2[2]	42.0	14.6	4.30	16.35	57.90	6.22	38.7	0.88	100	96	0.77
TMR 3[2]	41.4	14.7	4.30	17.35	57.39	6.26	42.0	0.79	102	94	0.71
TMR 4[2]	41.7	15.2	3.99	17.43	57.42	5.94	41.2	0.81	103	95	0.71

[1] For ingredient composition of concentrate mixtures and complete diets (TMR) for different feeding groups, see Table 1.

[2] Physical structure of TMR diets (percentage of feeds on different sieves – 1, 2, 3; respectively): TMR 1 – 12.5, 39.0, 48,5; TMR 2 – 13.5, 38.5, 48.0; TMR 3 – 15.5, 39.4, 45.1; TMR 4 – 17.0, 38.0, 45.0 for groups: MS/GS-I, MS/GS-II, BS/GS-I and BS/GS-II, respectively.

Results

The chemical composition and nutritive value of the feeds, expressed according to the INRA system, are presented in Table 2. The data show that the nutrient content and nutritive value of the roughages and concentrates corresponded to the values characteristic of domestic medium or good quality feeds (IZ PIB, 2010).

Mean daily intake of dry matter and nutrients in different feeding groups (Table 3) was similar to the values determined in the rations for multiparous cows weighing about 650 kg and yielding 30 kg of milk containing 4.2% fat and 3.3% protein. Cows fed diets with barley silage as the basal energy roughage (groups BS/GS) consumed slightly more dry matter and protein (CP, PDIN, PDIE) and less energy (UFL) and fill units for dairy cows (UEV) compared to animals fed diets with maize silage (MS/GS). The BG/GS groups were also characterized by higher dry matter and protein intake, with similar UFL and UEV use per kg milk production in all the groups.

Before the experiment began, the body weight of the cows did not differ significantly (P>0.05) between the groups (Table 4). No significant differences were found between the groups in milk yield and in the content of basic nutrients and urea in milk. Groups MS/GS-I and MS/GS-II, however, tended to have a higher total and daily milk yield (by approximately 5 and 8% on average) compared to groups BS/GS-I and BS/GS-II.

Table 3. Mean feed intake and use per kg of milk produced

Item	Groups			
	MS/GS-I	MS/GS-II	BS/GS-I	BS/GS-II
Feed intake:				
dry matter (kg)	21.0	21.6	22.6	22.1
crude protein (g)	3234	3154	3322	3359
PDIN[1] (g)	2121	2160	2305	2276
PDIE[2] (g)	2079	2074	2124	2099
UFL[3]	18.7	19.0	17.9	17.9
UEV[4]	17.0	16.6	16.0	15.7
Feed use/kg milk produced:				
dry matter (kg)	0.72	0.73	0.81	0.81
crude protein (g)	111.1	106.9	119.5	123.0
PDIN (g)	72.9	73.2	82.9	83.4
PDIE (g)	71.4	70.3	76.4	76.9
UFL	0.64	0.64	0.64	0.66
UEV	0.58	0.56	0.58	0.57

[1,2,3,4] – According to IZ PIB-INRA (2009).

Fatty acid content of milk is given in Table 5. No significant differences (P>0.05) were detected between the groups in the content of different types of fatty acids, including conjugated linoleic acid (CLA), in milk fat. However, compared to cows fed diets with barley silage as the basic energy feed, the milk of cows fed maize silage diets tended to have higher CLA content and a narrower *n-6:n-3* PUFA ratio.

Table 4. Body weight and milk yield and chemical composition of milk

Item	Groups				SEM
	MS/GS-I	MS/GS-II	BS/GS-I	BS/GS-II	
Body weight (kg)[1]	642	648	655	650	15.7
Milk yield (kg/day)	29.1	29.5	27.8	27.3	2.46
Milk yield (total, kg)[2]	2623	2655	2493	2457	235.3
Content in milk (%)[3]:					
fat	4.15	4.12	4.19	4.22	0.235
total protein	3.36	3.31	3.29	3.34	0.208
casein	2.83	2.81	2.78	2.85	0.197
lactose	4.88	4.75	4.81	4.82	0.141
solids	12.85	12.76	12.68	12.57	0.789
urea (mg/l)	186.2	196.1	202.4	199.8	35.73

[1] 7–10 days before the beginning of the experiment.
[2] From 91 to 180 days of lactation.
[3] Mean values from three determinations per cow during the experiment (2, 6 and 13 weeks of analysed lactation).

Table 5. Fatty acids profile in milk fat (% of total FA)

Fatty acids	Groups				SEM
	MS/GS-I	MS/GS-II	BS/GS-I	BS/GS-II	
C8:0	1.62	1.57	1.68	1.58	0.209
C10:0	3.76	3.49	3.90	3.45	0.717
C12:0	4.30	3.97	4.50	4.63	0.778
C14:0	10.19	11.23	12.11	10.74	1.385
C16:0	32.64	32.82	33.29	32.30	1.820
C18:0	9.74	9.74	9.11	10.07	1.319
C18:1	28.12	27.80	26.70	28.30	2.838
C18:2	1.91	1.98	2.27	2.11	0.448
Gamma C18:3	0.022	0.026	0.033	0.029	0.013
C20-4	0.205	0.182	0.215	0.212	0.062
C18-3	1.263	1.290	1.278	1.307	0.126
EPA	0.141	0.148	0.137	0.139	0.011
DHA	0.016	0.018	0.013	0.015	0.008
SFA	63.98	64.22	63.77	63.89	3.047
MUFA	30.29	28.28	28.27	29.73	2.711
PUFA	4.162	4.302	4.503	4.382	0.781
PUFA-6	2.137	2.188	2.518	2.351	0.492
PUFA-3	1.427	1.456	1.428	1.461	0.133
PUFA 6/3	1.497	1.502	1.763	1.609	0.188
CLA*	0.605	0.658	0.570	0.570	0.313

n-6 acids: C18-2, C20-4, gamma 18-3; *n-3* acids: C18-3, EPA, DHA.
*CLA – total isomers of conjugated linoleic acid: c9t11; t10c12; c9c11; t9t11.

Table 6. Traits of technological suitability of milk and quality traits of milk products

Item	Groups				SEM
	MS/GS-I	MS/GS-II	BS/GS-I	BS/GS-II	
Milk:					
pH	6.78	6.77	6.69	6.58	0.947
titratable acidity (ºSH)					
Schern test (sec.)	7.20	6.80	7.00	6.60	0.919
fermentation test[1]	208	218	227	222	39.09
fermentation-rennet test (type)[2]	Gl3	Gl3/S1	Gl3	Gl1/Gl2	
Major protein and protein substance fractions (%):	I	I/II	II	I/II	
total nitrogen	3.19	3.14	3.23	3.34	0.716
total protein	3.09	2.85	3.07	3.11	0.606
total casein	2.45	2.43	2.49	2.57	0.100
total albumins	0.42	0.39	0.50	0.44	0.083
total globulins	0.088 bAB	0.135 aA	0.039 cB	0.045 cB	0.029
proteoses and peptones	0.071 aA	0.036 cB	0.041 cB	0.059 bA	0.008
non-protein nitrogen	0.200 abA	0.195 bA	0.158 cB	0.229 aA	0.022
Curd cheese:					
solids (%)	28.1 dC	35.17 cB	38.24 bB	44.24 aA	1.663
fat (%)	9.75 cC	14.00 bB	16.25 aA	16.50 aA	0.951
fat (% DM)	34.81 cB	39.81 abAB	42.33 aA	37.61 cbAB	2.615
yield/100 l milk (kg)	16.58	15.22	24.48	15.04	
Soft rennet cheese:					
solids (%)	35.84 D	40.17 C	50.31 A	44.13 B	1.643
fat (%)	19.25 dD	22.75 cC	25.50 bB	27.50 aB	0.578
fat (% DM)	53.72 cCB	56.64 bB	50.75 bB	62.31 aA	1.799
yield/100 l milk (kg)	23.77	17.30	17.81	20.59	
Creamery butter[3]					
water (%)	13.41 bA	11.67 cB	14.01 aA	12.17 cB	0.390
solids not fat (%)	1.27 B	1.66 A	1.30 B	1.73 A	0.123
fat (%)	85.32 cB	86.67 aA	84.69 dB	86.10 bA	0.390

a, b, c, d – P≤0.05; A, B, C, D – P≤0.01.

[1] Form of clot.

[2] Type of clotting.

[3] From pure milk fat.

Regardless of the type of TMR diets, the milk of cows was characterized by desirable traits of technological suitability and similar content of total nitrogen, total protein, total casein and total albumin (Table 6). Milk samples from cows from groups MS/GS-I and MS/GS-II had a significantly (P≤0.5 or P≤0.01) greater content of globulin compared to the other groups, with the content of proteoses, peptones and non-protein nitrogen differing between the groups. When evaluating the quality traits of the milk products, it was found that curd cheese and soft rennet cheese from the milk of cows fed diets with barley silage or the diet with a lower proportion of maize silage (group MS/GS-II) had a significantly (P≤0.01) greater content of solids and fat compared to analogous products from cows receiving the diet with a higher proportion of maize silage (MS/GS-I). The curd cheese from BS/GS-I and MS/GS-II cows and the rennet cheese from BS/GS-II and MS/GS-II cows had a significantly greater percentage of fat in solids. The highest yield of curd cheese was obtained from the milk of BS/GS-I cows, and that of rennet cheese from the milk of MS/GS-I cows. Butter made from the milk of cows fed TMR diets with a lower (50% in DM) proportion of "energy" silages (groups MS/GS-II and BS/GS-II), with a similar proportion of wilted meadow grass silage, had a significantly (P≤0.01) higher content of solids not fat and fat, and a lower content of water, compared to butter produced from the milk of cows few diets with a higher proportion of "energy" silages (MS/GS-I and BS/GS-I).

Table 7. Fatty acid profile of creamery butter fat (% of total FA)

Fatty acids	Groups				SEM
	MS/GS-I	MS/GS-II	BS/GS-I	BS/GS-II	
C4:0	2.143 dC	2.966 cB	3.897 aA	3.690 bA	0.122
C6:0	1.781 D	2.284 C	2.951 A	2.592 B	0.083
C8:0	1.282 D	1.425 C	1.936 A	1.630 B	0.043
C10:0	3.368 B	3.454 B	4.497 A	3.632 B	0.200
C10:1	0.312 B	0.323 B	0.538 A	0.342 B	0.027
C12:0	4.242 B	4.072 BC	5.088 A	3.830 C	0.144
C14:0	12.197 C	13.102 B	13.824 A	11.946 C	0.211
C16:0	30.534 C	32.753 B	34.223 A	34.749 A	0.572
C16:1 *n-9*	0.280 B	0.190 C	0.326 A	0.298 B	0.014
C16:1 *n-7*	1.699 A	1.577 B	1.715 A	1.371 C	0.051
C18:0	9.137 B	8.498 B	6.251 B	10.710 A	0.369
C18:1 *n-9*	21.232 aA	19.259 cB	16.246 cC	20.122 bB	0.386
C18:1 *n-7*	1.874 B	1.969 A	1.929 A	1.893 B	0.025
C18:2 *n-6*	2.496 A	2.332 A	2.174 B	1.736 C	0.051
C18:3 *n*-6	0.082 aA	0.078 aA	0.057 bAB	0.034 cB	0.013
C18-3 *n-3*	0.256 aA	0.253 aA	0.223 bA	0.225 bA	0.017
CLA	0.771 aA	0.673 bA	0.478 cB	0.557 dB	0.056

a, b, c, d – P≤0.05; A, B, C – P≤0.01.

The fatty acid profile of creamery butter is presented in Table 7. Butter from the milk of cows fed TMR diets with maize silage (groups MS/GS-I and MS/GS-II) was characterized by a significantly (P≤0.01 or P≤0.05) higher content of polyunsaturated fatty acids (including C18:2 *n-6*, C18:3 *n-6*, C 18:3 *n-3* and CLA) compared to butter from the milk of cows receiving barley silage diets (groups BS/GS-I and BS/GS-II). Samples of butter from the milk of cows fed diets with barley silage had a significantly (P≤0.01 or P≤0.05) higher content of short- and medium-chain fatty acids (from C-4 to C-16).

Table 8. Organoleptic evaluation[1] of milk products (on a scale of 1 to 5 pts.)[2]

Item	Groups			
	MS/GS-I	MS-GS-II	BS/GS-I	BS/GS-II
Curd cheese (scores):				
Total	4.63	4.35	4.87	4.29
aroma	4.50	4.25	4.83	4.00
colour	4.87	4.75	5.00	5.00
taste	4.50	4.25	5.00	4.37
consistency during cutting	4.62	4.75	4.67	4.37
consistency in mouth	4.75	3.75	4.67	3.50
Soft rennet cheese (scores):				
Total	4.75	4.14	4.32	4.29
aroma	4.50	4.25	4.50	4.00
colour	5.00	4.75	4.00	5.00
external and cross-sectional appearance	4.62	4.25	4.50	4.37
structure and consistency	4.62	3.87	4.33	4.37
taste	4.87	4.00	4.33	3.50
Creamery butter (scores):				
Total	4.61	4.81	4.56	4.69
aroma	4.50	4.33	4.00	4.37
colour	5.00	4.67	4.00	4.37
taste	4.50	4.47	4.37	4.87
consistency/spreadability	4.62	4.00	4.00	4.75

[1] Panel of 4 assessors.
[2] According to a 5-point organoleptic scale including quality characteristics and severity coefficient (5 – very good, 1 – very poor).

The results of organoleptic evaluation of milk products (curd cheese, soft rennet cheese, creamery butter) are presented in Table 8. The data show that regardless of the type of TMR diets, all the milk products produced using a laboratory method were characterized by higher overall organoleptic scores (taking account of the quality characteristics and the severity coefficient) and higher detailed scores (with regard to aroma, colour, taste and consistency). In the case of curd cheese, the highest overall scores were obtained in group BS/GS-I, intermediate in groups MS/GS-I and MS/GS-II, and the lowest in group BS/GS-II. The highest scores for aroma, colour and taste were characteristic of curd cheese made from the milk of BS/GS-II cows, and the highest consistency in mouth was characteristic of curd cheese from MS/GS-I cows. The poorest consistency during cutting and in mouth was noted for curd cheese from the milk of BS/GS-I cows. Overall and detailed scores for soft rennet cheese followed the same pattern as for curd cheese. The least variable overall and detailed scores were observed for butter.

Discussion

The values obtained for feed intake and milk yield of cows in different feeding groups largely confirm the results of some authors (Strzetelski et al., 2008; Bilik et al., 2010) that balancing the rations for energy and protein and the appropriate choice of feeds for every stage of the production cycle have an effect on consistent milk yields and desirable nutrient content of milk. Also the results obtained in different groups for milk urea content were within the range of values reported for milk-recorded Polish Holstein-Friesian cows (Borkowska et al., 2006). The non-significantly higher milk yield of the cows fed maize silage diets could result from the higher energy intake (UFL) and better protein and starch protection from ruminal degradation in these groups. It also cannot be excluded that TMR diets with maize silage had better digestibility, which could contribute to more efficient utilization of nutrients for milk production (Kung et al., 2000).

In addition to high biological value of protein, cow's milk is a valuable source of vitamins and minerals, especially calcium, as well as some casein enzymes, whey proteins and the protein coating of fat globules, which are of major importance for processing (Litwińczuk et al., 2011). Cow's milk fat consists predominantly of saturated fatty acids (C12:0, C14:0 and C16:0), which form about 68% of total fatty acids, with nutritionally desirable mono- (mainly C18:1) and polyunsaturated fatty acids (C18:2 and C18:3) constituting a much smaller proportion of milk fat at 29% and 3%, respectively (Obiedziński et al., 1996). Because of the low coefficients of heritability for EUFA content of milk fat, nutritional methods are considered to have a much greater possibility of affecting the content of desirable fatty acids and other functional components of milk and milk products (Pisulewski et al., 2001; Strzetelski et al., 2008). Giving cows fats protected from ruminal biohydrogenation in order to incorporate long-chain fatty acids into milk fat has been considered the most effective nutritional method (Kennelly and Glim, 1996). It was shown, however, that the effects of using some fat supplements are short term (Bauman et al., 2000), whereas high-fat diets often lower daily milk yield and milk protein content, due to the permanent reduction in the number of ruminal microorganisms (Benchaar et al., 2007). Much less attention has been given to the possibility of improving the functional properties of milk by differentiating the composition of diets in the type and proportion of energy roughages to protein roughages (Fitzgerald and Murphy, 1999). The results obtained in the present experiment for the fatty acid profile of milk samples indicate that replacing maize silage with winter barley silage in TMR diets, with the same proportion of wilted grass silage, the same feed components and a similar roughage to concentrate ratio (about 70:30% in DM) has no significant effect on changing the content of different fatty acid types in milk fat. The slightly higher content of conjugated linoleic acid (CLA) and the narrower *n-6:n-3* PUFA ratio in milk fat of cows fed the diets with whole-crop maize silage suggests that this feeding strategy provides more favourable conditions for endogenous synthesis of CLA in udder tissues. This indicates that the type of energy and protein wet roughages may influence rumen metabolism and the type of fatty acids synthesized by rumen microorganisms, including rumen bypass fatty acids and those that are absorbed and deposited in mammary gland tissues in unchanged form (Lock and Garnsworthy, 2003). It is also conceivable that the higher CLA content of milk from cows fed maize silage diets compared to barley silage diets could result from differences in the content of easily soluble sugars and digestible fibre. When studying the effect of the type of silages differing in the content of fatty acids and starch (maize silage vs. grass silage) on the content of fatty acids and CLA (trans C18:1) in cow's milk, Nielsen et al. (2006) showed higher concentrations of CLA isomers and a significant interaction between silage type and concentrate level for concentrations of cis-9, trans-11 and trans-10, cis-12 CLA isomers and trans11-C18:1 and trans10-C18:1 acids. In cows fed maize silage supplemented with high-energy concentrate, there was also a change in the biohydrogenation pathway of linolenic acid, resulting in an increased concentration of the trans-10, cis-12 CLA isomer. Such results were not observed when cows were fed grass silage supplemented with high-energy concentrate. Another study (Fitzgerald and Murphy, 1999) demonstrated that partial replacement (60%) of high-quality grass silage with an immature, low-starch maize silage had no significant effect on the yield of basic milk components.

The composition and quality of raw milk determines its technological suitability and the quality and storage life of finished milk products. The values obtained in our study for the traits of technological suitability of raw milk are similar to the parameters recommended for dairy breed cows (Jurczak, 2005). The milk obtained from cows fed barley silage diets was also characterized by a similar content of major protein fractions and protein substances (namely total nitrogen, total protein, total casein and total albumin) to that required by the dairy industry (Bielak, 1997; Kraszewski et al., 2002). The slight differences that we observed in the analysed milk samples in the content of other protein fractions (total globulins, proteoses, peptones and non-protein nitrogen) do not have such a significant effect on functional properties of raw milk (Król et al., 2010). Also the quality traits of milk products (curd cheese, rennet cheese and creamery butter) made using a laboratory method were similar to those reported by other authors (Bielak et al., 1997; Wawrzyńczak et al., 2005) in terms of solids, fat, and level of fat in solids. When evaluating the yield of rennet cheese and curd cheese, it should be stressed that it is determined by the nature of clot formation and thus the yield of curd cheese with the use of acid fermentation could be different from the yield of rennet cheese in the same feeding group. This means that milk of similar composition may have different applications in cheese making depending on the type of fermentation.

The organoleptic evaluation of milk products confirmed their high quality overall and in terms of aroma, colour, taste and consistency, because scores below 4 points on a 5-point scale were only obtained for some traits. In particular, this concerned curd cheese (in terms of consistency in mouth) obtained from the milk of cows fed diets with a lower proportion (50% in DM) of energy silages; rennet cheese (in terms of structure and consistency) made from the milk of cows fed the diet with a similar proportion of maize silage; and rennet cheese (in terms of taste) obtained from the milk of cows fed the diet with a similar proportion of barley silage. Based on the evaluation of both technological and organoleptic characteristics obtained for the milk products under laboratory conditions, it is confirmed that the analysed rations are suitable for feeding dairy cows in the second trimester of lactation using the TMR system.

The results obtained in our study for varying fatty acid profile of butter correspond with the observations of other authors (Strzetelski et al., 2008) that the type of ration contributes to changes in the content of individual types of fatty acids in this product, because feeding cows with TMR diets containing maize and wilted meadow grass silages resulted in butter characterized by a higher content of PUFA (including C18:2 *n-6*, C18:3 *n-6*, C:18:3 *n-3* and CLA) and a lower content of short- and medium-chain SFA compared to feeding the diets with the same proportion of barley and wilted meadow grass silages.

In conclusion, the present study showed that in the feeding of mid-lactation dairy cows using the TMR system, whole-crop barley silage can successfully replace whole-crop maize silage to obtain milk and milk products with desirable technological and functional characteristics. This concerns the chemical composition, protein content, physicochemical traits and organoleptic scores of the milk products, with a tendency towards higher CLA content and narrower *n-6:n-3* PUFA ratio in the fat of milk from the cows fed maize silage diets. Feeding the cows a TMR diet with a higher (70% in DM) proportion of barley silage results in a higher yield of curd cheese, and feeding the diet with a similar proportion of maize silage results in a higher yield of rennet cheese compared to feeding diets with a lower (50% in DM) proportion of these silages. When feeding the cows with maize silage as the basic energy roughage, the butter obtained has a higher content of PUFA, including CLA, and a lower content of short- and medium-chain SFA compared to the feeding of cows with barley silage diets.

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Wpływ rodzaju paszy objętościowej na skład chemiczny i wartość technologiczną mleka krów żywionych systemem TMR

STRESZCZENIE

Celem badań było określenie, w jakim stopniu żywienie krów rasy phf-cb dawkami TMR, zróżnicowanymi pod względem rodzaju pasz objętościowych „energetycznych" (kiszonka z całych roślin kukurydzy – KK lub kiszonka z jęczmienia ozimego – KJ) i ich stosunku (70% lub 50% w SM) do kiszonki z przewiędniętych traw łąkowych (KT), wpłynie na wydajność, skład chemiczny, profil kwasów tłuszczowych i cechy przydatności technologicznej mleka oraz cechy jakościowe i ocenę organoleptyczną wybranych produktów mlecznych (twaróg, serek podpuszczkowy miękki, masło śmietankowe) i profil kwasów tłuszczowych w tłuszczu masła. Badania przeprowadzono w drugiej tercji laktacji na 36 krowach, przydzielonych do czterech, analogicznych grup (po 9 szt.). Stwierdzono, że zastąpienie kiszonki z kukurydzy w dawkach TMR kiszonką z jęczmienia nie miało istotnego wpływu na wydajność, skład chemiczny, profil kwasów tłuszczowych i cechy przydatności technologicznej mleka, ani zawartość głównych frakcji białek i substancji białkowych. Twaróg i serek podpuszczkowy uzyskane z mleka krów żywionych dawkami z udziałem kiszonki z jęczmienia i przewiędniętej trawy łąkowej (grupy KJ/KT-I i KJ/KT-II) oraz masło śmietankowe uzyskane z mleka krów żywionych dawkami z niższym (50% SM) udziałem kiszonek „energetycznych" (KK/KT-II i KJ/KT-II) odznaczały się wyższą ($P \leq 0,01$) zawartością suchej masy i tłuszczu niż analogiczne produkty pochodzące od krów z pozostałych grup (KK/KT-I i KJ/KT-I). Masło uzyskane z mleka krów z grup: KK/KT-I i KK/KT-II odznaczało się istotnie większą zawartością PUFA (w tym: C18:2 *n-6*, C18:3 *n-6*, C18:3 *n-3* i CLA) i mniejszą SFA (od C-4 do C-16) w porównaniu z masłem uzyskanym z mleka krów z grup: KJ/KT-I i KJ/KT-II. Bez względu na rodzaj podawanej dawki kompletnej (TMR) w drugiej tercji laktacji, wyprodukowane mleko i przetwory mleczne charakteryzowały się pożądanymi walorami funkcjonalnymi i technologicznymi.