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NUTRITIONAL VALUE AND TECHNOLOGICAL PARAMETERS OF MILK FROM ORGANIC AND CONVENTIONAL FARMS IN POLAND*

Joanna Barłowska[1], Anna Wójcik-Saganek[2], Zygmunt Litwińczuk[2], Aneta Brodziak[1♦], Anna Teter[1], Monika Kędzierska-Matysek[1]

[1]Department of Quality Assessment and Processing of Animal Products, Faculty of Animal Sciences and Bioeconomy, University of Life Sciences in Lublin, Akademicka 13, 20-950 Lublin, Poland
[2]Department of Cattle Breeding and Genetic Resources Protection, Faculty of Animal Sciences and Bioeconomy, University of Life Sciences in Lublin, Akademicka 13, 20-950 Lublin, Poland
♦Corresponding author: aneta.brodziak@up.lublin.pl

Abstract

The aim of the study was to assess the nutritional value and technological parameters of milk produced in organic and conventional farming systems, taking into account the breeds of cow, feeding system, and season of production in Poland. A total of 413 milk samples were analysed, of which 220 were from Simmental cows raised on organic farms and 193 were from conventional farms, including 64 from Polish Black-and-White cows fed in a traditional system, as well as 65 from Simmental cows and 64 from Holstein-Friesian cows fed in a TMR (Total Mixed Ration) system. The milk was analysed for content of fat, protein, lactose, and urea; somatic cell count; suitability for processing (active and titratable acidity, casein content, protein-to-fat ratio, heat stability, and rennet coagulation); and content of biologically active substances (whey proteins, fatty acids, and macro- and microelements). Simmental cows from organic farms had the lowest daily milk yield, with the lowest concentrations of basic nutrients. However, it was a richer source of α-lactalbumin, lactoferrin and lysozyme and had the highest content of PUFAs. It also had a favourable protein-to-fat ratio and the shortest rennet clotting time, but it contained less Ca, Mg and Zn than milk from farms using a TMR system. The season of production had a greater influence on the composition, nutritional value and technological parameters of milk from farms using traditional feeding, including organic farms, compared to those using a TMR diet. Milk from organic farms obtained in the summer season contained more dry matter, including total protein, β-lactoglobulin, α-lactalbumin, lactoferrin, and lysozyme. It was also characterised by a more preferable fatty acid profile, i.e. lower content of SFA and higher of UFA, including MUFA and PUFA. In turn, milk from the winter season contained more fat and showed better heat stability. At farms using traditional feeding regimens, both organic and conventional, the production period had a more significant impact on the differentiation of the content of mineral components in milk (mainly macroelements).

Key words: milk, organic farms, conventional farms, nutritional value, technological parameters, whey proteins, mineral elements, fatty acids

As societal wealth and awareness increase, consumers are showing growing interest in proper nutrition and concern for their health, and consequently in organic agricultural food products, including milk and dairy products. To meet these demands, organic milk production in the EU nearly doubled from 2007 to 2019, from 2.4 to 5.3 million tonnes (Willer et al., 2020). The largest producers of organic milk in the EU in 2019 were Germany (1.19 million tonnes in 2019), France (1.03 million tonnes), Denmark (0.71 million tonnes), Austria (0.64 million tonnes), the United Kingdom (0.57 million tonnes) and Sweden (0.46 million tonnes), accounting for 83.4% of organic production in the EU (Brodziak et al., 2021 a). There is also an upward trend in organic milk production in Poland, as it increased from 25,900 tonnes produced on 550 farms in 2019 to 28,800 tonnes produced on 499 farms in 2020 (IJHARS, 2021).

The growing consumer interest in organic milk stems from the fact that it has been confirmed to be a richer source of health-promoting substances. Studies have shown that organic milk has higher levels of protein fraction components (β-lactoglobulin, α-lactalbumin, lactoferrin, and lysozyme) (Król et al., 2008; Kuczyńska et al., 2012; Brodziak et al., 2018, 2021 b), a more favourable fatty acid profile (Ellis et al., 2006; Collomb et al., 2008; Butler et al., 2011; Kuczyńska, 2011; Ferreiro et al., 2015; Średnicka-Tober et al., 2016), and higher concentrations of fat-soluble vitamins (A, D_3, E, K_2 and

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β-carotene) (Kuczyńska et al., 2012; Puppel et al., 2017; Brodziak et al., 2018, 2020) than milk from cows raised on conventional farms. The production system also significantly affects the content of mineral elements in milk (Rey-Crespo et al., 2013; Schwendel et al., 2014; Litwińczuk et al., 2018) and its technological parameters (Barłowska et al., 2012; Litwińczuk et al., 2015).

Management of an organic farm combines the best environmental practices, a high level of biodiversity, conservation of natural resources, and high animal welfare standards. Not all cattle breeds available for conventional dairy production are suitable for organic farming, which requires more 'robust' cows, capable of functioning in the organic farming environment and adapting to local ecological conditions, in order to obtain adequate longevity and productivity (Regulation, No 2018/848; Rodríguez-Bermúdez et al., 2019; 2020). In these conditions local cattle breeds or dual-purpose breeds adapted to the climate of a given region have proven successful.

It should be stressed that it is not only diet trends but also growing environmental and climate problems that have necessitated the search for effective agricultural solutions, and this favours the promotion of organic production. In December 2019 the European Commission issued a statement on the strategy for the European Green Deal, aimed at initiating international measures for achieving economic goals with much greater respect for pro-environmental and pro-climate practices. One of the priorities is the greening of common agricultural policy, including implementation of the 'from farm to table' strategy (EC, 2019, Migdał and Migdał, 2021). Food produced in Europe should be safe for health and have high nutritional value, including bioactive substances with health benefits. Moreover, it should be produced in a manner that is safe for the natural environment and climate-neutral (Wrzaszcz and Prandecki, 2020). Compared to many parts of the world, including Europe, organic food, including milk, is still not popular among Polish consumers, mainly due to high prices and low purchasing power. Organic agriculture is one of the priorities of the new Common Agricultural Policy (CAP) for the years 2023–2027 (WPR, 2023; MRiRW, 2023), which is meant to improve the situation in this area of agricultural activity (Groszyk, 2022).

Farmsteads in Podkarpackie Voivodeship tend to be small, typically ranging from 1 to 10 ha (GUS, 2022). Permanent pastures account for 36.4% of all agricultural land. The region is moderately industrialized (SWP, 2020). The areas of the Bieszczady Mountains and the Low Beskids that are dominated by pastures are particularly well predisposed for e.g. dairy farming, including under organic conditions. Simmental cattle is the most common in the region, with the Polish Black-and-White breed as well as Holstein-Friesian cows at farms geared towards particularly intensive production also present. Despite the region's potential, farmers in Podkarpackie Voivodeship are reluctant to introduce organic farming standards. In terms of organic production, the Voivodeship ranks average at best in the context of the whole country – in 2022, 934 producers farming 12,076 ha of arable land were registered there. Meanwhile, in the leading Polish region, Zachodniopomorskie Voivodeship, organic farms take up as much as 117,812 ha, while the greatest number of organic producers – 493 – are registered in Podlaskie Voivodeship (IJHARS, 2023). Most of the global literature discussing organic dairy production focuses on the efficiency of milk production (Rodríguez-Bermúdez et al., 2017; Manuelian et al., 2022), milk composition (Manuelian et al., 2022; Kouřimská et al., 2014; Křížová et al., 2014), including fatty acids profile (Popović-Vranješ et al., 2011; Schwendel et al., 2015), content of micro- and macroelements (Gabryszuk et al., 2008; Litwińczuk et al., 2018), and hygienic quality (Kouřimská et al., 2014; Abera and Angaw, 2015; Kučević et al., 2016; Manuelian et al., 2022), while research focusses mainly on breeds used exclusively in dairy production (Kouřimská et al., 2014; Křížová et al., 2014; Rodríguez-Bermúdez et al., 2017; Manuelian et al., 2022). Studies in this area have also been conducted by Polish authors (Bilik and Łopuszańska-Rusek, 2010; Brodziak et al., 2018; Gabryszuk et al., 2008; Kuczyńska et al., 2012; Kukułowicz, 2018; Litwińczuk et al., 2018; Puppel et al., 2017). However, none of the same have been conducted in Podkarpackie Voivodeship. Moreover, to the best of our knowledge, there have been few studies focusing on organic milk production that would account for such a broad spectrum of parameters, including in terms of technological usability of the product, while also considering three distinct breeds of cattle, in this case Simmental, Polish Black-and-White (dual-purpose utility type), as well as the highly efficient Polish Holstein-Friesian breed.

In view of the above, the aim of the present study was to assess the nutritional value (proximate composition, content of whey proteins and macro- and microelements, and fatty acid profile) and technological parameters (casein content, protein-to-fat ratio, heat stability and clotting time) of milk produced in organic and conventional agricultural systems, taking into account the breed of cow, feeding system, and season of production in the Podkarpackie Voivodeship in Poland.

Material and methods

Farms and animals

The analysis included 42 farms, mainly carrying out production of market milk, of which 32 were organic (with a certificate confirming the use of organic production methods) and 10 conventional, selling milk to local dairies in the Podkarpackie Voivodeship (southern Poland). Description of farms included in the study is presented in Table 1.

Table 1. Description of farms included in the study

Item	Organic farms	Conventional farms		
		Traditional feeding	TMR (Total Mixed Ration) feeding	
Number of farms	32	5	4	1
Average number of cows on farm	3–10	10–25	about 60–80	about 100
Cow breed	Simmental (SM)	Polish Black-and-White (ZB)	Simmental (SM)	Polish Holstein-Friesian Black-and-White (HO)
Housing system	Tie-stall (with straw bedding); access to open-air runs in winter	Tie-stall (with straw bedding)	Free-stall (separate bed boxes with mats)	Free-stall (separate bed boxes with mats)
Milking system	Manual/bucket/pipeline	Bucket/pipeline	Herringbone milking parlour/side-by-side	Herringbone milking parlour
Diet	Summer – pasture forage *ad libitum* + hay Winter – haylage Supplement – organic cereal meal	Summer – pasture forage *ad libitum* + hay Winter – haylage Supplement – cereal meal	Same TMR year-round, feed supplied from a feed wagon or manually (once a day)	Same TMR year-round, feed supplied from a feed wagon (once a day)

Research material

The material for analysis consisted of milk collected individually from each cow during two seasons, winter (January–March) and summer (June–July). An effort was made to collect milk samples from the same cows in both seasons.

A total of 413 milk samples were collected for analysis, of which 220 were from Simmental (SM) cows kept on organic farms (winter – 123, summer – 97) and 193 were from conventional farms, including 64 from Polish Black-and-White (ZB) cows fed in a traditional system (winter – 32, summer – 32), and as a reference group (farms with intensive milk production, using TMR feeding), 65 from Simmental cows (SM) (winter – 39, summer – 26) and 64 from Polish Holstein-Friesian Black-and-White (HO) cows (winter – 29, summer – 35).

The material was collected according to AOAC method No. 925.20 (2019) into sterile plastic 250 ml containers, cooled to about 6°C, and transported in thermal bags with freezer packs to the laboratory of the Department of Quality Assessment and Processing of Animal Products, University of Life Sciences in Lublin, where the analyses were performed.

Laboratory analyses

Each milk sample was analysed for somatic cell count (SCC) with the Somacount 150 (Chaska, MN, USA), active acidity (pH value) with the Pioneer 65 pH–meter (Radiometer Analytical, Mettler Toledo, Greifensee, Switzerland), titratable acidity (°SH) by the titration method according to Barłowska (2011), content of fat, protein and lactose with the Bentley Infrared Milk Analyzer (dry matter content and protein-to-fat ratio were calculated from the results), casein content according to AOAC method No. 998.06 (2000), urea content with the ChemSpec 150 analyser (Chaska, MN, USA), heat stability at 140°C in a TEWES–BIS oil bath (Barczewo, Poland) by White and Davies' method (Barłowska, 2011), and rennet clotting time by Schern's method (0.25 mL of 1:1000 strength rennet solution was added to 25 mL of milk heated to 35°C, mixed, placed in a water bath at 35°C ± 0.5°C and left until the first casein floccules appeared) (Barłowska, 2011).

The content of selected whey proteins (α-lactalbumin, β-lactoglobulin, bovine serum albumin, lactoferrin and lysozyme) was determined by reversed-phase high-performance liquid chromatography (RP–HPLC). All samples were prepared according to the methodology developed by Romero et al. (1996) with modifications by Brodziak et al. (2012). After thawing the material was defatted. Then 50 mL of raw milk was brought to pH = 4.6 using 0.1 mol/L HCL and left for 1 h at room temperature for acid coagulation of casein. Then 7 mL of separated whey was removed from each sample and centrifuged for 15 min at 14,500 rpm (Universal 320R centrifuge, Andreas Hettich GmbH & Co. KG, Tuttlingen, Germany) to separate the precipitate. Following filtration into vials through qualitative filter paper (diameter 125 mm, grammage 65 g/m^2, type 3 h) and sterile syringe filters with a pore diameter of 0.20 µm (Millipore type GSTF, Dublin, Ireland), the supernatants were stored in a refrigerator until analysis. Samples were injected into the chromatography system in the amount of 0.02 mL. Proteins were separated using the ProStar 210 liquid

chromatograph and UV–VIS ProStar 325 detector (Varian, Palo Alto, CA, USA). In all cases the measurements were made using a water–acetonitrile mobile phase in a flow gradient and a Nucleosil 300-5 C18 column, 250 mm in length and 4.6 mm in diameter. The mobile phase consisted of solvents A (90% water, 10% acetonitrile) and B (90% acetonitrile and 10% water), which were filtered with syringe filters with a pore diameter of 0.45 µm and degassed by ultrasound. The time of analysis of a single sample was 35 min, at a wavelength of 205 nm and column temperature of 37°C. Reference substances were analysed in identical conditions. Based on the resulting chromatograms, qualitative identification of individual substances was performed using Star 6.2 Chromatography Workstation software (Varian, Palo Alto, CA, USA), followed by determination of their concentrations. The chromatography system was calibrated for whey proteins by the external standard method. To this end, reference solutions of whey proteins were injected, i.e. α-LA (≥ 85%), β-LG (90%), BSA (≥ 96%), and Lf (90%) from bovine milk and lysozyme (95%) from chicken egg albumen (Sigma-Aldrich, Merck KGaA, Darmstadt, Germany). All reagents were of HPLC analytical purity.

A representative number of organic (59) and conventional (87) milk samples were analysed for content of fatty acids, following fat extraction by a modification of the Röse–Gottlieb method according to PN-EN ISO 1736 (2010). Lipids were converted to methyl esters (FAME) by transmethylation of the sample using a mixture of concentrated H_2SO_4 (95%) and methanol according to AOCS Official Method Ce 2-66 (2007). FAME separation was carried out by gas chromatography (GC) according to PN-EN ISO 12966-1:2015-01 (2015) and PN-EN ISO 5508 (1996) using the Varian GC 3900 chromatograph (Walnut Creek, CA, USA) with a flame ionization detector (FID). Fatty acids were identified by comparing the retention times of individual fatty acid methyl esters (FAMEs) with the retention times of reference FAMEs (Supelco 37 Component FAME Mix CRM 47885 Supelco, Sigma-Aldrich, Darmstadt, Germany) and literature data. The results of the measurements were computed using Star GC Workstation software ver. 5.5 (Varian, Palo Alto, CA, USA). The results obtained for fatty acid methyl esters were converted to values of fatty acids (FA) expressed in g/100 g FA, using correction factors for individual fatty acids and the Sheppard factor for converting FAME to FA. On this basis the following groups of fatty acids were calculated:

• saturated fatty acids (SFA), including short- and medium-chain fatty acids (SCFA+MCFA), from C4:0 to C12:0, and long-chain fatty acids (LCFA), from C13:0 to C22:0,

• unsaturated fatty acids (UFA), including monounsaturated (MUFA) and polyunsaturated (PUFA) fatty acids.

In addition, the ratios between these acids were calculated, i.e. SFA/UFA, MUFA/SFA and PUFA/SFA.

In 202 milk samples, including 73 from organic farms and 129 from conventional farms, the content of selected macro- (K, Ca, Na, and Mg) and microelements (Zn, Cu, Fe, and Mn) was determined by atomic absorption spectrometry (AAS) according to PN–EN 14084 (2004) and PN–EN 15505 (2009). Samples for analysis were prepared according to PN-EN 13804-2013-06 (2013).

After the samples were thawed and mixed, 1 mL of milk, 1 mL of 30% hydrochloric acid and 5 mL of 65% suprapure nitric acid were measured out into polytetrafluoroethylene flasks. The solutions were mineralized under increased pressure in a MARS 5 Xpress microwave oven (CEM, Matthews, NC, USA). The parameters of this process are presented in Table 2.

Table 2. Programme settings for the MARS microwave oven for digestion of milk samples

Step	Power (W/% max power)	Increase (min/°C)	Time held (min)
1	400 W / 25%	10 min / 1000°C	10 min
2	800 W / 50%	10 min / 1500°C	5 min
3	1600 W / 100%	15 min / 1900°C	15 min

Then the digests were transferred using deionized water into 25 cm^3 polymethylpentene (PMP) volumetric flasks. For determination of K, Ca, Na and Mg, buffer was added to the samples according to Schinkel (10 g/L CsCl + 100 g/L La) so that the final solution contained 1% of the buffer. Contents of K, Ca, Na, Mg and Zn were determined with an AA 240FS spectrometer (Agilent Technologies, CA, USA), using the flame technique in standard conditions (air-acetylene flame). The concentrations of Cu, Fe and Mn were determined in a graphite furnace with Zeeman background correction (in an argon atmosphere) with an AA 240Z spectrometer (Agilent Technologies, CA, USA). Blank samples were analysed alongside the test samples. To verify the method, a certified reference material, i.e. NCS ZC 73015 Milk Powder (NACIS, Beijing China), was analysed in exactly the same manner as the test samples. The concentrations of elements were read from a calibration curve.

Statistical analysis

StatSoft Inc. Statistica ver. 13.1 software (Dell, Round Rock, TX, USA) was used for the statistical analysis. The parameters given above were examined by one- and two-way analysis of variance using a general linear model (GLM) procedure. Significant differences between means in groups were determined using Tukey's test for unequal sample sizes, at significance levels of $P = 0.05$ and $P = 0.01$. The data were presented as means for individual traits ± standard deviation.

Table 3. Yield, basic chemical composition and somatic cell count in the organic and conventional milk

Item		Organic farms						Conventional farms					
		Traditional feeding						Intensive feeding – TMR					
		Cow breed											
		Simmental (SM)			Polish Black-and-White (ZB)			Simmental (SM)			Polish Holstein-Friesian Black-and-White (HO)		
		Winter	Summer	Average	Winter	Summer	Average	Winter	Summer	Average	Winter	Summer	Average
Number of samples		123	97	220	32	32	64	39	26	65	29	35	64
Milk yield (kg)	$\bar{x}$	13.8 A	18.1 B	16.3 X	17.0 A	18.8 B	17.9 X	19.6 A	21.8 B	20.9 XY	23.1 A	26.7 B	25.2 Y
	SD	8.6	7.2	9.1	6.4	8.0	6.9	5.8	7.1	6.7	4.3	6.2	5.9
Dry matter (%)	$\bar{x}$	11.9 A	12.5 B	12.2 x	13.3 A	12.6 B	13.0 xy	12.6 A	13.3 B	12.8 xy	12.6 A	13.3 B	13.1 y
	SD	0.9	0.8	0.9	0.9	0.7	0.9	0.7	0.6	0.7	0.6	0.9	1.0
Fat (%)	$\bar{x}$	3.9 a	3.6 b	3.8 x	4.3 A	3.9 B	4.2 y	4. 2 A	3.9 B	4.0 xy	4.3	4.1	4.2 y
	SD	0.5	0.5	0.5	0.8	0.5	0.7	0.6	0.4	0.5	0.6	0.4	0.5
Total protein (%)	$\bar{x}$	3.0 A	3.3 B	3.2 x	3.2 a	3.5 b	3.4 x	3.6	3.6	3.6 y	3.4	3.5	3.4 xy
	SD	0.4	0.3	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.4	0.4	0.4
Lactose (%)	$\bar{x}$	4.7 B	4.6 A	4.7 x	4.7 b	4.8 a	4.8 y	4.8 b	4.7 a	4.8 y	4.9	4.9	4.8y
	SD	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.2	0.3
Somatic cell count – SCC (thous./mL)	$\bar{x}$	296 A	442 B	330 y	356	408	373 y	233	229	231 xy	187 a	237 b	169 x
	D	220	239	241	289	315	216	221	114	184	316	310	252
Urea (mg/L)	$\bar{x}$	147 a	196 b	163	151 A	250 B	198	174	205	186	167	189	174
	SD	58	81	94	85	122	100	40	129	97	49	95	78

a, b, A, B – differences between the seasons within a breed; a, b – significant differences at P≤0.05; A, B – significant differences at P≤0.01.
x, y, X, Y – differences between the average values; x, y – significant differences at P≤0.05; X, Y – significant differences at P≤0.01.

Table 4. Selected indicators of suitability for processing of the organic and conventional milk

Item			Organic farms						Conventional farms					
			Traditional feeding						Intensive feeding – TMR					
			Cow breed											
			Simmental (SM)			Polish Black-and-White (ZB)			Simmental (SM)			Polish Holstein-Friesian Black-and-White (HO)		
			Winter	Summer	Average	Winter	Summer	Average	Winter	Summer	Average	Winter	Summer	Average
Number of samples			123	97	220	32	32	64	39	26	65	29	35	64
Acidity	pH value	$\bar{x}$	6.7 a 0.1	6.8 b 0.1	6.8 y 0.1	6.7 a 0.1	6.8 b 0.12	6.7 y 0.1	6.7 A 0.1	6.8 B 0.05	6.7 y 0.1	6.6 A 0.1	6.7 B 0.1	6.7 x 0.1
	Titratable (°SH)	SD	7.1 A 0.9	7.9 B 1.3	7.5 1.2	6.9 0.9	7.1 1.1	6.9 0.7	7.1 a 0.7	7.6 b 0.9	7.3 0.8	7.0 0.8	6.9 0.7	6.9 0.8
Casein (%)		$\bar{x}$ SD	2.4 A 0.3	2.6 B 0.3	2.5 X 0.3	2.3 A 0.3	2.6 B 0.4	2.5 X 0.4	2.6 0.4	2.6 0.4	2.6 XY 0.4	2.6 0.4	2.7 0.4	2.7 Y 0.4
Total protein/fat		$\bar{x}$ SD	0.9 a 0.10	0.9 b 0.1	0.9 Y 0.1	0.8 0.1	0.9 0.1	0.8 XY 0.1	0.9 a 0.1	1.0 b 0.1	0.9 Y 0.13	0. 8 A 0.1	0.8 B 0.1	0.8 X 0.1
Heat stability (min)		$\bar{x}$ SD	2:5 A 1:21	2:2 B 1:1	2:3 X 1:2	3:1 a 1:4	2:5 b 1:2	3:0 X 1:4	5:3 a 2:6	4:6 b 2:2	4:6 Y 1:2	5:0 a 2:4	4:2 b 2:1	4:5 Y 1:4
Clotting time (min)		$\bar{x}$ SD	3:4 a 3:3	2:5 b 3:1	2:4 X 1:4	4:6 a 3:3	4: 1 b 2:4	4:3 X 2:6	5:6 A 1:4	4:5 B 2:2	4:4 Y 2:3	5:4 a 2:4	4: 6 b 2:6	4:6 Y 2:0

a, b, A, B – differences between the seasons within a breed; a, b – significant differences at $P \leq 0.05$; A, B – significant differences at $P \leq 0.01$.
x, y, X, Y – differences between the average values; x, y – significant differences at $P \leq 0.05$; X, Y – significant differences at $P \leq 0.01$.

Results

Milk yield and composition

The data in Table 3 show that Holstein-Friesian (HO) cows fed on TMR system produced significantly (P≤0.01) more milk per day compared to Simmental (SM) cows kept on certified organic farms (by 8.9 kg) and local Polish Black-and-White (ZB) from conventional farms fed traditionally (by 5.6 kg). Simmental cows from farms using the intensive husbandry system obtained daily yield at a similar level as Holstein-Friesian cows. Organic milk also had the lowest content of dry matter (P≤0.05), including fat (P≤0.05), crude protein (P≤0.05) and lactose (P≤0.05). Milk from Simmental cows kept on organic farms had lower content of dry matter by 0.6 p.p. (percentage points), including fat (0.2 p.p.), crude protein (0.4 p.p.), and lactose (0.01 p.p.), than milk from the same breed fed in a TMR system. However, it was statistically confirmed (P≤0.05) only in the case of total protein and lactose content. Even greater differences were noted in comparison with the milk of HO cows fed in the TMR system: 0.9 (P≤0.05), 0.4 (P≤0.05), 0.2, and 0.1 p.p. (P≤0.05), respectively. Statistically significant (P≤0.05) differences between the organic milk and milk from ZB cows fed in the traditional system were stated for fat and lactose content, 0.3, and 0.1 p.p., respectively. The significantly (P≤0.05) highest values for somatic cell count (SCC) were noted for milk from ZB cows kept in a traditional system (373,000/mL) and from SM cows on organic farms (330,000/mL), while the lowest SCC values were observed in milk from HO cows kept in an intensive system (169,000/mL; Table 3). There were no significant differences between groups of cows for urea content in milk (Table 3). In all groups of cows (irrespective of the type of farm and feeding system), daily milk yield was significantly (P≤0.01) higher in summer than in winter (Table 3). Summer milk generally had higher (P≤0.01) content of dry matter, except for milk from ZB cows fed traditionally. Protein content during this season was higher in milk from SM cows on organic farms (P≤0.01) and ZB cows (P≤0.05). On the other hand, milk from all groups of cows had higher concentrations of fat in winter, which was confirmed statistically in SM cows from organic (P≤0.05) and conventional (P≤0.01) farms as well as in the ZB breed (P≤0.01). Milk lactose content was generally higher in winter, except in the case of ZB cows fed traditionally. On organic farms (SM breed) and those using a TMR diet (HO), the SCC in milk was significantly (P≤0.05) higher in summer. Urea content in milk was also higher during this season, which was confirmed statistically in milk from organic farms (P≤0.05) and conventional farms using a traditional feeding system (Table 3).

Suitability for processing

The data in Table 4 show that milk from organic farms (SM cows) and conventional farms with the local ZB breed had significantly (P≤0.01) lower casein content (2.5%) than milk from HO cows fed a TMR diet (2.7%). Milk from SM cows kept on organic farms compared to cows of the same breed fed a TMR diet contained 0.13 p.p. less casein. The protein-to-fat ratio was highest in milk from SM cows fed in the TMR system (0.9) and cows of the same breed kept on organic farms (0.9). It was significantly (P≤0.01) the lowest (0.79) in milk from HO cows from farms using an intensive system (Table 4). The active acidity of milk from SM cows from organic farms was similar to that of milk from cows of the same breed raised in a TMR system and ZB cows kept in a traditional system (pH 6.7–6.8). Acidity was significantly (P≤0.05) higher in the milk of Holstein-Friesians fed a TMR diet. However, there were no significant differences between groups for the titratable acidity of milk (Table 4). The milk of traditionally fed cows (Simmental cows from organic farms and Polish Black-and-White breed) was characterised by a significantly (P≤0.01) shorter rennet clotting time, as compared to milk obtained from cows fed under the TMR system (SM and HO breeds). The milk of cows fed in a TMR system, however, had the highest heat stability (nearly twice the time needed for the first casein floccules to appear in comparison to organic milk) (Table 4). The milk obtained during the summer season from SM cows kept at organic farms and ZB cows receiving traditional fodder contained more casein (P≤0.01). The protein-to-fat ratio was higher in summer in all groups of farms, which was confirmed statistically in all cases except ZB cows. Active acidity of milk was higher in the winter, while titratable acidity was higher in summer (P≤0.05; P≤0.01). The heat stability of milk was also significantly higher (P≤0.05; P≤0.01) in winter in all groups of farms, while the clotting time was shorter in summer (P≤0.05; P≤0.01; Table 4).

Biologically active components

Whey proteins

The data in Table 5 show that the milk of SM cows from organic farms and ZB cows fed traditionally had the highest content of β-lactoglobulin, lactoferrin and lysozyme (P≤0.01), while the content of these proteins was lowest in milk from HO cows fed a TMR diet. Irrespective of the type of farm and feeding system, the content of lactoferrin and lysozyme in the milk was significantly (P≤0.01; P≤0.05) higher in the summer. A similar pattern was noted for the concentration of β-lactoglobulin (P≤0.01; P≤0.05) in the milk, except for the group of HO cows (fed a TMR diet). Higher α-lactalbumin content in summer was shown only in milk from Simmental cows raised on organic or conventional farms. The content of serum albumin was higher (P≤0.01) in winter in the SM cows from organic farms and in the HO cows (TMR system; Table 5).

Table 5. Content of selected whey proteins in the organic and conventional milk

Item		Organic farms						Conventional farms					
		Traditional feeding						Intensive feeding – TMR					
		Cow breed											
		Simmental (SM)			Polish Black-and-White (ZB)			Simmental (SM)			Polish Holstein-Friesian Black-and-White (HO)		
		Winter	Summer	Average	Winter	Summer	Average	Winter	Summer	Average	Winter	Summer	Average
Number of samples		123	97	220	32	32	64	39	26	65	29	35	64
α-lactalbumin (g/L)	$\bar{x}$	1.0 a	1.1 b	1.1	1.1	1.1	1.1	1.0a	1. 1b	1.1	1.0	1.0	1.0
	SD	0.1	0.2	0.2	0.1	0.2	0.1	0.1	0.2	0.2	0.1	0.1	0.1
β-lactoglobulin (g/L)	$\bar{x}$	3.2 A	3.6 B	3.4 Y	3.4 a	3.6 b	3.4 Y	3.2 A	3.5 B	3.3 Y	2.9	3.0	3.0 X
	SD	0.3	0.4	0.5	0.4	0.6	0.5	0.3	0.6	0.4	0.3	0.3	0.3
Bovine serum albumin – BSA (g/L)	$\bar{x}$	0.5 A	0.4 B	0.5	0.5	0.4	0.4	0.5	0.5	0.5	0.5 A	0.5 B	0.5
	SD	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Lactoferrin (mg/L)	$\bar{x}$	111.9 A	143.7 B	125.9 Y	112.9 A	139.5 B	123.7 Y	100.7 A	123.5 B	109.8 X	90.9 a	96.8 C	96.8 X
	SD	12.8	21.8	23.5	15.6	28.4	27.2	12.0	13.9	17.0	17.5	19.4	19.4
Lysozyme (μg/L)	$\bar{x}$	10.6 A	11.9 B	11.2 Z	10.8 A	13.4 B	12.0 Z	9.8	10.2	9.9 Y	6.1 A	6.9 C	6.9 X
	SD	2.6	3.9	3.3	2.7	4.0	3.2	3.1	2.7	2.9	2.0	2.4	2.4

a, b, A, B – differences between the seasons within a breed; a, b – significant differences at P≤0.05; A, B – significant differences at P≤0.01.
X, Y, Z – differences between the average values; significant at P≤0.01.

Table 6. Profile of fatty acids in the organic and conventional milk (%)

Item			Organic farms						Conventional farms					
			Traditional feeding						Intensive feeding – TMR					
			Cow breed											
			Simmental (SM)			Polish Black-and-White (ZB)			Simmental (SM)			Polish Holstein-Friesian Black-and-White (HO)		
			Winter	Summer	Average	Winter	Summer	Average	Winter	Summer	Average	Winter	Summer	Average
Number of samples			28	31	59	15	13	28	15	17	32	12	15	27
Fatty acids (%)	SFA	$\bar{x}$	68.2 B	64.5 A	66.3 X	68.7 B	65.6 A	67.1 X	70.9 b	69.0 a	69.9 Y	71.6	70.2	70.8 Y
		SD	4.8	3.4	4.5	8.9	7.1	8.3	5.9	5.7	5.8	3.5	4.7	4.2
	SCFA+MCFA	$\bar{x}$	10.4 a	11.2 b	10.8 X	10.7	11.2	11. 0 X	11.7	11.3	11.5 Y	12.0	11.5	11.7 Y
		SD	3.8	3.6	3.7	2.6	2.4	2.6	2.0	3.8	3.1	1.3	2.2	1.85
	LCFA	$\bar{x}$	57.8 B	53. 4 A	55.5 X	58.1 B	54.4 A	56.3 X	59.2 b	57.7 a	58.3 Y	59.6	58.8	59.1 Y
		SD	4.2	2.4	4.0	8.7	7.5	8.0	6.0	7.9	7.0	3.5	4.86	4.3
	UFA	$\bar{x}$	31.8 A	35.5 B	33.7 Y	31.3 A	34.4 B	33.9 Y	29.1 a	31.0 b	30.1 X	28.4 a	29.8 b	29.2 X
		SD	4.8	3.4	4.5	8.9	7.1	8.3	5.9	5.7	5.8	3.5	4.7	4.2
	MUFA	$\bar{x}$	27.4 A	29.7 B	28.6 y	27.0 A	29.1 B	28.0 y	25.8 a	27.4 b	26.7 x	25.6 a	26.8 b	26.3 x
		SD	4.4	3.1	3.9	6.5	4.78	6.1	5.5	4.9	5.12	3.1	4.5	3.9
	PUFA	$\bar{x}$	4.4 A	5.8 B	5.1 Y	4.3 A	5.3 B	5.147 Y	3.2 a	3.6 b	3.4 X	2.8	3.0	2.9 X
		SD	0.6	0.6	0.9	4.3	4.9	3.7	1.3	2.8	2.2	0.6	0.6	0.6
Proportion	SFA/UFA	$\bar{x}$	2.2 A	1.8 B	2.0 X	2.5 A	2.0 B	2. 3 XY	2.6 a	2.3 b	2.4 Y	2.6	2.4	2.5 Y
		SD	0.47	0.3	0.4	1.0	0.6	0.8	0.7	0.6	0.7	0.4	0.6	0.5
	MUFA/SFA	$\bar{x}$	0.4 A	0.5 B	0.4 y	0.4 A	0.5 B	0.4 y	0.4 a	0.4 b	0.4 x	0.4 a	0.4 b	0.4 x
		SD	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
	PUFA/SFA	$\bar{x}$	0.1 A	0.1 B	0.1 Y	0.1 a	0.1 b	0.1 Y	0.1	0.1	0.1 X	0.0	0.0	0.0 X
		SD	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0

SFA – saturated fatty acids; SCFA+MCFA – short- and medium-chain fatty acids; LCFA – long-chain fatty acids; UFA – unsaturated fatty acids; MUFA – monounsaturated fatty acids; PUFA – polyunsaturated fatty acids.
a, b, A, B – differences between the seasons within a breed; a, b – significant differences at P≤0.05; A, B – significant differences at P≤0.01.
x, y, X, Y – differences between the average values; x, y – significant differences at P≤0.05; X, Y – significant differences at P≤0.01.

Table 7. Content of selected macro- and microelements in the organic and conventional milk (mg/L)

Item		Organic farms						Conventional farms					
		Traditional feeding						Intensive feeding – TMR					
		Cow breed											
		Simmental (SM)			Polish Black-and-White (ZB)			Simmental (SM)			Polish Holstein-Friesian Black-and-White (HO		
		Winter	Summer	Average	Winter	Summer	Average	Winter	Summer	Average	Winter	Summer	Average
Number of samples		39	34	73	15	17	32	28	24	52	20	25	45
K	$\bar{x}$	1592.8 A	1799.2 B	1688.9 Y	1065.5	1080.2	1072.8 X	1694.8 B	1505.3 A	1607.3 Y	1794.8	1791.0	1792.7 Z
	SD	222.8	331.4	295.4	126.7	119.6	120.2	156.6	273.4	236.2	96.6	272.2	210.8
Ca	$\bar{x}$	1019.9 B	893.0 A	960.8 X	840.7 A	1088.1 B	964.4 X	1327.2	1349.1	1337.3 Z	1196.7	1109.8	1148.4 Y
	SD	243.7	192.3	228.8	161.9	207.1	169.4	229.6	196.8	213.3	150.2	193.3	179.0
Na	$\bar{x}$	397.7 A	518.4 B	453.9 y	442.1 b	345.4 a	393.8 x	402.0	469.4	433.1 y	477.7	468.0	472.3 y
	SD	136.4	182.5	169.6	189.1	74.8	148.5	62.5	198.1	144.6	98.5	93.5	94.8
Mg	$\bar{x}$	95.2	88.6	92.1 x	116.8	109.8	113.3 y	114.4	108.8	111.8 y	134.4 A	119.6 B	126.2 y
	SD	17.2	15.0	16.4	12.3	19.1	16.1	15.7	19.8	17.8	14.0	15.8	16.6
Zn	$\bar{x}$	4.5	3.7	4.1 x	5.5 b	2.7 a	4.1 x	5.3	5.5	5.4 y	4.45	4.9	4.7 xy
	SD	1.9	1.5	1.8	1.6	1.9	0.2	2.3	1.3	1.9	2.2	2.3	2.2
Fe	$\bar{x}$	0.7 B	0.4 A	0.5 Y	0.2	0.3	0.2 X	0.9	1.1	1.0 Z	0.5	0.7	0.6 Y
	SD	0.3	0.2	0.3	0.1	0.1	0.1	0.8	1.24	1.0	0.3	0.5	0.4
Cu	$\bar{x}$	0.05	0.05	0.05 X	0.04	0.06	0.04 X	0.11	0.13	0.11 Y	0.08 a	0.06 b	0.07 X
	SD	0.04	0.04	0.04	0.02	0.03	0.03	0.08	0.11	0.06	0.05	0.04	0.05
Mn	$\bar{x}$	0.04	0.04	0.04	0.02	0.04	0.03	0.04	0.06	0.05	0.03	0.04	0.03
	SD	0.02	0.02	0.02	0.01	0.01	0.02	0.04	0.05	0.04	0.01	0.01	0.01

a, b, A, B – differences between the seasons within a breed; a, b – significant differences at P≤0.05; A, B – significant differences at P≤0.01.
x, y, X, Y, Z – differences between the means; x, y – significant differences at P≤0.05; X, Y, Z – significant differences at P≤0.01.

Fatty acids

The milk of cows from farms using traditional feeding, both organic and conventional, was shown to have lower levels of saturated fatty acids (SFA), including short- and medium-chain (SCFA+MCFA) and long-chain (LCFA) fatty acids, and higher content of unsaturated fatty acids (UFA), including mono- (MUFA) and polyunsaturated (PUFA) fatty acids, in comparison to milk from farms using intensive TMR feeding ($P \leq 0.01$; $P \leq 0.05$; Table 6). This translated to a more favourable, i.e. lower, SFA/UFA ratio and higher MUFA/SFA and PUFA/SFA ratios in the milk of cows fed traditionally, from both organic and conventional farms. It should also be noted that the PUFA percentage in milk from organic farms (5.1%) was 1.5 times higher than in milk from farms using a TMR diet (2.9–3.4%; Table 6). Milk from cows fed traditionally, both SM cows from organic farms and ZB cows from conventional farms, was shown to have a more favourable fatty acid profile in the summer, with a lower share of SFAs and a higher share of UFAs, including MUFAs and PUFAs ($P \leq 0.01$). Similar relationships, but less significant ($P \leq 0.05$), were found for the milk of SM cows raised intensively. The production season did not affect the fatty acid profile of the milk of HO cows raised intensively (Table 6).

Mineral elements

The data in Table 7 indicate that the milk of cows fed a balanced TRM diet generally had higher content of macro- and microelements. The milk of HO cows had the highest concentrations of K, Na and Mg, while milk from SM cows had the highest content of Ca, Zn, Cu and Fe. The milk of SM cows from organic farms contained significantly less Ca, Mg and Zn, while that of ZB fed traditionally had lower content of K, Ca, Na, Zn, Cu and Fe. On farms using traditional feeding, both organic and conventional, the production season had a greater influence on the content of mineral elements in the milk (mainly macroelements) than on farms using a balanced TMR diet (Table 7).

Discussion

Milk yield and composition

The lower milk yield obtained in the present study in cows from organic farms is the confirmation of other authors' results (Bilik and Łopuszańska-Rusek, 2010; Rodríguez-Bermúdez et al., 2017; Manuelian et al., 2022). Bayram at al. (2021) reported that the milk yield of cows kept in organic conditions is 10–35% lower than on conventional farms. They explained the lower productivity of cows on organic farms by the limited use of concentrate feeds and a high level of roughage with low protein and energy content. According to Roesch et al. (2005), however, the lower milk yield of cows on organic farms and integrated farms is due to a number of individual factors at the level of the animals and the farms, such as breed, diet, management, and udder health. Bilik and Łopuszańska-Rusek (2010) showed that organic feeding of Red-and-White × Red-and-White Holstein-Friesian cows (on average 67.5% HF) kept in natural conditions and producing about 7,000 kg of milk per lactation reduced milk production by 9–15% in comparison to conventional (TMR) feeding (6,666.7 vs. 7,353.4 kg). Similar results were reported by Rodríguez-Bermúdez et al. (2017), who compared the lactation yield of Holstein-Friesian cows kept on organic farms and on conventional farms in northern Spain, with or without pasture grazing. Cows from organic farms produced about 30% less milk (6,962 kg) than cows on conventional farms without grazing (9,987 kg) and about 10% less than on farms with grazing (7,757 kg). Brodziak et al. (2018) evaluated the milk of Simmental cows and showed that their daily milk yield in summer was about 20% lower on organic farms than on conventional farms using intensive feeding (PMR) and 8% lower than on conventional farms using traditional feeding, while in winter the corresponding differences were 31% and 5%, respectively. Król et al. (2016) found that organic and traditional milk production systems did not fully meet the nutrient requirements of cows. The lower daily milk yield of cows of the local ZB breed raised on conventional farms using traditional feeding (pasture in summer and haylage in winter) compared to cows fed intensively is the confirmation of our earlier research (Barłowska et al., 2012; Litwińczuk et al., 2012).

The lower concentrations of basic nutrients in milk from cows from organic farms compared to conventional farms is generally the confirmation of other authors' results (Kuczyńska et al., 2012; Kouřimská et al., 2014; Kučević et al., 2016; Manuelian et al., 2022). Manuelian et al. (2022) evaluated milk from 12 organic and 12 conventional farms with HF cows (21 herds) or ≥50% HF cows (3 herds) and showed that the former had lower concentrations of protein (by 0.12 p.p.), fat (by 0.16 p.p.) and lactose (by 0.02 p.p.). Kouřimská et al. (2014) compared the composition of milk from the same breed and reported that the protein and lactose content were higher in the milk from cows kept on conventional farms, while the fat content was higher in the milk from organic farms. Brodziak et al. (2018) also observed lower content of protein (by 0.22 p.p.) and fat (by 0.31 p.p.) in the milk of Simmental cows from organic farms in comparison to farms using an intensive PMR feeding system. In the case of somatic cell count, results are not consistent; Kuczyńska et al. (2012) and Manuelian et al. (2022) indicate a higher SCC in milk from organic farms, while Kouřimská et al. (2014) and Kučević et al. (2016) report higher SCC in milk from conventional farms. The seasonal differences shown in the milk yield of cows and milk composition between groups of farms may be due to multiple factors. On farms with pasture feeding (organic and conventional – traditional feeding) they are mainly due to seasonal differences in feed quality. The main feed in the summer is young green forage rich in

protein, which increases milk yield (Auldist et al., 2013). In cows fed a TMR diet, these differences may be due to factors such as the stage of lactation or the animals' overall health condition (Jóźwik et al., 2012; Bondan et al., 2021). Differences in milk composition between seasons were described by many authors analysing milk from both organic farms (Kuczyńska et al., 2011) and conventional farms, mainly those using traditional feeding (Barłowska and Litwińczuk, 2006; Barłowska et al., 2013; Brodziak et al., 2020; Florio et al., 2022). Most authors generally report higher milk fat concentrations in winter and higher protein content in summer. This mainly applies to cows fed green forage in summer and haylage or hay in winter.

Suitability for processing

The suitability of milk for processing is determined by factors such as casein content, protein-to-fat ratio, acidity, heat stability, and rennet clotting time. To the best of our knowledge, however, there have been few studies on these dependencies in organic milk. In the case of casein, Manuelian et al. (2022) and Kouřimská et al. (2014) confirmed that its content is lower in the milk of cows from organic farms as compared to conventional farms. In the present study, the more favourable protein-to-fat ratio in the milk of Simmental cows in comparison to Holstein-Friesian cows is the confirmation of our own earlier research (Barłowska et al., 2009, 2014; Litwińczuk et al., 2012). The milk from all groups of farms met the criteria for fresh milk (Barłowska, 2011). The heat stability of milk is an important criterion of its suitability for processing into products with a long shelf life (UHT milk and cream, condensed milk and powdered milk). The ability of milk to withstand a specific heat treatment without perceptible changes such as protein flocculation is commonly described as heat stability (Dumpler et al., 2020). The results obtained for this parameter and the relationships between breeds and feeding systems are in agreement with those obtained in our previous research (Barłowska and Litwińczuk, 2006; Barłowska et al., 2012; Litwińczuk et al., 2012), which showed that Holstein-Friesian cows fed in a TMR system and Simmental cows kept on conventional farms and fed traditionally produced milk with significantly ($P \leq 0.01$) higher heat stability than that of milk from local breeds (Polish Black-and-White and Polish Red) fed traditionally (pasture feeding). An important factor for the production of rennet cheese is the enzymatic coagulation time of milk, which significantly affects the firmness of the curd (Barłowska et al., 2014). Coagulation parameters are influenced by various factors, including the concentrations of casein, calcium and phosphorus, titratable acidity, genetic variants of milk proteins, somatic cell count, type of feed, and stage of lactation (Barłowska et al., 2014; Weerasingha et al., 2020). According to Jõudu et al. (2007) and St-Gelais and Hache (2005), milk with the longest rennet clotting time is highly resistant to the effects of high temperature. This is partially supported by the results of the present study. Most authors report that the milk of local breeds (usually fed in a traditional system with pasture) has better coagulation parameters than the milk of highly productive breeds (De Marchi et al., 2007; Bittante et al., 2012; Litwińczuk et al., 2012; Weerasingha et al., 2020). In the present study, the clotting time of milk from the local Polish Black-and-White breed was intermediate between that of the milk from organic farms (the shortest) and from Holstein-Friesians fed a TMR diet (the longest). According to De Marchi et al. (2007), differences in the clotting parameters of milk are determined mainly by genetic factors. Milk from Simmental cows fed traditionally has comparable coagulation parameters (shorter rennet clotting time) to milk from local breeds (Barłowska and Litwińczuk, 2006; Bittante et al., 2012; Litwińczuk et al., 2012), but in intensive production conditions (TMR feeding) its clotting time is longer (Barłowska et al., 2014). This is supported by the present study, in which the clotting time of the milk of this breed from organic farms was half that of milk from cows of the same breed kept on farms using TMR feeding. The shorter clotting time of milk obtained in summer in all groups of farms is the confirmation of our previous research (Barłowska et al., 2012, 2014). The reverse pattern, however, was reported by Teter et al. (2020), who showed that rennet clotting time (RCT) and curd firmness (A_{30}) were more favourable for milk obtained in autumn and winter. The authors claim that this is due in part to the susceptibility of cows to heat stress in summer, and that native breeds are more tolerant of high temperatures.

Biologically active components

Whey proteins

The higher content of whey proteins (especially β-lactoglobulin, lactoferrin and lysozyme) in milk from organic farms and conventional farms using traditional feeding, in comparison to intensive TMR feeding, is the confirmation of other authors' results (Król et al., 2008; Kuczyńska et al., 2012; Puppel et al., 2017; Brodziak et al., 2018, 2020). However, it should be noted that this is a narrow area of research and there are few new studies investigating these relationships in the case of organic milk. Brodziak et al. (2018) showed that milk from farms using organic and traditional systems had higher content of whey proteins (especially lactoferrin and lysozyme) than milk from intensive systems (PMR). In addition, content of individual whey proteins was significantly higher in milk from summer. Kuczyńska et al. (2012) reported higher content of β-lactoglobulin ($P \leq 0.01$), lactoferrin ($P \leq 0.05$) and lysozyme in organic milk (4.12 g/L, 334.9 mg/L, 15.68 µg/L, respectively) at the end of the pasture season (September) than in conventional milk (2.68 g/L, 188.0 mg/L, 12.56 µg/L, respectively). Organic milk obtained at the start of barn feeding (in November, when there was no longer access to fresh green forage) had significantly ($P \leq 0.01$) lower concentrations of BSA (118.65 vs. 146.47 g/L), lactoferrin

(185.27 vs. 215.49 g/L) and lysozyme (13.23 vs. 16.64 μg/L). The effect of the season on the content of whey proteins (α-lactalbumin, β-lactoglobulin and lactoferrin) was also the subject of research by Bär et al. (2020). The study included 12 conventional dairy farms in Switzerland, differing in the proportions of fresh and preserved herbs in the diet and in the breeds of cattle. The content of β-lactoglobulin in bulk milk was varied during the year, reaching the lowest values in February and September, while the content of lactoferrin was higher in winter than in summer on all farms. Overall, the content of whey proteins was more varied in the milk of cows whose diet contained a large amount of herbs and least varied in milk from cows receiving small amounts of herbs. The results are in agreement with those reported by Křížová et al. (2014), who observed a decline in the total content of whey proteins in milk from Czech Fleckvieh and Holstein cows in the summer compared to the winter. Furthermore, the content of all protein fractions was lower in milk from grazing cows compared to non-grazing cows. The results of these two studies conflict with those cited earlier. Mackle et al. (1999) showed that an increase in energy intake from feed increases the concentration of whey proteins in milk. They reported an increase in the content of whey proteins in milk from traditional and organic systems (more roughage) compared to milk from cows fed a limited amount of green forage (intensive system). Therefore environmental factors (feeding system, location of the farm, or season) play a significant role, and this type of research should be continued in different parts of the world.

Fatty acids

In the present study milk from organic farms and conventional farms using traditional feeding had a more favourable fatty acid profile (lower level of SFAs and higher levels of MUFAs and PUFAs) than milk from farms using intensive TMR feeding, which is the confirmation of other authors' results (Battaglini et al., 2009; Kučević et al., 2016; Popović-Vranješ et al., 2011). Battaglini et al. (2009) showed that milk produced in compliance with organic methods, during both pasture feeding and barn feeding, had a more favourable level of PUFAs, by 0.45 p.p. and 0.82 p.p., respectively ($P<0.001$), than conventional milk. Popović-Vranješ et al. (2011), in a study carried out in Serbia, obtained significantly ($P<0.01$) higher levels of PUFAs (by 0.44 p.p.) and n-3 fatty acids (by 0.38 p.p.) in milk from organic farms. However, it also had a higher SFA level (by 0.67 p.p.) and a lower MUFA level (by 1.51 p.p. at $P<0.05$), which was not confirmed in the present study. Many authors (Fall and Emanuelson, 2011; Popović-Vranješ et al., 2011; Litwińczuk et al., 2012) link pasture feeding to the production of milk with increased content of polyunsaturated fatty acids. This influences seasonal differences in the fatty acid profile, confirmed in the present study in the case of farms producing organic milk and those using a traditional feeding system. Schwendel et al. (2015) compared organic and conventional milk produced using year-round pasture grazing in New Zealand and found that the levels of linoleic acid and α-linolenic acid were higher in organic milk, while those of conjugated linoleic acid (CLA) and vaccenic acid were higher in conventional milk. The concentrations of the first three fatty acids (linoleic acid, α-linolenic acid and CLA) were higher in milk produced in autumn than in spring.

Mineral elements

In considering the content of mineral elements in milk, it should be stressed that environmental factors, mainly the feeding system and feed quality, have the greatest influence on their intake by the animal. The content of mineral elements in feed prepared on the farm is strictly dependent on local soil and climate conditions and on the use of mineral and vitamin supplements in the diet of cows (Zamberlin et al., 2012; Litwińczuk et al., 2018; Kao et al., 2020). Factors influencing the mineral content of soil and pastures include fertilizers, the amount of sewage sludge, the type of soil, and the proximity of mining and industrial areas (Schwendel et al., 2014; Karbivska et al., 2020). In conventional agriculture soil fertility can be increased by using mineral fertilizers enriched with selected microelements. In addition, the diet of cows is supplemented with mineral mixtures. Both of these methods are restricted in organic agriculture (Regulation, 2018/848). The most popular system for feeding highly productive cows is currently the use of a mixture of roughage and concentrate feeds supplemented with vitamins and mineral elements (TMR – Total Mixed Ration and PMR – Partial Mixed Ration). The feed must be complete, meeting the requirements for all essential nutrients, as any deficiencies can negatively affect the animals' health as well as the quality and quantity of milk produced (Winnicki et al., 2012; Litwińczuk et al., 2018).

There is a lack of current literature reports with which the results of the present study could be compared, especially as concerns organic milk. Reports on the effect of the organic production system on the content of mineral elements in milk are not conclusive. Some studies (Hermansen et al., 2005; Kuczyńska, 2011; Koperska et al., 2013) indicate that such milk may have lower content of numerous elements, which may be linked to their low content in the soil and thus in the feed. This is consistent with the results of the present study, in which milk from cows fed intensively had higher content of all elements analysed than organic milk. This is also reported in a study by Koperska et al. (2013), in which milk from organic farms had significantly ($P\leq0.05$) lower content of the elements analysed (Ca, Mg, Zn, Mn and Cu) than milk from conventional farms. Only the Fe concentration was significantly ($P\leq0.01$) higher. Gabryszuk et al. (2008) also showed a higher concentration of Fe, but also of Ba, Co, Ge, Cr, Si, Li and Zn, in organic milk in comparison to milk from intensive production. Milk from extensive farms (conventional and organic), on which cows

used pasture, had lower content of P, B, I, Ni, Sr and V. In contrast, Kuczyńska (2011) reported that grazing (supplemented with maize silage or haylage) has a positive effect on the P concentration in organic milk. Samples from cows fed in a TMR system, including in summer, had the highest Ca level (1,102.2 mg/l) and Ca/P ratio (1.380). Results reported by Król et al. (2010), on the other hand, suggest that pasture forage positively affects the content of macroelements involved in the formation of bone tissue, i.e. Ca ($P \leq 0.05$) and Mg ($P \leq 0.05$), in milk. This is partially in agreement with results reported by Qin et al. (2021) in a study including 43 conventional farms and 27 organic farms in the United Kingdom. Organic milk contained more Ca (1,049.5 vs. 995.8 mg/kg), K (1,383.6 vs. 1,362.4 mg/kg), P (806.5 vs. 792.5 mg/kg) and Mo (73.3 vs. 60.6 µg/kg), but less Cu (52.4 vs. 60.6 µg/kg), Fe (0.66 vs. 2.03 mg/kg), Mn (28.8 vs. 45.0 µg/kg), Zn (4.51 vs. 5.00 mg/kg) and Al (0.32 vs. 1.14 µg/kg) than conventional milk. The authors observed significant seasonal variation in these mineral elements, as most of them (except Fe) had higher concentrations in winter (January–March) than during the rest of the year. According to Rey-Crespo et al. (2013), this is due to higher concentrate intake and lower grazing intake. As in the study by Qin et al. (2021) and in many cases in the present study, concentrations in the milk were lower in summer and higher in winter, which was confirmed statistically (Ca – $P<0.001$, P – $P<0.001$, Mg – $P<0.002$). Valuable milk can be obtained from cows grazing on high-quality pastures. For this reason its production on organic farms seems to be the simplest and cheapest way to increase its content of health-promoting substances (Kuczyńska and Puppel, 2010; Metera et al., 2010; Kuczyńska, 2011).

Conclusions

The comprehensive study of organic milk obtained from Simmental cows representing the dual-purpose type in comparison to milk from conventional farms with cows of the same breed and highly-productive (Holstein-Friesian) cows kept in intensive systems, as well as cows of a local breed (Polish Black-and-White) kept in a traditional system, is the confirmation of previously published results on the lower productivity of animals from organic farms as well as lower concentrations of basic nutrients in the milk. However, the organic milk was of good quality in terms of somatic cell count (indicating a healthy udder) and technological parameters indicating suitability for processing, especially a high protein-to-fat ratio and the shortest rennet clotting time, which is important in cheese production. Moreover, it had higher content of biologically active compounds (mainly whey proteins and unsaturated fatty acids, especially PUFAs) than milk from conventional production. However, it was less rich in Ca, Mg and Zn than milk from farms using TMR feeding. The season of production had a greater influence on the composition, nutritional value, and technological parameters of milk from farms using traditional feeding, including organic farms, compared to those using TMR.

During the summer season, cows kept at organic farms produced more milk with a higher content of dry matter, including total protein. Furthermore, it contained more β-lactoglobulin, α-lactalbumin, lactoferrin, and lysozyme. It was also characterised by a more preferable fatty acids profile, i.e. a lower content of SFA and higher of UFA, including MUFA and PUFA. In turn, milk from the winter season contained more fat and showed better heat stability. At farms using traditional feeding regimens, both organic and conventional, the production period had a more significant impact on the differentiation of the content of mineral elements in milk (mainly macroelements).

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