Scientific Annals of Polish Society of Animal Production - Vol. 9 (2013), No 4, 39-52

Characteristics of chemical composition and lipid fraction of semi-hard ripening cheese produced from sheep and sheep-cow milk during summer season

Anna Jarzynowska, Eugeniusz Kłopotek

National Research Institute of Animal Production,
Kołuda Wielka Experimental Station,
ul. Parkowa 1, 88-160 Janikowo; e-mail: ajarzynowska@onet.pl

The aim of the studies was to determine the effect of partial substitution of sheep milk (MO) with cow milk (MK) on production effectiveness of semi-hard ripening cheese and its composition, with consideration of lipid fraction. The studies were carried out in Institute of Animal Production – State Research Institute (IZ-PIB), Experimental Station in Kołuda Wielka in 2009 and 2010. The semi-hard ripening cheese was produced in summer, from milk of dairy--prolific Kołuda ewes and mixtures of the mentioned milk with cow milk in ratio 6:4 (6/4) and 4:6 (4/6). Production effectiveness of raw material for cheese manufacture was determined on the grounds of cheese mass yield. In raw materials and cheese, the content of basic components, cholesterol and fatty acid profile were determined. It was found that the substitution (replacement) of the sheep milk with the cow milk in the quantity of 40 and 60% caused a significant decrease of the level of dry solids, protein, fat and cholesterol in raw materials for cheesemaking what was reflected in lower yield of fresh cheese obtained from raw materials 6/4 and 4/6 in relation to the sheep milk, by 5.35 and 8.31 percentage points, respectively and of ripened cheese – by 4.84 and 7.34 percentage points, respectively (P≤0.01). The 60-% substitution of the sheep milk with cow milk as compared to 40%, lowered the yield of fresh cheese by 2.96 percentage points and of the ripened cheese – by 2.50 percentage points (P≤0.01). On the other hand, any effect of the replacement of the sheep milk with cow milk on chemical composition of semi-hard ripening cheese was not found, except for significantly higher level of ash in cheese 4/6 as compared to the sheep cheese and 6/4. The substitution of the sheep milk with the cow milk in the quantity of 40 and 60% deteriorated health-promoting properties of fat of the raw materials and by this, of the cheese, due to significant lowering of the content of acids from MCFA and PUFA group, including PUFA n-3 and CLA as compared to the sheep milk.

KEY WORDS: sheep cheese / sheep-cow cheese / cheese yield / fatty acids / CLA

Cheese yield, i.e. the amount of cheese produced from a specific amount of milk, is one of the factors determining profitability of cheese making. It is affected e.g. by the cheese production technology and contents of chemical milk components. The chemical composition of milk is dependent on many factors, e.g. the species and breed of animals from which milk is collected, their age, lactation stage, milk yield, health status of the udders as well as nutrition [11, 13, 18, 20, 21, 26, 27]. Research at the National Research Institute of Animal Production, the Kołuda Wielka Experimental Station showed that ewes of the Koluda sheep differ in milk yield and composition depending on the milking season [6, 15]. Milk of the prolific dairy Koluda sheep produced in the spring and summer months had lower contents of milk solids, protein and fat in comparison to milk of sheep milked in the summer-autumn season, with the differences of 1.26, 0.96 and 0.42 percentage points (pp), respectively [15]. A similar dependence between the milking season and both milk yield and contents of milk components was found in dairy cattle [8, 10]. As it was mentioned above, milk composition is also dependent on the animal breed. It was shown that ewes of the Polish Merino, East Friesian sheep and crosses of these breeds milked in the same period produced milk differing in composition and the yield of semi-hard cheese [23]. Milk of Merino sheep had the greatest concentration of milk components, thus it yielded more semi-hard cheese than milk of the other breeds (on average by 2.22 pp).

The primary factor affecting milk composition is also connected with the species of animals, from which milk is collected. Sheep milk is characterised by a higher concentration of protein and fat than cow milk [4, 13]. Studies conducted on the substitution of milk from the Coloured Merino with cow milk showed a reduction in the yield of ripening cheese from the mixed sheep-cow milk, resulting from the lower concentration of protein and fat in the mixed origin processing material [13].

Cheese yield is also influenced by the type of production technology [11, 21, 23]. The formulation of semi-hard ripening cheese from sheep milk, developed at the Kołuda Wielka Experimental Station, trade name Ser Kołudzki, yields more curd in comparison to the cheese production technology from cooked curds for Wędzonka Kołudzkiego (in absolute values on average by 39.9%), while the yield is lower than in the production of Bundz cheese (on average by 47.7%) [11].

Production profitability is to a considerable extent dependent on the consumer demand for a specific product. Present-day food scandals persuade consumers to search for safe food, having a health-promoting effect on the human organism. Milk fat, thanks to its contents of short- and medium-chain fatty acids (SCFA and MCFA), is the primary source of energy and the most readily digestible animal fat. The health-promoting properties of this fat result from the contents of unsaturated fatty acids (MUFA, PUFA), including CLA [2]. The composition of the lipid fraction in milk and thus also of dairy produce, is dependent e.g. on the animal species, breed, milk yield, feeding season, lactation stage [2, 5, 19, 25, 28], while cholesterol level, as it is reported by Bonczar et al. after Kisza et al. [3] additionally depends on fat content and technological processes applied. Felkner-Nowakowska et al. [8] at the year-round PMR feeding system of cows showed the effect of the feeding season on changes in the fatty acid profile of milk, i.e. increased contents of polyunsaturated fatty acids in the summer period and increased contents of saturated fatty acids in the winter season. The effect of feeding and production season on the fatty acid profile of milk and dairy products was also confirmed in studies conducted by other authors [5, 6, 17, 19, 25, 28]. As it was mentioned above, milk fat composition depends also on the species of milked animals. Studies concerning the fatty acid profile of fat in cheeses made from mixed sheep-goat and sheep-cow milk showed the effect of mixing various milk types in cheese making on the composition of the lipid fraction in the resulting cheese [1, 4].

Sheep milk due to its high concentration of chemical components, particularly protein and fat, is characterised by a greater cheese yield than cow milk [13]. Additionally, fat in sheep milk in comparison to cow milk fat is richer in fatty acids exhibiting health-promoting effects, which is reflected in the great consumer interest in sheep dairy products. Unfortunately, a decrease in the sheep population in Poland has reduced the available volume of this valuable cheese making material and as a result has forced producers of sheep cheeses, mainly Polish Oscypek and Bundz cheeses, to partially substitute sheep milk with cow milk [14].

For this reason it was decided to undertake studies on the effect of substitution of sheep milk with cow milk on the composition and production efficiency of the resulting semi-hard ripening cheese. This study presents the effects of adding cow milk (from cows fed TMR) to milk of the prolific dairy Koluda sheep (collected in the summer feeding season) on the yield and composition of the produced ripening cheese, taking into consideration its lipid fraction.

Material and methods

The experiments were conducted at the National Research Institute of Animal Production, the Kołuda Wielka Experimental Station in the years 2009 and 2010 (referred to as year 1 and 2, respectively). Sheep milk (MO) was collected from dams of the prolific dairy Koluda sheep fed a mixture of concentrates and bulky feeds available on the farm (lucerne green forage, hay). Sheep milk (MO) was replaced partly with cow milk (MK) coming from dairy cows fed total mixed ration (TMR). In each year of the study a total of 5 batches of sheep milk (raw material / control cheese) as well as sheep and cow milk mixed at a 6:4 (6/4) and 4:6 (4/6) ratio were processed to produce ripening semi-hard cheese. The input material was pasteurised in a vat at 75°C for 30 min. Protein coagulation in the processed material was run at 34°C (±0.5°C) with the addition of calcium chloride, mesophilic cheese starter cultures and rennet. Cut curd was processed following the production technology of Ser Kołudzki, developed at the Kołuda Wielka Experimental Station [12]. Cheese slurry was transferred to cheese moulds pressed (for approx. 24 h) at a mean load of 16 kg/mould (i.e. 2-2.5 kg/kg cheese mass). Cheese blocks were salted in 16% saline brine for approx. 24 h, dried and ripened at the air temperature of 10-12°C and 75-85% relative humidity. After approx. 10 days cheeses were vacuum packed and their ripening was continued, assuming the minimum ripening period of 4 to 6 weeks. Cheeses were considered ripe when their flesh became elastic and was of a uniform texture and colour.

In samples of raw materials and cow milk from each batch of the product the contents of dry matter (solids), protein, fat and lactose were determined. The analyses were conducted at the Regional Dairy Cooperative in Inowrocław using the MilkoScan apparatus. Production efficiency was established based on the amount of produced cheese in relation to the amount of processed raw material. The chemical composition of ripe cheeses was analysed by determining contents of dry matter (by the oven dry method), protein (according to Kjeldahl), fat (according to Soxhlet), ash (by incineration at 550-600°C) [7]. The energy of cheeses was determined based on the chemical composition and the respective reference values [16].

In the second year of the study the fatty acid profiles were analysed in samples of the processed raw materials, cow milk and cheeses. Fat from the tested products was extracted following the standard procedures presented by Folch et al. [9]. Fatty acids were assayed using the gas chromatography technique [16], as modified at the Institute of Agricultural and Food Biotechnology in Warsaw. The percentage composition of fatty acids was determined using a 6890 model gas chromatograph by Hewlett Packard, equipped with a flame ionisation detector with the Rtx-2330 column of 105 m x 0.25 m x 20 μ.

Results were analysed statistically using the STATISTICA 6 PL software package applying one-or two-way analysis of variance ANOVA. Statistical differences between the processed raw materials were verified using Duncan's test.

Results and discussion

Cow milk (MK) in comparison to sheep milk (MO) was characterised by lower (mean) contents of solids (by 34.1%), solids-not-fat (by 27.7%), protein (by 53.7%) and fat (by 46.2%) as well as an inferior protein : fat ratio (by 13.3%) – Table 1. When compared to sheep milk the substitution of sheep milk with cow milk at 40 and 60% in the obtained raw materials caused a decrease in contents of solids by 12.5 and 20.3%, solids-not-fat by 11.5 and 16.8%, protein by 22.3 and 32.5%, fat by 15.6 and 27.6%, respectively; all the differences were significant at $P \leq 0.01$. The raw material obtained at a 4/6 substitution ratio, in comparison to that with the 6/4 substitution ratio, had contents of solids, solids--not-fat, protein and fat lower by 8.9, 5.9, 13.0 and 14.2%, respectively; all the differences were significant at $P \leq 0.01$. It was also found that materials for cheese making in the 2nd year of the study in comparison to year 1 contained less solids-not-fat (by 4.8%) and protein (by 9.4%), which resulted in a less advantageous protein : fat ratio (by 12.1%); all the differences were significant at $P \leq 0.01$.

Milk of the Koluda sheep and the raw materials produced by mixing milk of those sheep and cow milk contained less protein and fat than milk of Merino sheep during the winter feeding period and analogous mixtures with cow milk [13]. In turn, when compared with the milk of Coloured Merino sheep in the summer feeding period milk of the Koluda sheep was characterised by greater contents of protein and lower contents of fat and a more advantageous protein : fat ratio [20]. Sheep milk analysed in this study contained more protein and fat in comparison to milk of the East Friesian sheep and crosses of that breed with Merino sheep processed to produce ripening cheese [23].

The compared materials differed in terms of their cheese yields (Table 2). A 40 and 60% substitution of sheep milk with cow milk resulted in the yield of fresh cheese lower by 20.1 and 31.2%, respectively, and the yield of ripe cheese lower by 21.1 and 32.0%, respectively; all the differences were significant at $P \leq 0.01$. Moreover, the yield of fresh and ripe cheese from the material mixed at a 4/6 ratio in comparison to that

Table 1
Chemical composition cow milk and of raw materials for cheesemaking

Specification	MK	Raw material for cheesemaking			Year		SEM
		MO	sheep-cow 6/4	sheep-cow 4/6	1	2	
n	10	10	10	10	15	15	
Dry matter	12.10	18.37^{AB}	16.08^{BC}	14.64^{AC}	16.53	16.20	0.308
Solids-not-fat	8.38	11.57^{AB}	10.24^{BC}	9.63^{AC}	10.74^{A}	10.22^{A}	0.170
Protein	2.88	6.22^{AB}	4.83^{BC}	4.20^{AC}	5.33^{A}	4.83^{A}	0.176
Fat	3.72	6.92^{AB}	5.84^{BC}	5.01^{AC}	5.84	6.01	0.014
Lactose	4.79	4.65	4.71	4.73	4.71	4.69	0.018
Protein/fat	0.77	0.90^{Aa}	0.83^{A}	0.84^{a}	0.91^{A}	0.80^{A}	0.014

MK – cow milk
MO – sheep milk
AA, BB, CC – P≤0.01, aa – P≤0.05
SEM – standard error of the mean

Table 2
Yield of cheese mass (kg/100 kg milk)

Specification	Raw material for cheesemaking			Year		SEM
	MO	sheep-cow 6/4	sheep-cow 4/6	1	2	
n	10	10	10	15	15	
Yield of fresh cheese mass	26.61^{AB}	21.26^{BC}	18.30^{AC}	22.32	21.80	0.696
Ripening period (days)	53.9	53.9	53.9	51.6	56.2	2.36
Yield of ripened cheese mass	22.93^{AB}	18.09^{BC}	15.59^{AC}	19.50^{a}	18.23^{a}	0.702
Loss of cheese mass during ripening (%)	13.79	14.31	14.90	12.18^{a}	16.49^{a}	0.829

MO – sheep milk
AA, BB, CC – P≤0.01; SEM – standard error of the mean

mixed at 6/4 was lower by 13.9 and 13.8%, respectively. Materials for cheese making in the 2nd year of the study when compared to the 1st year gave a lower yield of ripe cheese (by 6.5%; P≤0.05). The lower yield of ripe cheese resulted from the markedly greater losses (by 35.4%; P≤0.05), caused by their longer ripening period in year 2 (by 8.9%; NS).

The yield of ripe cheese from milk of the Koluda sheep and the material mixed at a 6/4 ratio was greater than in the experiments conducted in the summer feeding period on milk of Merino sheep, East Friesian sheep and crosses of these breeds (17.6, 15.1, 15.8%, respectively) [23]. In turn, cheese yield from milk mixed at a 4/6 ratio was comparable to that of milk of the above-mentioned breeds. Production efficiency, i.e. the yield of ripe cheese from milk of Koluda sheep and mixtures with cow milk in the summer feeding period was lower than in the analogous experiments on milk of Coloured Merino sheep and its 4/6 and 6/4 mixtures with cow milk (mean 27.39, 22.39 and 19.75%, respectively) in the winter feeding season [13]. In turn, when comparing the production efficiency of ripening cheese made from sheep milk and from a mixture of Koluda sheep and cow milk a much greater yield of ripening cheese was recorded than in the making of Salami cheese produced solely from cow milk (8.8-9.7%) [27]. The above-mentioned differences in the production efficiency probably resulted from the lower protein content in the raw material for cheese making. The dependence between casein content in milk (and thus protein content) and cheese yield is confirmed by observations reported by other authors [26].

Fat in cow milk compared to that of sheep milk contained by 31.4% lower levels of medium chain fatty acids (MCFA), including C 8:0 and C 10:0 (Table 3), which was reflected in their significantly lower content in the fatty acid pool in the materials mixed at 6/4 and 4/6. In cow milk fat a greater content of C 14:1 (by 82.7%) was recorded at a lower level of C 18:1 TR (by 25.8%), resulting in significant differences in the contents of these acids in mixed materials in comparison to sheep milk. Analysis of the lipid fraction profile of the raw materials showed no effect of sheep milk substitution with cow milk on the shares of SFA and UFA, including MUFA in the mixed materials. In cow milk fat contents of PUFA, including *n-3* PUFA and CLA, in comparison to sheep milk were lower by 30.5, 81.5 and 89.7%. This resulted in a reduced share of PUFA in the materials mixed at 6/4 and 4/6 in relation to sheep milk fat by 9.0 (P≤0.05) and 14.3% (P≤0.01), including *n-3* PUFA by 20.4 and 30.6%, respectively, and CLA by 14.3 and 30.8% (all the differences were significant at P≤0.01). Moreover, a CLA content lower by 19.2% (P≤0.01) was recorded in fat of the processing material mixed at a 4/6 ratio in comparison to that mixed at 6/4. Mixing sheep milk with cow milk at 6/4 and 4/6 ratios also resulted in a significant deterioration of PUFA/SFA, PUFA/MUFA and *n-6/n-3* PUFA ratios.

Substitution of sheep milk with 40 and 60% cow milk resulted in a decrease of cholesterol content in mixed sheep and cow milk by 15.4 (P≤0.05) and 22.7% (P≤0.01), respectively, which resulted from its content lower by 38.9% in cow milk when compared to sheep milk, connected with the lower fat content in cow milk.

Fat in milk of Koluda sheep had lower contents of SFA, PUFA, including n-6 PUFA, and greater contents of UFA, including MUFA and n-3 PUFA, than fat in milk of Merino sheep in a study conducted by Pakulski et al. [22] in the production of ripening cheese in the winter feeding period (70.2, 5.7, 3.9, 29.5, 23.7, 0.87%). These differences probably resulted from the type of feeds used in the summer and winter feeding periods. When comparing the results of this study with those reported by Wójtowski et al. [28] from their experiments on sheep milk (the control) of the dairy line 05, it may be stated that

Table 3

Fatty acids profile in fat of cow milk and of raw materials for cheesemaking (g/100 g) and cholesterol content (mg/100 g milk)

Specification	MK	Raw material for cheesemaking			SEM
		MO	sheep-cow		
			6/4	4/6	
n		5	5	5	
C 4:0	2.30	2.28	2.18	2.08	0.041
Σ MCFA	8.92	13.00^{a}	11.94	11.42^{a}	0.275
including:					
C 6:0	1.70	1.82	1.76	1.76	0.036
C 8:0	1.16	1.82^{Aa}	1.58^{a}	1.48^{A}	0.049
C 10:0	2.98	5.80^{AB}	4.86^{B}	4.42^{A}	0.190
C 12:0	2.76	3.62	3.32	3.26	0.093
C 14:0	10.02	10.32	10.22	10.36	0.129
C 14:1	1.06	0.58^{AB}	0.70^{Ba}	0.76^{Aa}	0.022
C 15:0	1.10	1.20	1.16	1.12	0.016
C 16:0	31.92	27.96	29.36	30.28	0.417
C 16:1	2.08	1.90	1.76	2.02	0.052
C 17:0 ISO	1.04	1.28	1.26	1.18	0.021
C 18:0	9.32	7.34	8.12	8.28	0.274
C 18:1 TR	1.61	2.17^{A}	2.02	1.90^{A}	0.043
C 18:1 C9	22.36	21.20	21.88	21.64	0.412
C 18:1 C11	0.68	0.64	0.66	0.64	0.013
C 18:1 C IN	1.16	1.34	1.34	1.30	0.012
C 18:2 (LA)	2.24	2.44	2.32	2.34	0.041
C 18:2 C9T11 (CLA)	0.48	0.91^{AC}	0.78^{BC}	0.63^{AB}	0.035
C 18:3 (ALA)	0.42	0.66^{Aa}	0.56^{ab}	0.48^{Ab}	0.023
C 20:4 (AA)	0.18	0.30^{ab}	0.24^{b}	0.22^{a}	0.013
SFA	65.82	65.32	65.62	65.92	0.427
UFA	33.79	33.87	33.82	32.54	0.439
w tym – including:					
MUFA	30.15	29.11	29.50	29.50	0.420
PUFA	3.64	4.75^{Aa}	4.32^{a}	4.07^{A}	0.099
w tym – including:					
n-3	0.54	0.98^{AB}	0.78^{B}	0.68^{A}	0.039
n-6	2.42	2.74	2.65	2.56	0.050
UFA/SFA	0.513	0.518	0.515	0.494	0.010
PUFA/SFA	0.055	0.073^{Aa}	0.066^{a}	0.052^{A}	0.002
PUFA/MUFA	0.122	0.164^{Aa}	0.147^{a}	0.138^{A}	0.004
PUFA *n-6/n-3*	5.21	2.81^{AB}	3.30^{BC}	3.77^{AC}	0.119
Cholesterol	12.04	19.70^{Aa}	16.66^{a}	15.23^{A}	0.695

MK – cow milk

MO – sheep milk

AA, BB, CC – P≤0.01; aa, bb – P≤0.05; SEM – standard error of the mean

MCFA – medium-chain acids (as in Table + C 10:1 and C 12:1);

SFA (C 4:0, C 6:0, C 8:0, C 10:0, C 12:0, C 13:0, C14:0, C 15:0 ISO, C 15:0, C 16:0, C 17:0 ISO, C 17:0, C 18:0, C 20:0, C 22:0);

UFA (C 10:1, C 12:1, C 14:1, C 15:1, C 16:1, C 17:1, C 18:1 TRANS, C 18:1 C9, C 18:1 C11, C 18:1C IN, C 18:2, C 18:3, C 20:1, C 20:2, C 20:3, C 20:4, C 20:5, C 22:5, C 22:6);

MUFA (C 10:1, C 12:1, C 14:1, C 15:1, C 16:1, C 17:1, C 18:1 TRANS, C 18:1 C9, C 18:1 C11, C 18:1C IN, C 20:1);

PUFA (C 18:2, C 18:2 C9T11, C 18:3, C 20:2, C 20:3, C 20:4, C 20:5, C 22:5, C 22:6);

PUFA *n-3* (Σ C 18:3, C 20:5, C 22:5, C 22;6);

PUFA *n-6* (C 18:2, C 20:2, C 20:4)

the content of UFA, including CLA, was greater, while that of SFA was lower in milk fat of Koluda sheep. This may have resulted from a different feeding regime or the effect of genotype. In a study conducted by Bonczar et al. [4] milk fat of the mountain sheep grazing on pastures in comparison to milk fat of the Koluda sheep was characterised by a much greater content of CLA at lower contents of C18:1, C18:2 and C18:3. In this study intermediate levels of fatty acids were recorded in the mixed sheep and cow milk in comparison to the fat in sheep and cow milk.

Partial substitution of sheep milk with cow milk had no effect on the composition of cheeses or their energy content, apart from the significantly greater content of minerals (ash) in cheeses made from the material mixed at a 4/6 ratio in comparison to those made from sheep milk or the milks mixed at 6/4, with the difference of 26.3% ($P \leq 0.01$) and 17.5% ($P \leq 0.05$) – Table 4. Cheeses produced in the 2nd year of the study in comparison to year 1 were characterised by a greater content of solids (by 6.8%; $P \leq 0.01$), solids-not-fat (by 6.9%; $P \leq 0.05$), fat (by 6.6%; $P \leq 0.05$) and ash (by 17.4%; $P \leq 0.05$), as well as greater energy value (by 6.1%; $P \leq 0.01$). These differences probably resulted from greater water losses, caused by a longer cheese ripening period in the 2nd year of the study or the fact that cheese was produced in a vat, in which it is difficult to maintain standard technological parameters.

Table 4
Chemical composition and nutritive value of cheeses made

Specification	Cheeses produced from:			Year		SEM
	MO	sheep-cow milk		1	2	
		6/4	4/6			
Chemical composition of cheese (g/100 g):						
n	10	10	10	15	15	
dry matter	53.36	54.57	55.11	52.56^{A}	56.12^{A}	0.487
solids-not-fat	30.09	30.86	30.74	29.54^{a}	31.58^{a}	0.427
protein	23.14	23.59	22.98	22.85	23.62	0.360
fat	23.26	23.71	24.37	23.02^{a}	24.54^{a}	0.361
ash	3.77^{A}	4.05^{a}	4.76^{Aa}	3.86^{a}	4.53^{a}	0.154
protein/fat	0.99	0.99	0.94	0.99	0.96	0.026
Calorific value of cheese (kcal/100 g)	314	321	322	310^{A}	329^{A}	2.960

MO – sheep milk
AA –$P \leq 0.01$; aa – $P \leq 0.05$; SEM – standard error of the mean

Analogous studies [13] conducted in the winter feeding period on the effect of mixing milk of Merino sheep with cow milk also showed no effect of the composition of the material used in cheese production on the composition of ripening cheese. Cheeses of the Ser Kołudzki type made from sheep milk and mixed sheep and cow milk in the above-mentioned study were characterised by a lower energy value, as they contained lower levels of solids, solids-not-fat, fat and ash, while the protein content and protein : fat ratio were comparable to those of cheeses produced from milk of Koluda sheep. Available literature on the subject [21, 22] indicates considerable fluctuations in the composition of Ser Kołudzki made experimentally from sheep milk, i.e. contents of protein ranging from 18.2 to 23.1%, fat at 28.1-32.1% and the protein : fat ratio of 0.58-0.80. Cheeses from sheep milk and mixed sheep and cow milk based on milk of Koluda sheep had greater protein contents and lower fat contents, as well as a more advantageous protein : fat ratio compared to cheeses produced using the same technology. When comparing the composition of ripening cheeses from sheep and mixed sheep and cow milk in this study with the composition of ripening acid-rennet cheeses produced from cow milk, lower contents of protein and fat are recorded in cheeses made from sheep milk and mixed sheep and cow milk. Cheese of the Ser Kołudzki type produced from sheep and mixed sheep and cow milk contained less fat and protein than ripening acid-rennet cheeses made from cow milk (Salami and Gouda 24.6 and 25.7% fat content; 28.4 and 27.0% protein content, respectively) [24, 27], while fat content was lower than in a study conducted by Rutkowska et al. [25] (25.3-28.7%), except for Salami cheese (20.30%). A lack of a dependence between the composition of the raw material used in cheese making and levels of individual components in cheeses was also confirmed in other studies [4, 21, 29]. Bonczar et al. [4] found significant differences in the chemical composition of sheep, cow and mixed sheep and cow milk; however, they had no effect on the composition of produced Bundz cheese. The Bundz type cheese made from the raw material of the lowest concentrations of individual chemical components contained the greatest amounts of fat and the lowest levels of protein in comparison to the cheese produced from the other materials.

Analyses of the lipid fraction composition in sheep cheeses and in those made from mixed milk showed that a 60% addition of cow milk to sheep milk resulted in an increased content of C 4:0 acid (by 12.8%; $P \leq 0.01$) in relation to that in sheep cheese (Table 5.). Similarly as in the case of milk for cheese production, cow milk added to sheep milk at 40 and 60% caused a significant decrease in total MCFA, including C 8:0 and C 10:0, in comparison to sheep milk. In fat of cheese from the 4/6 milk mixture a significantly greater content of C 14:1 ($P \leq 0.05$) was found at a lower C15:0 content ($P \leq 0.01$) in comparison to fat in sheep cheese. Fat in cheeses from mixed milk with a 40 and 60% cow milk addition had a significantly lower content of C17:0 ISO and C18:1 TR acids, while that in cheese from milk mixed at a 6/4 ratio, in comparison to that mixed at 4/6, contained less C17:0 ISO. However, no effect of sheep milk substitution with cow milk was found on the lipid fraction composition for total SFA, UFA and MUFA. Mixing of sheep milk with cow milk at a 6/4 and 4/6 ratio resulted in PUFA contents in cheese fat decreased by 8.0 ($P \leq 0.01$) and 16.1% ($P \leq 0.05$), respectively, including CLA, by 10.71 and 26.09% ($P \leq 0.01$), in comparison to sheep milk. Moreover, a lower content of PUFA, including CLA, was recorded in fat of cheese made from the 4/6 mixture in relation to that with a 6/4 ratio, by 8.7 ($P \leq 0.05$)

Table 5

Fatty acids profile in fat of semi-hard ripening cheeses (g/100 g) and cholesterol content (mg/100 g cheese)

Specification	Cheeses produced from:			SEM
	MO	sheep-cow milk		
		6/4	4/6	
n	5	5	5	
C 4:0	2.18^{A}	2.30	2.46^{A}	0.043
Σ MCFA	13.40^{Aa}	11.86^{a}	11.26^{A}	0.339
w tym – including:				
C 6:0	1.78	1.74	1.84	0.027
C 8:0	1.72^{Aa}	1.58^{a}	1.50^{A}	0.034
C 10:0	5.62^{Aa}	4.92^{a}	4.44^{A}	0.166
C 12:0	3.54	3.36	3.28	0.087
C 14:0	10.48	10.30	10.40	0.443
C 14:1	0.64^{a}	0.70	0.78^{a}	0.027
C 15:0	1.22^{A}	1.16	1.12^{A}	0.016
C 16:0	28.98	29.38	30.28	0.339
C 16:1	1.82	1.92	1.96	0.032
C 17:0 ISO	1.32^{Ab}	1.24^{ab}	1.14^{Aa}	0.023
C 18:0	7.44	7.98	8.16	0.219
C 18:1 TR	2.09^{A}	2.00^{B}	1.85^{AB}	0.032
C 18:1 C9	20.80	21.64	21.49	0.333
C 18:1 C11	0.62	0.60	0.66	0.011
C 18:1 C IN	1.32	1.30	1.24	0.016
C 18:2 (LA)	2.36	2.32	2.28	0.043
C 18:2 C9T11 (CLA)	0.84^{AC}	0.75^{BC}	0.62^{AB}	0.027
C 18:3 (ALA)	0.66^{Aa}	0.56^{a}	0.46^{Aa}	0.025
C 20:4 (AA)	0.30^{A}	0.26^{a}	0.20^{Aa}	0.013
SFA	66.32	65.82	66.30	0.352
UFA	33.07	33.55	32.99	0.351
w tym – including:				
MUFA	28.47	29.32	29.13	0.328
PUFA	4.60^{Ab}	4.23^{ab}	3.86^{Aa}	0.082
w tym – including:				
n-3	0.86^{AB}	0.60^{B}	0.46^{A}	0.053
n-6	2.66	2.58	2.48	0.049
UFA/SFA	0.499	0.510	0.498	0.007
PUFA/SFA	0.069^{A}	0.064	0.058^{A}	0.001
PUFA/MUFA	0.162^{AB}	0.144^{Ba}	0.132^{Aa}	0.004
PUFA *n-6/n-3*	3.19^{AB}	4.35^{Ba}	5.43^{Aa}	0.280
Cholesterol	54.16	56.48	52.45	1.750

MO – sheep milk
AA, BB, CC – P≤0.01; aa, bb – P≤0.05; SEM – standard error of the mean
MCFA – medium-chain acids (as in Table + C 10:1 and C 12:1);
SFA (C 4:0, C 6:0, C 8:0, C 10:0, C 12:0, C 13:0, C14:0, C 15:0 ISO, C 15:0, C 16:0, C 17:0 ISO, C 17:0, C 18:0, C 20:0, C 22:0);
UFA (C 10:1, C 12:1, C 14:1, C 15:1, C 16:1, C 17:1, C 18:1 TRANS, C 18:1 C9, C 18:1 C11, C 18:1C IN, C 18:2, C 18:3, C 20:1, C 20:2, C 20:3, C 20:4, C 20:5, C 22:5, C 22:6);
MUFA (C 10:1, C 12:1, C 14:1, C 15:1, C 16:1, C 17:1, C 18:1 TRANS, C 18:1 C9, C 18:1 C11, C 18:1C IN, C 20:1);
PUFA (C 18:2, C 18:2 C9T11, C 18:3, C 20:2, C 20:3, C 20:4, C 20:5, C 22:5, C 22:6);
PUFA *n-3* (Σ C 18:3, C 20:5, C 22:5, C 22;6);
PUFA *n-6* (C 18:2, C 20:2, C 20:4)

and 17.3% ($P \leq 0.01$), respectively. In comparison to sheep cheese, substitution of sheep milk with cow milk at 40 and 60% also caused a decrease of total *n-3* PUFA in fat of cheeses from mixed milk by 30.2 and 46.5%, respectively (all the differences significant at $P \leq 0.01$), mainly by reducing C 18:3 and C 20:4 contents. Thus mixing sheep milk with cow milk at 6/4 and 4/6 significantly deteriorated the PUFA/MUFA and *n-6/n-3* PUFA ratios, while mixing at a 4/6 ratio affected also PUFA/SFA in comparison to sheep milk. It was also found that fat in 4/6 cheeses had significantly less advantageous PUFA/MUFA and *n-6/n-3* PUFA ratios in comparison to 6/4 cheeses.

No significant effect of cow milk addition to sheep milk was observed on cholesterol content in ripening semi-hard cheeses.

A review of literature on the subject confirms the effect of breed, animal species and nutrition on the fatty acid profiles of milk fat and the resulting products. Fat of ripening sheep cheeses in this study was characterised by a lower content of SFA and a higher UFA content (including MUFA) in comparison to the results given by Pakulski et al. [22] in the production of such cheese from milk of Merino sheep (68.9, 30.8, 24.1%). Those authors obtained cheeses with greater levels of *n-6* PUFA and CLA (4.76 and 0.95%, respectively) and found no effect of production technology on the composition of the lipid fraction in the products. Differences between the fatty acid profiles of ripening cheeses in the above--mentioned paper and in this study probably resulted from the differences in the milk fat composition between the Merino and Koluda sheep breeds. However, when comparing the fatty acid profiles of cheese fat in this study with the fat of sheep Bundz cheese we may observe greater contents of C12:0, C14:0 and CLA, and lower C16:0, C18:2 and C18:3 levels in the latter [4]. The effect of mixing milk coming from various animal species on changes in the fatty acid profile of fat in mixed milk derived products was also confirmed in studies conducted by other authors [1, 4]. Those analyses confirmed intermediate values in the fatty acid profiles of fat between cheeses made form sheep, cow and goat milk, analogous to the composition of fat in mixed milk, from which they were produced. A comparison of the lipid fraction composition in Ser Kołudzki type cheese made from sheep and mixed sheep and cow milk with ripening cheeses made from cow milk presented by Rutkowska et al. [25] indicated a lower content of PUFA in the latter (1.4-3.5%). It needs to be stressed here that those authors reported considerable fluctuations in CLA content in cheese fat, ranging from 0.4 to 1.3%, which may have resulted from regional differences in cattle rearing.

Summing up it may be stated that a 40 and 60% substitution of sheep milk with cow milk:

– resulted in a decrease of protein and fat concentrations in the raw material and thus caused a proportionally lower cheese yield from mixed milk;

– had no effect on protein and fat contents in ripening cheeses, while it significantly increased the content of minerals in cheese produced from milk mixed at a 4/6 ratio in relation to cheeses made from sheep milk or from milk mixed at a 6/4 ratio;

– affected the lipid profile of raw material for cheese production and cheeses, reducing (in proportion to the share of cow milk in the mixed raw material) contents of MCFA and PUFA, including CLA and *n-3* PUFA, at the same time increasing the content of C 4:0 in cheese produced from milk material mixed at a 4/6 ratio;

– had no effect on cholesterol content in cheeses, despite the significant reduction of its content in mixed sheep and cow milk used for cheese production.

REFERENCES

1. BARAN J., PIECZONKA W., POMPA-ROBORZYŃSKI M., 2011 – Sery owczo-kozie jako propozycja nowego produktu. Żywność Projektowana. Oddział Małopolski Polskiego Towarzystwa Technologów Żywności, Kraków, Część II, 22-31.
2. BARŁOWSKA J., LITWIŃCZUK Z., 2009 – Właściwości odżywcze i prozdrowotne tłuszczu mleka. ***Medycyna Weterynaryjna*** 65 (3), 171-174.
3. BONCZAR G., CHRZANOWSKA K., MACIEJOWSKI K., WALCZYCKA M., 2011 – Zawartość cholesterolu i jego pochodnych w mleku i produktach mleczarskich – uwarunkowania surowcowe i technologiczne. ***Żywność Nauka Technologia Jakość*** 1 (74), 15-27.
4. BONCZAR G., REGUŁA-SARDAT A., PUSTKOWIAK H., ŻEBROWSKA A., 2009 – Wpływ substytucji mleka owczego mlekiem krowim na właściwości bundzu**. *Żywność Nauka Technologia Jakość*** 5 (66), 96-106.
5. BORYS B., BORYS A. GRZEŚKIEWICZ S., 2008 – Wpływ żywienia owiec nasionami rzepaku i lnu na skład chemiczny mleka w okresie doby. Cz. II. Profil lipidowy. ***Roczniki Naukowe Polskiego Towarzystwa Zootechnicznego*** 4 (1), 79-91.
6. BORYS B., MROCZKOWSKI S., JARZYNOWSKA A., 2000 – Charakterystyka składu mleka owiec z okresu żywienia letniego i zimowego. ***Zeszyty Naukowe AR we Wrocławiu*** 399, 83-90.
7. BUDSŁAWSKI J., 1963 – Chemia i analiza mleka oraz jego przetworów. PWRiL, Warszawa.
8. FELKNER-PÓŹNIAKOWSKA B., PIETRZAK-FIEĆKO R., KOTLARSKA M., KACPRZAK S., 2012 – Skład kwasów tłuszczowych tłuszczu mleka krów z chowu alkierzowego w okresie letnim i zimowym. ***Żywność Nauka Technologia Jakość*** 1 (80), 81-92.
9. FOLCH J., LEES W., STANLEY G.H.S., 1957 – A simple method for the isolation and purification of total lipids from animal tissues. ***Journal of Biological Chemistry*** 226, 247-262.
10. GÓRSKA A., MRÓZ B., RYMSZA K., DĘBSKA M., 2006 – Zmiany w zawartości białka i tłuszczu w mleku krów czarno-białych i czerwono-białych w zależności od stadium laktacji i pory roku. ***Roczniki Naukowe Polskiego Towarzystwa Zootechnicznego*** 2 (1), 113-199.
11. JARZYNOWSKA A., PAKULSKI T., 2009 – Ocena wpływu technologii produkcji na efektywność przerobu mleka owczego na sery. Materiały konferencyjne „Małe przeżuwacze elementem ekosystemu lądowego", Lublin, 19-20.
12. JARZYNOWSKA A., PAKULSKI T., 2011 – Warzenie dojrzewającego sera półtwardego z mleka owczo-krowiego w warunkach przyfermowych. Instrukcja wdrożeniowa nr 2/2011. Instytut Zootechniki – Państwowy Instytut Badawczy, Kraków.
13. JARZYNOWSKA A., PAKULSKI T., 2012 – Wpływ częściowej substytucji mleka merynosa mlekiem krowim na jakość półtwardego sera dojrzewającego i efektywność jego produkcji. ***Roczniki Naukowe Polskiego Towarzystwa Zootechnicznego*** 8 (1), 47-61.
14. KĘDZIOR W., 2005 – Owcze produkty spożywcze. Polskie Towarzystwo Ekonomiczne, 158-172.
15. KORMAN K., JARZYNOWSKA A., Osikowski M.A., 2009 – Wpływ pory roku na użytkowość mleczną dojonych owiec. ***Roczniki Naukowe Polskiego Towarzystwa Zootechnicznego*** 5 (1), 21-32.

16. KUNACHOWICZ H., NADOLNA I., IWANOW K., PRZYGODA B., 2005 – Wartość odżywcza wybranych produktów spożywczych i typowych potraw. Wydawnictwo Lekarskie PZWL, Warszawa.
17. LIPIŃSKI K., STASIEWICZ M., RAFAŁOWSKI R., KALINIEWICZ J., PURWIN C., 2012 – Wpływ sezonu produkcji mleka na profil kwasów tłuszczowych tłuszczu mlekowego. ***Żywność Nauka Technologia Jakość*** 1 (80), 72-80.
18. LOPEZ GALLEGO F., LOPEZ PARRA M.M., PICON SANCHEZ F., 2001 – Effect of different feed patterns on milk and cheese yield and composition in sheep extensive systems. Options méditerranéennes, serie A: Séminaries Méditerranéens No 46. Production systems and product quality in sheep and goats. CIHEAM, FAO. Murcia 2001, 121-125.
19. NAŁĘCZ-TARWACKA T., ZDANOWSKA-SĄSIADEK Ż., 2011 – Wpływ żywienia na zawartość skoniugowanego kwasu linolowego (CLA) w mleku przeżuwaczy. ***Przegląd Hodowlany*** 3, 19-22.
20. PAKULSKI T., 2006 – Wpływ poziomu żywienia białkowo-energetycznego dojonych maciorek merynosa na wydajność i skład produkowanego mleka. ***Roczniki Naukowe Polskiego Towarzystwa Zootechnicznego*** 2 (1), 73-82.
21. PAKULSKI T., DULEWICZ R., 2000 – Zmiany składu mleka owczego a efektywność jego przerobu w przyfermowej przetwórni. ***Zeszyty Naukowe AR we Wrocławiu***, 241-246.
22. PAKULSKI T., PAKULSKA E., 2009 – Skład frakcji tłuszczowej w serach z mleka merynosów barwnych w zależności od technologii ich produkcji. ***Roczniki Naukowe Polskiego Towarzystwa Zootechnicznego*** 5 (2), 167-176.
23. PAKULSKI T., PAKULSKA E., BORYS B., 2006 – Przydatność mleka owiec wschodnio-fryzyjskich, merynosa polskiego i ich mieszańców do produkcji serów podpuszczkowych. ***Roczniki Naukowe Polskiego Towarzystwa Zootechnicznego*** 2 (1), 141-147.
24. PLUTA A., BERTHOLD A., KIELAK J., 2006 – Zmiany wybranych cech fizykochemicznych, reologicznych i sensorycznych w czasie dojrzewania sera typu holenderskiego o różnej zawartości tłuszczu. ***Żywność Nauka Technologia Jakość*** 2 (51), 40-50.
25. RUTKOWSKA J., SADOWSKA A., TABASZEWSKA M., STOŁYHWO A., 2009 – Skład kwasów tłuszczowych serów podpuszczkowych pochodzących z rejonów Polski: północnego, wschodniego i centralnego. ***Bromatologia i Chemia Toksykologiczna,*** XLII, nr 4, 1104-1110.
26. SEVI A., ALBENZIO M., MARINO R., SANTILLO A., MUSCIO A., 2004 – Effects of lambing season and of lactation on ewe milk quality. ***Small Ruminant Research*** 51 (3), 251-259.
27. SZPENDOWSKI J., SZYMAŃSKI E., BIAŁOBRZEWSKA M., KWIATKOWSKA A., 2008 – Wpływ dodatku chlorku wapnia i ogrzewania mleka na skład chemiczny i wartość odżywczą sera salami. ***Żywność Nauka Technologia Jakość*** 1 (56), 126-137.
28. WÓJTOWSKI M., CIEŚLAK A. SCHUMACHER-STRABEL M., STANISZ M., CZYŻAK-RUNOWSKA G., BIELIŃSKA S., 2012 – Suplementy dawek pokarmowych małych przeżuwaczy podwyższające zawartość składników bioaktywnych w mleku owiec i kóz.

Materiały Sympozjum Naukowego projektu „Biożywność – innowacyjne, funkcjonalne produkty pochodzenia zwierzęcego**.** Instytut Genetyki i Hodowli Zwierząt PAN, Jastrzębiec, 10 października 2012 r., 60-65.

29. WSZOŁEK M., BONCZAR G., 2002 – Właściwości oszczypków z mleka owczego, krowiego i mieszaniny mleka krowio-owczego. ***Przemysł Spożywczy*** 9, 14-19.