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Effect of partial substitution of Merino milk with cow milk on the quality and production efficiency of semi-hard maturing cheese

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The aim of the study was to determine the effect of partial substitution of sheep milk (SM) with cow milk (MK) on the quality and production efficiency of semi-hard maturing cheese. The study was conducted at the Kołuda Wielka Experimental Station of the National Research Institute of Animal Production in 2009 and 2010. Semi-hard maturing cheese was produced from the milk of Coloured Merino sheep and its mixture with standardized cow's milk (SCM) – experiment I, or raw cow milk (RCM) – experiment II. In both experiments SM was replaced with 40% (6/4) and 60% (4/6) of CM. Technological suitability of the raw material for cheese--making was determined in terms of milk coagulation time, quality of cheese clot, and yield of cheese mass. The raw materials and cheeses were analyzed for the content of basic chemical components. The cheeses were subjected to organoleptic evaluation and a simplified calculation of the cost of raw materials used to produce 1 kg of semi-hard cheese was carried out. It was found that the substitution of sheep milk with 40 and 60% of cow milk caused a significant increase in lactose concentration and reduction in the content of solids, protein and fat in the raw materials for cheese-making. Mixing SM with CM at a ratio of 6:4 and 4:6 decreased cheese yield by 4.90 and 6.94 percentage units for SCM and by 5.10 and 8.35 percentage points for RCM, respectively ($P \leq 0.01$). The substitution of sheep milk with 60% compared to 40% RCM reduced cheese yield by 3.25 percentage points ($P \leq 0.01$). The replacement of sheep milk with cow milk had no effect on chemical composition of semi-hard maturing cheeses. Cow milk from a dairy farm showed better technological suitability as a replacement of SM compared to cow milk from a dairy plant. Organoleptic scores tended to be more favourable for cheese made from sheep milk substituted with 60% of RCM, and unfavourable for sheep milk made from SCM, compared to that produced from SM. The substitution of sheep milk with cow milk had no significant effect on the cost of raw material used to produce 1 kg of the cheese.

KEY WORDS: maturing sheep-cow cheese / cheese yield / chemical composition of cheese / sensory quality

Efficiency of cheese production depends, among other things, on contents of chemical components in milk and the applied cheese making technology [7, 8, 14, 18, 20, 21]. The chemical composition of milk is affected by many factors: the animal species, from which it is collected, the breed, age, stage of lactation, udder health status and feeding. Sheep milk in comparison to cow milk exhibits better technological suitability (processability) for cheese production thanks to its high dry matter content, particularly protein and fat [11].

The milking season has a major effect on milk yield and its composition. Studies conducted at the Kołuda Wielka Experimental Station, the National Research Institute of Animal Production, on dairy sheep showed differences in milk yield and its composition between sheep of the same breed milked in different seasons of the year [2, 12]. In milk of prolific-dairy Kołuda sheep milked in the spring-summer season percentage contents of dry mass, protein and fat were by 1.26, 0.96 and 0.42 p.p. lower than in the summer-autumn months [12]. A similar dependence between milking season and both milk yield and milk components was observed in dairy cattle [6]. Milk chemical composition is also dependent on sheep breed. Ewes of the Polish Merino, East Friesian sheep and their hybrids milked in the summer feeding period produced milk differing in its composition and yield of semi-hard cheese [16]. Merino sheep milk had the greatest concentration of milk components, thanks to which more semi-hard cheese was produced (mean by 2.22 p.p.) than from milk of other sheep breeds. The yield of cheese is also affected by the type of adopted technology. The formulation developed at the Kołuda Wielka Experimental Station for semi-hard ripening cheese from sheep milk, commercially available under the Ser Kołudzki trade name, provides a greater yield of cheese mass (in absolute values average by 39.9%) in comparison to the production from steamed cheese mass (Wędzonek Kołudzki), while it is lower than in the production technology for Bundz cheese (mean by 47.7%) [7].

Production of cheese from sheep milk dates back to distant past in the Mediterranean region. As reported by Kędzior after Harbutt [11], at present among 30 traditional Italian cheeses with protected geographical indications and designations of origin only 1/3 are produced from sheep milk or with its addition. The decrease in the sheep population in Poland has reduced sheep milk supply for the production of cheese, a product increasingly popular among consumers. Oscypek and Bryndza Podhalańska are the best known Polish cheeses originally produced solely from sheep milk. Presently a 40% sheep milk substitution with cow milk is admissible in their production technology [5]. Studies conducted in Poland have concerned the effect of the sheep and cow milk composition on the composition and quality mainly in Bundz and Oscypek [1, 23]. Thus it was decided in this study to evaluate processability (technological quality) of the sheep and cow mixed milk to produce semi-hard ripening cheese and to determine its composition and quality.

Material and Methods

Investigations were conducted in 2009 and 2010 at the Kołuda Wielka Experimental Station, the State Research Institute of Animal Production. In each year from February to April two experiments were carried out, in which sheep milk was collected from Coloured Merino ewes fed a mixture of concentrate and preserved bulky feeds available on the farm (hay, silage from grass and lucerne in 2009, while in 2010 it was silage from milk-dough stage maize).

In experiment I (2009) sheep milk was substituted with drinking cow milk (SCM) purchased from the District Dairy Cooperative (corrected for 3.2% fat content, with 3.0% nominal protein content). In turn, in experiment II (2010) sheep milk was substituted with raw cow milk purchased directly from a dairy cattle farm (RCM). In each experiment 5 series of technological operations were performed on sheep milk (SM) (milk/control cheese) and on sheep and cow milk mixed at the 6:4 (6/4) and 4:6 (4/6) ratios in order to produce semi-hard ripening cheese. Milk for cheese production was pasteurised in bulk vats at a temperature of 75°C for 30 minutes. Protein coagulation in the raw material was run at a temperature of 34°C (±0.5°C) by adding calcium chloride (0.2 g/kg milk), mesophilic cheese starter cultures (*Lactococcus lactis* – 66%, *Lactococcus cremoris* – 33%; 0.026 g/kg milk) and rennet (0.15 ml/kg milk). Cut curd was processed following the production technology for the Ser Kołudzki cheese, developed at the Kołuda Wielka Experimental Station [9]. In the cheddaring production step the cheese curd mass was placed in moulds and pressed at mean 16 kg/mould (i.e. 2-2.5 kg/kg curd mass) for 24 h. Cheese blocks were placed in 16% brine for 24 h, then they were surface dried and ripened at air temperature of 10-12°C and 75-85% relative humidity. After approx. 10 days cheeses were vacuum packaged and the ripening process continued for the next 4-6 weeks. Cheeses were considered ripe when their flesh became elastic and it was uniform in terms of its structure and colour.

Samples of milk raw material for cheese production and cow milk were analysed to determine the contents of dry matter (solids), protein, fat and lactose using the MilkoScan apparatus. Processability (technological quality) of the raw material for cheese production was determined based on milk coagulation time after the addition of rennet (using the casein test [3]), as well as quality of the produced curd and yields of fresh and ripe cheese mass. Before the formed curd was cut it was evaluated in a 3-point scale, where: 1 point – loose curd structure, no syneresis (i.e. no whey expulsion); 3 points – dense curd structure, porcelain-white at the cross-section, expulsion of clear whey.

Analyses of the chemical composition were conducted on ripe cheeses to determine the contents of solids (dry matter) (by the oven drying method), protein (according to Kjeldahl), fat (according to Soxhlet) and ash (by combustion at a temperature of 550 – 600°C) [3]. Based on the chemical composition and tabulated values the energy value of cheeses was established [13]. Moreover, organoleptic analysis of produced cheeses was conducted using a 5-point scale (min. - max.) with a blank test [22]. A 4-person panel evaluated the following attributes: texture (1 point – hard, brittle; 5 points – elastic), structure (1 point – quark interior, detectable grains, dry; 5 points – homogeneous structure), rind (1 point – moist, sticky, uneven; 5 points – dry, smooth), eye distribution (1 point – atypical eyes: netlike, slits; 5 points – regular, oval or round eyes), saltiness (1 point – too salty, insufficiently salty; 5 points – optimal), aroma (1 point – atypical, pungent, acid, indistinct; 5 points – aromatic, mild, slightly acid), flavour (1 point – bitter, acid, bland; 5 points – slightly savoury, typical of hard cheese), colour (1 point – white, uneven colouring; 5 points – ivory, yellow, uniform colour), assigning an additional score also for overall flavour and visual perception. Samples for analyses were coded with numbers (1, 2, 3 and 4, including the control sample) and they were presented to the assessors in a random order.

A simplified calculation was performed for costs of raw materials used to produce 1 kg tested cheeses. The cost of SM was adopted based on market clearing prices applied in the Kołuda Wielka Experimental Station, i.e. 2.20 PLN/kg, SCM according to purchase prices at the dairy – 1.50 PLN/kg, while for RCM purchased directly from the dairy farm it was the wholesale purchase price applied by the dairy – 1.00 PLN/kg.

Results were analysed statistically using the STATISTICA 6 PL package, applying one--way analysis of variance ANOVA. Statistical differences between milk material for cheese production were verified by the Duncan test. Coefficients of variation were calculated to assess variability (V%).

Results and Discussion

In standardised cow milk (SCM) used in experiment I, which consisted in the substitution of sheep milk for cheese production, a markedly lower concentration of milk components was recorded in comparison to Coloured Merino milk (Table 1). Standardised cow milk contained by 41.7% less solids, at over 2-fold lower contents of protein and fat, while lactose content was by 12.6% higher. Additionally, SCM had a more advantageous protein to fat ratio. In comparison to SM the content of lactose in SCM solids was almost 2-fold greater, while contents of protein and fat were lower, in absolute values by 23.4 and 31.9%, respectively.

In comparison to SM, substitution of sheep milk with SCM at 40 and 60% in the obtained milk raw material caused a decrease in the contents of dry matter by 14.8 and 24.2%, solids-not-fat by 9.1 and 16.8%, protein by 23.2 and 33.5% and fat by 22.9 and 33.6%, respectively, while lactose content increased by 6.2 and 10.1%. All these differences were significant at $P \leq 0.01$ (Table 1). Introduction of SCM to milk raw material at 60%, in comparison with the 40% substitution, resulted in a decrease in dry matter content by 11.1% ($P \leq 0.01$), solids-not-fat by 8.5% ($P \leq 0.05$) and protein by 13.8% ($P \leq 0.01$). Analysed raw materials for cheese making had a balanced protein to fat ratio, while they differed highly significantly in protein and lactose contents in dry matter. The 40 and 60% shares of SCM in the mixed milk material reduced protein contents in absolute values in relation to SM by 9.8 and 12.2% ($P \leq 0.01$), while lactose content increased by 24.5 and 45.4%, respectively ($P \leq 0.01$). Dry matter in the 4/6 raw material was characterised by a statistically significantly ($P \leq 0.05$) higher lactose content in comparison to the 6/4 material; in absolute values it was by 16.8%.

In experiment II raw cow milk (RCM) in comparison to SM contained lower levels of solids (by 35.1%), solids-not-fat (by 30.7%) and fat (by 42.6%), while protein content was over 2-fold lower; moreover, it was characterised by an inferior protein to fat ratio (Table 1). In turn, compared to SM in the dry matter of RCM analyses showed lower levels of protein (in absolute values by 28.0%) and fat (by 11.4%), while lactose content was higher (by 50.4%).

Substitution of sheep milk with RCM at 40 and 60% reduced concentrations of milk components in mixed milk for cheese making in comparison to SM: the content of solids by 12.8 and 21.4%, solids-not-fat by 13.0 and 18.7%, protein by 22.0 and 32.4%, fat by 12.4 and 25.9%. All the differences were significant at $P \leq 0.01$ (Table 1). Introduction of

Table 1
Chemical composition of raw materials for cheese making

Specification		Cow milk (MK)	Raw material for cheese making			SEM
			MO	sheep and cow milk		
				6/4	4/6	
Experiment I						
Chemical composition (g/100 g)						
dry matter	x	12.12	20.78^{AB}	17.70^{BC}	15.74^{AC}	0.548
	V%	1.4	6.6	3.6	4.3	
solids-not-fat	x	8.36	12.14^{AB}	11.04^{Ba}	10.10^{Aa}	0.216
	V%	1.2	2.8	1.8	4.0	
protein	x	3.25	7.28^{AB}	5.59^{BC}	4.84^{AC}	0.275
	V%	2.8	11.5	6.3	6.2	
fat	x	3.43	8.64^{AB}	6.66^{B}	5.74^{A}	0.356
	V%	3.4	12.1	16.0	8.7	
lactose	x	4.74	4.15^{AB}	4.40^{B}	4.57^{A}	0.108
	V%	1.7	15.2	9.5	4.0	
Protein: fat	x	0.95	0.84	0.84	0.84	0.026
	V%	1.7	8.6	16.9	5.2	
Solids content of chemical components (%)						
protein	x	26.82	35.03^{AB}	31.58^{B}	30.75^{A}	0.609
	V%	1.5	7.3	5.8	2.9	
fat	x	28.32	41.58	37.63	36.47	0.945
	V%	2.4	5.9	14.2	5.7	
lactose	x	39.10	19.97^{AB}	24.86^{Ba}	29.03^{Aa}	1.07
	V%	2.3	18.5	10.4	4.1	
Experiment II						
Chemical composition (g/100 g)						
dry matter	x	12.90	19.89^{AB}	17.35^{BC}	15.64^{AC}	0.481
	V%	3.4	3.3	2.0	2.9	
solids-not-fat	x	8.64	12.47^{AB}	10.85^{BC}	10.14^{AC}	0.265
	V%	1.7	2.1	1.6	1.2	
protein	x	3.27	7.00^{AB}	5.46^{BC}	4.73^{AC}	0.260
	V%	5.2	3.6	3.6	3.7	
fat	x	4.26	7.42^{AC}	6.50^{BC}	5.50^{AB}	0.230
	V%	7.7	7.0	4.5	7.0	
lactose	x	4.66	4.77	4.69	4.71	0.017
	V%	2.6	0.7	1.2	1.7	
Protein: fat	x	0.77	0.95^{Aa}	0.84^{A}	0.86^{a}	0.017
	V%	4.9	6.2	5.0	5.6	
Solids content of chemical components (%)						
protein	x	25.35	35.20^{AB}	31.47^{Ba}	30.23^{Aa}	2.312
	V%	3.0	2.5	2.7	2.3	
fat	x	33.02	37.27^{b}	37.46^{a}	35.13^{ab}	0.437
	V%	4.5	4.1	2.9	4.3	
lactose	x	36.12	24.02^{AC}	27.03^{BC}	30.16^{AB}	0.713
	V%	4.6	3.6	3.0	4.4	

MO – sheep milk
AA, BB, CC – statistically significant differences at $P \leq 0.01$; aa, bb – at $P \leq 0.05$
SEM – standard error of mean

60% RCM to the milk material, in comparison to 40%, reduced contents of milk solids (by 9.9%), solids-not-fat (by 6.5%), protein (by 13.4%) and fat (by 15.4%); P≤0.01. The sheep-cow milk mixed at 6/4 and 4/6 had a less advantageous protein to fat ratio than SM, by 8.9% (P≤0.05) and 11.1% (P≤0.01), respectively. Moreover, a significantly lower protein content in dry matter of the 6/4 and 4/6 mixed milks was recorded in relation to the levels in SM, in absolute values by 10.6 and 14.2% (P≤0.01), while in the dry matter of the 4/6 mix it was by 3.9% lower than in the 6/4 mixed milk (P≤0.05). The 4/6 processing milk was also characterised by a lower fat content in dry matter in relation to the 6/4 mix and SM, which in absolute value was by 6.2 and 5.7%, respectively (P≤0.05). Lactose content in the dry matter of the 6/4 and 4/6 mixed milks compared to SM increased by 12.5 and 25.6%, while in the 4/6 mix in comparison to the 6/4 mix it was by 11.8%, with all the differences significant at P≤0.01.

In experiment I mixed milks coagulated on average by 15.1 min (i.e. by 30.2%) longer than SM; P≤0.01 (Table 2). A marked trend was also observed for a deterioration of curd quality with an increase in the share of SCM in the milk material. The 6/4 and 4/6 mixed milks gave lower yields of both fresh and ripe cheese mass compared to SM, for fresh cheese mass by 17.4 and 24.6% (P≤0.01), while for ripe cheese mass it was by 18.0 and 25.4% (P≤0.01). Cheeses made from mixed milks matured on average by 6.8 days longer (by 10.0%); however, these differences were not confirmed statistically due to the high variability of the analysed parameter (V% 19.0 - 30.4). No significant differences between compared cheeses were recorded in terms of losses of cheese mass during ripening.

In experiment II substitution of sheep milk with RCM resulted in a prolonged milk coagulation time, which was not confirmed statistically due to the high variability of this parameter (Table 2). It needs to be stressed that coagulation of mixed milks lasted longer than in the case of substitution with SCM and the curd received higher scores than in experiment I. It was characterised by good cohesion and adequate syneresis (expulsion of whey). Analogously as in experiment I, substitution of sheep milk with RCM resulted in a reduced cheese mass yield; from the 6/4 and 4/6 mixed milks the fresh cheese mass yield was smaller than from SM by 17.1 and 27.5% (P≤0.01), while ripe cheese mass yield – by 18.5 and 30.3%, respectively (P≤0.01). Mixing sheep and cow milks at 4:6, in comparison to the 6:4 ratio, produced smaller yield of fresh cheese mass (by 12.5%; P≤0.05) and ripe cheese mass (by 14.5%; P≤0.01). Cheeses produced from mixed milks matured on average by 5.9 days faster (i.e. by 7.5%) than those from sheep milk (NS). During ripening greater losses of mass were found for cheeses produced from the 6/4 mixed milk (by 1.3 p.p.) and 4/6 mix (by 3.0 p.p.) compared to those from sheep milk. However, these differences were not confirmed statistically due to the high variability of the parameter (V% >43.0).

Analysis of results from both experiments indicates that substitution of Coloured Merino milk (SM) with standardised cow milk (SCM) and raw cow milk (RCM) resulted in a reduced concentration of basic milk components in sheep-cow mixed milks (in proportion to the amount of the substitute in the processing material), and thus in a lower yield of cheese mass. It was also found that mixing SM with RCM at the 4:6 ratio resulted in a significant decrease in contents of milk components in the processing material, which reduced its yield in comparison to the 6:4 ratio. In turn, the varied share of SCM in the raw material for cheese making had no effect on the significant variation in the chemical composition of

Table 2
Technological parameters of cheese making and yield of cheese mass

Specification		Cheeses made from			SEM
		MO	sheep and cow milk		
			6/4	4/6	
Experiment I					
Milk coagulation time (min)	x	50.3^{AB}	66.7^{A}	64.2^{B}	3.491
	V%	18.6	19.9	26.8	
Curd score (1-3 pts)	x	2.6	2.4	2.1	0.111
	V%	23.3	9.8	8.0	
Ripening period (days)	x	68.2	76.2	73.8	3.921
	V%	30.4	19.0	22.0	
Yield of fresh cheese mass (kg/100 kg milk)	x	32.64^{AB}	26.96^{B}	24.61^{A}	0.972
	V%	7.1	10.3	8.0	
Yield of ripe cheese mass (kg/100 kg milk)	x	27.27^{AB}	22.37^{B}	20.33^{A}	0.871
	V%	10.3	5.8	9.0	
Loss of cheese mass during ripening (%)	x	16.55	16.86	17.32	1.088
	V%	31.0	26.1	29.6	
Experiment II					
Milk coagulation time (min)	x	84,8	96.6	107.4	6.772
	V%	24.3	19.8	33.6	
Curd score (1-3 pts)	x	2.65	2.70	2.65	0.047
	V%	8.4	7.7	5.2	
Ripening period (days)	x	79.0	74.8	71.4	3.022
	V%	26.3	25.0	24.5	
Yield of fresh cheese mass (kg/100 kg milk)	x	33.13^{AB}	27.47^{Ba}	24.03^{Aa}	1.131
	V%	7,1	7.5	8.3	
Yield of ripe cheese mass (kg/100 kg milk)	x	27.52^{AB}	22.42^{BC}	19.17^{AC}	0.961
	V%	4.1	4.1	6.8	
Loss of cheese mass during ripening (%)	x	16.00	17.33	18.98	1.983
	V%	52.0	46.1	43.0	

MO – sheep milk
AA, BB, CC – statistically significant differences at P≤0.01, aa –at P≤0.05
SEM – standard error of mean

the mixed milks and the yield of cheese. In comparison to SCM purchased from the dairy, RCM collected directly from the farm contained more solids and fat and had a lower protein to fat ratio (Table 1). Despite varying concentrations of milk components in SCM and RCM no marked differences were found between the experiments in the composition of analogous mixed milks. This resulted from the differences in the composition of sheep milk, probably caused by the difference in feeding of sheep in 2009 and 2010. Sheep milk in 2010, in comparison to 2009, was characterised by lower contents of solids and fat, and a greater lactose content as well as a more advantageous protein to fat ratio (Table 1).

Sheep milk substituted with 40 and 60% CM coagulated over a longer period, while in the case of substitution with SCM it formed curd of lower processability (exhibiting looser consistency and showing no marked syneresis). Inferior coagulation of sheep-cow processing milks in experiment I (which was not observed in the substitution of sheep milk with RCM) was probably caused by technological processes applied by the dairy in the production of drinking milk (pasteurisation, standardisation). This may indirectly lead to a prolonged ripening time (on average by 6.8 days) for cheeses produced at sheep milk substitution with SCM, while it is shorter (mean by 5.9 days) at the addition of RCM compared to cheese produced from SM. Cheeses made at an addition of RCM ripened faster, which probably resulted from the greater lactose content in the dry matter of processing milk, from which lactic acid, responsible for the cheese ripening process, is formed at the addition of bacterial starter cultures.

Milk of Coloured Merino sheep, processed in both experiments to make Ser Kołudzki, had a greater protein content and a comparable protein content as those reported in studies by Pakulski et al. (protein content from 5.8 to 6.1%; fat from 7.7 to 8.9%) when Kłobudzki cheese was produced from this milk [15, 16]. This probably resulted in a greater yield of semi-hard sheep cheese (from 17.6 to 21.3%) in comparison to other studies [14, 15, 16].

A decrease in the contents of milk components in sheep-cow mixed milks in relation to sheep milk resulted in a significant reduction in yield for these processing milks. Similar dependencies were observed in experiments conducted by the authors of this study [8], at the 40 and 60% substitution of the Kołuda sheep milk with raw cow milk; however, in that case the yield of fresh cheese mass was much smaller, i.e. 20.98 and 18.65%, respectively. The lower yield of cheese mass from sheep-cow mixed milk recorded in this study resulted from the lower concentration of components in the Kołuda sheep milk and cow milk. It also needs to be stressed that in both experiments the mean yield of Ser Kołudzki from the Coloured Merino milk mixed with cow milk at the 6:4 and 4:6 ratio was 22.39 and 19.75%, respectively, and it exceeded the yields of cheese from the Coloured Merino milk [15, 16] and a comparable cheese from milk of Spanish Merino sheep [14]. Such a high production efficiency of sheep-cow mixed milks probably results from their higher protein contents and a more advantageous protein to fat ratio (in both experiments for the 6/4 and 4/6 mixed milks – mean 0.84) than in milk of the Coloured Merino sheep in the above-mentioned studies (from 0.55 to 0.77). The dependencies between casein content in milk (and thus also protein content) and the yield of cheese were confirmed by observations of other authors [20]. The yield of semi-hard ripening cheeses produced from sheep-cow mixed milks was greater than from cow milk reported in other studies; the yield of sheep-cow Ser Kołudzki was over 2-fold greater than that of Salami cheese produced solely from cow milk [21].

Table 3
Chemical composition and nutritive value of cheeses made

Specification		Cheeses made from			SEM
		MO	sheep and cow milk		
			6/4	4/6	
Experiment I					
Chemical composition of cheese (g/100 g):					
dry matter	x	51.15	50.30	48.51	0.802
	V%	6.9	8.3	4.7	
solids-not-fat	x	29.91	29.71	28.37	0.568
	V%	9.0	9.0	6.8	
protein	x	23.57	23.19	21.99	0.628
	V%	12.6	12.4	10.7	
fat	x	21.25	20.58	20.14	0.532
	V%	8.7	16.0	7.6	
ash	x	3.13	3.17	3.51	0.153
	V%	20.4	18.7	21.8	
Protein: fat	x	1.11	1.15	1.10	0.037
	V%	13.8	17.7	12.7	
Energy value of cheese (kcal/100 g)	x	298	291	281	5.751
	V%	7.3	11.3	5.9	
Experiment II					
Chemical composition of cheese (g/100 g)					
dry matter	x	51.53	51.33	50.73	0.542
	V%	5.6	3.5	3.6	
solids-not-fat	x	27.85	27.77	27.77	0.378
	V%	5.9	5.6	5.6	
protein	x	22.12	22.02	22.07	0.338
	V%	5.4	8.4	4.6	
fat	x	23.68	23.56	22.96	0.345
	V%	5.3	8.6	8.1	
ash	x	3.35	3.53	3.30	0.138
	V%	19.7	13.9	16.2	
Protein: fat	x	0.93	0.94	0.97	0.023
	V%	0.6	13.7	10.5	
Energy value of cheese (kcal/100 g)	x	311	309	304	3.883
	V%	5.2	5.7	4.6	

MO – sheep milk
SEM – standard error of mean

It was also stated that substitution of sheep milk with cow milk had no significant effect on the composition of cheeses in both experiments (Table 3). However, a marked trend was observed towards lower contents of solids (by 5.2%), solids-not-fat (by 5.1%), protein (by 6.7%) and fat (by 5.2%) and greater contents of minerals (by 12.1%) in cheese produced from processing milk with a 60% share of SCM than in the case of SM. The lower contents of basic components in cheese at the 60% replacement of sheep milk with SCM resulted in a 5.7% reduction of energy value of this cheese. No significant differences were found in the protein to fat ratio in cheeses produced from the analysed milks.

All cheeses produced in experiment II, in comparison to those from experiment I, were characterised by greater contents of fat (on average by 13.4%,) and lower protein contents (on average by 3.7%), which resulted in a less advantageous protein to fat ratio (on average by 15.0%) and their higher energy value (on average by 6.2%). The higher retention of fat and the lower retention of protein in experiment II probably resulted from the fact that cheese was produced in vats, when it is difficult to maintain standard technological parameters. Available literature on this subject indicates considerable fluctuations in the composition of Ser Kołudzki made from milk of the Coloured Merino sheep at the micro-production scale, i.e. protein at 18.2-22.7%, fat 23.31-32.10% and the protein to fat ratio of 0.61-0.80 [16, 17]. Sheep cheeses and sheep-cow cheeses produced in both experiments were characterised by greater protein contents and lower fat contents, as well as a more advantageous protein to fat ratio in comparison to cheeses produced using the same technology in the cited studies.

A lack of dependencies between the composition of processing milk and contents of components in cheeses was confirmed in other studies [1, 8, 17, 23]. Bonczar et al. [1] reported significant differences in the chemical composition of sheep milk, cow milk and sheep and cow milks mixed at the 1:1 ratio, which however had no effect on the composition of bundz cheese produced from those milks. Bundz made from the processing milk with the lowest concentration of chemical components contained the greatest amounts of fat and the lowest protein content in comparison to cheeses produced from other milk types. Sheep and sheep-cow Ser Kołudzki produced in both experiments contained less protein and fat than ripening acid-rennet cheeses (Salami and Gouda: fat at 24.6 and 25.7%, protein at 28.4 and 27.0%, respectively) produced from cow milk [19, 21].

No statistically significant differences were found between scores for sensory attributes of cheeses from SM and substituted SCM (experiment I), except for the less uniform rind and more salty taste of the 4/6 variant compared to sheep cheese, with the differences by 12.5 and 8.0%, $P \leq 0.05$ (Table 4). However, lower scores were given for sheep-cow cheeses compared to sheep cheese, in proportion to the SCM share in the milk. Satisfactory scores (3.5 - 3.9 pts.) were given to all cheeses for flavour, in those from the 6/4 and 4/6 variants - also for texture (firmness) and structure. All cheeses received high scores for rind quality, eye distribution, saltiness, aroma and colour, while sheep cheese - also for firmness (over 4.0 pts.). Sheep cheese and the 6/4 cheese received high overall scores (over 4.0 pts.), while cheese from the 4/6 variant was given a score slightly below 4.0 points.

Similarly, substitution of sheep milk with RCM (experiment II) had no effect on significant variation in organoleptic attributes. All cheeses received high scores ranging from 4.0 to 4.5 points, with rind quality, eye distribution, saltiness and colour given scores of over 4.5 points. We need to stress a trend towards more advantageous scores for cheeses produced with the 60% share of RCM, while in the case of the 60% substitution with SCM the scores were lowest.

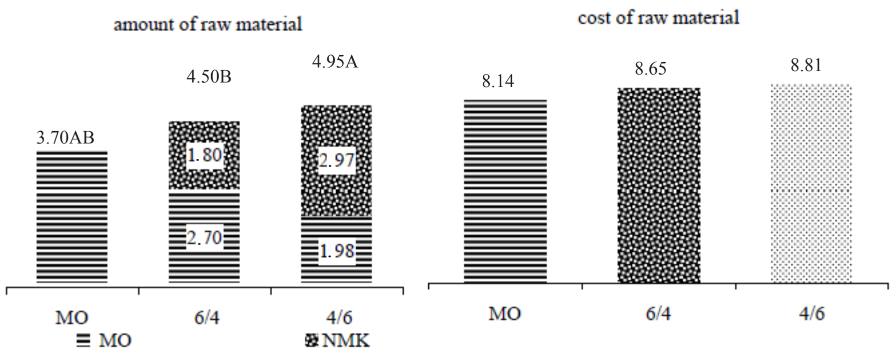
Cheeses made in experiment I received lower scores for organoleptic attributes than in experiment II or in a study by Pakulski et al. (overall score of 4.59 points) [16]. Sheep-cow cheeses in experiment I were hard, their interior was more brittle, flavour resembled quark,

Table 4
Organoleptic scores of mature semi-hard cheeses (pts)

Specification		Cheeses made from			SEM
		MO	sheep and cow milk		
			6/4	4/6	
Experiment I					
Elasticity	x	4.10	3.92	3.65	0.104
	V%	12.5	10.3	9.3	
Structure	x	4.01	3.77	3.67	0.119
	V%	9.7	14.1	16.3	
Rind	x	4.55[a]	4.25	3.98[a]	0.100
	V%	4.0	9.2	12.0	
Eyes	x	4.40	4.36	4.13	0.086
	V%	5.1	11.3	8.2	
Salt content	x	4.60[a]	4.42	4.23[a]	0.056
	V%	4.0	5.4	4.1	
Aroma	x	4.26	4.24	4.12	0.074
	V%	7.0	8.8	7.5	
Flavour	x	3.99	3.71	3.53	0.116
	V%	9.8	10.8	17.3	
Colour	x	4.46	4.25	4.17	0.094
	V%	7.5	8.9	11.7	
Overall score	x	4.29	4.11	3.94	0.074
	V%	4.7	7.4	9.1	
Experiment II					
Elasticity	x	4.27	4.20	4.37	0.102
	V%	6.3	11.6	9.5	
Structure	x	4.35	4.35	4.50	0.095
	V%	8.0	8.5	8.1	
Rind	x	4.70	4.65	4.77	0.052
	V%	4.5	4.8	2.2	
Eyes	x	4.55	4.65	4.75	0.079
	V%	8.4	5.2	3.7	
Saltiness	x	4.65	4.68	4.70	0.043
	V%	4.4	2.4	3	
Aroma	x	4.45	4.48	4.43	0.081
	V%	4.7	7.0	9.3	
Flavour	x	4.27	4.32	4.35	0.094
	V%	1.3	7.8	12.3	
Colour	x	4.65	4.53	4.70	0.052
	V%	3.5	5.3	4.5	
Overall score	x	4.42	4.39	4.52	0.078
	V%	3.8	7.5	7.7	

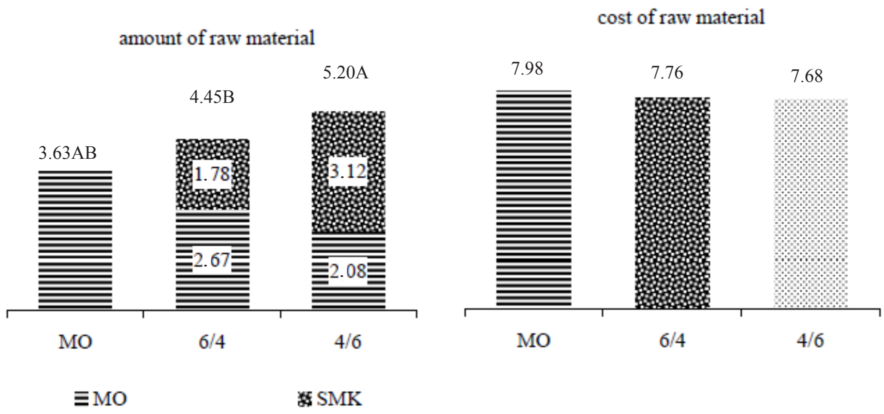
MO – sheep milk
aa – statistically significant differences at $P \leq 0.05$
SEM – standard error of mean

which indicates an inappropriate course of the ripening process. More advantageous scores for cheeses produced in experiment II could have also resulted from the higher fat content, undesirable from the dietary point of view, but improving cheese structure and flavour. Analyses of sensory quality of products, from which fat was removed partly or completely, indicate a deterioration of the sensory profile in comparison to their traditional equivalents [4, 10]. Jaworska [10] reported a lower consumer acceptance of quark with a reduced fat



AA, BB, CC – statistically significant differences at P≤0.01
Price: MO – 2.20 PLN/kg; NMK – 1.5 PLN/kg

Fig. 1. Amount (kg) and cost (PLN) of raw material used for making 1 kg of semi-hard maturing cheese – experiment I



AA, BB, CC – statistically significant differences at P≤0.01
Price: MO – 2.20 PLN/kg; SMK – 1.00 PLN/kg

Fig. 2. Amount (kg) and cost (PLN) of raw material used for making 1 kg of semi-hard maturing cheese – experiment II

content in relation to full-fat and semi-fat quarks, while the highest score for sensory quality was given to cheese with the highest fat content.

Figures 1 and 2 present results of simplified cost calculations for raw materials used to produce 1 kg semi-hard cheese. It was found that at the significantly higher amount of milk used per 1 kg Ser Kołudzki in the 6/4 (by 21.6%) and 4/6 variants (by 33.8%) compared to SM, their cost in experiment I was only slightly higher, by 8.2 and 6.3%, respectively, while in experiment II it was almost identical. This results from the SCM price lower by 31.8% and an over 2-fold lower price of RCM compared to the price of SM. The lower costs of the RCM substituted material in relation to SCM was caused by the lower price (by 33.3%) of milk purchased directly from the producer compared to that purchased from the dairy.

Summing up it may be stated that the 40 and 60% substitution of sheep milk (SM) with cow milk:

– resulted in decreased contents of dry matter (milk solids), protein and fat, while in experiment I – in an increased lactose level, in proportion to the share of cow milk in processing milk;

– resulted in a prolonged coagulation time of processing milks, while in the case of standardised cow milk (SCM) it also caused a deterioration in curd quality and an extension of cheese ripening time;

– had no significant effect on the chemical composition and energy value of cheeses, at a trend towards a decrease in the contents of dry matter, protein and fat, and thus also energy value of cheeses produced using an addition of standardised cow milk;

– resulted in an overall deterioration of sensory quality of cheeses at SM substitution with standardised cow milk (SCM), while for substitution with raw cow milk (RCM) – a trend towards more advantageous scores for cheeses with the 60% share of cow milk;

– resulted in a significantly higher consumption of processing milk per 1 kg produced semi-hard ripening cheese, whereas it did not affect its cost due to the lower price of cow milk in relation to sheep milk.

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