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PHYSICOCHEMICAL, MECHANICAL AND SENSORY PROPERTIES OF LONG-RIPENED POLISH AND ITALIAN CHEESES AND THEIR CONTENT OF SELECTED MINERALS

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ABSTRACT

An evaluation was conducted of six original long-ripened cheeses produced in Italy, i.e. Parmigiano-Reggiano (from two manufacturers), Grana Padano, Fontina, Caciotta Stagionato, and Pecorino Toscano Stagionato, and four produced in Poland: Szafir, Rubin, and Bursztyn (aged for 6 and 12 months). Their basic chemical composition was determined, as well as the content of macro- (K, Ca, Na and Mg) and micronutrients (Zn, Fe, Cu and Mn), colour in the CIE L* a* b* system, and mechanical properties on the basis of maximum shear force (N) and shear energy (J). A sensory evaluation was performed using a 5-point scale for intensity of flavour and odour, consistency, and structure. The Polish long-ripened cheeses were found not to differ significantly from the Italian cow cheeses in terms of basic chemical composition, but the cheese from buffalo and sheep milk contained more fat in their dry matter and more salt. The Polish cheeses had significantly ($p \leq 0.01$) more red (a*) and yellow (b*) colour than the Italian cheeses made from cow milk, which was probably linked to the use of annatto as a colourant in the production process. The Italian cheeses made from cow milk contained more ($p \leq 0.01$) copper than the other cheeses, while the sheep cheese contained the most iron. The highest ($p \leq 0.05$) magnesium concentration and the lowest ($p \leq 0.05$) potassium concentration were noted in the buffalo and sheep cheeses. The lowest shear force (6.32 N) and shear energy (0.01 J) were noted for Pecorino Toscano, which may be indicative of its less compact structure in comparison with the other cheeses. Consistency was rated highest in Parmigiano Reggiano, Caciotta Stagionato and Bursztyn (aged 12 months). In terms of flavour and odour, the sheep cheese Pecorino Toscano Stagionato received the highest scores and the cheese from buffalo milk (Caciotta Stagionato) was rated the lowest.

Keywords: long-ripened cheeses, macro- and microelements, chemical composition, shear force, colour.

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INTRODUCTION

Global cheese production in 2013 was 21.3 million tonnes, and the leading producer was the United States (5.2 million tonnes). Italy, ranking the 4th in the world, produced 1.2 million tonnes of cheese, while Poland produced 0.74 million tonnes and ranked the 6th (FAOSTAT 2017). Among Polish cheeses, unripened cheeses and quarks predominate (58%), with ripened rennet cheeses accounting for the rest (CSO 2016).

The primary raw material for cheese production is cow milk, although the milk of other animal species is used as well. In 2013, Italy produced 1,157,700 tonnes of cheese from cow milk, 52,500 tonnes from sheep milk, 15,700 tonnes from buffalo milk and 1,200 tonnes from goat milk. In Poland, the use of milk from other animal species for cheese production is marginal. In 2013, only 47 tonnes of sheep cheese was produced, as compared to 744,000 tonnes from cow milk (FAOSTAT 2016). In Poland, the tradition of making cheese from sheep milk is associated with the mountain region of Podhale, and originated with the Vlachs arriving in this area in the 15th century. Oscypek is a hard cheese registered with a protected designation of origin (PDO) in the European system for protecting regional and traditional products (KĘDZIERSKA et al. 2014).

The flagship Italian cheeses, recognized worldwide, are Parmigiano Reggiano and Grana Padano, which are among the oldest cheeses in Europe (JASTER et al. 2014). Parmigiano Reggiano is a hard cheese produced from raw milk with a 1:1 proportion of milk from evening milking (partly skimmed in the natural cream separation process) and morning milking (whole milk). It is obtained as a result of coagulation following the application of calf rennet, after which it is thermally treated (cooked) and ripened slowly, without additives (SUMMER et al. 2014). To produce milk for this cheese, silage is completely eliminated from the cows' diet (Council Regulation No. 510/2006, 'Parmigiano Reggiano'). Grana Padano cheese is produced from raw, partially skimmed milk from two complete daytime milkings, coagulated using calf rennet, boiled, and slowly ripened. It can be produced year round. The milk is obtained from cows whose main dietary component is green forage or dried fodder, and in the case of Grana Padano cheese of the 'Trentingrana' type, the use of silage is strictly prohibited. The cheese is hard, with a fine grainy texture and radial fracture, separating into scales and with barely visible eyes. It has a distinct aroma and delicate flavour and is white or straw-coloured, due to the inclusion in the cows' diet of maize silage or fresh maize harvested at the waxy stage (Council Regulation No. 510/2006 'Grana Padano'). Parmigiano Reggiano and Grana Padano have a long ripening period lasting 20 to 24 months or even longer, i.e. over 30 months in the case of Parmigiano Reggiano Gold Label (GATTI et al. 2014). Milk for Fontina cheese comes from the Valle d'Aosta region from cows of the Valdostana breed (Pezzata Rossa, Pezzata Nera or Castana), which must be

fed on hay and grass from the region where the cheese is produced. The use of silage and fermented products in the cows' diet is prohibited. It is permissible to add indigenous cultures of lactic acid bacteria (called enzymes), which are kept under the supervision of the Consortium of Producers and Protection of Fontina PDO and distributed to all producers of Fontina PDO cheese (Council Regulation No. 510/2006 'Fontina').

Pecorino is the popular name for a large group of Italian cheeses made from sheep milk. Pecorino Toscano Stagionato is produced from whole sheep milk from Tuscany. It is a semi-hard, long-ripened cheese with a characteristic consistency. The cheese has a compact structure and is difficult to cut. It is irregularly dotted with holes. It is an aromatic cheese with a distinct flavour. The sheep must be fed on green or dried forage from local pastures, which may be supplemented with hay and concentrated straight feeding-stuffs (Council Regulation No. 510/2006 'Pecorino Toscano').

Ripened cheeses are becoming increasingly popular among Polish consumers. One dairy in the south-eastern part of the country has responded to this trend and begun to specialize in the production of hard, long-ripened cheeses, named after precious stones: Bursztyn (amber), Rubin (ruby), and Szafir (sapphire). Their exceptional flavour is due to the high quality of the raw material, produced on farms pasturing cows in the meadows of Polesie and Podlasie.

The recipe and technology for producing Bursztyn cheese was developed in 2002. It owes its unique, slightly spicy flavour and aroma to a long ripening period in suitably chosen conditions, during which it is closely guarded by the cheesemakers. Each wheel is carefully attended to and the surface of cheese is rubbed with special coating for six months, which gives the rind a black colour and also protects the cheese against the mould contamination. The body of the cheese has a compact and slightly friable structure with perceptible crystals, which increase in number as the cheese matures. Szafir (minimum ripening period of 4 months) is distinguished by a deep but mild flavour and a creamy consistency. It is made using wine yeast, which gives it a characteristic flavour and consistency. The recipe and production technology for Rubin cheese were developed in 2009. It matures for a minimum of three months and has a distinct buttery aroma.

Cheese consumption is of considerable nutritional importance, particularly owing to its content and proportions of minerals (LUCAS et al. 2008). Mineral compounds take part in the coagulation of milk and affect the draining of whey and the texture of curd. During cheese ripening, some mineral salts may migrate from the outer layer to the core of the cheese block or vice versa (GAMBELLI et al. 1999). GONZÁLEZ-MARTÍN et al. (2009), in their evaluation of cheeses made from milk of different ruminant species (cow, goat and sheep), showed that the percentage of cow's milk has a significant effect on the concentrations of iron, potassium, phosphorus and zinc in cheeses. The percentage of ewe's milk has a significant effect on the concentration

of potassium and the percentage of goat's milk has a significant effect only on the concentration of potassium.

The aim of the study was to evaluate the physicochemical, mechanical and sensory properties and content of selected minerals in Polish long-ripened cheeses and regional Italian cheeses made from cow, sheep and buffalo milk.

MATERIALS AND METHODS

Research material

The material for the study consisted of six original long-ripened rennet cheeses purchased in Italy and four produced in Poland. Italian cheeses made from the milk of different animal species were chosen for the study: cow milk – Parmigiano Reggiano (from two manufacturers), Grana Padano, and Fontina; buffalo milk – Caciotta Stagionata; and sheep milk – Pecorino Toscano Stagionato. The Italian cheeses Parmigiano Reggiano, Grana Padano and Fontina were purchased in a large-format store belonging to one of the retail chains operating in Rome. The Caciotta Stagionata and Pecorino Toscano Stagionato were purchased in a shop operating on the farm 'La Maremmana Caseificio Inno al Sole', with 500 buffaloes, including 300 females (BARŁOWSKA, LITWINCZUK 2015). The Polish cheeses, Szafir, Rubin and Bursztyn (ripened 6 and 12 months), made exclusively from cow milk, were purchased from a retail chain in Lublin. According to the manufacturer, they were produced using lactic acid bacteria, calcium chloride, lysozyme from chicken egg white, and annatto as a colourant (E-160b). Only calf rennet is used to produce the Italian cheeses, and in the case of Fontina the addition of indigenous lactic acid bacterial cultures is also permissible.

The cheeses Parmigiano Reggiano, Grana Padano, Fontina, and Pecorino Toscano Stagionato all had a note about protected designation of origin (PDO) on the labels.

Analytical procedures

Physicochemical characteristics

Physicochemical, mechanical and sensory evaluations of cheese samples were carried out. The physicochemical tests were conducted in three replications according to PN-73/A-86232 and comprised determination of titratable acidity ($^{\circ}\text{SH}$) and active acidity (pH) with an Elmetron CP-401pH meter, moisture content by drying at 102°C, fat content in dry matter by the butyrometric method, and content of table salt by the Mohr's method. The total nitrogen content was determined by the Kjeldahl method, and the result was converted to a percentage content of protein using the conversion factor of 6.38 (PN-EN ISO 8968:2004). The crude ash content was determined by the gravimetric method according to AOAC (2012).

The content of selected macro- (K, Ca, Na and Mg) and microelements (Zn, Fe, Cu and Mn) was determined by atomic absorption spectrophotometry. Mineralization of cheese samples in an environment of 65% nitric acid (ULTRANAL) was carried out in flasks under high pressure in a MARS 5 Xpress microwave digester by CEM. The content of elements was determined using Varian spectrometers: AA 240FS (K, Ca, Na, Mg and Zn) and AA 240Z (Fe, Cu and Mn). To compensate for interference in determining K, Ca, Na and Mg, buffer was added to the samples according to Schinkel (10 g l⁻¹ CsCl + 100 g l⁻¹ La). Blank samples were included in the series of analytical assays. To determine recovery (%), certified reference material NCS ZC 73015 Milk Powder was analysed in parallel with the experimental samples. The content of elements was read from a calibration curve.

The colour of the cheeses in a cross-section was determined using a Minolta CR-310 colorimeter (Minolta Camera Co. Ltd., Osaka, Japan). The results of the measurements were given as trichromatic values in the CIE L* a* b* system (CIE 1976), where: L* – lightness, a* – green-red, b* – yellow-blue. Saturation (C) and hue (h°) were determined as well.

Mechanical characteristics

The mechanical characteristics of the cheeses were measured using a Zwick/Roell ProLine Z0.5 single-column testing machine and a Warner-Bratzler knife, determining the maximum shear force (N) and shear energy (J) required for a 10x10x50 mm cheese sample. The crosshead velocity was 100 mm min⁻¹. The measurements and results obtained were analysed using testXpert® II software.

Sensory evaluation

The sensory evaluation of the cheeses was performed by a team of eight individuals selected among employees of the University of Life Sciences in Lublin, who first passed a general test of sensory abilities. Prior to the evaluation, the cheese samples were cut into 1.5 cm cubes, coded and left for 1 h at room temperature, and then presented to the testers together with a sensory evaluation questionnaire. A five-point scale was used to evaluate the intensity of characteristics of flavour, odour, consistency and structure. The testers expressed their impressions regarding the sensory attributes first descriptively, and then as point values. The scale for flavour and odour intensity comprised 5 basic levels: 5 – very strong, 4 – strong, 3 – moderate, 2 – weak, and 1 – slightly perceptible or borderline. For the consistency and structure of the cheeses, the following levels were used: 5 – very hard, 4 – hard, 3 – somewhat hard, 2 – neither hard nor soft, and 1 – somewhat soft (PN-ISO 4121: 1998).

Statistical analysis

The results were analysed statistically using one-way analysis of variance supported by StatSoft Inc. Statistica software ver. 6. Values were given for individual cheese characteristics and with the standard deviation for groups of cheeses, distinguishing cow, sheep and buffalo cheese. Significance of differences between means for the groups of cheeses was determined by the Fisher's LSD test ($p \leq 0.05$ and $p \leq 0.01$).

RESULTS AND DISCUSSION

The results indicate that the Polish cheeses did not differ significantly from the Italian cheeses made from cow milk in terms of their basic components, i.e. dry matter, fat in dry matter, protein and salt or acidity. The cheeses made from sheep and buffalo milk had the significantly highest ($p \leq 0.01$) content of fat in dry matter and of salt, while having the lowest protein content (Table 1). The high fat concentration in the cheeses is unquestionably linked to its higher content in the raw material. In a review of several dozens of scientific publications, BARŁOWSKA et al. (2011) reported that the mean fat content is over 7 g 100 g⁻¹ in buffalo milk and 6.99 g 100 g⁻¹ in sheep milk, as compared to 4.09 g 100 g⁻¹ in cow milk. SCHIRONE et al. (2013), analysing the physicochemical properties of 12 types of Pecorino cheese from different regions of Italy, with varying degrees of maturity (from three to ten months), found substantial differences in the parameters evaluated. The moisture content in cheeses ranged from 26.86 g 100 g⁻¹ to 65.93 g 100 g⁻¹, protein in dry matter from 35.32 g 100 g⁻¹ to 80.10 g 100 g⁻¹, fat in dry matter from 31.08 g 100 g⁻¹ to 83.71 g 100 g⁻¹, and pH from 5.33 to 6.77.

The differences in the salt content in the cheeses evaluated in our study are linked to the brining process, i.e. the concentration of brine and the soaking time. Significantly ($p \leq 0.01$) the most salt (3.151 g 100 g⁻¹) was noted in the sheep cheese Pecorino Toscano Stagionato, produced using 17-19 g 100 g⁻¹ brine, with the cheese left in the salt solution for at least 12-14 h (Council ... 'Pecorino Toscano'). Considerably less salt was contained in the cheese from buffalo milk (2.081 g 100 g⁻¹) and the Italian cheeses from cow milk (1.852 g 100 g⁻¹), and the least salt (1.627 g 100 g⁻¹) was determined in the Polish cheeses.

The colour of the cheeses was evaluated using achromatic (lightness) and chromatic parameters (a^* and b^* values, saturation C^* and hue h°). The lightness of all the cheeses analysed was similar, within a range of 73.39-78.77. However, statistically significant differences were found for the remaining colour parameters, in part due to species differences, the production technology used and, in some cases, the use of additives. The Polish cheeses had more than twice as much ($p \leq 0.01$) red colour and 1.5-fold more yellow in comparison with the Italian cheeses made from cow milk.

Table 1

Chemical composition and physicochemical properties of the cheeses

Specification	Italian						Polish				Italian		Italian											
	Parmigiano (1)		Parmigiano (2)		Grana Padano		Fontina		mean		Bursztyn (ripened 6 mos)		Szafir		Rubin		Bursztyn (ripened 12 mos)		mean		Caciotta Stagionata		Pecorino Toscano Stagionato	
	\bar{x}	SD	\bar{x}	SD	\bar{x}	SD	\bar{x}	SD	\bar{x}	SD	\bar{x}	SD	\bar{x}	SD	\bar{x}	SD	\bar{x}	SD	\bar{x}	SD	\bar{x}	SD	\bar{x}	SD
Moisture content (g 100 g ⁻¹)	32.09	31.26	33.03	33.42	32.45 ^b	0.93	33.72	33.40	35.72	25.34	32.34 ^b	4.06	23.34 ^a	0.35	31.77 ^b	0.58								
Dry matter content (g 100 g ⁻¹)	67.91	68.74	66.97	66.58	67.55 ^a	0.93	66.28	66.60	64.28	74.66	67.66 ^a	4.06	76.66 ^b	0.35	68.23 ^a	0.58								
Protein content (g 100 g ⁻¹)	31.80	32.55	32.88	30.40	31.91 ^c	0.98	30.65	30.05	31.98	30.44	31.40 ^c	1.66	20.06 ^a	0.12	23.73 ^b	0.70								
Ash content (g 100 g ⁻¹)	4.610	3.810	4.731	3.652	4.201 ^a	0.55	5.170	6.173	6.063	6.381	5.902 ^b	0.70	4.472 ^a	0.89	5.382 ^b	0.28								
Fat content DM (g 100 g ⁻¹)	42.33	46.92	41.81	49.94	45.25 ^a	3.45	46.04	42.80	45.12	45.77	45.00 ^a	1.40	59.13 ^b	0.27	54.23 ^b	0.47								
Acidity	^o SH	99.30	85.31	80.00	23.31	72.00	30.4	86.00	77.00	69.01	95.00	10.8	67.32	5.0	66.00	5.3								
	pH	5.431	5.520	5.663	6.530	5.662	0.39	5.932	6.001	5.971	5.831	5.930	0.07	5.353	0.02	5.491	0.01							
Salt content (g 100 g ⁻¹ DM)		1.809	1.901	1.802	1.911	1.852 ^a	0.11	1.301	1.503	1.804	1.844	1.627 ^a	0.26	2.081 ^b	0.07	3.151 ^c	0.09							
	L	76.08	76.94	76.99	75.32	76.33	0.79	74.42	75.47	75.91	66.86	73.39	3.69	77.82	1.10	78.77	0.66							
Colour according to CIE	a*	5.981	5.352	3.684	5.096	5.033 ^b	0.88	11.20	10.97	9.072	13.99	11.18 ^c	1.81	1.992 ^a	0.16	2.770 ^a	0.36							
	b*	14.68	20.74	18.73	20.90	18.76 ^b	2.58	28.87	29.47	30.27	26.30	28.82 ^c	1.53	20.66 ^b	0.94	14.91 ^a	0.95							
	C	15.85	21.41	19.09	21.51	19.47 ^b	2.37	30.96	31.44	31.67	29.78	31.00 ^c	0.82	20.75 ^b	0.92	15.17 ^a	0.87							
^o h	67.92	75.58	78.96	76.40	74.72 ^b	4.28	68.86	69.68	73.36	62.08	68.78 ^a	4.15	84.54 ^d	0.65	79.50 ^c	1.84								

A, B, C, D – differences significant at $P \leq 0.01$

The significantly lower ($p \leq 0.01$) colour saturation (C^*) of the Italian cheeses was probably due to the fact that the Italian recipes do not permit the use of any additives in the production process, including colourants. The Polish cheeses were made using the colourant annatto (E-160b), which is a mixture of carotenoids obtained naturally from the seeds of the tropical achiote tree (*Bixa orellana* L.) (KRÓL, BRODZIAK 2014). Less of the colour yellow (b^*) in the Grana Padano cheese may be the direct effect of the use in the cows' diet of maize harvested at the waxy stage (fresh or silage), which has a lower content of colouring agents such as carotene, anthocyanins and chlorophyll than green forage or hay (Council ... 'Grana Padano'). The least ($p \leq 0.01$) red colour was noted in the cheese from buffalo milk, i.e. Caciotta Stagionata ($a^* - 1.992$), and sheep milk – Pecorino Toscano Stagionato ($a^* - 2.770$), which can be linked to the natural white colour of the milk. PARK (2007) and BARŁOWSKA et al. (2011) report that in the milk of these species all of the beta-carotene is transformed into retinol, and in consequence sheep milk is porcelain white, while buffalo milk, due to the presence of the pigment biliverdin, is white with a slight green hue (ABD EL-SALAM, EL-SHIBINY 2011). The natural greenish hue of buffalo milk is mainly reflected in the significantly lower ($p \leq 0.01$) a^* value (1.992) of the cheese. SIMÕES et al. (2013) showed that cheese from 100% buffalo milk had an a^* value of 5.41, but as the percentage of cow milk increased, the a^* parameter increased while the amount of green decreased. The results of our study may suggest that the milk of another animal species may have been also used to make the Caciotta Stagionata cheese.

The total content of the evaluated minerals for the Italian cheeses made from cow milk was 45% of the ash content, in buffalo cheese – 44.5% and in sheep cheese – 41% while in the Polish cheeses it made up 34% of the ash content. The data in Table 2 show that the Italian and Polish cheeses from cow milk had similar content of calcium, sodium, potassium, magnesium, zinc and iron. It was only in the Fontina cheese that the calcium content was lower (656.9 mg 100 g⁻¹), which is confirmed by the results obtained by LAWLOR et al. (2001), who found that the content of this element was 679.00 mg 100 g⁻¹. Varied calcium content in cheeses is usually linked to the production process, i.e. the time when the curd is drained, which also influences the texture of cheese (SIMÕES et al. 2013). BORYS et al. (2006), in a study on cheeses produced from sheep milk, reported substantial differences in the profile of macro- and micronutrients, which in their opinion are explained by differences in the production process.

However, it is noteworthy that the copper content in the Italian cheeses made from cow milk was ten times higher (0.564 mg 100 g⁻¹) than in the other cheeses evaluated. This can probably be attributed to the use of copper cauldrons in the process of milk coagulation and curd handling. The cheeses from buffalo (Caciotta Stagionata) and sheep milk (Pecorino Toscano Stagionato) had a significantly ($p \leq 0.01$) higher magnesium content and the

Table 2

Content of selected macro- and microelements in the cheeses (mg 100 g⁻¹)

Element	Cheeses from cow milk												Cheese from buffalo milk		Cheese from sheep milk	
	Italian						Polish						Italian		Italian	
	Parmigiano (1)	Parmigiano (2)	Grana Padano	Fontina	mean	Bursztyn (ripened 6 mos)	Szahr	Rubin	Bursztyn (ripened 12 mos)	mean	SD	\bar{x}	SD	\bar{x}	SD	\bar{x}
Ca	1016.1	919.7	1020.3	656.9	903.3 ^{Ba}	1011.6	1013.5	985.9	1114.9	1027.8 ^{Bb}	49.30	984.3 ^{Bb}	0.2	767.3 ^{Aa}	1.5	
Na	870.5	711.4	802.5	892.3	819.2 ^A	685.9	842.6	927.6	865.6	827.8 ^A	96.14	833.2 ^A	0.3	1269.7 ^B	0.5	
K	127.1	120.7	121.2	141.4	127.6 ^B	121.8	137.8	126.4	131.8	128.9 ^B	6.08	112.7 ^A	1.4	116.2 ^A	0.3	
Mg	40.64	38.35	43.88	20.85	35.93 ^A	43.46	41.81	37.53	46.57	42.34 ^A	3.38	52.81 ^B	1.2	50.87 ^B	0.2	
Zn	4.532	4.251	5.001	3.492	4.321 ^B	4.382	4.191	3.831	4.571	4.231 ^B	0.28	3.881 ^B	0.4	1.771 ^A	0.3	
Fe	0.391	0.253	0.242	0.310	0.302 ^A	0.291	0.382	0.372	0.300	0.330 ^A	0.04	0.363 ^A	5.0	0.613 ^B	1.7	
Cu	0.552	0.901	0.501	0.323	0.564 ^B	0.040	0.039	0.034	0.069	0.045 ^A	0.014	0.036 ^A	1.3	0.055 ^A	4.2	
Mn	0.034	0.030	0.036	0.037	0.034 ^A	0.045	0.048	0.045	0.043	0.045 ^C	0.002	0.036 ^A	9.5	0.040 ^B	7.4	
Average total content of minerals	2064.1	1796.3	1994.5	1715.9	1892.5 ^A	1867.5	2039.7	2081.5	2163.8	2035.4 ^{AB}	21.37	1987.5 ^A	2.6	2206.6 ^B	2.2	

A, B, C – differences significant at $P \leq 0.01$; a, b – significant at $P \leq 0.05$

lowest potassium content. The significantly lowest calcium ($767.3 \text{ mg } 100 \text{ g}^{-1}$) and zinc ($1.771 \text{ mg } 100 \text{ g}^{-1}$) were noted in the sheep cheese Pecorino Toscano Stagionato; this cheese, however, had the highest concentrations of sodium ($1269.7 \text{ mg } 100 \text{ g}^{-1}$) and iron ($0.613 \text{ mg } 100 \text{ g}^{-1}$). LUCAS et al. (2006) reported a significantly ($p < 0.001$) higher magnesium content and a lower ($p < 0.05$) content of phosphorus and zinc in sheep cheeses as compared to cheeses produced from cow milk. In the present study, the Polish cheeses contained the most ($p \leq 0.01$) manganese ($0.045 \text{ mg } 100 \text{ g}^{-1}$). According to KONCEWICZ-BARAN and GONDEK (2010), the main source of trace elements in food is soil, from which they enter plants and continue further into the food chain.

The results presented in Figures 1 and 2 show that the Pecorino Toscano Stagionato sheep cheese was characterized by the lowest shear force (6.32 N) and shear energy (0.01 J). In the Italian cheeses made from cow milk, the

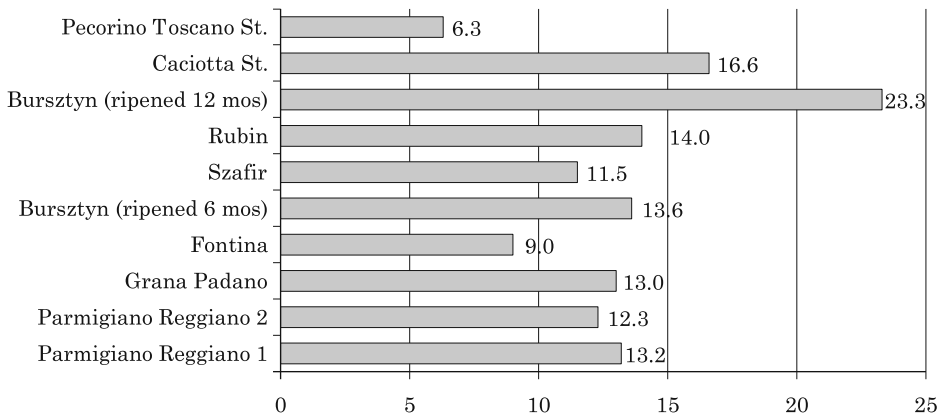


Fig. 1. Results of instrumental evaluation of the mechanical properties of the cheeses (shear force – N)

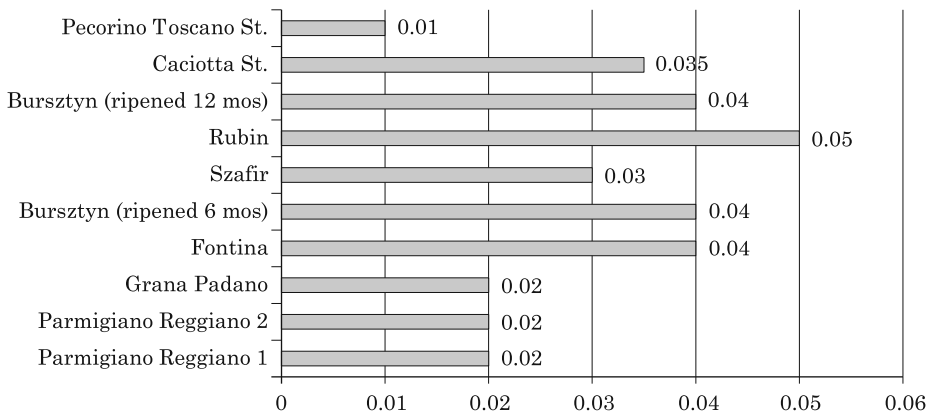


Fig. 2. Results of instrumental evaluation of the mechanical properties of the cheeses (shear energy – J)

shear force ranged from 9.03 to 13.15 N (mean 12.14 N), and in the Polish cheeses it varied from 11.5 to 23.3 N (mean 15.60 N). The texture of cheese is determined by a number of factors, including the chemical composition of the milk, moisture and salt content, pH, and the degree of protein proteolysis during maturation (DA CUNHA et al. 2006). According to HABIB et al. (2012), the pressing process is also important, as the application of appropriate pressure is conducive to interactions between proteins and other curd components and can transfer tension between polymer units, resulting in a more compact curd and greater springiness.

The results of the sensory evaluation, presented in Figure 3, show that with respect to consistency the cheeses Parmigiano Reggiano, Caciotta Sta-

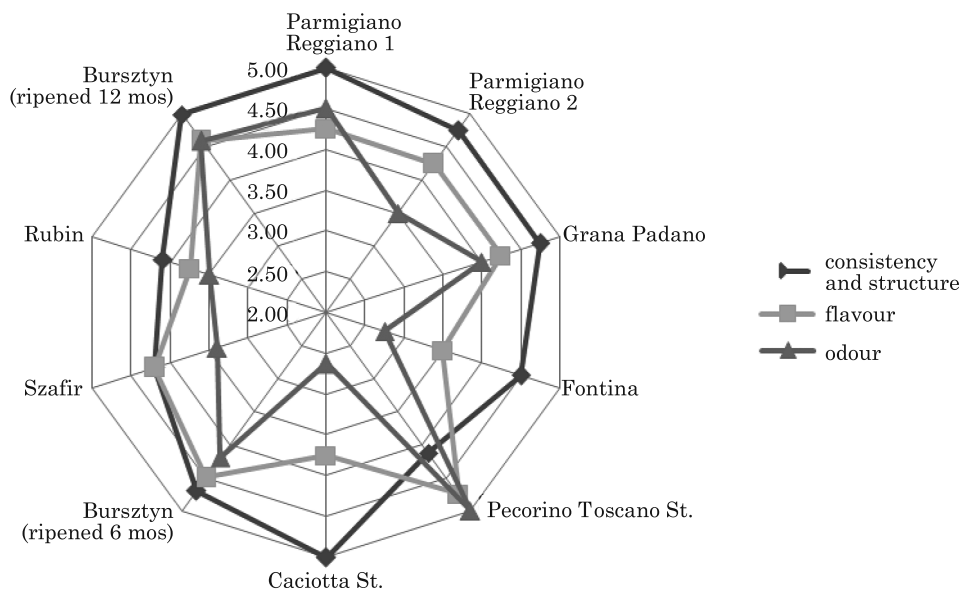


Fig. 3. Comparative profilogram of attributes from the sensory evaluation of the cheeses

gionata, and Bursztyn ripened for 12 months received the highest possible score (5 pts). The sheep cheese Pecorino Toscano received a slightly lower score for consistency (4.13 pts). The results of the sensory evaluation of consistency were generally reflected by the results of the instrumental test, i.e. the cheeses assessed by the consumers as the hardest also had the highest shear force values. The sheep cheese Pecorino Toscano Stagionato received the highest scores for flavour and odour, 4.75 and 5, respectively, while the buffalo cheese Caciotta Stagionato received the lowest scores for these features – 3.75 and 2.63, respectively. The cheeses made from cow milk (both Italian and Polish) received similar scores for these quality attributes.

The perception of cheese flavour is significantly influenced by volatile substances. According to PAPETTI and CARELLI (2013), the typical aroma of cheese arises from the formation of volatile compounds during lipolysis, pro-

teolysis, and metabolism of lactose, lactates and citrates. They showed that the hardness and chewiness of Caciottina di Amaseno cheese increases with ripening time. The complex sensory profile of the cheeses they evaluated was mainly determined by the heterogeneous microflora of the buffalo milk and the starter cultures used in production. SMIT et al. (2005) also report an increase in the palatability of cheese as the ripening time is prolonged.

CONCLUSIONS

The Polish cheeses evaluated (all made from cow milk) had similar content of dry matter, protein and fat as the brand-name Italian cheeses made from cow milk. Differences were noted in the content of minerals and in colour parameters, which was due to the type of raw material used and to different production technologies. In the sensory evaluation, the consistency and structure of the Italian cheeses received higher ratings, while in terms of the intensity of flavour and odour characteristics the results were similar. The long-ripened Polish cheeses (despite their short history) attained favourable results, which raises hope that in the future they will be able to aspire to being registered in the European system for protection of regional and traditional products.

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