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Original Scientific Paper

QUALITY OF TRADITIONAL HERZEGOVINIAN GOAT CHEESE WITH RIPENING IN ANIMAL SKIN (SIR IZ MIJEHA)

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Abstract: Sir iz mijeha is a traditional product from the Herzegovina region, recognizable by its distinctive aroma, taste, and texture, representing an important part of cultural heritage and reflecting the natural resources of the region. The aim of this study was to investigate the quality and bioactive properties of Sir iz mijeha produced from goat milk from Herzegovina. Physicochemical parameters of goat milk and Sir iz mijeha were analyzed, including moisture, ash, protein, fat content, pH, titratable acidity, water activity, colour, mineral and fatty acid composition, antioxidant capacity, and sensory properties. The results showed that goat milk had a high fat (5.88%) and protein content (4.36%), while pH (6.55), titratable acidity (7.90°SH), and specific gravity (1.0327 g cm^{-3}) indicated good product quality. The cheese exhibited high nutritional value, with a total fat content of 30% and protein content of 19.04%, while water activity (a_w=0.8200) and pH (4.98) suggested good microbiological stability and an advanced stage of lactic acid fermentation. Colour parameters (C*=14.68; h°=91.7; WI=81.33) confirmed a light, slightly yellowish hue, characteristic of cheeses ripened in animal skin. Measurements of total phenolics, flavonoids, and non-flavonoid compounds, as well as standard FRAP, DPPH, and ABTS assays, showed a high level of antioxidant activity in milk and cheese, suggesting the presence of bioactive compounds that may contribute to protection against oxidative stress and promote consumer health. Sensory analysis highlighted the characteristic appearance, odour, flavour, and consistency of the cheese, confirming its high quality and authenticity. The study emphasizes the importance of preserving and promoting Sir iz mijeha as both a cultural and gastronomic heritage product and as a functional food with potential positive effects on consumer health.
Keywords: goat milk, quality, traditional cheese

INTRODUCTION

Goat milk represents a valuable and increasingly popular food, rich in nutrients, medium-chain fatty acids, vitamin A, B-complex vitamins, and minerals such as calcium, phosphorus, and zinc (Park, 2009; Silanikove et al., 2010). Its lower content of alpha-s1-casein contributes to hypoallergenic properties, while the smaller size of fat globules and specific protein profile influence the texture, flavour, and functionality of dairy products (Park et al., 2007). Additionally, the presence of bioactive components with potential anti-inflammatory effects and microorganisms with probiotic potential makes it suitable for individuals with mild cow's milk intolerance (Lad et al., 2017).

Goat cheese is an important part of traditional diet in many regions due to its nutritional composition and specific sensory characteristics (Popović Vranješ, 2015; Park et al., 2017; Barłowska et al., 2018). Of particular significance is the traditional anaerobically ripened cheese matured in lamb skin, known as Sir iz mijeha, which represents an important part of Herzegovina's cultural and gastronomic heritage. The traditional production of this cheese contributes to preserving cultural identity, supporting rural development, and sustaining the local economy, connecting generations of producers and consumers (Samardžija, 2009; Blažević et al., 2020). Similar cheeses are produced in other countries, such as Croatia (Sir iz mišine), Turkey (Tulum), Algeria (Bouhezza), and Lebanon (Darfiyeh) (Tudor Kalit et al., 2010).

Sir iz mijeha is characterized by a specific method of production and ripening in animal skin, resulting in intense proteolytic and lipolytic processes, a complex composition of volatile compounds, and a distinctive microbiota (Frece et al., 2016; Vrdoljak et al., 2018; Rako et al., 2019; Zekić et al., 2024). In Herzegovina, this cheese is traditionally made from unpasteurized milk (cow, sheep, goat, or a mixture), with filtration, heating, addition of rennet, salting, and shaping. The prepared lamb skin is cleaned, smoked, and dried, then filled with cheese and pressed to remove air. Ripening lasts 2-3 months, during which the characteristic flavour, aroma, and texture develop (Samardžija, 2009). The use of animal skin allows controlled dehydration and the formation of an aromatic profile rich in fatty acids, esters, ketones, and alcohols, while the skin's microclimatic conditions promote lipolysis and proteolysis, contributing to unique sensory properties (Gursoy et al., 2018; Tekin and Guler, 2021). The skin also acts as a natural ripening medium, limiting the growth of undesirable microorganisms and allowing the preservation of the traditional character of the product. Anaerobic conditions and the skin microbiota accelerate casein breakdown and the release of free fatty acids, enhancing texture and aroma compared to cheeses ripened in open air (Tudor Kalit et al., 2020). The microbiological profile of the cheese is enriched with autochthonous lactic acid bacteria and other natural microorganisms, contributing to both safety and distinctive characteristics (Frece et al., 2016).

Despite representing an important part of Herzegovina's culinary heritage, Sir iz mijeha has been relatively little studied in the scientific literature, and data on its composition, bioactive properties, and quality are limited. The aim of this study was to investigate in detail the quality and bioactive properties of traditional Sir iz mijeha from the Herzegovina region, as well as the goat milk from which the cheese was produced.

MATERIALS AND METHODS

Cheese production

The cheese was produced from raw goat milk using a traditional production method. After milking, the milk was filtered to remove any impurities and then heated to 35°C. Two tablespoons of rennet were added per 10 L of milk, after which the milk was gently stirred, and coagulation was allowed to proceed for 60 minutes. The formed curd was cut, left to stand for a few minutes, then crumbled and separated from the whey. The curd was placed in sterile cheesecloth and pressed for 5 hours to remove the remaining whey. Before placing the curd into the prepared lamb skin, the curd was broken into pieces and salted. Ripening of the cheese in the skin lasted 60 days.

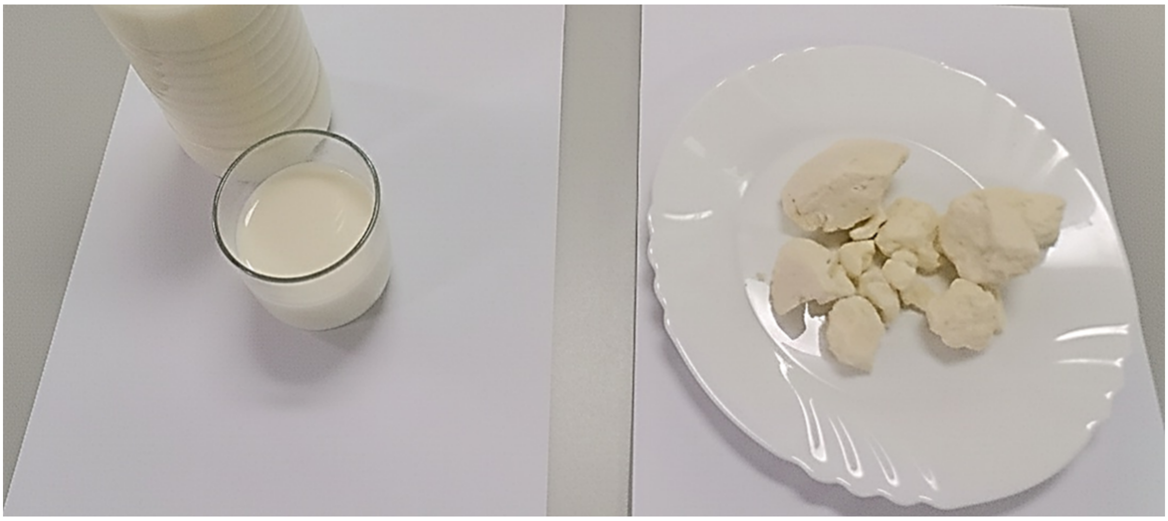

Figure 1. Goat milk and goat Sir iz mijeha

Analysis of composition and physicochemical properties

In this study, samples of raw goat milk and the produced Sir iz mijeha were analyzed (Figure 1). The specific gravity of milk was determined using a lactodensimeter, while the acidity of milk and cheese was measured according to the Soxhlet-Henkel method, and pH values were determined using a pH meter (Hanna Instruments, HI 2211) (Carić et al., 2000). Water activity (aw) of cheese was measured using an aW meter (Novasina LabMaster-AW 1119971). Moisture and total solids content in milk and cheese samples were determined by the drying method (ISBIH, 2010; ISBIH, 2006). Ash content was determined by burning the organic matter and incinerating the mineral residue at 550°C (Carić et al., 2000). Protein content was calculated based on total nitrogen determined by the Kjeldahl method, using a conversion factor of 6.38 (ISBIH, 2015a). Fat content was analyzed using the acid-butyrometric Gerber method (ISBIH, 2012). Chloride content was determined by potentiometric titration (ISBIH, 2015b). Lactose content in milk was measured polarimetrically using clarified milk serum, with the angle of rotation of polarized light used to calculate lactose concentration.

Instrumental colour values of cheese samples were determined using a CM-2600d spectrophotometer (Konica Minolta, Japan) in the CIE L*a*b* system. The whiteness index (WI), hue angle (h°), and chroma (C) were calculated according to Wrolstad and Smith (2010) as follows:

$$WI = 100 - [(100-L)^2 + a^2 + b^2]^{0,5}$$

$$h° = \tan^{-1} [b/a]$$

$$C = (a^2 + b^2)^{0.5}$$

Instrumental colour measurements of the cheese were performed in ten replicates, while all other analyses were conducted in triplicate.

Mineral composition analysis

Milk and cheese samples were prepared for mineral analysis by wet digestion using a mixture of nitric and perchloric acids. Macro- and microelements were analyzed by ICP-OES (Optima 8000, Perkin Elmer), calibrated with certified reference materials (CRM, 100 μg mL^{-1}) (Savanović et al., 2023). All analyses were performed in triplicate.

Fatty acid analysis

For the analysis of fatty acids, fatty acid methyl esters (FAME) were prepared by direct esterification using KOH in methanol. The analysis was performed by gas chromatography (GC) on a Clarus 680 instrument equipped with an FID detector and an Elite-Wax L column (60 m × 0.32 mm × 0.5 μm). The injector and detector temperatures were set at 250°C, and the injection volume was 1 μL. The temperature program was as follows: 60°C for 2 min, increased at 10 °C min^{-1} to 200°C, then 5°C min^{-1} to 240°C, held for 30 min (total 54 min). Nitrogen was used as the carrier gas at a flow rate of 1.5 mL min^{-1}. Fatty acids were expressed as relative percentages of the total identified fatty acids. Analyses were performed in triplicate.

Antioxidant activity analysis

For the analysis of antioxidant activity, cheese samples were extracted in 80% ethanol using an ultrasonic bath under reflux. Working solutions (100 g L^{-1}) were prepared for the analyses. Total phenolic content (TPC) was determined using the Folin-Ciocalteu method (Wolfe et al., 2003). Non-flavonoid content was determined by the formaldehyde method (Alberto et al., 2006), while flavonoid content was calculated by difference. Antioxidant activity was assessed using DPPH (Liyana-Pathirana and Shahidi, 2005), ABTS (Re et al., 1999), and FRAP (Benzie and Strain, 1996) assays. All analyses were performed in triplicate.

Sensory analysis

Sensory analysis of milk and cheese was performed using a descriptive method to comprehensively assess product quality and highlight their characteristic sensory attributes. Five trained panelists evaluated the appearance, odour, flavour, and consistency, following standardized protocols for descriptive analysis, ensuring high objectivity, accuracy, and repeatability of the results (ISBIH, 2011).

RESULTS AND DISCUSSION

Physicochemical Properties

Goat milk, due to its chemical composition, represents a food suitable for human consumption. The main components of goat milk are fats, proteins, minerals (ash), vitamins, lactose, and enzymes. Although goat milk is widely recognized for its high nutritional value and balanced composition, its quality and composition depend on various factors, such as breed, nutritional status, udder morphology, body weight, and litter size. In addition, the variability of milk composition is influenced by genetic inheritance, lactation stage, season, diet, udder health, and other physiological factors. All of these factors together affect the content of proteins, fat, lactose, and total solids, which ultimately reflect the technological properties and nutritional profile of goat milk (Park, 2009; Getaneh et al., 2016).

The conditions that raw goat milk must meet are prescribed by relevant regulations (Propis, 2011a; Propis, 2015), according to which goat milk must contain at least 2.80% milk fat, at least 2.50% protein, at least 7.50% total solids excluding fat, a density of 1.024-1.040 g cm^{-3} at 20°C, an acidity of 6.5-8.0°SH, a pH of 6.4-6.7, and a freezing point not higher than −0.540°C.

As shown in Table 1, all examined quality parameters of the goat milk were within the prescribed limits. The raw goat milk in this study contained 84.00% water and 16.00% total solids. A high content of fat (5.88%) and protein (4.36%) confirms that goat milk represents a valuable source of essential nutrients and is suitable for the production of cheese with high nutritional value. The lactose content was 4.51%, which is consistent with average values for goat milk (Lad et al., 2017). Minerals were present at 1.04% ash, while chloride concentration was 156.20 mg 100 mL^{-1}. These values confirm that goat milk contains significant amounts of minerals important for human nutrition (Park, 2009). Physicochemical parameters such as pH (6.55), titratable acidity (7.90°SH), and density (1.0327 g cm^{-3}) indicate good hygienic quality and freshness of the milk, which is a prerequisite for obtaining high-quality cheese (Popović Vranješ, 2015).

The moisture content of the examined cheese was 38.19%, while the total solids were 61.81%. Considering the moisture content in the fat-free matter of cheese (54.55%), which is at the lower limit of semi-hard cheeses (54-69%) according to the Regulation on the quality of milk products (Propis, 2011b), the tested cheese can be classified as semi-hard. Literature reports indicate that cheeses ripened in animal skins can be classified as semi-hard or hard (Tudor Kalit et al., 2010; Rako et al., 2019). Tudor Kalit (2014) reported that Sir iz mišine, made from sheep milk according to standard semi-hard cheese technology (considering curd grain size and heating temperature), after 60 days of ripening, had 53.30% moisture in the fat-free matter and was classified as hard cheese. On the other hand, Rako et al. (2019) recorded a slightly higher value (60.77%)

for sheep Sir iz mišine after 30 days of ripening. Similar research on Turkish semi-hard Tulum cheese, after 90 days of ripening, reported 65.27% moisture in fat-free matter (Yilmaz et al., 2005). These differences most likely result from lower ripening temperatures of Tulum cheese (6-10°C), which allow higher moisture retention, whereas Sir iz mišine ripened at higher temperatures (16-18°C), resulting in greater moisture loss. Sihufe et al. (2007) further emphasize that, at the end of the ripening period, the average moisture content in Argentinian Reggianito cheese was 27.60% at 12°C, compared to 24.30% at 18°C, confirming the importance of temperature for moisture retention in cheese. Tudor Kalit et al. (2012) showed that cheeses ripened in lamb skins have higher moisture content and significantly lower total solids, fat, protein, and salt compared to cheese ripened in a wooden container throughout the process, highlighting the technological significance of traditional ripening media.

The total fat content of the examined cheese was 30%, and based on fat in total solids (48.54%), the cheese is classified into the group of full-fat cheeses (Propis, 2011b). This value was lower than those reported by Tudor Kalit et al. (2014) for Sir iz mišine (52.96%) and Yilmaz et al. (2005) for Tulum cheese after 90 days of ripening (54.64%). These differences in fat content may be attributed to variations in milk composition, lactation stage, cheese-making process, or farm practices. The analyzed cheese contained 19.04% protein, slightly lower than values reported by Rako et al. (2019) (22.18%) and Tudor Kalit et al. (2014) (23.93%). The cheese had a relatively high ash content (6.23%), indicating significant nutritional value and a pronounced mineral concentration. The chloride content (4.43%) further confirms the pronounced mineral profile, contributing to the specific flavour of this type of cheese.

The acidity profile of the cheese (pH 4.98; titratable acidity 65.5°SH) indicates an advanced stage of lactic acid fermentation. Obtained values are consistent with previous studies of cheeses ripened in animal skins, where the pH at the end of ripening ranged from 3.99 to 5.42 (Tudor Kalit et al., 2020). Rako et al. (2019) emphasize that progressive proteolysis during ripening contributes to increased pH and the development of a more complex aromatic profile. Water activity (a_w=0.820) was relatively low, indicating good microbiological stability.

Standard colorimetric parameters of the analyzed cheese were: chroma C=14.68, hue angle h°=91.70°, and whiteness index WI=81.33. The C value indicates medium colour saturation, while h° confirms that the cheese colour belongs to the yellow spectrum. Relatively high WI indicates that the cheese is bright but not completely white, which is consistent with the characteristics of cheeses ripened in animal skins with elevated fat content and the typical visual profile of this traditional type of cheese. These results are consistent with findings of Tekin and Guler (2021) for Tulum cheese. The hue angle of Tulum cheese was also in the yellow spectrum, similar to the examined goat Sir iz mijeha. In their study, Tulum cheese had lower WI values and higher chroma compared to cheeses ripened in plastic barrels, indicating more intense colour saturation with less white. Differences in cheese colour can be explained by moisture loss, fat and dry matter concentration, as well as specific ripening conditions (Tekin and Guler, 2021). The more intense yellow colour and higher colour saturation represent a characteristic visual attribute of traditional cheeses in animal skin, contributing to their recognizability and consumer appeal. Colorimetric analyses confirm that traditional ripening in skins provides a specific visual profile, with a light, slightly yellow hue and medium saturation, in agreement with previous studies.

Table 1. Physicochemical characteristics of raw goat milk and goat Sir iz mijeha

Parameter	Goat milk	Goat Sir iz mijeha
Water (%)	84.00	38.19
Total solids (TS, %)	16.00	61.81
Fat-free solids (FFS, %)	10.12	31.81
Fat (%)	5.88	30.00
Moisture in fat-free matter (MFFM, %)	-	54.55
Fat in total solids (FTS, %)	-	48.54
Protein (%)	4.36	19.04
Ash (%)	1.04	6.23
Lactose (%)	4.51	-
Chlorides (mg 100 mL^{-1} or %)	156.20	4.43
pH	6.55	4.98
Density (g cm^{-3})	1.0327	-
Titratable acidity (°SH)	7.9	65.5
Water activity (aw)	-	0.8200
Colour parameters	-	C=14.68 h°=91.70° WI=81.33

Mineral Composition

Minerals are essential nutrients that play a key role in human health, regulating numerous physiological functions, including bone development, enzyme activity, nerve signaling, and immune response. Milk is an important source of calcium and other essential minerals, including phosphorus, magnesium, zinc, and selenium. The mineral composition, which includes both macro- and microelements, varies depending on the animal species, lactation stage, diet, genetic, and other factors (Cashman, 2006; Vahčić et al., 2010; Gaucheron, 2011). Analysis of the mineral composition (Table 2) showed that goat milk had a high level of calcium (2.187 mg g^{-1}), potassium (1.688 mg g^{-1}), and phosphorus (1.571 mg g^{-1}), confirming its importance as a source of macroelements necessary for human nutrition (Table 2). Sodium (Na) was present in moderate amounts (0.608 mg g^{-1}), as was magnesium (0.231 mg g^{-1}), which plays an important role in metabolic functions. Among microelements, zinc (4.815 µg g^{-1}) and iron (1.118 µg g^{-1}) were the most abundant, while manganese (0.158 µg g^{-1}) and aluminum (0.406 µg g^{-1}) were also present. The selenium (Se) concentration in milk was below the detection limit. This mineral profile confirms that goat milk is a rich source of key elements, with particularly notable zinc and iron content, contributing to its nutritional value.

Milk from different animal species has a specific mineral profile. Goat milk contains higher amounts of potassium, calcium, phosphorus, selenium, zinc, and copper compared to cow's milk (Lopez-Aliaga et al., 2005; Slačanac et al., 2010). Due to its higher mineral content, goat milk can be considered a better dietary supplement compared to cow's milk, although neither can fully replace human milk for infant nutrition.

The examined goat cheese showed a significant increase in sodium concentration (14.380 mg g^{-1}) and calcium (8.733 mg g^{-1}) compared to milk, resulting from mineral concentration during production and ripening. Phosphorus (5.215 mg g^{-1}) and magnesium (0.496 mg g^{-1}) concentrations also increased, while potassium content (1.263 mg g^{-1}) slightly decreased, reflecting changes in mineral balance during cheese production. Among microelements, zinc (10.997 µg g^{-1}) showed a significant increase, whereas iron (0.897 µg g^{-1}) decreased, likely due to protein precipitation and oxidative processes during ripening. Selenium was present in the cheese at 0.228 µg g^{-1}, while manganese (Mn) was below the detection limit. Aluminum (0.152 µg g^{-1}) was present at lower concentrations compared to milk. These results indicated that the cheese production and ripening process significantly affect the concentration and redistribution of macro- and microelements, enhancing the nutritional potential of the final product.

The mineral composition of cheese may be influenced by various factors, including milk composition, production technology during the season, geographic location, and the acidity of the cheese during processing. As a result, significant variability in the mineral profile of cheeses has been reported in the scientific literature (Bilandžić et al., 2015; Savanović et al., 2022; Savanović et al., 2023).

Table 2. Content of macro- and microelements in the analyzed samples

Element	Goat milk	Goat Sir iz mijeha
Macroelements (mg g^{-1})		
Na	0.608	14.380
K	1.688	1.263
Ca	2.187	8.733
Mg	0.231	0.496
P	1.571	5.215
Microelements (µg g^{-1})		
Zn	24.815	100.997
Fe	1.118	0.897
Mn	0.158	n.d.
Al	0.406	0.152
Se	n.d.	0.228

*n.d. - not detected

Fatty Acid Content

Fatty acids are the main components of lipids and key sources of energy for the human body. They participate in numerous metabolic functions in the organism. The fatty acid composition of goat milk and cheese is presented in Table 3. In milk, saturated fatty acids dominated, particularly palmitic (22.73%), myristic (8.33%), and stearic acid (6.46%). The total saturated fatty acid content in milk was 53.67%, while in cheese it increased to 57.66%, with short-chain fatty acids showing a rise, while myristic and stearic acids also increased, and palmitic acid remained relatively stable. Unsaturated fatty acids in milk were characterized by oleic (15.12%) and eicosadienoic acid (25.86%), while other unsaturated fatty acids were present in lower proportions. In cheese, there was a slight decrease in the concentration of monounsaturated fatty acids, while the oleic acid content slightly increased. The concentrations of linoleic acid and eicosadienoic acid decreased, whereas erucic acid appeared in cheese at a small proportion (0.08%). These trends reflect a combination of lipid concentration and partial lipolysis, contributing to the characteristic flavour and nutritional profile of the cheese.

Although cheeses ripened in animal skins can be produced using different technologies and from different types of milk, long-chain fatty acids always dominate at the end of the ripening period (Tudor Kalit et al., 2014; Yilmaz et al., 2005; Sert et al., 2014). Tudor Kalit et al. (2014) reported that in Sir iz mišine, the most abundant free long-chain fatty acids were palmitic (C16:0), oleic (C18:1), and stearic (C18:0), similar to Tulum cheese made from goat milk (Sert et al., 2014). In Tulum cheese from cow's milk, the dominant acids were C16:0, C18:1, and myristic (C14:0) (Yilmaz et al., 2005).

A positive correlation was observed between the content of fatty acids C14:0, C14:1, C16:0, C17:0, C18:0, C18:2n-6, C18:3n-3, and C23:0 and the intensity of cheese aroma, whereas fatty acids C8:0, C12:0, C14:0, C16:0, C16:1, C17:0, C18:0, C18:1n-9t, C18:3n-3, C21:0, C22:0, and C23:0 were positively associated with cheese taste. Long-chain fatty acids contribute to lower sensory scores of Sir iz mišine after 60 days of ripening, serving as precursors in the synthesis of short-chain fatty acids and alcohols, while C4:0, C6:0, and C8:0 accumulate due to the duration and conditions of ripening (Tudor Kalit et al., 2016). Overall, the transformation of fatty acids from milk to cheese demonstrates a balance between preserving the nutritional profile and developing sensory characteristics, with both saturated and unsaturated fatty acids contributing to the specific character of goat cheese.

Table 3. Fatty acid composition of the analyzed samples

Fatty acid	Goat milk (%)	Goat Sir iz mijeha (%)
Butyric (C4:0)	1.07	1.42
Caproic (C6:0)	1.18	1.60
Caprylic (C8:0)	1.46	2.08
Capric (C10:0)	5.48	7.36
Undecanoic (C11:0)	0.86	-
Lauric (C12:0)	2.55	3.64
Tridecanoic (C13:0)	0.91	0.40
Myristic (C14:0)	8.33	9.78
Pentadecanoic (C15:0)	1.05	0.96
Palmitic (C16:0)	22.73	22.09
Heptadecanoic (C17:0)	1.59	0.38
Stearic (C18:0)	6.46	7.95
Myristoleic (C14:1)	0.49	0.37
cis-10-Pentadecenoic (C15:1)	0.71	0.40
Palmitoleic (C16:1)	2.01	1.37
cis-10-Heptadecenoic (C17:1)	0.32	n.d.
Oleic (C18:1 c+t)	15.12	16.05
Linoleic (C18:2 c+t)	1.83	1.68
Eicosadienoic (C20:2)	25.86	22.41
Erucic (C22:1)	n.d.	0.08

*n.d. - not detected

Antioxidant Properties

Table 4 presents the phenolic content and antioxidant activity of the tested milk and cheese samples. Phenolic compounds, due to their pronounced antioxidant capacity, play a key role in neutralizing free radicals and reducing oxidative stress, thereby contributing to the prevention of chronic diseases. Their presence in the diet has been associated with beneficial effects on cardiovascular health, immune protection, and the slowing of aging processes (Hernández-Miranda et al., 2025). Goat milk was found to contain a total of 276.16 µg GAE g^{-1} of phenolic compounds, with non-flavonoids predominating (240.23 µg GAE g^{-1}), while flavonoids accounted for a smaller portion (35.92 µg GAE g^{-1}). The antioxidant capacity measured by the FRAP method was 0.25 µmol Fe^{2+} g^{-1}, while the DPPH and ABTS activities were 43.77 µmol TE g^{-1} and 134.54 µmol TE g^{-1}, respectively. These results indicate a significant antioxidant potential of goat milk, primarily due to its total phenolic content. The antioxidant capacity of dairy products depends on the quality of raw milk and the bacterial cultures used, as well as the animal species and genetic background, which together determine the chemical composition of milk (Fardet and Rock, 2018; Stobiecka et al., 2022).

Analyses showed that goat cheese ripened in an animal skin contained a total of 1366.86 μg GAE g^{-1} of phenolic compounds, with non-flavonoids accounting for 607.41 μg GAE g^{-1} and flavonoids for 758.27 μg GAE g^{-1}. The antioxidant capacity measured by the FRAP method was 0.63 μmol Fe^{2+} g^{-1}, DPPH activity 37.51 μmol TE g^{-1}, and ABTS activity was significantly higher at 1379.77 μmol TE g^{-1}. Hilario et al. (2010) reported that soft cheeses obtained from pasture-fed goats have total phenolic contents ranging from 300 to 780 μg g^{-1}, while goat cheeses produced from the milk of goats fed indoors contained only 50-60 μg g^{-1}. Similarly, Guzmán et al. (2024) demonstrated that the total phenolic content in soft goat cheeses can be increased by supplementing the goats' diet with dehydrated orange pulp, with values ranging from 315 to 500 μg g^{-1}. In contrast to previous findings, this study found that goat cheese ripened in animal skin had a significantly higher total phenolic content, suggesting that specific technological processes and traditional ripening conditions contribute to the higher antioxidant potential of the product. The results indicate that cheese production and ripening increase the concentration of bioactive compounds, especially flavonoids, resulting in a higher overall antioxidant capacity. The increase in phenolic content may be due to component concentration during whey separation, interactions with proteins, and enzymatic and microbial activities during fermentation and ripening. This effect confirms that the traditional method of cheese production in animal skins contributes to the preservation and potential enhancement of the bioactive properties of dairy products, thereby improving the nutritional and functional value of the product.

Table 4. Phenolic content and antioxidant activity of the tested samples

Parameter	Goat Milk	Goat Sir iz mijeha
Total phenolics (μg GAE g^{-1})	276.16	1366.86
Non-flavonoids (μg GAE g^{-1})	240.23	607.41
Flavonoids (μg GAE g^{-1})	35.92	758.27
FRAP (μmol Fe^{2+} g^{-1})	0.25	0.63
DPPH (μmol TE g^{-1})	43.77	37.51
ABTS (μmol TE g^{-1})	134.54	1379.77

Sensory Properties

The sensory properties of milk and dairy products are specific to each type or group of products, provided that the raw materials are of appropriate quality and the products are processed to be appealing and pleasant for consumption (Savanović et al., 2021). The sensory characteristics of the tested samples are presented in Table 5. In general, both raw goat milk and goat Sir iz mijeha exhibited typical appearance, odour, flavour, and consistency of these products.

Goat milk was homogeneous, with a light colour typical of fresh milk, a pleasant and mild aromatic profile, and no off-flavours. The consistency of the milk was fluid and suitable for immediate consumption.
Goat Sir iz mijeha showed a bright, uniform colour and characteristic appearance, while the odour was mildly acidic, pronounced, and free of unpleasant notes. The flavour of the cheese was salty, with a recognizable goat cheese flavour and no foreign aromas, while the consistency was moderately firm and appropriate for a matured cheese, contributing to a positive sensory experience. These results confirm that the traditional production and ripening process in animal skins significantly affects the sensory characteristics of the product, making it authentic and recognizable to consumers.

Table 5. Sensory properties of the analyzed samples

Sensory Attribute	Goat Milk	Goat Sir iz mijeha
Appearance	Characteristic appearance, white colour typical of milk	Characteristic appearance, appropriate colour
Odour	Free of off-odours	Mildly acidic, pronounced, free of unpleasant odours
Flavour	Pleasant, without off-notes	Salty, pronounced, characteristic goat cheese flavour, free of off-notes
Consistency	Fluid, suitable for consumption	Appropriate, moderately firm

CONCLUSION

The analyzed goat milk demonstrated chemical composition with high contents of fat, protein, and essential minerals (calcium, phosphorus, potassium, and zinc), confirming its nutritional value and suitability for human consumption. Its antioxidant potential, reflected in total phenolic content and FRAP, DPPH, and ABTS activities, indicates the presence of bioactive compounds that may contribute to consumer health. Sensory characteristics, such as typical appearance, colour, pleasant aroma, and fluid consistency, further confirm its quality and acceptability for direct consumption.
The traditional Herzegovinian goat milk product, Sir iz mijeha, exhibited increased levels of dry matter, fat, protein, and minerals compared to milk, reflecting the concentration of nutrients and bioactive components during production and ripening. Fatty acid analysis indicated a balance of saturated and unsaturated acids, contributing to the specific taste and aroma of the cheese. The high phenolic content, particularly flavonoids, along with the antioxidant capacity, confirm that ripening in animal skins

positively affects the bioactive properties of the cheese. Sensory attributes (appearance, odour, flavour, and consistency) highlight the product's authenticity and make it easily recognizable to consumers.

These results suggest that using high-quality raw milk combined with traditional production and ripening processes in animal skins contributes to the formation of goat Sir iz mijeha with high nutritional, functional, and sensory quality, emphasizing the importance of preserving traditional methods in producing dairy products with enhanced nutritional and sensory value.

Conflict of interest statement: The authors declare that there is no conflict of interest.

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