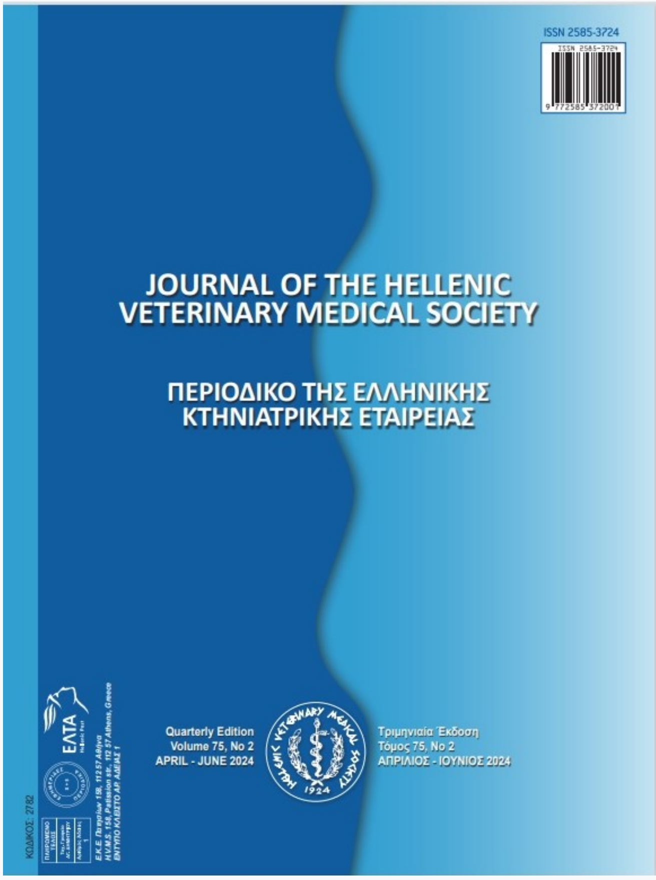
Journal of the Hellenic Veterinary Medical Society

Vol 75, No 2 (2024)



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doi: 10.12681/jhvms.34578

J HELLENIC VET MED SOC 2024, 75 (2): 7387-7396
ΠΕΚΕ 2024, 75 (2): 7387-7396

Research article
Ερευνητικό άρθρο

Comparative investigation of the nutritional value of cow, goat, and sheep white cheeses in brine

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ABSTRACT: In the present work, three different types of cheese in brine were compared based on their nutritional quality parameters. The cheeses were made from cow's milk (commercial cheese) and goat's and sheep's milk (traditional cheese). The cheeses' physicochemical composition, fatty acid profile, amino acid profile, and related health lipid indices were studied. The study revealed a significant difference ($p<0.05$) between the cheeses studied in brine regarding physicochemical composition. In particular, goat and sheep brine cheeses have a higher concentration of dry matter, fat, and protein. Conversely, the Ca content was significantly higher in the commercial cheeses ($p<0.05$), as was the Ca/protein ratio (mg g^{-1} protein). The results also highlighted the health-promoting fatty acid profile of sheep and goat brine cheeses, in particular the more favourable values of the nutritional indices: atherogenic, thrombogenic, and health-promoting index, as well as hypocholesterolemic/hypercholesterolemic and n-6/n-3 ratio compared to commercial cow brine cheeses. The lipid composition of goat and sheep brine cheeses contained significantly lower amounts of long-chain saturated fatty acids and higher amounts of short- and medium-chain saturated and polyunsaturated fatty acids. The amino acid profile analysis showed that goat brine cheeses were rich in branched-chain amino acids (BCAA) and had the best essential/non-essential amino acid ratio compared to sheep and cow brine cheeses. With their higher nutritional content, traditional brine cheeses made from sheep and goat milk should be highlighted as important providers of health-promoting compounds to increase the sustainability of their production.

***Keywords*:** white-brined cheeses; fatty acids; amino acids; nutritional value

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Date of initial submission: 24-05-2023
Date of acceptance: 04-12-2023

INTRODUCTION

White brine cheeses are produced and consumed in many countries, and in recent years they have gained popularity and expanded into new markets (Hayaloglu, 2017). The chemical composition of these cheeses can vary from country to country, depending on the raw materials and technology used. Typically, white brine cheeses are produced on a large industrial scale by ultrafiltration of pasteurized cow's milk using large-capacity stainless steel cheese ripening tanks (Massouras et al., 2023). They are ripened in brine with different NaCl concentrations (10-18% NaCl), where the salt concentration is selective for the resident microbiota (Hayaloglu, 2016). The texture of white brine cheeses generally varies from soft to semi-hard (Massouras et al., 2023).

Traditionally, white brine cheeses are produced as artisanal (Jokanović et al., 2021). Locally produced cheeses can help preserve heritage and contribute to economic, environmental, and community development (Pappa et al., 2023). The nutritional value of cheeses depends on the type of milk used in their production, and milk is generally considered an important source of protein, present in varying amounts in cow, sheep, and goat milk (Filipczak-Fiutak et al., 2021). Nutritionally, a protein source must be able to provide defined metabolic effects relevant to optimal health, and casein, a major component of milk proteins, lacks sulphur-containing amino acids (Borad et al., 2017). Research on goat's white brine cheese has shown its high nutritional value and protein recovery in the curd (Paskaš et al., 2023). Goat and sheep milk proteins are high-quality proteins, and cheeses made from goat and sheep milk have long been appreciated for their specific chemical composition and amino acid profile (Ogunlade et al., 2019; Popović-Vranješ et al., 2017).

Due to the differences in composition and physicochemical properties between goat, sheep, and cow milk, their fatty acid profiles also differ. Compared to bovine milk, goat milk contains more short- and medium-chain fatty acids and more unsaturated fatty acids, while the ewe's milk lipid fraction contains higher proportions of medium-chain fatty acids (Faye and Konuspayeva, 2012). The composition of milk used for cheese production and the cheese production technology led to differences in fatty acid composition and lipid quality indices (Paszczyk and Luczyńska, 2020; Szterk et al., 2022). In particular, sheep's and goat's milk cheeses were characterized by high levels of polyunsaturated fatty acids compared to cow's milk cheeses. Furthermore, cheeses from intensively or semi-intensively reared cows had lower levels of healthy fatty acids than those from extensive dairy farms (Szterk et al., 2022). These days, a variety of health indices are used to assess the nutritional content of milk and cheese fat, including PUFA/SFA, the n-6/n-3 ratio, hypocholesterolemic/hypercholesterolemic, and thrombogenicity and health-promoting index. Furthermore, targeted modification of the fatty acid profile could lead to dairy products with higher added value and health benefits (Hanuš et al., 2018). Faye and Konuspayeva (2012) highlighted that cheeses made from non-bovine milk contribute to the diversity of human nutrition and represent a significant advantage for producers and the dairy sector. Besides, non-bovine milk (particularly sheep and goat milk) could be a viable substitute for cow's milk to maintain or improve cardiometabolic health (Penhaligan et al., 2022). Finally, to achieve consumer-oriented modifications of these products, it is critical to investigate and document the fundamental parameters of brine cheeses, such as texture and rheology, structure, and sensory properties (Hayaloglu et al., 2008).

This study aimed to evaluate the physicochemical composition, fatty acid profile, nutritional indices, and amino acid profile of white brine cheeses made from cow, goat, and sheep milk using different cheese-making processes (industrial and traditional). The white brine cheeses were also compared and discussed in terms of their health and nutritional aspects.

MATERIALS AND METHODS

Sampling and physicochemical analysis

Samples of commercial white-brined cow cheese (n1=9) were purchased from three local supermarkets in Serbia, while samples of goat and sheep white-brined cheese (n2=9; n3=9) were collected from local dairy farms (three goats and three sheep farms). The cheese-making procedure outlined by Paskaš et al. (2023) is followed in the production of traditional goat and sheep brine cheeses. The main stages in the industrial production of white brine cheese are coagulation (30°C × 30-40'), cutting of the curd into blocks of 500 to 1000g, acidification (24 hours × 25°C, up to pH 4.8), separation of the whey, addition of salts up to 4.0%, ripening (3 days at 18°C), and packaging of the cheese in containers or cans with brine containing 4% salt at 4°C.

The chemical composition of the cheeses was determined using standard techniques: total dry matter was determined using the weight loss after drying (AOAC 926.08-1927); protein was determined using the Kjeldahl-Van Slyke method (AOAC 2001.14); cheese fat was determined using the Van Gulik method (IDF, 2008); and ash was determined using dry ash at 550°C (AOAC 935.42). The pH was measured using a pH meter (WTW, type pH inoLab 720). Spectrophotometry was used to measure phosphorus using a PG Instruments spectrophotometer (type T80+). The samples were dried at 105°C for at least 4 h, incinerated at 550°C for 30 min, and extracted with 6 M HCl heated to boiling point. Following AOAC method 995.11, the extracts were subjected to calorimetry analysis utilizing the molybdenum blue method. The Ca and Na levels of the cheeses were measured using a flame photometer (Sherwood Flame Photometer 410, Sherwood Scientific Ltd., Cambridge, UK) by following the method Kirk and Sawyer (1991) described. The energy value was calculated according to the current Serbian regulations (SR) (2014).

Profile of fatty acids and nutritional indices

Triacylglycerol (fat) and fatty acids (FA) were extracted from goat, sheep, and cow cheeses and methylated to fatty acid methyl esters with boron trifluoride in methanol according to the AOAC Official Method (996.0). Fatty acid methyl esters were then quantitatively measured using a Shimadzu gas chromatograph (GC 2010, Shimadzu, Kyoto, Japan) with a flame ionization detector (FID) and an Intercap WAX column (length 30m, inner diameter 0.25mm, film thickness 0.25μm, Agilent Technologies, Santa Clara, CA, USA) as described by Pajor et al. (2019). The atherogenicity index (AI) and thrombogenicity index (TI) were calculated according to Ulbricht and Southgate (1991).

AI = (C12:0+4(C14:0) +C16:0)/ ΣUFA

TI = (C14:0+C16:0+C18:0)/(0.5MUFA+0.5PUFA-n6+3PUFAn3+PUFA-n3/PUFA-n6)

The health-promoting index (HPI), linoleic acid/α-linolenic acid ratio (LA/ALA), and hypocholesterolemic/hypercholesterolemic ratio (HH) were determined according to Chen and Liu (2020).

HPI = ΣUFA/(C12:0+(4xC14:0) + C16:0)

HH = (cis-C18:1 + ΣPUFA)/ (C12:0 + C14:0+ C16:0)

Profile of amino acids

The profile of amino acids (AA) of the studied brine cheeses (cow, goat, and sheep) was carried out according to the protocol of Henderson et al. (2000). Cheese samples were analyzed for amino acid content using a high-performance liquid chromatograph (Chromaster, Zorbax Eclipse-AAA column (150mm × 4.6mm, i.d., particle size 5μm) (Agilent Technologies, Santa Clara, CA, PN 5980-1193E) fitted with a multiple wavelength detector (G1315C) and a diode array detector (DAD-3000). Cheese samples were weighed into vacuum hydrolysis tubes, and 7cm3 of 6mol dm-3 HCl containing 0.1% phenol was added and gently mixed. Hydrolysis was carried out at 150°C for 6 hours. After hydrolysis, the samples were cooled to room temperature and evaporated to dryness using a heating/mixing module and evaporator at 70°C under a nitrogen stream. According to Henderson et al. (2000), the hydrolyzed samples or solutions of the standard amino acid mixture were automatically derivatized using o-phthaldehyde OPA and 9-fluorenyl methyl chloroformate FMOC. After derivatization, 0.5μL of each sample was injected into a Zorbax Eclipse-AAA column at 40°C with detection at λ1 = 340nm and λ2 = 450nm.

Statistical analysis

Results were expressed as the arithmetic mean, standard deviation, and coefficient of variation based on statistical analysis. A one-way ANOVA followed by Tukey's test at $p<0.05$ determined the significant difference between means. Statistical analysis was performed using Statistica 10 (StatSoft Statistica 10.0.0).

RESULTS

Physicochemical composition of commercial and traditional white-brined cheeses

Table 1 displays the physicochemical compositions of the white-brined cheeses that were examined. Comparison of the cheeses revealed significant differences ($p<0.05$) in dry matter, protein, fat, ash, and sodium content, with goat and sheep cheeses being higher. The Ca content was statistically higher ($p<0.05$) in cow and goat than sheep brine cheeses. The results showed that the content of macroelements (Ca, P, and Na) was the most inconsistent component of cow brine cheeses, whereas goat brine cheeses showed variations in fat, protein, and dry matter content. The variation in the chemical composition of goat brine cheeses can be explained by the lack of standardisation in the processing technology. The different production techniques also had an impact on the fat on a dry matter basis (FDM) and moisture on a fat-free basis (MFFB) values; commercial cheeses made from cow's milk were classified as semi-fat in terms of FDM, while cheeses made from goat and sheep's milk were classified as full-fat (Table 2) (SR, 2014). Differences were also found in the MFFB, with cow's milk cheeses belonging to the soft cheese category and sheep's and goat's milk cheeses varying in texture between the soft and semi-hard cheese categories (SR, 2014).

Profile of fatty acids and nutritional indices of white-brined cheeses

Cheese's fatty acid composition plays a major role in determining its nutritional and health benefits. Table 3 shows the findings of this analysis.

Significant differences ($p<0.05$) were found in the content of SSCFA, which was highest in sheep brine cheeses. Furthermore, goat and sheep brine cheeses had a higher amount of SMCFA. On the other hand, cow brine cheeses were statistically more abundant in SLCFA and total SFA ($p<0.05$). When these values are expressed as a percentage of the total, the percentage of PUFA in the fat of cow's milk cheeses was 2.71%, while in goat's and sheep's milk cheeses, it was 4.25% and 4.56%, respectively. Furthermore, the percentages of MUFA were 26.07%, 26.28%, and 27.09%; SLCFA were 39.23%, 40.57%, and 52.31%; and total SFA were 69.60%, 69.15%, and 70.21% in goat, sheep, and cow brine cheeses, respectively. Finally, the percentages of SSCFA and SMCFA were 6.38%, 9.02%, and 2.05%; 23.99%, 19.56%, and 15.84% in goat, sheep, and cow brine cheeses, respectively.

Table 4 shows the nutritional indices and the ratios of their fatty acid groups. Sheep and goat brine cheeses had a significantly higher ($p<0.05$) PUFA/SFA ratio than cow's milk cheeses, indicating a more favourable nutritional effect. Sheep brine cheeses also contained the highest amount of n-3 PUFA, while goat brine cheeses contained more EPA and DHA. The n-6/n-3 ratio, AI, and TI were lower in sheep and goat brine cheeses. Sheep and goat brine cheeses were also found to have greater nutritional and health benefits, as indicated by the higher HH and HPI indices.

Amino acid composition of white-brined cheeses

The amino acid composition of the cheeses in the study is shown in Table 5. Goat cheeses differed from cow and sheep cheeses, particularly in the content of the most essential amino acids. Commercial

Table 1.Physicochemical composition of white-brined cheeses

Parameters	Cow-brined cheese		Goat-brined cheese		Sheep-brined cheese	
	χ± sd	cv (%)	χ± sd	cv (%)	χ± sd	cv (%)
Dry matter (%)	$34.80^{a} \pm 1.21$	3.48	$48.62^{b} \pm 8.62$	17.72	$48.87^{b} \pm 1.95$	3.98
Fat (%)	$13.11^{a} \pm 0.29$	2.23	$23.08^{b} \pm 3.70$	16.03	$24.17^{b} \pm 1.23$	5.07
Protein (%)	$11.97^{a} \pm 0.49$	4.19	$18.86^{b} \pm 3.18$	16.87	$17.62^{b} \pm 1.13$	6.44
Ash (%)	$3.19^{a} \pm 0.20$	6.26	$4.71^{b} \pm 0.37$	7.85	$3.83^{c} \pm 0.31$	8.22
Ca (%)	$0.41^{a} \pm 0.05$	12.25	$0.45^{a} \pm 0.04$	8.03	$0.32^{b} \pm 0.05$	16.01
P (%)	0.22±0.05	22.74	0.24±0.01	4.79	0.23±0.02	9.72
Na (%)	$0.71^{a} \pm 0.11$	16.14	$1.69^{b} \pm 0.10$	6.20	$1.18^{c} \pm 0.05$	4.28
pH	$4.74^{a} \pm 0.09$	1.82	$4.87^{b} \pm 0.13$	2.71	$5.28^{c} \pm 0.05$	1.02

χ± sd - arithmetic mean + standard deviation; cv - coefficient of variation; Means within a row marked with the different letters differ significantly ($p<0.05$);

Table 2. The FDM, MFFB, and Ca/P values of white-brined cheeses

Parameters	Cow-brined cheese		Goat-brined cheese		Sheep-brined cheese	
	χ± sd	cv (%)	χ± sd	cv (%)	χ± sd	cv (%)
FDM (%)	$37.72^{a} \pm 1.64$	2.23	$47.31^{b} \pm 1.96$	4.14	$49.53^{b} \pm 3.25$	6.56
MFFB (%)	$75.04^{a} \pm 1.45$	1.92	$66.59^{b} \pm 4.89$	7.35	$67.44^{b} \pm 2.80$	2.80
Ca/P (%)	$1.96^{a} \pm 0.35$	18.14	$1.89^{a} \pm 0.25$	13.13	$1.40^{b} \pm 0.25$	18.08
Ca/protein (mg g^{-1} of protein)	$34.0^{a} \pm 3.77$	11.07	$24.14^{b} \pm 3.05$	12.65	$18.20^{c} \pm 3.11$	17.08
M/P	$5.46^{a} \pm 0.26$	4.82	$2.84^{b} \pm 0.79$	27.73	$2.92^{b} \pm 0.21$	7.19
Energy value kcal/100g	$193.85^{a} \pm 4.86$	2.51	$300.12^{b} \pm 45.27$	15.08	$310.34^{b} \pm 12.70$	4.09

FDM (%) - fat on a dry matter basis; MFFB (%) - moisture on a fat-free basis; M/P - moisture/protein; χ± sd - arithmetic mean + standard deviation; cv - coefficient of variation; Means within a row marked with the different letters differ significantly ($p<0.05$);

Table 3. The fatty acid composition of white-brined cheeses (g/100g)

Parameters	Cow-brined cheese		Goat-brined cheese		Sheep-brined cheese	
	χ± sd	cv (%)	χ± sd	cv (%)	χ± sd	cv (%)
$C_{4:0}$	1.19ᵃ±0.07	5.95	1.42ᵃ±0.06	4.62	2.54ᵇ± 0.26	10.23
$C_{6:0}$	0.02ᵃ±0.01	50.0	1.95ᵇ±0.01	0.78	2.74ᶜ±0.10	3.74
$C_{8:0}$	0.75ᵃ±0.29	38.39	2.38ᵇ±0.14	6.13	2.59ᵇ±0.23	8.96
$C_{10:0}$	1.99ᵃ±0.44	22.11	8.06ᵇ ±1.11	13.72	5.94ᶜ±0.17	2.82
$C_{12:0}$	2.66ᵃ±0.22	8.31	3.86ᵇ±0.78	20.33	2.70ᵃᵇ±0.13	4.66
$C_{14:0}$	10.49±1.08	10.33	9.65±0.83	8.56	8.43±0.79	9.33
$C_{16:0}$	36.56ᵃ±1.20	3.29	24.22ᵇ±0.72	2.97	23.13ᵇ±0.77	3.33
$C_{18:0}$	12.43±1.17	9.43	10.06±1.86	18.54	11.46±0.77	6.72
$C_{18:1}$	25.87±0.69	2.66	23.45±0.43	1.83	22.95±2.44	10.65
$C_{18:2}$	2.27ᵃ±0.28	2.27	3.04ᵇ ±0.20	6.60	2.82ᵃᵇ±0.33	11.66
$C_{18:3}$	0.26ᵃ±0.09	36.69	0.23ᵃ±0.04	15.68	1.02ᵇ±0.12	11.92
$C_{20:0}$	0.16ᵃ±0.13	81.25	0.07ᵃᵇ±0.01	7.87	0.33ᵇ±0.06	19.92
$C_{22:0}$	0.70±0.55	79.19	0.65±0.34	52.00	0.62±0.13	20.88
$C_{24:0}$	0.10ᵃ±0.02	20.14	0.29ᵇ±0.07	24.19	0.21ᵃᵇ±0.07	32.92
$C_{20:5}$	0.05ᵃ±0.03	52.91	0.57ᵇ±0.27	47.50	0.11ᵃ±0.04	36.36
$C_{22:6}$	0.01ᵃ±0.00	0.0	0.04ᵇ±0.01	25.00	0.03ᵃᵇ±0.01	45.82
ΣMUFA	25.87±0.69	2.66	23.45±0.43	1.83	22.95±2.44	10.65
ΣSSCFA	1.96ᵃ±0.34	17.60	5.74ᵇ±0.09	1.64	7.87ᶜ±0.14	1.77
ΣSMCFA	15.13ᵃ ±1.01	7.08	21.58ᵇ±2.35	12.56	17.08ᵃ±0.88	5.17
ΣSLCFA	49.96ᵃ ±1.95	3.91	35.29ᵇ±2.23	6.32	35.42ᵇ±0.73	2.05
ΣSFA	67.05ᵃ ±2.01	3.00	62.61ᵇ±0.57	0.91	60.37ᵇ±0.74	1.22
ΣPUFA	2.59ᵃ ±0.37	14.25	3.82ᵇ±0.21	5.51	3.98ᵇ±0.47	11.88

MUFA - monounsaturated fatty acids; SSCFA - saturated short-chain fatty acids; SMCFA - saturated medium-chain fatty acids; SLCFA - saturated long-chain fatty acids; SFA - total saturated fatty acids; PUFA - polyunsaturated fatty acids; χ± sd - arithmetic mean + standard deviation; cv - coefficient of variation; Means within a row marked with the different letters differ significantly ($p<0.05$);

Table 4. Nutritional indices of cow, goat, and sheep white-brined cheeses

Parameters	Cow-brined cheese		Goat-brined cheese		Sheep-brined cheese	
	χ± sd	cv (%)	χ± sd	cv (%)	χ± sd	cv (%)
PUFA/SFA	0.04ᵃ ±0,01	17.35	0.06ᵇ±0.01	5.47	0.07ᵇ±0.01	12.56
∑ *n* -6 PUFA	2.27ᵃ±0.28	12.39	3.04ᵇ±0.20	6.60	2.82ᵃᵇ±0.03	11.66
∑ *n* -3 PUFA	0.32ᵃ±0.10	33.07	0.84ᵇ±0.25	29.47	1.16ᵇ±0.14	12.44
∑ *n* -6 PUFA/∑ *n* -3 PUFA	7.58ᵃ±2.37	31.27	3.83ᵇ±1.08	28.14	2.42ᵇ±0.03	1.22
AI	2.81ᵃ±0.24	8.76	2.45ᵃᵇ±0.16	6.52	2.22ᵇ±0.20	8.86
TI	4.73ᵃ±0.27	5.65	3.39ᵇ±0.30	8.86	2.92ᵇ±0.32	10.98
HPI	0.35ᵃ±0.03	9.10	0.41ᵃᵇ±0.03	6.45	0.45ᵇ±0.04	9.18
HH	0.57ᵃ ±0.04	7.05	0.72ᵇ±0.03	3.92	0.79ᵇ±0.07	9.02
ΣEPA+DHA	0.06 ᵃ±0.03	44.09	0.61ᵇ±0.28	45.90	0.14ᵃ±0.03	24.50
LA/ALA	9.41ᵃ±3.02	32.06	13.38ᵃ ±1.64	12.25	2.76ᵇ±0.09	3.13

n -6 PUFA-polyunsaturated n-6 fatty acids; n -3 PUFA-polyunsaturated n -3 fatty acids; AI - atherogenic index; TI - thrombogenic index; HPI - health promoting index; HH - hypocholesterolemic/hypercholesterolemic ratio; EPA+DHA - docosahexaenoic+eicosapentaenoic acids; LA/ALA - linoleic acid/α-linolenic acid ratio; χ± sd - arithmetic mean + standard deviation; cv - coefficient of variation; Means within a row marked with the different letters differ significantly ($p<0.05$);

cow cheeses were rich in Lys, Iso, and Leu. Similarly, goat cheeses were also rich in Lys, Leu, Iso, and Val, whereas sheep cheeses were rich in Leu, Iso, Lys, and Thr. The mean values for non-essential amino acids showed that glutamic acid was present in high concentrations in all cheeses. Differences were found in the branched-chain amino acids (BCAAs) (leucine, isoleucine, and valine), which represented 49.30%,

Table 5. Sheep, goat, and cow white brined cheeses' amino acid composition (g/100g)

Parameters	Cow-brined cheese		Goat-brined cheese		Sheep-brined cheese	
	χ± sd	cv (%)	χ± sd	cv (%)	χ± sd	cv (%)
Essential amino acid (EAA)						
Histidine	0.17ᵃ±0.05	29.04	0.53ᵇ±0.03	6.67	0.18ᵃ ±0.01	7.16
Threonine	0.73ᵃ±0.05	6.25	0.45ᵇ±0.03	5.99	0.77ᵃ±0.13	18.45
Valine	0.58ᵃ±0.06	10.51	1.56ᵇ±0.82	52.22	0.66ᵃ±0.10	15.90
Methionine	0.53ᵃ±0.14	25.98	1.36ᵇ±0.10	17.81	0.76ᵃ±0.03	4.57
Phenylalanine	0.67ᵃᵇ±0.07	10.17	0.73ᵃ±0.04	4.95	0.53ᵇ±0.09	16.72
Isoleucine	0.93ᵃ±0.06	6.20	1.46ᵇ±0.49	33.24	0.88ᵃ±0.10-	11.55
Leucine	0.89ᵃ±0.06	7.09	1.71ᵃ±0.13	7.35	1.16ᵇ±0.14	5.35
Lysine	1.09ᵃ±0.13	12.35	1.83ᵇ±0.19	10.49	0.78ᵃ±0.04	5.35
Non-essential amino acid (NEAA)						
Asparatic acid	1.28ᵃ±0.08	6.17	2.20ᵇ±0.22	10.11	1.08ᵃ±0.06	5.91
Glutamic acid	3.59ᵃ ±0.32	8.82	4.33ᵇ±0.23	5.21	3.84ᶜ±0.13	3.40
Serine	0.91ᵃ±0.27	29.76	1.69ᵇ±0.15	9.05	0.83ᵃ±0.10	12.54
Glycine	0.41ᵃ±0.04	8.87	1.04ᵇ±0.06	5.82	0.26ᵃ±0.08	31.85
Arginine	0.47±0.10	21.57	1.19±0.20	16.85	0.31±0.01	3.81
Alanine	0.63±0.19	29.69	0.72±0.11	15.33	0.64±0.12	18.50
Tyrosine	0.78ᵃ ±0.10	12.81	1.64ᵇ±0.15	8.97	0.88ᵃ±0.07	8.23
*EAA/NEAA	40.84/59.16		42.86/57.14		42.25/57.75	

EAA/NEAA: The ratio of essential/non-essential amino acids; χ± sd - arithmetic mean + standard deviation; cv - coefficient of variation; Means within a row marked with the different letters differ significantly (p<0.05);

46.73%, and 42.93% of the total essential amino acid content in goat, sheep, and cow cheeses, respectively. Goat cheeses also had a higher ratio of essential to non-essential amino acids.

DISCUSSION

The nutritional value of a cheese is influenced by many variables, including the type of milk it is made from (species, breed, stage of lactation) and the way it is manufactured and ripened

The cheeses analysed in the study differed significantly ($p<0.05$) in most of their components. In particular, goat and sheep's milk brine cheeses had higher fat, protein content, and energy value than commercial cow's milk brine cheeses. The results obtained in the present study for sheep's milk brine cheese were higher for protein and similar for fat content compared to the findings of Massouras et al. (2023) for the protein and fat content of industrially produced sheep's milk brine cheeses placed in two different ripening containers. Similar to this, the present study's findings regarding the fat content of sheep's milk brine cheese differed significantly from those of Iranian sheep white brine cheese (Alizadeh and Lavasani, 2013) while remaining consistent with the findings of Panayotov et al. (2019). The results of the fat content of white goat's cheese in the current study are in line with the study of Paskaš et al. (2023) for brine goat's cheese from the grazing system (23.57%). The fat globules in goat's milk are smaller than those in cow's milk and have known properties that make them more digestible, nutritious, and easily absorbed in the digestive tract (Attaie and Richter, 2000). Compared to fresh cow and mild cheeses, the lipids of goat cheese were more digestible than those of fresh cow and mild cheeses. Conversely, the protein digestibility of fresh and matured (mild or aged) cow cheese was higher than that of fresh goat cheese (Asensio-Grau et al., 2019).

White-brined cheeses are highly salted. The cheeses in the study contain different amounts of sodium, with goat's milk cheeses having the highest levels. During production, they were immersed in a brine solution containing 6% (traditional) and 4% (industrial) NaCl and kept at different temperatures, resulting in different Na contents. Kaminarides et al. (2019) observed a progressive decrease in moisture content with increasing brine concentration. At a low brine concentration (e.g., 7% NaCl), water is transferred from the brine into the cheese to reach osmotic pressure equilibrium. In contrast, the cheese kept in 13% brine loses water. Salt alters the water-binding capacity of the casein in the cheese matrix, thereby affecting the physical properties of the cheese. As the salt concentration in brine increased, cheese's total ash, salt, fat, and protein content increased, while the moisture content decreased (Alizadeh and Lavasani, 2013). The pH value was significantly different ($p<0.05$) between the cheeses in the current study. The lowest and most optimal value was found in the cow brine cheeses, which was also influenced by the different production technologies and ripening times. The desirable pH value for white brine cheese is around 4.5, and in the research of Massouras et al. (2023), the pH values decreased to 4.43 and 4.45 after 10 days of ripening. Different pH values influenced the hardness of Turkish white brine cheeses, with those packaged at pH 4.7 being harder than those packaged at pH 5.0 and 5.3 (Pamuksuz et al., 2020). They found no correlation between cheese packing pH and crumb size, but there was a significant negative correlation between packing pH and crumb weight. Cheeses packaged at pH 5.0 and 5.3 showed increased slicing adhesiveness during storage.

The human diet includes a wide variety of foods containing calcium, but milk and dairy products are the most valuable sources of this vital nutrient, preventing its deficiency, which leads to osteoporosis (Kłobukowski et al., 2014). Mature cheeses have the highest calcium content, while fermented milk drinks and fresh cheeses have a lower calcium content (Kłobukowski et al., 2014). A Ca/P ratio of 1:1 to 1.5:1 is recommended for optimal bone health (Schaffer et al., 2001). Accordingly, the sheep's brine cheeses studied had a favourable Ca/P ratio of 1.40, while cow's brine cheeses had the least desirable value of 1.96. Compared to traditional Serbian brine cheeses made from cow and sheep milk, where C/P ranged from 0.70 to 1.33 (Barać et al., 2018), the current research found higher values. According to Klobukowski et al. (2014), cheeses made in brine have reduced calcium bioavailability, regardless of whether the cheese is submerged in regular brine (NaCl solution) or modified brine (NaCl and KCl solution). In general, calcium absorption and retention are higher in fresh cheeses than in mature or unmatured cheeses, and fermentation appears to increase calcium solubilization during digestion (Alizadeh and Lavasani, 2013). Nega et al. (2011) reported that calcium concentration was strongly positively correlated with cheese pH and negatively correlated with cheese moisture, and thus calcium content largely configures the specific textural characteristics of each cheese category. The dietary calcium/protein ratio (mg Ca per gram protein) was found to be a very useful index to determine the influence of dietary protein content on calcium homeostasis and bone health status (Kerstetter et al., 2003). The values of this parameter differed significantly ($p<0.05$) among the cheeses studied and were the highest in cow's milk cheeses.

Traditional white brine cheeses have a high SFA content (Barać et al., 2018; Paskaš et al., 2023). All cheeses studied contained high levels of myristic, palmitic, and stearic acids, but commercial cow brine cheeses contained higher concentrations of SLCFAs compared to goat and sheep brine cheeses. In particular, the ratio of SLCFAs in cow brine cheeses was 52.31%, while it was only 39.23% in goat and 40.57% in sheep brine cheeses. Conversely, sheep and goat cheeses had higher proportions of SSCFA and SMCFA and a higher PUFA content. The highest levels of butyric and caproic acid-free fatty acids were found in goat's milk cheeses in the Filipczak-Fiutak et al. (2021) study, but in our study, sheep's milk cheeses had significantly higher levels ($p<0.05$) than goat's milk and bovine`s milk cheeses. The adverse association between SFAs and poor cardiovascular health has been studied extensively (Feeney et al., 2021; Penhaligan et al., 2022). Consumption of SFAs alone is associated with increased levels of LDL cholesterol in the blood, leading to an increased risk of coronary heart disease. However, recent studies have suggested that the food/dairy matrix containing these fatty acids may influence some health outcomes (Feeney et al., 2021). Machlik et al. (2021) found that the associations between fermented dairy product intake and blood lipid concentrations depended on the type of dairy product, the fat content, and the structure of the dairy matrix. Among fermented dairy products, cheese intake showed the most favourable associations, being positively associated with HDL-C and inversely associated with LDL-C and triglyceride concentrations.

In the present study, sheep's milk cheeses were found to have the best nutritional indices. Conversely, commercial cow's milk cheeses had the least favourable values, especially the high n-6/n-3 ratio (7.58). Dairy products with high HPI and HH values are considered to be more beneficial for human health, and the HH index of dairy products ranges from 0.31 to 1.29 and the HPI from 0.16 to 0.68 (Chen and Liu, 2020). The values obtained in this study were within this range, thus confirming the nutritional value of these products. The consumption of foods with a lower TI is useful for the prevention of cardiovascular diseases. This index represents the thrombogenic potential of FAs, which indicates the tendency to form clots in blood vessels and represents the contribution of different FAs (Chen and Liu, 2020). It is also hypothesised that milk fat with high AI and TI values is more likely to contribute to the development of atherosclerosis or coronary thrombosis in humans, and conversely, milk with high HPI and HH values may have a protective effect against cardiovascular disease (Hanuš et al., 2018). During the ripening of sheep's cheese, AI and TI decreased, and the n-6/n-3 ratio was 1:1 in ripened cheese in the study by Panayotov et al. (2019). The study by Santurino et al. (2020) reported that the consumption of naturally enriched goat cheese with PUFA, n-3 acids, and CLA may have a potential role as a food of high nutritional value for improving health status. Moreover, PAF (platelet-activating factor), a crucial inflammatory mediator involved in atherogenesis, has inhibitors found in the total lipids of white goat cheese (Santurino et al., 2020).

Numerous factors, including the source of the milk, the method of processing, the stage of ripening, and the starter culture, influence the content and profile of amino acids. BCAAs (valine, leucine, and isoleucine) account for about 35% of the essential amino acids in the milk of all mammals (Du et al., 2022). The present investigation revealed that the highest percentage of branched amino acids (49.30%) was found in goat brine cheeses, followed by sheep brine cheeses (46.73%). BCAAs play an important role in protein synthesis, regulating the synthesis of neurotransmitters and the mechanistic target of rapamycin (mTOR). Their deficiency is also associated with many metabolic disorders, such as insulin resistance, obesity, and heart failure (Du et al., 2022). Sheep and goat's milk are rich sources of BCAAs, especially Leu, which may help prevent metabolic disorders (Penhaligan et al., 2022). In the study by Pappa and Sotirakoglou (2008), total free amino acids (TFAA) in Turkish Teleme white brine cheeses were higher in cow's milk cheeses than in goat's and sheep's milk cheeses. Furthermore, Leu, Glu, Phe, Val, and Lys were the main FAAs in Teleme cheeses at all stages of ripening, regardless of the type of milk and culture used. The present results of amino acid content agree with the research of Atanasova et al. (2021), where Leu, Phe, Arg, Val, and Lys were detected at the highest levels during ripening in goat, sheep, and cow's milk cheeses. Glutamic acid is the most abundant non-essential amino acid in milk and cheese (Ogunlade et al., 2019), which this study confirms. Additionally, Leu and Phe were found to be the two most significant essential amino acids in soft sheep's cheese in their study. This is somewhat consistent with the current study, which found that Leu and Iso were the two most common amino acids in sheep's cheese. Gly was found to be the lowest in cow's and sheep's milk cheeses, whereas Ala was found to be the lowest in goat's milk cheeses.

CONCLUSION

A comparison of white brine cheeses showed that goat and sheep brine cheeses had better nutritional values, whereas cow brine cheeses had high AI and TI and an unfavourable n-6/n-3 ratio. In addition, the levels of less desirable SFAs, especially SLFCA, were higher in commercial cow brine cheeses. The goat brine cheeses, however, were found to have a favourable ratio of essential and non-essential amino acids and were therefore found to be a rich source of branched amino acids. The lipid indices and ratios and the amino acid profile results indicate that goat and sheep brine cheeses represent a low-risk factor for human health and a good source of essential nutrients.

ACKNOWLEDGMENT

The study was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Contract number 451-03-47/2023-01/200143), Project No. TR31085.

CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

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