Chemical composition and fatty acid profile of Alpine and Saanen goat milk from Bosnia and Herzegovina

A. Vulić, N. Kudumija, T. Lešić, S. Tanković, V. Jelušić, J. Ferizbegović, N. Bilandžić and J. Pleadin*

Abstract

Interest in the production and sale of goat milk products has been growing over the past 20 years. The chemical composition of goat milk, which greatly affects its nutritional and therapeutic value, makes its products more acceptable to consumers. The aim of this study was to compare the chemical composition and fatty acid profile of Alpine and Saanen goat milk. The results showed that there were differences in certain chemical components between the milk of these two breeds. Protein, fat and ash content in Alpine goat milk was 4.53 g/100 g, 4.65 g/100 g and 0.94 g/100 g, respectively, and these values were higher than in Saanen goat milk (3.64 g/100 g, 3.20 g/100 g and 0.88 g/100 g, respectively). Differences in the fatty acid profile were also observed. Despite being kept under different breeding regimes, no statistically significant differences were observed in the total saturated fatty acids (SFA) or polyunsaturated fatty acids (PUFA) between breeds. Although there was no difference in total SFA content, there was less palmitic acid (C16:0), as the predominant fatty acid in goat milk, in Alpine (26.94 g/100 g of fat) than in Saanen goat milk (28.60 g/100 g of fat). Unlike SFA and PUFA content, differences were observed in total monounsaturated fatty acids (MUFA), with 22.8 g/100 g of fat in Alpine goat milk and 24.0 g/100 g of fat in Saanen goat milk. Based on these findings, it can be concluded that the implemented breeding regimes in different geographical areas with different pasture, together with genetic factors of breeds, greatly affect the goat milk chemical composition and fatty acid profile.

Key words: *goat milk; Alpine goat; Saanen goat; chemical composition; fatty acid profile*

Ana VULIĆ*, BSc, PhD, Senior Scientific Associate (Corresponding author, e-mail: vulic@veinst.hr), Nina KUDUMIJA, BSc, PhD, Postdoctoral Researcher, Tina LEŠIĆ, MSc, BSc, Expert Associate, PhD student Nina BILANDŽIĆ, Grad. Biotechnology Eng., PhD, Scientific Advisor in Tenure, Jelka PLEADIN, BSc, PhD, Scientific Advisor in Tenure, Associate Professor, Croatian Veterinary Institute, Zagreb, Croatia; Sanin TANKOVIĆ, PhD, DVM, Vedrana JELUŠIĆ, DVM, Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina, Veterinary office of Bosnia and Herzegovina, Sarajevo, Bosnia and Herzegovina; Jasmin FERIZBEGOVIĆ, DVM, Professor, director, JP Veterinary Practice Bukinje, Tuzla, Bosnia and Herzegovina

Introduction

In addition to cow and buffalo milk, which together account for 98% of world milk production, the interest for goat milk production has been constantly on the rise over the past 20 years (Antunac and Samaržija, 2000; Božanić et al., 2002; Silanikove et al., 2010; Popescu, 2013). Most livestock is situated in Asia (59.5%), followed by Africa (34%), America (4.3%), Europe (1.8%) and Oceania (0.4%). Goat milk production is mainly located in developing countries and the main world producer is India, with approximately 21% of world production (Biadała and Konieczny, 2018). Among European countries, Greece, Spain and France are the top producers of goat milk, with 70.1% of total European production (Žan et al., 2006; Popescu, 2013). In these Mediterranean countries, there is also tradition of goat cheese production and most of the produced milk is used for this purpose (Božanić et al., 2002).

The chemical composition of goat milk greatly affects its nutritional and therapeutic value. This makes goat milk and its products more acceptable to consumers. Cow and goat milk have a similar chemical composition, though goat milk has more fat, proteins and ash, while cow milk has a higher lactose content. According to the literature, goat milk has 3.8% milk fat, 3.5% proteins, 4.1% lactose and 0.8% ash while cow milk has 3.6% milk fat, 3.3% proteins, 4.6% lactose and 0.7% ash. Besides these basic nutrients, goat milk is richer in minerals: calcium (134 mg/100 g), phosphorus (141 mg/100 g), magnesium (16 mg/100 g), potassium (134 mg/100 g), and chlorine (150 mg/100 g), while cow milk contains more sodium (58 mg/100 g). There is also a small difference in the vitamin content between cow and goat milk. Goat milk has more vitamin A (185 I.U./100 g), vitamin D (2.3 I.U./100g), thiamine (0.068 mg/100 g), riboflavin (0.21 mg/100 g), niacin (0.27 mg/100 g), vitamin B_6 (0.046 mg/100 g) and vitamin C (1.29 mg/100 g), while cow milk is richer in pantothenic acid (0.32 mg/100 g), folic acid (5 μg/100 g), biotin (2 μg/100 g) and vitamin B_{12} (0.357 μg/100 g) (Antunac and Samaržija, 2000; Božanić et al., 2002; Park, 2010).

The most variable component of goat milk is fat. Fat content in goat milk can range from 2–8 % depending on breed, lactation stage, feeding and time of year (Silanikove et al., 2010, Guo et al., 2001, Antunac and Samaržija, 2000). Goat milk fat has smaller fat globules than cow and buffalo milk, 3.49 μm *vs*. 4.55 μm and 5.92 μm, respectively, making it easier to digest and giving it a production also advantage for milk products since the texture of these product is softer. Another advantage of goat milk fat is the significantly higher level of short and medium-chain length fatty acids (C4-C14) compared to cow and buffalo milk, making it convenient for fat malabsorption treatments. The main carbohydrate in both cow and goat milk is lactose, which varies between cow and goat milk at 4.7% *vs*. 4.1%. Although the lactose content is lower in goat milk, it is not a suitable alternative for people suffering from lactose intolerance. Goat milk proteins are more digestible compared to cow milk, and absorption of amino acids is more efficient. The free amino acid content and free amino acid content is also higher in goat than in cow milk. In general, the nutritional value of goat milk is higher than cow milk, and therefore future demands for goat milk and its products can be expected to increase.

There are many factors affecting goat milk composition: breed, stage of lactation, parity, pasture, and kidding season (Mioč et al., 2008; Eknæs et al., 2009; Goetsch et al., 2011; Rojo-Rubio

et al., 2016; Žan-Lotrič et al., 2017). Alpine and Saanen goats are the most common milk goat breeds. The average milk production of Saanen goats is 1325 kg/season with 3.1 and 4.1 g proteins and fat per 100 g, while Alpine goat has average milk production of 1135 kg/season with 3.3 and 4.3 g proteins and fat per 100 g, respectively, and the chemical composition differs slightly between these two breeds (Rojo-Rubio et al., 2016). The present study aimed to compare the chemical composition and fatty acid profile of Alpine and Saanen goat milk from Bosnia and Herzegovina with regard to pasture type and breeding regime.

Materials and Methods

Collection of milk samples

The study was conducted on Alpine (30) and Saanen (30) goats from Bosnia and Herzegovina. Alpine goats were kept in an extensive breeding regime, at pasture at elevations of 800 to 1200 meters for 8 months. Saanen goats were kept in an intensive breeding regime in stables year-round. Milk samples were collected during the autumn season.

Reagents and standards

Petrol ether, hydrochloric acid, sulphuric acid, sodium hydroxide, sodium chloride and boric acid were obtained from Sigma (Missouri, USA). Hexane and isooctane were from Merck (Germany). Reagents for lactose determination were provided by the enzyme kit manufacturer (R-Biopharm, Germany). The standard solution of fatty acids methyl esters (FAME) was prepared by dissolving 100 mg standard SupelcoTM 37 Component FAME Mix (Pennsylvania, USA) in 10 mL hexane. Ultra-pure water with electrolytic conductivity of ≤ 0.05 S/cm was obtained using Millipore Direct-Q 3UV (Merck, Germany).

Compositional analysis

Compositional analysis (g/100 g) was performed by applying validated standard and internal analytical methods. Determination of water (HRN ISO 6496:2001) and ash (HRN ISO 5984:2004) content was performed by gravimetric methods with the use of a thermostat (UF75 plus, Memmert, Germany) and muffler burning furnace (Program Controller LV 9/11/P320, Nabertherm, Germany). Crude protein content was determined by the Kjeldahl method (HRN ISO 5983-1:2008 and HRN ISO 5983-2:2010), which involves the destruction of organic matter at 420 °C in a block digestion unit (Unit 8 Basic, Foss, Denmark) combined with titration and distillation unit (Vapodest 50s, Gerhardt, Germany). Crude fat content was determined by the Soxhlet method (HRN ISO 1443:1999) that includes fat hydrolysis and fat extraction with petrol ether on an extraction device (Soxtherm 2000, Gerhardt, Germany). Salt content was determined by the potentiometric method that includes sodium determination on an EasyPlus™ Analyzer (Easy Na), Mettler Toledo, USA) and calculating the salt content by applying the factor 2.5 arising from the stochiometric ratio of sodium/sodium chloride. Lactose content was determined using the enzymatic method and with a commercial enzyme kit (Lactose/D-Glucose, R-Biopharm, Germany).

Fatty acid methyl ester (FAME) analysis

Extracted fat was used for fatty acid methyl ester preparation according to EN ISO 5509:2000 with some modifications. A total of 60 mg extracted fat was dissolved in 4 mL isooctane, with the addition of 200 μL 2N-methanolic potassium hydroxide solution. Samples were shaken for 60 seconds. Then 4 mL saturated sodium chloride solution (300 g/L) was added, samples were vortexed

and kept at room temperature to allow layer separation. The upper isooctane layer was removed to another test tube, 2 g anhydrous sodium hydrogen sulphate was added and samples were centrifuged for 15 min at 3000 rpm at 15°C. Then 200 mL of each sample was filtered through a PTFE filter (0.2 µm pore size) into vials for analysis. Methyl esters of fatty acids were analysed by the GC-FID method using a gas chromatograph 7890 A (Agilent Technologies, USA) with the DB-23 capillary column (60 m length, internal capillary diameter 0.25 mm and thickness of stationary phase of 0.20 µm (Agilent Technologies, USA). The carrier gas was helium, set at constant flow mode at 2 mL/min. The oven temperature program was as follows: initial temperature of 120 °C for 1 min, then increase at the rate 10 °C/min to 175 °C, maintaining for 10 min, then increase at the rate 5 °C/min to 210 °C, maintaining for 5 min, then increase at the rate 5 °C/min to the final temperature of 230 °C, which was maintained for 5 min. The FID detector was set at 280 °C, and hydrogen flow was set at 40 mL/min, air flow at 450 mL/min and nitrogen flow at 30 mL/min. The split/splitless injector was set at 250 °C and a 1 µL sample was injected in the split ratio 1:50. Identification of FAME was performed by retention time comparison of FAME in the sample *vs*. FAME in the standard solution mixture. As the FAME method was modified from the standard method, the quality control CRM BCR163 (Institute for Reference Materials and Measurements, Belgium) reference material was used. The content of seven individual fatty acids obtained in the reference material analysis was compared with the certified values and tolerances were assigned.

Statistical analysis

Statistical differences of data were examined using the one-way ANOVA test, with statistical significance set at $P<0.05$. Statistical analysis was carried out using Excel software (Microsoft, WA, USA).

Results and discussion

Analysis of goat milk from two different breeds and breeding regimes revealed several interesting findings and differences in chemical composition. Figure 1 shows the average water, fat protein, ash, salt and lactose content (g/100 ± standard deviation) in Alpine (a) and Saanen (b) goat milk.

The average water content in Alpine and Saanen goat milk was 85.9 g/100 g and 88.4 g/100 g, respectively. The average water content in Saanen goat milk is comparable with previous reports where average water content, calculated from total solids, were 87.14 g/100 g and 88.06 g/100 g, respectively (Clark and Garcia, 2017; Božanić et al., 2002). The water content in Alpine goat milk is not comparable with literature data and there is a statistically significant difference ($P > 0.05$) in water and consequently solid content between these two breeds.

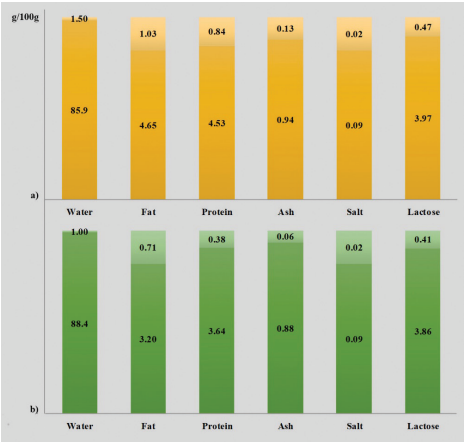

Figure 1. The average water, fat, protein, ash, salt and lactose content (g/100 g ± SD) content in Alpine and Saanen goat milk

According to the literature, the average protein content in goat milk from different breeds ranges from 2.95 to 3.71 g/100 g (Božanić et al., 2002; Žan et al, 2006; Clark and Garcia, 2017; Lotrič et al., 2017). Our study revealed that the average protein content was is higher in Alpine (4.53 g/100 g) than in Saanen (3.64 g/100 g) goat milk, and this difference was statistically significant ($P < 0.001$). The higher average protein content in Alpine goat milk obtained corresponds to Žan et al. (2006), who reported a protein content range from 2.30 g/100 to 5.08 g/100 g in Alpine goat milk.

The most valuable component in goat milk is milk fat, as the nutrient associated with health benefits (Silanikove et al., 2010). The average fat content was 4.65 g/100 g in Alpine goat milk and 3.20 g/100 g in Saanen goat milk, and this difference was statistically significant ($P<0.001$). These finding are in accordance with other studies, where the mean fat content ranges from 3–6% (Goetsch et al., 2011). Lotrič et al. (2017) analysed Croatian and Slovenian Alpine and Saanen goats and found that the fat content in the milk of both breeds ranged from 3.18 to 3.40 g/100 g (*i.e.* Croatia: Alpine 3.40 g/100 g, Saanen 3.30 g/100 g; Slovenia: Alpine 3.18 g/100 g, Saanen 3.23 g/100 g), though these differences were not statistically significant.

The average lactose content in goat milk is lower than in cow milk. The literature data report values ranging from 4.2 to 5.0 g/100 g (Mioč et al., 2008; Silanikove et al., 2010; Getaneh et al., 2016), which an average content of 4.1%. In the present study, the average lactose content in Alpine goat milk was 3.97 g/100 g as compared to 3.86 g/100 g in Saanen goat milk, and this difference was not statistically significant. These findings are consistent with the literature reports. Salt content was the same in both Alpine and Saanen goat milk (0.09 g/100g).

As expected and reported elsewhere (Bondesan et al., 2013), there are differences in the major chemical components between Alpine and Saanen goat milk. The average water (solid) content in Alpine goat milk was lower than in Saanen goat milk, and consequently, the protein, fat and ash contents were higher. This difference may be due to the different breeding regime, especially different pasture conditions (Goetsch et al., 2011).

The mean SFA, MUFA and PUFA contents in Alpine and Saanen goat milk are presented in Figure 2.

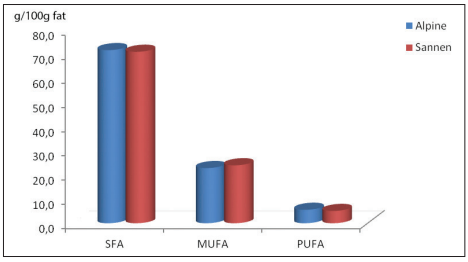

Figure 2. Saturated (SFA), monounsaturated (MUFA) and polyunsaturated (PUFA) fatty acid content (g/100 g of fat) in Alpine and Saanen goat milk

The milk fatty acid profile is generally characterised by high levels of saturated fatty acids (60-70%), 20-30% of monosaturated fatty acids, and low levels (<10%) of polysaturated fatty acids. This fatty acid profile is common for all ruminants (Lindmark Månsson, 2008; Markiewicz-Keszycka et al., 2013). The average saturated fatty acid (SFA) content determined in this study was 71.6 g/100 of fat in Alpine and 71.0 g/100 of fat in Saanen goat, which coincides with previous reports.

Although goats were kept under different breeding regimes, there was no statistically significant differences ($P>0.05$) in the SFA content or in the polysaturated fatty acid (PUFA) content between Alpine (5.5 g/100 g of fat) and

Saanen (5.1 g/100 g of fat) goat milk. According to the literature, the sum of PUFAs in goat milk is lower than found in this study. Cossignani et al. (2014) revealed an average PUFA content in goat milk of 3.8 g/100 g of fat, while Žan et al. (2006) reported an average PUFA content from 3.24 g/100 g of fat (mountain flock) to 3.73 g/100 g of fat (highland flock). These differences can be attributed either to different breed or pasture conditions.

Unlike SFAs and PUFAs, this study

Table 1. Fatty acid profile (average content ± SD g/100 g fat) in Alpine and Saanen goat milk

Fatty acid empirical formula	Average fatty acid content ± SD (g/100 g of fat)	
	Alpine goat milk	Saanen goat milk
C4:0	2.90 ± 0.28	2.38 ± 0.39
C6:0	2.53 ± 0.25	2.29 ± 0.35
C8:0	2.68 ± 0.32	2.53 ± 0.37
C10:0	9.29 ± 1.13	9.27 ± 1.02
C11:0	0.05 ± 0.03	0.11 ± 0.04
C12:0	4.20 ± 0.72	5.02 ± 1.03
C14:0	11.22 ± 1.75	11.21 ± 0.95
C14:1	0.17 ± 0.16	0.33 ± 0.09
C15:0	0.83 ± 0.08	1.07 ± 0.25
C16:0	26.94 ± 2.96	28.60 ± 2.68
C16:1n7t	0.27 ± 0.04	0.30 ± 0.03
C16:1n7c	0.83 ± 0.27	0.92 ± 0.41
C17:0	1.09 ± 0.18	1.01 ± 0.14
C17:1	0.29 ± 0.05	0.36 ± 0.10
C18:0	9.06 ± 2.45	6.90 ± 1.13
C18:1n9t	0.36 ± 0.06	0.50 ± 0.08
C18:1n9c	20.43 ± 2.34	21.07 ± 2.23
C18:1n7	0.43 ± 0.13	0.49 ± 0.09
C18:2n6t	0.95 ± 0.19	0.60 ± 0.18
C18:2n6c	2.31 ± 0.28	3.19 ± 0.47
C18:3n3 (ALA)	1.19 ± 0.19	0.59 ± 0.18
C18:4n3	0.81 ± 0.19	0.44 ± 0.16
C20:0	0.38 ± 0.17	0.24 ± 0.06
C20:4n6	0.11 ± 0.02	0.19 ± 0.04
C22:0	0.17 ± 0.04	0.11 ± 0.04
C24:0	0.14 ± 0.04	N.D.

Red lines – saturated fatty acids (SFAs); blue lines – monounsaturated fatty acids (MUFAs); yellow lines – polyunsaturated fatty acids (PUFAs); N.D. – not detected

revealed that there is a statistically significant difference (P<0.05) in the MUFA content between Alpine and Saanen goat milk, where the average content in Alpine goat milk was 22.8 g/100 g of fat and in Saanen goat milk 24.0 g/100 g of fat.

The fatty acid profile (average content ± SD g/100 g total fat) in Alpine and Saanen goat milk is presented in Table 1.

The specific flavour and aroma of goat milk derives from three medium chain fatty acids (FA): caproic (C6:0), caprylic (C8:0) and capric (C10:0) acid (Božanić et al., 2002; Eknæs et al., 2009; Silanikove et al., 2010). These fatty acids together contribute to the specific, desirable flavour of goat milk (Clark and Garcia, 2017). These three fatty acids contributed almost 15% to the total fatty acid profile of goat milk, while in cow milk they contribute only 5% (Haenlein, 1993). Our findings are consistent with previously published data, as the sum of C6:0, C8:0 and C10:0 was 14.51 g/100 g of fat in Alpine goat milk and 14.08 g/100 g of total fat in Saanen goat milk. When comparing these three fatty acids separately, caproic acid content (C6:0) was higher in Alpine than Saanen goat milk and the difference was significant (P<0.05). Another medium chain fatty acid present in goat milk, though but unlike caproic, caprylic and capric acid it does not contribute to the specific flavour, is lauric acid (C12:0). The average content of this fatty acid was 4.20 g/100 g of fat and 5.02 g/100 g of fat in Alpine and Saanen goat milk, respectively. The statistically significant higher content of lauric acid in Saanen goat milk determined in this study was also presented in other studies (Žan et al., 2006).

The predominant fatty acid in goat milk is palmitic acid (C16:0), a long chain SFA. The average palmitic acid content was 26.94 g/100 of total fat in Alpine goat milk and 28.60 g/100 g of total fat in Saanen goat milk, and this difference was statistically significant (P<0.05). Žan et al. (2006) reported an average palmitic acid content, recalculated from milligrams per 100 g milk, of 29.46 g/100 of fat and 26.10 g/100 g of fat and in Alpine and Saanen goat milk, respectively. The palmitic acid content in this study are opposed to the findings of Žan et al. (2006), which may be due to the different botanical pasture in Slovenia *vs.* Bosnia and Herzegovina. Oleic acid (C18:1n9) is the predominant MUFA in both Alpine and Saanen goat milk, with average content of 20.43 g/100 g of fat and 21.07 g/100 g of fat, respectively. Žan et al. (2006) also found that oleic acid was the predominant MUFA in goat milk, with an average content 19.1 g/100 g and 19.8 g/100 g in Saanen and Alpine goat milk, respectively. As in this study, there was no statistically significant difference in oleic acid content between Alpine and Saanen goat milk.

Although PUFAs are present in goat milk in low levels, there was no statistically significant difference between the sums of PUFAs between these two breeds, though there were some differences in individual fatty acids. The average stearidonic fatty acid (C18:4n3) content in Alpine goat milk (0.81 g/100 g of fat) was twice as high as in Saanen goat milk (0.44 g/100 g of fat). Also, the content of α-linolenic acid (ALA, C18:3n3), an omega-3 fatty acid with a cardio-protective role (Geleijnse et al., 2010), was twice as high in Alpine goat milk (1.19 g/100 g of fat) than in Saanen goat milk (0.59 g/100 g of fat). These findings are contrary to the findings of Žan et al. (2006), who reported higher α-linolenic acid content in Saanen goat milk. Given the vegetation differences between Slovenia and Bosnia and Herzegovina, these differences could be attributed to different pasture.

Furthermore, there was also a statistically significant difference (P<0.05) in linoleic (C18:2n6c) and linolelaidic (C18:2n6t) acid contents. The average linoleic acid content was 2.31 g/100 g of

fat and 3.19 g/100 g of fat in Alpine and Saanen goat, respectively. These findings, with regard to average linoleic acid content and the higher content in Saanen goat milk, are in accordance with findings of Žan et al. (2006) and Cossignani et al. (2014).

Conclusions

Analysis of Alpine and Saanen goat milk indicated their significant differences in chemical composition. Protein, fat and ash content was significantly higher in Alpine goat milk, while there were no differences in salt or lactose content. Differences were also observed in the fatty acid composition and profile in regard to MUFAs content, which was significantly higher in Saanen goat milk. These results show that animal breed with diverse genetic factors, together with pasture and geographical characteristics, contribute to the chemical composition and fatty acid profile of goat milk.

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Kemijski sastav i profil masnih kiselina mlijeka alpske i sanske pasmine koza iz Bosne i Hercegovine

Dr. sc. Ana VULIĆ, dipl. ing., viša znastvena suradnica, dr. sc. Nina KUDUMIJA, dipl. ing., postdoktorantica, mr. sc. Tina LEŠIĆ, mag. ing. mol. biotehnol., viša stručna suradnica, dr. sc. Nina BILANDŽIĆ, dipl. ing. biotehnol., znanstvena savjetnica u trajnom zvanju, dr. sc. Jelka PLEADIN, dipl. ing. biotehnol., znanstvena savjetnica u trajnom zvanju, izvanredna profesorica, Hrvatski veterinarski institut, Zagreb, Hrvatska; dr. sc. Sanin TANKOVIĆ, dr. med. vet., Vedrana JELUŠIĆ, dr. med. vet., Ministarstvo vanjske trgovine i ekonomskih odnosa Bosne i Hercegovine, Ured za veterinarstvo BiH Sarajevo, Bosna i Hercegovina; Jasmin FERIZBEGOVIĆ, dr. med. vet., profesor, direktor, JP Veterinarska stanica Bukinje, Tuzla, Bosna i Hercegovina

Interes za proizvodnju kozjeg mlijeka i proizvode od kozjeg mlijeka tijekom posljednjih 20 godina u stalnom je porastu. Kemijski sastav kozjeg mlijeka, koji uvelike utječe na njegovu hranjivu vrijednost, zajedno s terapijskom vrijednošću, čini kozje mlijeko i proizvode od kozjeg mlijeka prihvatljivijim za potrošače. Cilje je ove studije bio usporediti kemijski sastav i profil masnih kiselina kozjeg mlijeka alpske i sanske pasmine koza. Rezultati su pokazali da postoje razlike u određenim kemijskim komponentama kozjeg mlijeka alpske i sanske pasmine. Sadržaj bjelančevina, masti i pepela u kozjem mlijeku pasmine alpina iznosio je 4,53 g/100 g, 4,65 g/100 g i 0,94 g/100 g, a njihov sadržaj bio je veći nego u kozjem mlijeku sanske pasmine (3,64 g/100 g, 3,20 g/100 g, odnosno 0,88 g/100 g). Uočene su i razlike u profilu masnih kiselina. Iako su koze držane u različitim uzgojnim režimima, nije bilo statistički značajne razlike u ukupnom sadržaju zasićenih masnih kiselina (SFA) i polinezasićenih masnih kiselina (PUFA) između istraživanih pasmina. Iako nije bilo razlike u ukupnom sadržaju SFA između ovih dviju pasmina, sadržaj palmitinske kiseline (C16:0), prevladavajuće masna kiselina u kozjem mlijeku, bio je niži u kozjem mlijeku pasmine alpina (26,94 g/100 g masti) nego u mlijeku sanske pasmine koza (28,60 g/100 g masti). Za razliku od sadržaja SFA i PUFA, uočena je razlika u sadržaju ukupnih mononezasićenih masnih kiselina (MUFA). Ukupni sadržaj MUFA u kozjem mlijeku pasmine alpina iznosio je 22,8 g/100 g masti, a u kozjem mlijeku sanske pasmine 24,0 g/100 g masti. Na temelju ovih rezultata može se zaključiti da sustavi uzgoja koji se provode na različitim zemljopisnim područjima s različitom ispašom, zajedno s genetskim čimbenicima različitih pasmina koza, znatno utječu na kemijski sastav kozjeg mlijeka i profil masnih kiselina.

Ključne riječi: *kozje mlijeko, alpska koza, sanska koza, kemijski sastav, profil masnih kiselina*