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Influence of two feed supplements on technological properties of goat's milk

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Abstract

Goat's daily diet is usually based on grazing, hay and/or feed supplements. Feed supplements are crucial in the diet of high productive goats to achieve their genetic potential and breeders must choose balanced feeding regime to produce large quantities of milk without affecting the technological quality of milk. In the present study, we evaluated the influence of two commercially available feed supplements on goat milk coagulation properties and rheological properties of yoghurts. Goats of the Slovenian Alpine breed (61) were fed with two feed supplements during the 3-year experiment. Feed supplement 1 (FS1) had higher proportions of barley and alfalfa, while feed supplement 2 (FS2) had added premix of minerals and vitamins and had higher proportions of wheat and sunflower meal. Consequently, FS1 had more crude fibres, which is the most probable reason for approximately 15 % higher firmness, consistency and cohesiveness ($P<0.05$) of yoghurts in FS1 group, compared to the FS2 group. Moreover, the rennet coagulation time (r) was shorter ($P<0.05$) in the FS1 group, compared to the FS2 group. Curd firmness 30 min after enzyme addition (a_{30}) was also higher in FS1 group although the results were not statistically significant. Taking together, our results indicate that goats fed with FS1 produced milk with better technological properties compared to those fed with FS2, despite the fact that there were no significant differences in chemical composition of milk from each group. We showed that careful selection of feed supplement's constituents could improve technological properties of goat milk. However, further studies are needed to evaluate the mechanisms of the observed differences.

Key words: **goat milk, coagulation properties, rheological properties, yoghurt, feed supplements**

Introduction

Goat's daily diet is usually based on grazing, hay and/or feed supplements. The ratio between these components in daily ration depends on the level of intensity of the production system (Morand-Fehr et al., 2007). For example, feed supplements are crucial in the diet of high productive goats to reach their genetic potential and for maintaining a high milk yield throughout the lactation (Marques de Almeida and Haenlein, 2017). However, if feed supplements or concentrates are rich in starch and/or maize then the ration becomes poor in fibres, which may reduce the quality of milk and subsequently the quality of cheese (Morand-Fehr et al., 2007). Consequently, breeders must choose balanced feeding regimes to produce large quantities of milk without affecting the technological quality of milk.

From the technological aspect, goat milk is less suitable for further processing into dairy products in comparison to cow milk. According to Barlowska et al. (2011) and Park (2006), goat milk has longer hydrolysis time, weaker coagulum, lack of consistency in curd tension and viscosity upon agitation. Ideal cheese milk should have an optimal ratio between coagulation time (r) and curd firmness after 30 minutes (a_{30}) (Bittante et al., 2012). The latter is primary coagulation property that influences cheese quality, yield and economic returns (Pretto et al., 2013). In comparison to cow milk, characteristics of goat milk curd are mainly affected by the different proportions of caseins, especially lower levels of α_{s1}-casein, which vary according to breed, genotype, season, stage of lactation and diet (Clark and Sherbon, 2000). Indeed, an increased casein content (at constant crude protein content) caused an increase of the curd firming rate and the achievement of higher curd firmness (Stocco et al., 2018). Diet is one of possible ways to improve milk casein content. Namely, Ramos-Morales et al. (2008) reported significant correlations between quantities of α_{s1}- and α_{s2}-casein in goat milk and lysine, tyrosine and aspartic acid in the rumen-non-degradable protein fraction in diet.

The objective of this study was to evaluate the effect of two commercially available feed supplements, which differed in contents of individual components and added premix, on coagulation properties of goat milk as well as rheological properties of goats' yoghurts.

Materials and methods

Animals

In the present study, 61 goats of the Slovenian Alpine breed were randomly divided into two groups. One group (30 goats) was fed with feed supplement 1 (group FS1) and the other (31 goats) with feed supplement 2 (group FS2). Animals were reared at the Educational research centre (ERC) Logatec (operates under the auspices of Department of Animal Science, Biotechnical Faculty, University in Ljubljana). In the first year, all goats were in their first lactation. Due to the late insemination, they gave births from April to June, while in the second and in the third year they gave births in shorter period from March to April. The milking period started when kids were weaned at the average age of 60 days old.

Feed composition

The base diet of both groups was hay, produced at the ERC Logatec and Infrastructure Centre Jable, Slovenia. Both groups had a free access to its own part of the pasture, available for the whole time during the study. Goats in the FS1 group were supplemented with commercially available supplement 1 (0.80 kg/animal/day) and in the FS2 group with commercially available supplement 2 (0.85 kg/animal/day) (Table 1). Supplement 1 was composed of corn (49.06 %), barley (35.00 %), alfalfa (9.82 %), calcium carbonate (2.47 %), sugar beet molasses (2.00 %), sodium chloride (0.93 %) and monocalcium phosphate (0.72 %). Supplement 2 was composed of corn (51.70 %), wheat (30.00 %), sunflower meal (6.42 %), barley (5.57 %), calcium carbonate (2.11 %), sugar beet molasses (2.00 %), monocalcium phosphate (0.72 %), sodium bicarbonate (0.30 %), sodium chloride (0.33 %), lignosulfonate (0.35 %) and premix of minerals and vitamins (0.50 %). Wheat in FS2 was replaced with barley in FS1, which resulted in a larger proportion of barley in FS1 (35.00 %), compared to FS2 (5.57 %). The supplements also differed in contents of alfalfa (9.82 % in FS1) and sunflower meal (6.42 % in FS2).

TABLE 1. Chemical composition of the two feed supplements (S1 and S2) used in the study

Component	S1[1]	S2[1]
Crude proteins (%)	9	10
Crude fibres (%)	6.1	3
Crude fat (%)	2	2.3
Ash (%)	6.8	5.6
Na (%)	0.4	0.22
Vitamin A (I.E./kg)		10.000
Vitamin D3 (I.E./kg)		1.000
Vitamin E (mg/kg)		25
Copper sulphate pentahydrate (mg/kg)		80
Manganese dioxide (mg/kg)		64
Zinc oxide (mg/kg)		124
Cobaltous carbonate monohydrate (mg/kg)		0.93
Potassium iodide (mg/kg)		1.32
Sodium selenite (mg/kg)		0.66

[1]S1 = supplement 1; S2 = supplement 2

Milk sampling

In the first two years of the study, samples of bulk tank milk from the FS1 and the FS2 group were sampled monthly. The samples for FS1 and the FS2 group were taken in the period from June/July to October/November. At each sampling, two litres of bulk milk from each group were collected and the milk yield was recorded. The analysis of milk composition and production of yoghurts was performed on the same day, while the measurements of yoghurt's rheological properties were executed on the following day.

In the third year, milk samples were collected individually from 22 randomly selected goats from each experimental group, biweekly from May to July. At each sampling two samples from each individual goat were collected, one for milk coagulation properties, which was immediately frozen at -20 °C, and one for milk composition analysis. Analysis of milk coagulation properties was performed within the same week, while the milk composition analysis was performed on the same day. Milk from first two years of the study was used for yoghurt production and further analysis of yoghurt's rheological properties. Milk sampled in the last, third year of the study was used for determination of coagulation properties.

Milk composition (routine analysis)

Contents of milk fat, proteins, lactose and total solids were determined with CombiFoss 5000 (Foss, Denmark) using the standard method ISO 9622/IDF 141 (ISO/IDF, 2013a), somatic cell count with Fossomatic 5000 (Foss, Denmark) according to ISO 13366-2/IDF 148-2 (ISO/IDF, 2006) and the total bacterial count with Bactoscan FC (Foss Electric, Denmark) according to ISO 16297/IDF 161 (ISO/IDF, 2013b). The used instruments were calibrated prior to analysis according to the above mentioned standards.

Yoghurt production and pH measurements

At each sampling, we used two litres of bulk tank milk from each group for the production of yoghurt. Prior to yoghurt production, pH (Mettler Toledo, Switzerland) of each sample was measured. Milk was then pasteurised at 95 °C for five minutes, cooled to 44 °C, inoculated with 0.02 % freeze-dried thermophilic starter culture YC-X11 (Chr. Hansen, Denmark) and filled up into acrylic glass cups of 50 mm diameter. The samples were incubated at 44 °C until measured pH reached pH 4.6. Yoghurts were then stored overnight in the refrigerator (at 2-4 °C).

Rheological properties of yoghurts

Rheological properties of yoghurts were analysed with the Texture Analyser TA.XT Plus (Stable Micro System Ltd., GB) and the related software Exponent 6.1.10.0. The firmness, consistency and cohesiveness of samples were measured in acrylic glass cups with an acrylic probe, which compressed the coagulum to the depth of 15 mm, at compression rate of 10 mm/s. Each sample was measured in six replicates.

Coagulation properties of goat milk

In the 3[rd] year of the study, rennet coagulation time (r) and curd firmness after 30 minutes (a_{30}) were measured with computerised renneting meter (Polo Trade, Monselice, Italy). Prior to the analysis, milk samples were thawed and aliquots of 10 mL were warmed to 35 °C in an aluminium block. Finally, 200 μL of enzyme solution (NATUREN® Premium 225 (Chr. Hansen, Denmark) diluted to 2.58 international milk clotting units (IMCU)/mL in distilled water) was added. Samples were then mixed for 30 seconds and subjected to a 30-minute analysis. All samples were analysed in duplicates.

Statistical analysis

Data of milk coagulation properties and rheological properties of yoghurts were statistically analysed by GLM procedure in the statistical software package SAS/STAT 9.4 (SAS, 2017) . The following model for the observed traits (firmness, cohesiveness, consistency of produced yoghurts and milk coagulation properties as a_{30} and r) (y_{ijklm}) considered the sampling (S_i) (i = 1, 2, 3, 4 and 5), year (Y_j) (j=1, 2), type of feed supplement (T_k) (k = supplement 1, supplement 2) as fixed effects. The interaction of year and feed supplement (YT_{jk}) was also included in the model. The protein content was included in the model as linear regression. Results were expressed as least square means (LSM) ± standard errors (SE). Differences were considered significant at P<0.05. Differences in chemical composition of milk were calculated by the Sigmaplot 11.0 (Systat Software, Germany) software using the t-test.

$$y_{ijklm} = \mu + S_i + Y_j + T_k + YT_{jk} + b\,(x_{ijk\,l} - \bar{x}) + e_{ijklm}$$

Results and discussion

In present study, we evaluated the differences in chemical composition, technological and coagulation properties of goat milk, where animals were fed with two feed supplements commercially available in Slovenia. The main difference between the two supplements was the content of barley, alfalfa, sunflower meal and wheat. Since barley and alfalfa have higher content of crude fibres than wheat and sunflower meal (CVB, 2016; Rodehutscord et al., 2016), the FS1 had higher content of crude fibres too. On the other hand, FS2 had a slightly increased content of crude proteins since wheat and sunflower meal are richer in crude proteins (CVB, 2016) compared to barley and alfalfa. The third difference was in the added premix of minerals and vitamins, which was included into FS2.

Goat milk composition and milk yield

There were no significant differences in milk composition and milk yield between the FS1 and the FS2 group (Table 2). Several studies on cow milk suggested that certain feeds or added premix of minerals and vitamins could affect the milk yield as well as its composition (Mckay et al., 2019; Santana et al., 2019; McDonnell and Staines, 2017; Johansson et al., 2014). However, comparable nutritional studies on small ruminants are much more limited. For example, the milk yield was lower if goats were fed with sunflower silage instead of corn silage, although there were no significant differences in the milk composition (Gholami-Yangije et al., 2019). Sanz Sampelayo et al. (1998) studied the effect of different feed concentrates on the milk composition and concluded, that milk from goats fed with concentrates based on the sunflower cake, had lower content of crude proteins. Tufarelli et al. (2011) reported that ewes fed with premix-supplemented diet had a higher milk yield and milk fat content. In addition, higher fat content in goat milk was observed when diet was supplemented with selenite (Pechova et al., 2008). It should be noted that many differences, such as experimental design, breed and base diet, existed between this and published studies, that could contribute to the observed discrepancies.

Evaluation of technological properties of goat milk

Regardless of the production year, yoghurts from the FS1 group had significantly different rheological properties compared to yoghurts from the FS2 group (Figure 1). On average, firmness, consistency and cohesiveness of yoghurts in the FS1 group, were approximately 15 % higher ($P<0.05$) than yoghurts from the FS2 group. Beside rheological properties of yoghurts, the rennet coagulation time (r) was shorter ($P<0.05$) in milk from the FS1 group when compared to the FS2 group (Figure 1 (d)). Namely, milk from the FS1 group started to coagulate on average 152 seconds earlier than milk from the FS2 group, and these differences were observed irrespective of the month of sampling (data not shown). Curd firmness, measured 30 min after enzyme addition (a_{30}), was also higher in the FS1 group but the results were not statistically significant ($P=0.822$). This could be due to syneresis which starts earlier, if *r* is shorter and, consequently, the maximum curd firmness is reached earlier than in 30 minutes (Bittante et al., 2015). Thus, due to the substantial syneresis at 30 minutes, a_{30} is subjected to considerable variation, which masks differences in maximal curd firmness between the groups. Taking together, these results indicate that goat milk from the FS1 group had better technological properties compared to the FS2 group, despite the fact that there were no significant differences in chemical composition of milk between the groups.

Main differences in chemical composition of the two feed supplements in this study were in the

TABLE 2. Composition of milk from goats fed with one of the feed supplements (FS1 or FS2) during three years of the study. Results are shown as average ± standard error

Experimental year	2015			2016			2017		
Group	**FS1**	**FS2**	**p-value**	**FS1**	**FS2**	**p-value**	**FS1**	**FS2**	**p-value**
Milk yield (kg/goat)	444.9 ± 24.7	467.5 ± 20.3	0.490	655.9 ± 39.3	673.5 ± 33.7	0.739	497.8 ± 38.5	584.9 ± 25.1	0.175
Total solids (g/100 g)	11.05 ± 0.11	11.03 ± 0.10	0.871	10.86 ± 0.17	10.79 ± 0.24	0.841	10.91 ± 0.01	10.76 ± 0.2	0.819
Fat (g/100 g)	2.94 ± 0.12	2.94 ± 0.49	0.991	2.90 ± 0.09	2.94 ± 0.16	1.000	2.89 ± 0.06	2.94 ± 0.11	0.589
Proteins (g/100 g)	3.16 ± 0.09	3.09 ± 0.51	0.615	2.99 ± 0.12	2.90 ± 0.09	0.421	2.90 ± 0.02	2.90 ± 0.02	0.987
Lactose (g/100 g)	4.23 ± 0.07	4.27 ± 0.68	0.717	4.23 ± 0.05	4.23 ± 0.03	0.898	4.27 ± 0.04	4.28 ± 0.07	0.994
SCC (x1000/mL)	691 ± 71.9	766 ± 177.6	0.597	849 ± 170.9	869 ± 116.0	0.932	321 ± 82.2	400 ± 30.6	0.650
TBC (x1000 cfu/mL)	33 ± 6.4	30 ± 2.2	0.663	29 ± 5.1	45 ± 6.4	0.116	nd	nd	nd
pH	6.60 ± 0.06	6.67 ± 0.04	0.783	6.48 ± 0.02	6.52 ± 0.03	0.336	nd	nd	nd

SCC = somatic cells count, TBC = total bacteria count, nd = no data contents of crude fibres, crude proteins and in added premix. According to Bovolenta et al. (2002), milk from cows fed with more fibrous diet, had shorter r and firmer coagulum, which supports our results, since the supplement 1 used in this study had more crude fibres compared to supplement 2. However, Tsiplakou et al. (2017) found no differences in milk coagulation properties of goats fed with different starch/neutral detergent fibre ratios.

Another reason for differences in technological properties of milk from the FS1 group could also be in the presence of alfalfa. According to Wang et al. (2018) and Edmunds et al. (2013), rumen-non-degradable fraction of alfalfa is rich in lysine, tyrosine and aspartic acid, which strongly influences the amount of α_{s1}-casein in milk (Ramos-Morales et al., 2008). On the other hand, sunflower meal in FS2 has less of above-mentioned amino acids (Sanz Sampelayo et al., 1998). Since the amount of α_{s1}-casein in milk strongly influences the curd firmness, a slight decrease in its content could contribute to the less desired technological properties of milk from the FS2 group.

Regarding the addition of premix in the diet, these results were opposite to the results of Tufarelli et al. (2011), who reported shorter r and higher a_{30} in milk from ewes, supplemented with premix. However, they assumed that the differences could be also due to lower SCC and pH. Rennetability was also higher in goat milk, when inorganic selenite was added to their diet (Pechova et al., 2008). As shown in this experiment, the premix, added in FS2, did not improve technological properties of goat milk or maybe the feed components in FS1 group had greater effect on measured parameters than the premix in FS2.

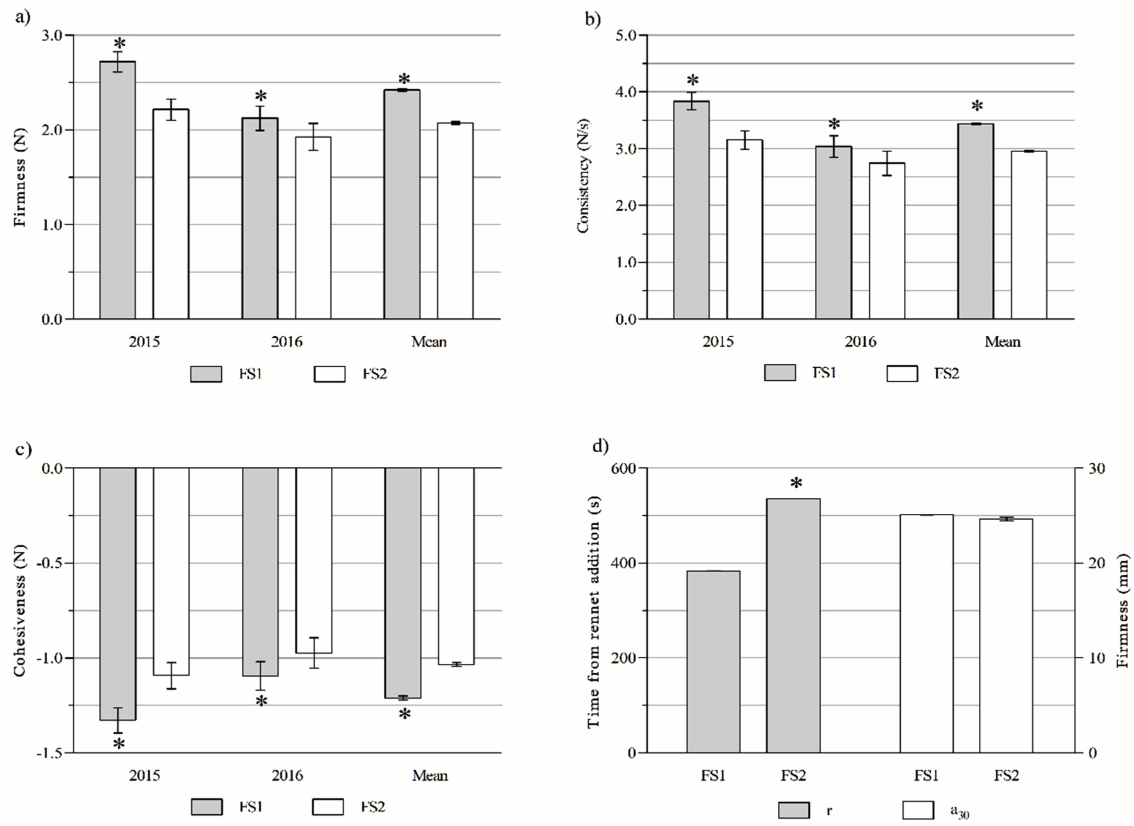

FIGURE 1. Differences in rheological properties of yoghurts and in milk coagulation properties of milk from FS1 and FS2 group, fed with supplement 1 and supplement 2 respectively. Rheological properties are presented as measurements of firmness (a), consistency (b) and cohesiveness (c). Milk coagulation properties (d) are presented as measurements of time after rennet addition (r) and curd firmness after 30 minutes (a30). Results are presented as LSM ± SE

* - $P<0.05$

Conclusion

Results of this study confirm that the diet considerably affects goat milk coagulation properties and, consequently, the rheology of dairy products. We showed that the technological properties of milk from the FS1 group were better compared to milk from the FS2 group, despite there were no significant differences in milk composition between the FS1 and the FS2 group. According to previous studies, the reason for those differences was probably due to higher content of crude fibres and the presence of alfalfa in supplement 1. Rumen-non-degradable fraction of alfalfa is rich in amino acids, which are in strong positive correlation with the amount of α_{s1}-casein in milk, as the main casein fraction responsible for suitable coagulation properties of different milk types, including goat milk. In conclusion, we showed that careful selection of feed supplement's constituents could improve technological properties of goat milk. However, further studies are needed to evaluate the mechanisms of the observed differences.

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Utjecaj dvaju suplemenata u hranidbi koza na tehnološka svojstva kozjeg mlijeka

Sažetak

Hranidba koza na dnevnoj bazi sastoji se od ispaše, sijena i/ili suplemenata. Suplementi su neophodni u hranidbi visokoproduktivnih pasmina koza u svrhu postizanja genetskog potencijala i uzgajivači moraju odabrati režim hranidbe koji osigurava proizvodnju velikih količina mlijeka bez neželjenih promjena u tehnološkoj kvaliteti mlijeka. U ovom istraživanju određivan je utjecaj dva komercijalno dostupna suplementa na sposobnost koagulacije kozjeg mlijeka te na reološka svojstva jogurta od kozjeg mlijeka. Ukupno 61 koza pasmine slovenska alpska koza hranjena je s dva suplementa tijekom tri godine. Prvi suplement (FS1) imao je viši udjel ječma i lucerne, dok je drugi suplement (FS2) imao dodane mineralne tvari i vitamine te više udjele pšenice i suncokretove pogače. Posljedično, FS1 je imao više sirovih vlakana, što je vrlo vjerojatno rezultiralo 15 % većom čvrstoćom, konzistencijom i kohezivnosti ($P<0,05$) jogurta iz skupine FS1 u odnosu na jogurte iz skupine FS2. K tomu je i vrijeme koagulacije (r) bilo kraće ($P<0,05$) kod jogurta iz skupine FS1 u usporedbi s jogurtima iz skupine FS2. Čvrstoća gruša 30 min nakon dodatka enzima (a_{30}) također je bila veća u skupini FS1, iako te razlike nisu bile statistički značajne. Uzimajući sve navedeno u obzir, dobiveni rezultati ukazuju kako su koze hranjenje suplementom FS1 proizvodile mlijeko boljih tehnoloških svojstava nego koze hranjene suplementom FS2, unatoč činjenici da nisu utvrđene statistički značajne razlike u kemijskom sastavu mlijeka iz obiju navedenih skupina. Ova studija pokazala je da se pažljivim odabirom suplementa u hranidbi mogu poboljšati tehnološka svojstva kozjeg mlijeka. Međutim, potrebno je provođenje daljnjih istraživanja u svrhu određivanja specifičnih mehanizama koji su doveli do prethodno navedenih razlika.

Ključne riječi: **kozje mlijeko, sposobnost koagulacije, reološka svojstva, jogurt, suplementi, hranidba**

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