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Inclusion of rapeseed and pumpkin seed cakes in diets for Murciano-Granadina goats alters the fatty acid profile of milk

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Abstract

The objective of this research was to assess the effects of including oil-rich feedstuffs in diets for lactating goats on the fatty acid (FA) profile of their milk. Thirty-six Murciano-Granadina goats were randomly assigned to three treatment groups, namely a control diet (CTRL), a diet based on whole rapeseed (RS), and a diet based on pumpkin seed cake (PSC). The diets were composed of 1 kg hay (70 % Italian ryegrass, 30% alfalfa) and 1.24 kg concentrate, and were formulated to be isoenergetic and isonitrogenous. Milk yield and its contents of protein, fat and lactose did not differ significantly among the groups. However, including oil-rich feeds in the diet altered the fatty acid profile of the milk significantly, decreasing its saturated fatty acid (SFA) content and increasing its content of unsaturated fatty acids (UFAs). Effects on polyunsaturated fatty acids (PUFAs), conjugated linoleic acid (CLA), and the n-6 to n-3 ratio depended on the source of dietary lipids. The PSC augmented diet increased the relative amount of PUFAs and fatty acid methyl esters (FAME) in milk (+25 %) significantly In comparison with CTRL, whereas the RS diet produced a limited and statistically insignificant increase (+7.5%). The concentration of CLA was higher in milk from does fed the PSC diet, whereas the n-6 to n-3 ratio was lower in milk from does fed RS. These preliminary results form the basis for developing premium dairy products that are enriched in fatty acids that are more favourable for human health.

Keywords: oilseeds, premium dairy products, unprotected dietary lipids
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Introduction

Although milk represents a major source of nutrients for human nutrition (Pereira 2014), there is concern that high consumption of milk fat (Ventto *et al.*, 2017) is a source of health problems for the consumers. The fat is one of the most important components of goat milk, because of its nutritional value, physical and sensory characteristics (Amigo & Fontecha, 2011). The main component of milk fat is represented by the triglycerides, made up of almost 60% SFA, about 30% monounsaturated fatty acids (MUFAs) and a lower content of PUFA, as a result of ruminal biohydrogenation (Valdez-Arjona & Ramírez-Mella, 2019). Indeed, the FA composition of the milk fat produced by ruminant animals was influenced significantly by ingestion of dietary lipids (Toral *et al.*, 2018).

Some SFAs that are common in milk, such as lauric acid (C12:0), myristic acid (C14:0), and palmitic acid (C16:0), are highlighted by nutritionists for their negative effects on consumer health, especially the risk of cardiovascular diseases. But milk and dairy products are a major source of SFAs for human nutrition (Gebreyowhans *et al.*, 2019). Consequently, researchers and practitioners try to find practical methods to improve the milk FA profile to lower the incidence of associated chronic diseases (Shingfield *et al.*, 2013) and even to enhance consumer health by providing them with functional foods. A more beneficial profile of FAs refers to increased amounts of unsaturated FAs (UFAs), with the emphasis on PUFAs (Morsy *et al.*, 2015) and a lower n-6 to n-3 PUFA ratio (Husted & Bouzinova, 2016).

Milk FA composition can change significantly in response to the feeding regimen (Ollier *et al.*, 2009) and the improvement of the quality of dairy products through tailored feeding strategies is a feasible and often successful approach. However, because of the high diversity of feed particularities and the complexity

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of the ruminal environment (for example on animal species and category), there are many gaps in knowledge of the effects of these strategies and on the mechanisms involved.

The most common feeding strategy to improve the milk FA profile is supplementation with dietary fat sources (Cappucci *et al.*, 2018; Kliem *et al.*, 2019; Gebreyowhans *et al.*, 2019), such as oilseeds. Oilseeds are rich sources of UFAs, predominantly oleic, linoleic and linolenic acid, and their inclusion in ruminant diets can lead to changes in the lipid metabolism and mammary secretion of FA. Oilseed cakes, which are by-products of the cold-press oil extraction process, are an underutilized protein source (Popović *et al.*, 2017) but have a fairly high content of residual fat.

The classical approach, with acknowledged positive effects on the ruminant milk FA profile, is the inclusion of linseed in the diet (Tudisco *et al.*, 2014; Martínez Marín *et al.*, 2015, Castro *et al.*, 2019). Also, the use of rapeseed (*Brassica napus*) in ruminant diets in the form of pure oil (Inglingstad *et al.*, 2017), rapeseed meal, rapeseed cakes and partially processed seeds (Schmidely, 2011; Lerch *et al.*, 2012; Brask *et al.*, 2013) was frequently reported, but results on the effects of whole seeds are scarce.

The lipids contained in rapeseed ('canola' in Canada and United States) are characterized by low quantities of SFAs (less than 7%) (Ghazani & Marangoni, 2016) compared with other common vegetable oils, which makes it an excellent choice as low SFAs are the target of diet formulation (Aukema & Campbell, 2011). When the whole seed is used, the strong pericarp could prevent rumen degradation (Huard *et al.*, 1998), thus the lipid fraction may have reduced vulnerability to ruminal biohydrogenation, leading to greater amounts of UFAs being available for further digestion and absorption processes (Hoffmann *et al.*, 2016). However, research results are incomplete and inconsistent.

Although sunflower, soybean, and rapeseed are processed mainly in factories that are able to extract most of the oil, the other oilseeds are processed in small factories, using cold-press extraction, which leads to by-products (cakes) that have a high content of residual oil, which is a valuable source of energy and of particular FAs for animal diets.

Pumpkin seed (*Cucurbita* sp.) cake is a good example. Pumpkin seeds are a valuable nutritional source, with positive effects in human diets (Patel, 2013) and are a high natural source of magnesium, vitamins and MUFAs, which are favourable for the heart function (Senyilmaz-Tiebe *et al.*, 2018). Pumpkin seed oil, which is still found in fairly high quantities in the cold-pressed cakes, is known for its strong antioxidant activity, being a highly unsaturated oil (Stevenson *et al.*, 2007). Various studies have confirmed the properties of *Cucurbita maxima* and *Cucurbita pepo L.* seeds, and their chemical composition, but, except for Klir *et al.* (2017), there are apparently no data on the inclusion of pumpkin seeds, oil and pumpkin seed cake in dairy goat diets.

The objective of the experiment was to assess the effects of two dietary strategies on the FA profile of milk produced by dairy goats, one based on RS and the other on PSC.

Material and methods

The experiment complies with Directive 2010/63/EU on the protection of animals used for scientific purposes. All the procedures involving animals were approved by the Ethical Commission of National Research and Development Institute for Biology and Animal Nutrition, Balotesti, Romania.

The experiment and was conducted at Agrivalahia dairy goat commercial farm, in south-east Romania beginning in mid August. It lasted for 28 days (seven days for adaptation to the diets and 21 days for data collection). Thirty-six multiparous Murciano-Granadina goats were randomly assigned to three dietary treatment groups CTRL (N = 12), RS (N = 12), and PSC (N=12). This resulted in groups of does that were comparable in age, days in milk (DIM) and milk yield (Table 1).

Table 1 Description of Murciano-Granadina dairy goats that were allotted to each treatment at the beginning of the experiment

	CTRL	RS	PSC
Age, years	4.00 ± 0.94	4.05 ± 1.44	4.15 ±1.44
Days in milk	243.33 ± 145.23	242.67 ± 139.43	243.00 ± 139.43
Average milk yield, kg/day	1.27 ± 0.43	1.25 ± 0.59	1.24 ± 0.59

CTRL: control, RS: rapeseed, PSC: pumpkin seed cake

The rapeseed *(Brassica napus)* in the experiment was produced by Agrivalahia farm and used in the goat diets as whole seeds. The pumpkin seed cakes (*Cucurbita maxima*) were purchased from a local oil producing company, S.C OLEOMET-S.A. S.R.L., which uses the cold-press method to extract oil, with a yield of approximately 60%. Rapeseed had a lower crude fat and higher crude fibre content than the values usually reported in the literature, whereas the pumpkin seed cake had a higher crude fibre content and, consequently, a lower protein and fat content (Table 2).

Table 2 Chemical composition and profile of fatty acids methyl esters for the main dietary ingredients used this study to feed lactating Murciano-Granadina dairy goats

Chemical composition		Rapeseed	Pumpkin seed cake	Hay[1]
Dry matter, g/kg		936.00	907.70	860.00
Organic matter, g/kg DM		958.34	924.86	932.38
Crude protein, g/kg DM		193.50	429.65	110.70
Crude fat, g/kg DM		305.90	112.37	8.48
Crude fibre, g/kg DM		194.60	230.80	444.88
Nitrogen-free extract, g/kg DM		264.23	152.03	368.32
Ash, g/kg DM		41.65	75.13	67.62
Fatty acids, g FAME/100 g total FAME				
Capric acid	C10:0		0.02	
Lauric acid	C12:0		0.01	
Myristic acid	C14:0	0.14	0.12	
Pentadecanoic acid	C15:0	0.04	0.08	
Palmitic acid	C16:0	5.15	12.30	
Palmitoleic acid	C16:1	0.32	0.16	
Heptadecanoic acid	C17:0	0.08	0.07	
Heptadecenoic acid	C17:1	0.17		
Stearic acid	C18:0	1.84	5.16	
Oleic cis acid	C18:1n9c	62.39	28.75	
Linoleic acid	C18:2n6	19.99	51.18	
Linolenic α acid	C18:3n3	8.26	0.49	
Linolenic γ acid	C18:3n3	0.03		
Octadecatetraenoic acid	C18:4n3	0.38	0.38	
Arachic acid	C20:0	0.04		
Eicosadienoic acid	C20:2n6	0.89	0.07	
Arachidonic acid	C20:4n6	0.07		
Behenic acid	C22:0		0.13	
Docosadienoic acid	C22:2n6		0.29	
Docosatrienoic acid	C22:3n6		0.19	
Eicosapentaenoic acid	C20:5n3		0.26	
Lignoceric acid	C24:0		0.29	
Other fatty acids		0.23	0.05	

[1] Italian ryegrass and alfalfa hay (70:30 mixture)
FAME: fatty acid methyl esters

All three diets were formulated to be isoenergetic and isonitrogenous (Table 3). Therefore, as the proportion of energy supplied by the dietary fats increased, the dietary carbohydrates decreased**,** with the amounts of corn and barley in the dietary treatments being adjusted accordingly. Likewise, the sunflower

meal was retained in the RS diet to compensate the low protein content of the rapeseed. However, inclusion of sunflower meal in the PSC diet was not necessary to maintain a protein content that was similar to the CTRL diet.

Table 3 Experimental diets for feeding lactating dairy goats and their nutritive contents

Ingredients	CTRL	RS	PSC
70% Italian ryegrass and 30% alfalfa hay, kg/day	1.00	1.00	1.00
Concentrate mixture, kg/day	1.24	1.24	1.24
Concentrate mixture ingredients, %			
Corn grains	54.90	46.80	48.40
Barley	29.00	28.20	37.10
Sunflower meal	13.70	10.50	
Whole rapeseed		12.10	
Pumpkin seed cake			12.10
Monocalcium phosphate	0.80	0.80	0.80
Calcium carbonate	0.80	0.80	0.80
Salt	0.80	0.80	0.80
Nutritional content of the diets			
Dry matter, kg/day	1.92	1.92	1.91
Net energy for lactation, UFL[1]/kg DM/day)	1.81	1.83	1.81
PDIN[2], g/day	167.90	168.40	167.60
PDIE[3], g/day	187.40	174.09	181.40
Ether extract, g/day	43.49	100.17	61.30
Calcium, g/day	12.40	12.71	12.59
Phosphorus, g/day	8.57	8.59	8.41

CTRL: control, RS: rapeseed, PSC: pumpkin seed cake
[1] Milk feed unit, according to INRA system, 2007; 1 UFL = 1700 kcal
[2] Protein truly digested in the small intestine when the protein is the limiting factor, according to INRA system, 2007
[3] Protein truly digested in the small intestine when the energy is the limiting factor, according to INRA system, 2007

The goats were group-fed with restricted quantities to meet their nutritional requirements, calculated based on their weight, physiological status and targeted milk production. The animals had permanent access to fresh water. The goats were milked twice a day, at 06h00 and 16h30. Milk yield was recorded individually, and two sets of milk samples were collected individually, two days consecutively, at the end of the experiment: one set in 50 mL tubes, for proximate analyses and one set in 100 mL tubes, for FA determination. The proximate analyses were performed on the sampling day. To determine FAs, the samples were stored at -20 °C until the analyses were done.

The crude protein (CP) of the dietary ingredients was established with the Kjeldahl reference method using a semiautomatic Kjeltek auto 1030 (FOSS Tecator AB, Höganäs, Sweden) according to SR EN ISO 5983-2:2009 (International Organization for Standardization, 2009). The fat was extracted with continuous extraction in solvent, followed by fat measurement with Soxhlet after solvent removal (FOSS Tecator AB, Höganäs, Sweden) (SR ISO 6492: 2001) (International Organization for Standardization, 2001). Dry matter was measured with a gravimetric method after drying samples at 103 °C to constant weight in an oven (BMT model ECOCELL Blueline Comfort, Nuremberg, Germany) (Regulation (CE) 152/2009) and crude ash was ascertained by heating the samples at 550 °C for 24 hours using an ashing furnace (Nabertherm Labotherm L15/11/ P320 Comfort, Bremen, Germany) (Regulation (CE) 152/2009).

Milk fat, protein and lactose were determined by FTIR rotation scanning (FTIR LactoScope) with a CombiScope FTIR 200 device (Delta Instruments, Drachten, Holland) (ISO 9622:2013).

The FA composition of the milk and dietary ingredients was determined by gas chromatography (SR EN ISO 12966-2:2017 and SR CEN ISO/TS 17764-2:2008). Perkin Elmer gas chromatograph (Clarus 500,

USA) with capillary column injection system, flame ionization detector (FID) and column of high polarity stationary phase (SGE forte GC capillary column BPX70, 60 m; 0.25 mm inner diameter) were used to verify FAME.

The effects of diets were assessed with the general linear model procedure of Minitab software (version 16, Minitab® Statistical Software), with treatment as a fixed effect, according to this model:

$$y_{ij} = \mu + t_i + e_{ij}$$

where: Y_{ij} = the dependent variable,
t_i = the treatment and
ei_i = the error.

The analysis of variance was followed by Tukey's test to distinguish the significant differences among the diets. Statistical significance was declared at P <0.05. For P-values between 0.05 and 0.10, the differences were regarded as indicating tendencies.

Results and discussion

The most abundant FA in rapeseed is oleic acid, followed by linoleic, linolenic and palmitic acids. In PSC, linoleic acid had the highest proportion, followed by oleic and palmitic acid (Table 3). Their concentrations were in the range reported by other authors (Mitra *et al.*, 2009; Rezig *et al.*, 2012). Although the level of dietary fat supply varied among the three groups, the FA profile of the feeds (RS, PSC) determined the FA supplies of the overall diets. For instance, RS group was fed a higher quantity of fat than PSC group, but the palmitic acid supplementation was still lower for animals consuming rapeseed.

Goat milk yield and proximate milk quality were not influenced significantly by the experimental diets (Table 4). Previous studies such as Chichlowski *et al.* (2005), Ollier *et al.* (2009) and Schmidely & Andrade (2011) reported that higher yields of fat, protein and lactose were induced by the inclusion of rapeseed products such as ground canola seed, intact rapeseed and rolled canola seed in the diets for ruminants. In the present study, the RS group produced a non-significant but numerically higher milk yield and milk protein and fat content than the other two treatments. These divergent results might be partly explained by dietary energy and protein being nearly identical among the groups.

Table 4 Milk yield, milk constituents yield and milk composition for dairy goats fed a control diet, a diet supplemented with rapeseed and a diet supplemented with pumpkin seed cake

Specification	CTRL	RS	PSC	SE	*P*-value
Milk yield, kg/day	1.28 ± 0.10	1.41 ± 0.09	1.24 ± 0.12	108.2	0.517
Milk fat, %	4.42 ± 0.22	4.12 ± 0.18	4.74 ± 0.31	0.248	0.204
Milk protein, %	3.74 ± 0.12	3.67 ± 0.12	3.94 ± 0.18	0.145	0.447
Lactose, %	4.53 ± 0.05	4.61 ± 0.06	4.46 ± 0.04	0.053	0.149
Fat yield, g/day	53.31 ± 3.36	55.12 ± 2.81	52.02 ± 4.24	3.572	0.826
Protein yield, g/day	46.08 ± 3.12	49.93 ± 2.44	45.08 ± 4.14	3.381	0.567
Lactose yield, g/day	58.53 ± 4.80	65.18 ± 4.34	55.12 ± 5.43	4.978	0.353

CTRL: control, RS: rapeseed, PSC: pumpkin seed cake

Members of bacterial and protozoal communities hydrolyse the complex dietary lipids (e.g. triacylglycerols, phospholipids, and glycolipids) into long-chain fatty acids (LCFA), glycerol, and other organic compounds in the rumen (Buccioni *et al*., 2012). Rumen microorganisms responsible for hydrolysis of esterified lipids exist in small numbers, but their activity is highly specific and efficient, leading to a large proportion of dietary lipids (85–95%) reaching the duodenum in form of free FA (Loften *et al.*, 2014a). The FAs in goat milk come from FA de novo synthesized in the mammary gland (mainly short- and medium-chain SFA) or from plasma fatty acids absorbed through the ruminal wall, that is, LCFA and MUFAs (Kompan & Komprej, 2012). Medium-chain SFA decreased, whereas LCFA increased (Table 5), suggesting that the increase of the lipid supply in the diets was associated with a decrease of de novo synthesis of FA.

Caproic acid in the milk increased for both the RS and PSC groups (P =0.025), whereas the proportions of caprylic and capric acids were not influenced by the diet. Caprylic, capric and caproic acids are responsible for the characteristic odour and flavour of goat milk (Amigo & Fontecha, 2011) and represent approximately 15–18% of the total FAs compared with only 5–9% in cow's milk. These FAs have higher digestibility than LCFA and their being saturated is not viewed as problematic owing to their direct availability as an energy source and because they are not stored in body tissues (Verruck *et al.*, 2019).

The lauric acid content of the milk in the present study was reduced significantly in both RS and PSC groups in contrast to CTRL. Also, myristic and palmitic acids decreased significantly in both groups compared with CTRL, the decrease being more striking for the RS group. The cholesterol-raising potency of the SFAs was lower in the stearic acid (C18:0) but higher in the palmitic (C16:0), myristic (C14:0) and lauric (C12:0) acids, the latter two being highly and positively correlated with higher cholesterol levels (German & Dillard, 2010). Myristoleic (n-5) and palmitoleic acids (n-7), which are constituents of the glycerides of human adipose tissue, are biosynthesized from myristic and palmitic acid respectively. In the present study, they decreased with that their precursors.

Table 5 Fatty acid methyl ester profile of goat milk, expressed as g/ 100 g total FAME

Fatty acid		CTRL	RS	PSC	SE	*P*-value
Caproic acid	C6:0	1.27 ^{b}	1.46^{a}	1.44^{ab}	0.054	0.025
Caprylic acid	C8:0	3.12	3.26	3.32	0.133	ns
Capric acid	C10:0	12.52	11.86	12.11	0.304	ns
Undecanoic acid	C11:0	0.49	0.45	0.51	0.169	0.076
Lauric acid	C12:0	7.24^{a}	5.82^{b}	6.03^{b}	0.201	<0.001
Myristic acid	C14:0	12.67^{a}	10.79^{b}	11.75^{a}	0.277	<0.001
Myristoleic acid	C14:1	0.82^{a}	0.63^{b}	0.71^{ab}	0.034	0.001
Pentadecanoic acid	C15:0	0.28	0.27	0.28	0.010	ns
Pentadecenoic acid	C15:1	1.14	1.06	1.00	0.058	ns
Palmitic acid	C16:0	28.28^{a}	22.50^{c}	25.59^{b}	0.585	<0.001
Palmitoleic acid	C16:1	2.22^{a}	1.68^{b}	1.88^{b}	0.073	<0.001
Heptadecanoic acid	C17:0	0.36^{a}	0.32^{b}	0.36^{a}	0.010	0.005
Stearic acid	C18:0	5.84^{c}	9.72^{a}	7.13^{b}	0.360	<0.001
Oleic acid	C18:1n9-cis	18.33^{c}	24.53^{a}	21.70^{b}	0.579	<0.001
Linoleic acid	C18:2n6-trans	0.33^{c}	0.50^{a}	0.41^{b}	0.023	<0.001
Linoleic acid	C18:2n6-cis	1.93^{b}	1.92^{b}	2.59^{a}	0.073	<0.001
Linolenic α acid	C18:3n3	0.29^{b}	0.36^{a}	0.27^{b}	0.016	<0.001
Conjugated linoleic acid	CLA (c9, t11)	0.38^{ab}	0.30^{b}	0.42^{a}	0.027	0.008
Eicosadienoic acid	C20:2n6	0.10^{c}	0.19^{a}	0.13^{b}	0.008	<0.001
Other fatty acids		1.25^{a}	1.13^{b}	1.24^{a}	0.025	0.001
SFA, %		72.48^{a}	66.79^{b}	68.82^{b}	0.613	<0.001
MUFA, %		22.95^{c}	28.32^{a}	25.73^{b}	0.578	<0.001
PUFA, %		3.32^{b}	3.57^{b}	4.13^{a}	0.101	<0.001
UFA, %		26.27^{b}	31.89^{a}	29.86^{a}	0.604	<0.001
n-3 fatty acids		0.33^{b}	0.42^{a}	0.34^{b}	0.018	0.001
n-6 fatty acids		2.60^{b}	2.85^{b}	3.38^{a}	0.087	<0.001
ratio of n-6 to n-3 fatty acids		8.14^{b}	7.09^{b}	10.42^{a}	0.405	<0.001

FAME: fatty acid methyl ester: CTRL: control, RS: rapeseed, PSC: pumpkin seed cake, SFA: saturated fatty acids, MUFA: monounsaturated fatty acids, PUFA: polyunsaturated fatty acids

[a,b,c] Within a row, means with a common superscript were not significantly different

Although the proportion of heptadecanoic acid (C:17) in the total SFAs of ruminant milk is small, it is considered a biomarker of fat intake by consumers (Pfeuffer & Jaudszus, 2016). It decreased in RS group (P =0.005), but was not influenced by the inclusion of PSC in the diet.

Stearic acid, a product of PUFA biohydrogenation, increased in the milk from both experimental groups. This was associated with higher supplies of dietary unsaturated fat (compared with CTRL), which led to extensive biohydrogenation processes and finally to higher amounts of stearic acid leaving the rumen, as explained by Lock (2006) and reviewed by Loften *et al.* (2014), who concluded that the flow of C18:0 from the rumen may be several times greater (six times according to Wu *et al.* (1991)) than the amount consumed by the animal. Dietary C18:0 appears to have some beneficial effects on human health (Senyilmaz-Tiebe *et al.*, 2018). Unlike other SFAs, C18:0 does not increase the risk of atherosclerosis and reduces LDL cholesterol (Senyilmaz-Tiebe *et al.*, 2018). However, the most significant MUFA in nature, namely oleic acid, which is synthesized during the desaturation of C18:0 fatty acids inside the mammary epithelial cells (Shi, 2019), showed a significant positive response to lipid supplementation, which was more visible in the RS diet.

Despite the low transfer efficiency from dietary to milk PUFA, caused by the ruminal biohydrogenation process (Lopez *et al.*, 2019), PUFA quantities in ruminant milk are related strongly to the ingested amounts of these FAs (Khiaosa-Ard, 2010). The content in goat milk of linoleic acid (LA) was enhanced through administration of PSC (a rich source of LA) (Table 2) and the α-linolenic acid (ALA) content increased in the milk from the RS group (P <0.001).

Linoleic acid is the main precursor of CLA. Supplementation with dietary LA is often used as a strategy for enriching the ruminant milk CLA. The CLA content in the milk from the PSC group was significantly higher than in RS group, results that were in line with the previous findings.

Even if the n-3 FA content was increased significantly in the milk from RS group, the n-6 to n-3 ratio was not statistically decreased compared with CTRL. However, it was lower than PC group, where a negative effect was noticed on the n-6 to n-3 ratio, presumably because of the high amount of linoleic acid, which contributed to a significant increase in total n-6 FAs.

Both RS and PSC diets had positive effects on the total SFA content of the milk, which decreased (P <0.001), and on the total UFA content, which increased (P <0.001). Also, milk MUFA content increased in both groups (P <0.001) compared with CTRL, but to a higher extent in RS than PC. On the other hand, the PSC diet led to greater quantity of total PUFAs (+25%) (P <0.001) and higher n-6 to n-3 ratio, compared with the RS diet.

Conclusions

Alteration of dietary lipids by feeding RS and PSC in diets that were isocaloric and isonitrogenous did not have a detectable effect on milk yield or its proximate composition. However, the RS and PSC augmented diets both led to more beneficial FA profiles of the milk. Thus, including these ingredients in diets for lactating dairy goats could provide a means of producing premium milk products locally. These strategies rely on local and affordable feedstuffs, which meet the needs of farmers and consumers.

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Authors' Contributions

All authors contributed equally.

Conflict of Interest Declaration

The authors declare that there is no conflict of interest.

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