Effects of dietary supplementation with extruded linseed and oregano in autochthonous goat breeds on the fatty acid profile of milk and quality of Padraccio cheese

C. Cosentino,[1] M. A. Colonna,[2] M. Musto,[1] A. Dimotta,[3] P. Freschi,[1] S. Tarricone,[2*] M. Ragni,[2] and R. Paolino[1]

[1]School of Agricultural, Forestry, Food, and Environmental Sciences, University of Basilicata, Viale dell'Ateneo Lucano, 10, 85100 Potenza, Italy
[2]Department of Agricultural and Environmental Science, University of Bari Aldo Moro, Campus Universitario Ernesto Quagliariello, 70126 Bari, Italy
[3]Earth and Eco-System Expertise for Environmental Modeling and Restoration Company (EESEEMR), Synergy Center ITT Dublin, TU Dublin - Tallaght Campus, Dublin 24, D24 A386, Ireland

ABSTRACT

The study aimed to evaluate the effects of linseed and oregano supplementation to the diet of goats on fatty acid profile and sensory properties of Padraccio, a typical cheese produced during spring through summer in the Basilicata region (southern Italy). Extruded linseed and dried oregano inflorescences were integrated in the pelleted concentrate supplementation (500 g/head per day) in 21 grazing goats that were randomly assigned, 7 per group, to the following experimental treatments: concentrate, concentrate with addition of linseed, and concentrate with addition of linseed and oregano. Pooled milk from each group was used in cheesemaking. From a nutritional perspective, integration of extruded linseed in the goat diet improved the fatty acid profile of Padraccio cheese. Moreover, the cheese from this group evidenced the highest scoring on color, flavor, texture, and overall liking.

Key words: biodiversity, goat milk, linseed, fatty acid, Padraccio cheese, sensory analysis, autochthonous goat

INTRODUCTION

Ruminant milk fatty acid (FA) composition can be affected by feeding regimen. In particular, lipid supplementation has variable effects that depend on the added lipids and their interaction with types of forage and concentrate in the diet (Antongiovanni et al., 2003; Chilliard et al., 2003). Moreover, several studies (Renna et al., 2012; Cosentino et al., 2018; Valentini et al., 2018) show a strong relationship between the diet of lactating animals and the aromatic quality of milk and dairy products. Several oilseeds, such as sunflower and linseed, have been widely used in diets for small ruminants because they are rich in PUFA, which positively influence the FA profile of animal products, and thus have beneficial effects for human health (Giannico et al., 2009; Colonna et al., 2011; Facciolongo et al., 2018). In particular, linseed provides high amounts of dietary α-linolenic acid, which can represent more than 50% of total FA (Renna et al., 2013). In lactating goats, linseed has been used as whole (Luna et al., 2008), crushed (Kholif et al., 2015), extruded (Nudda et al., 2006; Bennato et al., 2020), or oil (Martínez Marín et al., 2012). Nudda et al. (2006) reported that the highest contents of CLA and vaccenic FA were found in the milk of grazing cows and sheep whose diet was supplemented with unsaturated oil, such as plant oils and seeds (soybean, sunflower, peanut, and linseed). Morsy et al. (2015a,b) evidenced that diets of dairy goats supplemented with whole sunflower seeds or sunflower seed oil increased milk production and milk fat content with a decrease of total SFA and an increase of total CLA. Luna et al. (2008) and Chilliard et al. (2009) evidenced that linseed and sunflower oils in the diets of lactating goats changed FA composition with a slight decrease of the secretion of medium-chain FA and a noticeable increase of α-linolenic, rumenic, and vaccenic acids. These characteristics were found also in processed cheese (Morsy et al., 2015a, b). Conjugated linoleic acids and n-3 FA have been shown to be beneficial and helpful for human health, especially for their protection against carcinogenesis, atherosclerosis, diabetes, inflammation, cardiovascular, and autoimmune diseases (Cosentino et al., 2016; Saturino et al., 2017; Forte et al., 2018). The importance of goat milk has grown due to its peculiar nutritional properties and sensory characteristics (Spiel et al., 2016). Modifications in milk FA composition through nutrition might result in positive or adverse changes in the flavor and nutritional properties of goat cheese. The characteristic flavor of goat cheese, for instance, is particularly affected by the content of short and medium-chain FA (C6 to C10). Considering that more and more consumers are demanding dairy products with a special flavor closely connected with the grazing characteristics, our goals in the present study were to assess the influence of linseed and dried oregano inflorescences supplementation in goat diet on chemical and sensory properties of Padraccio cheese. Such cheese is a typical product of the Basilicata region, obtained with sheep, goat, or mixed milk during spring and summer. It has no rind, and its white mixture is soft, quite elastic, acidic, and of low aromatic intensity. Being a fresh cheese of limited production and easily perishable, it is sold locally and, for this reason, it is almost unknown outside the production area.

MATERIALS AND METHODS

Animals, Diet, Management, and Cheese Making

The trial was carried out in spring in a dairy farm located in Matera province (latitude: 40.3785846, longitude: 16.1454083, 700 m above sea level). During spring 2019, 21 local goats of the autochthonous Facciuta breed were divided into 3 groups of 7 subjects each. Within each group, all of the goats had the same weight, parity, and milk yield. Groups were randomly assigned to 3 different formulations of the individual concentrate integration: 500 g/d of concentrate (**CON**); 500 g/d of concentrate + 3% extruded linseed (**L**); 500 g/d of concentrate + 3% extruded linseed + 0.6% dried oregano inflorescences (**LO**; Table 1). To meet the nutritional requirements of goats (INRA, 1988), supplementation was formulated to be isocaloric and isonitrogenous. Goats were fed on 500 g/head of pelleted feed in the stable after grazing at 1800 h in a spontaneous pasture characterized by several shrubs and grass species such as *Spartium* spp., *Rosa canina*, *Prunum spinosa*, *Quercus pubescens*, *Lolium perenne*, *Festuca* spp., *Trifolium pratense*, *Cichorium sativus*, *Avena fatua*, *Avena sterilis*, *Foeniculurn* spp., *Vicia sativa*, *Onobrychis viciifolia*, *Lotus corniculatus*, and *Thymus serpyllum*. Water was available at all times.

After a period of 60 d, pooled milk from each treated group (CON, L, LO) was used to produce Padraccio cheese. Goat milk was first pasteurized at 68°C for 15 min, and when temperature was dropped to 42°C, each vat (CON, L, LO) was inoculated with a starter culture of *Streptococcus thermophilus* (Lyofast ST 022 F, Sacco, Como, Italy). After 30 min, 1 mL of calf rennet (strength units 1:10,000; Prodor, Piacenza, Italy) was added per 10 L of pooled milk, and within an hour, the curd was obtained. Successively, the curd was broken into the size of rice grains and hand-worked until it took on the characteristic spherical shape. Fresh cheeses measuring 15 cm in diameter were then salted with dry salt and put into semispherical plastic molds. Eight cheeses were obtained for each group test.

Chemical Composition of Feeds, Milk, and Cheese

At the beginning of the trial, pasture samples were collected along transects according to methods from Freschi et al. (2015, 2016, 2017) and Rizzardini et al. (2019). Grass samples were dried in a stove, homogenized, and analyzed. Samples of the pelleted feeds and dried pasture were ground in a hammer mill with a 1-mm screen and analyzed using the following AOAC International (2004) procedures: DM (method 934.01), fat (method 920.39), ash (method 942.05), CP (method 954.01), crude fiber (method 945.18), ADF and ADL (method 973.18), and NDF (method 2002.04).

Individual milk samples were collected twice per day (at 0700 and 1800 h), stored at 4°C, and immediately transported to the laboratory for the analysis of fat, protein, lactose, and total solids with an infrared milk analyzer (Milkoscan 133-B, Foss Electric, Hillerod, Denmark) previously standardized for goat milk. Cheese samples were homogenized and lyophilized. Fat content was determined by the Soxhlet method (AOCS, 1996) and expressed as fat in DM. Total nitrogen was determined by the Kjeldahl method (AOAC, 1995) and expressed as protein content (nitrogen content × 6.38). In milk and cheese samples, ash content was detected

Table 1. Composition (%) of the experimental diets

	Treatment[1]		
Component	CON	L	LO
Dehulled soybeans (37%)	6.00	6.00	6.00
Corn	31.00	31.00	30.04
Barley	9.00	9.00	9.00
Wheat flour shorts	9.00	9.00	9.00
Fava bean	10.00	8.50	8.50
Bran	10.00	10.00	10.00
Sugar beet pulp dehydrated	6.00	6.00	6.00
Extruded linseed	—	3.00	3.00
Soybean oil	1.00	—	—
Sunflower meal	8.00	7.50	7.50
Molasses	3.00	3.00	3.00
Soybean hulls	4.00	4.00	4.00
Oregano (dried inflorescences)	—	—	0.06
Vitamin mineral premix	3.00	3.00	3.00

[1]CON = control feed; L = control feed + 3% extruded linseed; LO = control feed + 3% extruded linseed + 0.6% oregano.

after burning a lyophilized sample in a muffle furnace at 550°C for 5 h.

Fatty Acid Profiles of Feeds, Milk, and Cheese

Total lipids were extracted from the homogenized samples (100 g) according to the chloroform and methanol method described by Folch et al. (1957). Fatty acids were methylated by using a BF3-methanol solution (12% vol/vol; Christie, 1982). The FA profile was assessed with a Chrompack CP 9000 gas chromatograph with a silicate glass capillary column (70% cyanopropyl polysilphenylene-siloxane BPX 70 of SGE Analytical Science, Chebios S.r.l., Rome, Italy; length: 50 m; internal diameter: 0.22 mm; film thickness: 0.25 μm). The temperature program was 135°C for 7 min, followed by increases of 4°C per minute up to 210°C. Fatty acid peaks were identified by using a comparative analysis with standard reference mixtures. The fatty acid content was expressed as the percentage of total FAME (Table 2).

For cheese, FA methyl esters were prepared by direct transesterification (IUPAC, 1987, method 2.301). Fatty acid analysis was performed according to the procedure described by Caponio et al. (1998) using a capillary gas chromatograph (Fison high-resolution gas chromatography, HRGC Mega 2 series; Milan, Italy) equipped with a flame ionization detector fitted with wall-coated open tubular fused-silica capillary column (FFAP-CB coating, 25 m × 0.32 mm i.d. × 0.30 μm film thickness; Chrompack, Middleburg, the Netherlands). The separation was performed at preprogrammed temperatures as follows: 50°C for 3 min; 50 to 100°C at a rate of 20°C/min; 100°C for 2 min; 100 to 240°C at a rate of 20°C/min; 240°C for 15 min. Hydrogen was the carrier gas (flow rate, 2 mL/min). The injector temperature was 270°C (splitting ratio, 1:17), and the detector temperature was 300°C. Fatty acid peaks were identified by a comparative analysis with standard reference mixtures. Fatty acid content was expressed as percentage of the total identified FA.

Texture Profile Analysis

Evaluation of the rheological properties of Padraccio cheese was performed by Instron 5544 Universal Testing

Table 2. Chemical composition (% DM) and fatty acid profile (% FAME) of pasture, hay, and pelleted feeds

			Treatment[1]		
Variable	Pasture	Hay	CON	L	LO
Chemical composition					
DM (%)	15.68	89.50	88.40	89.10	89.30
CP	20.11	10.72	15.78	16.18	15.58
Fat	3.75	1.37	3.61	3.83	4.06
Ash	11.71	9.58	10.16	11.55	9.61
Crude fiber	21.69	33.94	9.09	8.67	8.33
N-free extracts	42.73	44.40	61.37	59.77	62.42
NDF	52.33	60.38	39.74	32.89	36.10
ADF	27.28	37.43	10.06	10.11	9.81
ADL	10.22	9.31	1.98	1.79	1.94
AIA[2]	0.58	0.72	0.21	0.25	0.34
Fatty acid					
C14:0 (myristic)	0.35	0.60	0.12	0.08	0.10
C15:0	0.05	0.09	0.06	0.03	0.03
C16:0 (palmitic)	13.98	13.45	15.14	12.50	13.35
C18:0 (stearic)	1.05	3.03	2.91	3.83	3.31
C18:1n-9 *cis* (oleic)	9.50	12.13	28.68	26.43	27.01
C18:2n-6 (linoleic)	15.37	31.00	45.82	36.27	36.14
C18:3n-3 (α-linolenic)	52.51	2.57	0.49	0.42	0.32
C18:3n-6 (γ-linolenic)	0.03	12.96	2.96	17.93	17.73
C20:4n-6 (arachidonic)	0.02	4.73	0.17	0.07	0.07
C22:5n-3 (DPA)	0.03	0.00	0.47	0.24	0.19
Total SFA[3]	20.57	18.04	18.39	16.55	16.84
Total MUFA[4]	10.67	22.96	29.54	27.09	27.49
Total PUFA[5]	68.06	54.42	50.28	55.06	54.55

[1]CON = control feed; L = control feed + 3% extruded linseed; LO = control feed + 3% extruded linseed + 0.6% oregano.

[2]AIA = acid insoluble ash.

[3]Sum of C12:0 + C14:0 + C15:0 + C16:0 + C17:0 + C18:0 + C22:0 + C24:0.

[4]Sum of C16:1n-7 + C18:1 *trans*-9 + C18:1 *cis*-9.

[5]Sum of C18:2 *cis*-9,*cis*-12 + C18:2 *cis*-9,*trans*-11+ C18:3 + C20:4 + C18:3 + C20:3 + C20:5 + C22:6.

Machine (Instron Corp., Canton, MA) equipped with a flat steel probe with 25-mm diameter, which simulated the conditions applied during mastication through a double compression test (texture profile analysis) produced by the incorporated software. The following experimental conditions were adopted: preload = 0.05 N; test speed = 1 mm/s; deformation = 50%. For each experimental group, cheese cubes of 1-cm side, kept at 20°C for 30 min, were evaluated in triplicate. Deformation (mm), springiness (mm), gumminess (N). and chewiness (N × mm) were evaluated.

Consumer Test

The acceptability was evaluated by 95 habitual consumers of cheese (48 men and 47 women, aged 18–71 yr). Consumer recruitment was carried out at the University of Basilicata (Potenza, Italy) and the University of Bari (Bari, Italy) campuses. A small amount (20 g) of each type of cheese (CON, L, LO) was identified by random 3-digit codes and served in random order under white fluorescent lighting to consumers. They were asked to evaluate color, odor, flavor, and texture using a 9-point hedonic scale (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither dislike nor like, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely). The consumer test was performed in individual booths.

Statistical Analysis

The experiment was conducted twice, and data were pooled and subjected to ANOVA. Means were separated and compared by Tukey's HSD.

RESULTS

Chemical and FA Composition of Milk

Diets L and LO resulted in a significantly ($P < 0.01$) lower DM in milk (Table 3). The CON diet showed a significantly higher concentration ($P < 0.05$) of N-free extracts in comparison with L and LO. Diet did not affect neither the CP nor the fat content concentration of goat milk. In accordance with our findings, Nudda et al. (2006) reported that the fat and protein concentrations of goat milk were not influenced by the addition of extruded linseed to the diet. Conversely, Rotondi et al. (2018) found that dietary linseed supplementation, with or without oregano, resulted in a slight increase in the ether extract content of goat milk, but it did not affect protein concentration. Supplementation to the dairy cow diet with 500 g of oregano leaves/d showed an increase in milk fat percentage and yield (Tekippe et al., 2011).

The FA composition of goat milk was significantly influenced by diet (Table 3). Dietary supplementation with extruded linseed, with or without oregano, increased ($P < 0.05$) butyric (C4:0) and caproic (C6:0) acid concentrations significantly along with the total short-chain FA content. This result agrees with Bennato et al. (2020), who studied milk from dairy goats fed a diet containing 10% extruded linseed. Dietary lipid source is known to have potential effects on milk FA profile because PUFA obtained by diet exert an inhibiting action on the synthesis of FA in the mammary gland (Nudda et al., 2014). The FA from C6:0 to C14:0 are synthesized ex novo by the mammary gland, while longer chain FA derive both from the diet and from synthesis ex novo. Also, Kholif et al. (2015) found a significant increase of short-chain FA concentration in milk of goats fed with extruded linseed or linseed oil. Among SFA, milk obtained from the CON group showed a significantly higher ($P < 0.05$) level of C18:0 and C20:0 in comparison with the L diet. This result agrees with previous findings in milk from dairy goats: Bennato et al. (2020) reported that dietary extruded linseed resulted in a significant increase of stearic acid (C18:0), which is the final product of the biochemical process of ruminal PUFA biohydrogenation.

In this study, the CON diet resulted in a markedly higher concentration of long-chain FA compared with the diets containing extruded linseed. Moreover, milk obtained from the CON group showed a significantly higher ($P < 0.01$) content of linoleic acid (C18:2n-6) with respect to the LO diet. Conversely, the 2 diets containing extruded linseed determined a significant ($P < 0.01$) increase of the α-linolenic acid concentration in milk in comparison with the CON group. Several studies reported that extruded linseed positively affects the FA profile of milk by enhancing the concentration of FA favorable to human health, such as those of the n-3 series and CLA (Devle et al., 2012; Renna et al., 2013). It is known that goat milk is different from cow milk due to its whey protein content and to the structure of the insoluble and soluble proteins and small fat globules resulting in better digestibility, especially for people with various disorders such as gastrointestinal disturbances (Morsy et al., 2015a; Spiel et al., 2016).

Chemical-Nutritional Composition of Padraccio Cheese

Comparison between LO and CON groups evidenced a lower ($P < 0.05$) crude protein content in LO cheese (Table 4). This result is in contrast with Mohamed et al. (2013), who did not find any significant effect of diets containing different essential oils on cheeses obtained from lactating goats. Also, Morsy et al. (2014) reported that supplementation with flaxseed or flaxseed oil had no significant effect on the cheese composition in lactating goats.

The supplementation with extruded linseed, with or without oregano, did not influence the concentration of FA from C4:0 to C13:0 (Table 4). The CON diet resulted in a significant ($P < 0.05$) increase of C14:0, C18:0, and C20:0 in comparison with L and LO. The decrease of the concentration of myristic and stearic acids is beneficial for human health because these acids are known to have hypercholesterolemic and thrombogenic effects in humans (Ulbricht and Southgate, 1991). The 2 extruded linseed-based diets resulted in a significant ($P < 0.05$) increase of the concentration of medium-chain and short-chain FA. The LO diet provided the highest concentration of C20:5n-3 (EPA), with significant differences ($P < 0.01$) in comparison with both the L and CON groups. The growing attention of consumers on the nutritional and health aspects of food has recently shifted the focus of milk producers toward achieving an

Table 3. Chemical and fatty acid (FA) composition of goat milk (mean ± SEM)

	Treatment[1]			
Variable	CON	L	LO	SEM
Chemical composition (% DM)				
DM	11.67^{A}	11.00^{AB}	10.08^{B}	0.336
CP	3.57	3.5	3.57	0.116
Fat	2.66	2.55	1.95	0.325
Ash	0.77	0.78	0.78	0.012
N-free extracts	4.83^{a}	4.17^{b}	3.79^{b}	0.299
FA composition (% FAME)				
C4:0	0.81^{b}	1.15^{a}	1.12^{a}	0.088
C6:0	1.14^{b}	1.41^{a}	1.40^{a}	0.073
C8:0	1.73	2.25	2.01	0.186
Short-chain FA	3.69^{b}	4.82^{a}	4.53^{a}	0.305
C10:0	7.75	8.69	7.47	0.556
C11:0	0.06	0.08	0.06	0.016
C12:0	3.58	3.55	3.29	0.270
C13:0	0.08	0.10	0.08	0.011
C14:0	9.13	8.87	9.30	0.452
C15:0	0.85	0.86	0.97	0.052
C16:0	25.67	25.93	24.80	0.690
C17:0	0.65	0.60	0.65	0.056
Medium-chain FA	47.78	48.64	46.62	1.254
C18:0	12.94^{a}	10.10^{b}	12.22^{ab}	0.816
C20:0	0.80^{a}	0.57^{b}	0.69^{ab}	0.064
C21:0	0.18	0.19	0.14	0.035
Long-chain FA	13.92^{a}	10.86^{b}	13.05^{ab}	0.814
Σ SFA	67.90	66.58	67.95	0.626
C14:1	0.43	0.44	0.41	0.037
C15:1	0.29	0.23	0.28	0.022
C16:1 *trans*	0.27	0.26	0.27	0.016
C16:1 *cis*	0.45	0.41	0.32	0.056
C17:1	0.18	0.16	0.20	0.023
C18:1n-9 *trans*	1.17	1.58	1.16	0.152
C18:1n-9 *cis* (oleic)	21.70	22.93	22.98	1.301
C20:1n-9	0.17	0.12	0.10	0.029
C24:1n-9	0.43	0.44	0.41	0.037
Σ MUFA	26.40	24.91	25.41	1.318
C18:2n-6 *trans*	0.22	0.30	0.33	0.033
C18:2n-6 *cis* (linoleic)	3.90^{A}	3.37^{AB}	3.00^{B}	0.208
C18:2 *cis*-9,*trans*-11 (CLA)	0.15	0.18	0.18	0.083
C18:2 *trans*-10,*cis*-12 (CLA)	0.05	0.08	0.09	0.004
C18:3n-6 (γ linolenic)	0.56	0.78	0.68	0.082
C18:3n-3 (α linolenic)	0.04^{B}	0.10^{A}	0.15^{A}	0.009
C20:2n-6	0.06	0.07	0.07	0.008
C20:3n-3	0.036	0.043	0.042	0.001
Σ PUFA	4.67	4.59	4.59	0.196

[A,B]Different uppercase letters in the same row represent significant difference: $P < 0.01$.

[a,b]Different lowercase letters in the same row represent significant difference: $P < 0.05$.

[1]CON = control feed; L = control feed + 3% extruded linseed; LO = control feed + 3% extruded linseed + 0.6% oregano.

Table 4. Chemical and fatty acid (FA) composition of Padraccio cheese (mean ± SEM)

Variable	Treatment[1] CON	L	LO	SEM
Chemical composition (% DM)				
DM	48.41	48.04	47.30	0.434
CP	16.89[a]	16.45[ab]	16.15[b]	0.182
Fat	22.17	22.47	22.49	0.195
Ash	8.91	8.87	8.29	0.269
N-free extracts	0.44	0.27	0.38	0.125
FA composition (% FAME)				
C4:0	1.74	1.51	1.72	0.089
C6:0	2.09	1.89	1.95	0.114
C8:0	2.67	2.45	2.53	0.125
C10:0	9.16	8.50	9.01	0.271
C11:0	0.12	0.10	0.11	0.038
C12:0	3.57	3.29	3.35	0.074
C13:0	0.06	0.05	0.05	0.002
C14:0	8.73[a]	8.25[b]	8.29[b]	0.131
C15:0	0.89	0.87	0.90	0.011
C16:0	24.13	24.00	24.53	0.185
C17:0	0.61	0.63	0.61	0.009
C18:0	13.60[a]	12.84[b]	12.85[b]	0.222
C20:0	1.32[a]	1.20[b]	1.25[b]	0.026
C21:0	0.11	0.12	0.10	0.005
Short-chain FA	6.50	5.85	6.21	0.302
Medium-chain FA	47.24[ab]	45.69[a]	47.56[b]	0.564
Long-chain FA	14.16[b]	15.04[a]	14.19[b]	0.247
Σ SFA	67.90	66.58	67.95	0.626
C14:1	0.39	0.44	0.30	0.071
C15:1	0.24	0.23	0.24	0.003
C16:1*trans*	0.38	0.44	0.42	0.027
C16:1 *cis*	0.38	0.3	0.28	0.034
C17:1	0.16	0.15	0.16	0.004
C18:1n-9 *trans*	1.55	1.58	1.62	0.1
C18:1n-9 *cis* (oleic)	21.45	22.36	21.47	0.387
C20:1n-9	0.05	0.07	0.06	0.005
C24:1n-9	0.03	0.03	0.033	0.004
Σ MUFA	24.65	25.6	24.57	0.436
C18:2n-6 *trans*	0.57	0.65	0.60	0.017
C18:2 *cis*-9,*trans*-11 (CLA)	0.15	0.21	0.22	0.110
C18:2 *trans*-10,*cis*-12 (CLA)	0.40	0.48	0.47	0.123
C18:2n-6 *cis* (linoleic)	1.86	1.76	1.82	0.161
C18:3n-6 (γ linolenic)	0.23	0.40	0.36	0.110
C18:3n-3 (α linolenic)	0.70	0.60	0.68	0.036
C20:2n-6	0.08	0.1	0.11	0.013
C20:3n-3	0.04	0.06	0.02	0.007
C20:5n-3 (EPA)	0.01[C]	0.06[B]	0.13[A]	0.004
Σ PUFA	3.52	3.74	3.61	0.217

[A–C]Different uppercase letters in the same row represent significant difference: $P < 0.01$.

[a,b]Different lowercase letters in the same row represent significant difference: $P < 0.05$.

[1]CON = control feed; L = control feed + 3% extruded linseed; LO = control feed + 3% extruded linseed + 0.6% oregano.

adequate milk lipid composition. To this concern, goat cheese is acquiring great significance in human nutrition for its high digestibility, hypoallergenic properties, and its low SFA content (Renna et al., 2012).

Texture Profile Analysis of Padraccio Cheese

The diet did not affect any of the rheological characteristics of Padraccio cheese (Table 5). Thus far, this is the first work that focused on the texture properties

Table 5. Texture profile analysis of Padraccio cheese (mean ± SEM)

Variable	Treatment[1] CON	L	LO	SEM
Deformation (mm)	8.42	8.32	8.42	0.107
Springiness (mm)	6.84	6.92	6.81	0.113
Gumminess (N)	17.89	14.72	16.68	1.462
Chewiness (N × mm)	122.46	102.09	96.39	13.354

[1]CON = control feed; L = control feed + 3% extruded linseed; LO = control feed + 3% extruded linseed + 0.6% oregano.

Table 6. Consumer liking score of Padraccio cheeses (mean ± SD)

Treatment[1]	Sensory characteristics				
	Color	Odor	Flavor	Texture	Overall liking
CON	$6.36^a \pm 1.25$	6.76 ± 1.43	6.71 ± 1.52	6.51 ± 1.41	$6.98^a \pm 1.27$
L	$7.08^b \pm 1.00$	6.75 ± 1.20	7.00 ± 1.60	6.86 ± 1.51	$7.51^b \pm 1.42$
LO	$7.06^b \pm 1.06$	7.32 ± 1.24	6.98 ± 1.33	6.74 ± 1.45	$7.09^{ab} \pm 1.25$

[a,b]Different letters in the same row represent significant difference: $P < 0.05$.

[1]CON = control feed; L = control feed + 3% extruded linseed; LO = control feed + 3% extruded linseed + 0.6% oregano.

of this typical Lucanian cheese. However, the texture profile analysis parameters are quite similar to other fresh goat cheeses and fall within ranges of overall acceptability.

Consumer Test

Table 6 shows the results of a consumer test in which 97 consumers were asked to indicate their cheese preference in terms of color, odor, flavor, texture, and overall liking. The average overall liking of Padraccio cheese obtained from goats fed the L diet was significantly higher ($P < 0.05$) in comparison with the CON group and judged as "like slightly" according to the evaluation scale. The goat diet affected only the color scoring of Padraccio cheese, which was significantly lower ($P < 0.05$) in the CON group as compared with both the groups containing dietary extruded linseed. The cheese obtained from goats fed the L diet was characterized by a good palatability that was perceived as more pleasant in comparison with Padraccio cheeses obtained from the CON and LO groups.

Few studies on the consumer acceptability of fresh goat cheeses are available. Furthermore, fresh caprine cheeses vary considerably among themselves according to the milks used (whole goat milk or mixtures), during the cheesemaking process or ripening times. Morsy et al. (2015a) reported that dietary supplementation with sunflower or sunflower oil did not influence the sensory parameters of goat cheeses. Grazing has been reported to enrich milk and cheese of small dairy ruminants in flavors due to the volatile organic compounds present in grass (Morand-Fehr et al., 2007). The general opinion expressed by the recruited consumers was particularly interesting in highlighting that the LO diet did not provide Padraccio cheese with any additional aromatic attribute.

CONCLUSIONS

Diets containing extruded linseed, with or without dried oregano supplementation, positively affected the FA profile of goat milk because they lowered the concentration of some SFA, such as C18:0 and C20:0, that are known to be detrimental to human health. This result was also confirmed for Padraccio cheese, showing better chemical-nutritional features following supplementation of extruded linseed to dairy goat diets. The recruited consumers preferred the Padraccio cheese obtained from goats fed the L diet, which was judged to have a better palatability in comparison with the other 2 groups. Further research is needed to evaluate the effect of increasing the percentage of extruded linseed supplementation in the dairy goat diet and to investigate whether its association with higher levels of oregano leaves or essential oil may improve the shelf life of Padraccio cheese.

ACKNOWLEDGMENTS

This research was supported by the Rural Development Programme 2014-2020 (Basilicata Region, Potenza, Italy), Measure 10—Environmental agroclimatic payments, Sub-measure 10.2. VAL.BI.OVI.CAP. Project "Valorization of sheep and goat genotypes production bred in Basilicata for the biodiversity preservation and conservation" with scientific coordinator Giuseppe Marsico (University of Bari). The authors are grateful to Pietro Mario Viola's dairy farm "Viola" (Gorgoglione, MT, Italy) for animal management and technical support in the cheesemaking process. The authors declare there are no conflicts of interest.

REFERENCES

Antongiovanni, M., A. Buccioni, F. Petacchi, P. Secchiari, M. Mele, and A. Serra. 2003. Upgrading the lipid fraction of foods of animal origin by dietary means: rumen activity and presence of trans fatty acids and CLA in milk and meat. Ital. J. Anim. Sci. 2:3–28. https://doi.org/10.4081/ijas.2003.3.

AOAC International. 1995. Official methods of analysis of association of official analytical chemists, 16th ed. Association of Official Analytical Chemists, Arlington, VA.

AOAC International. 2004. Official methods of analysis of association of official analytical chemists, 18th ed. Association of Official Analytical Chemists, Arlington, VA.

AOCS. 1996. Official methods and recommended practice of the American Oil Chemists Society. Methods Ai 3.75, Am 3.96. AOCS, Urbana, IL.

Bennato, F., A. Ianni, D. Innosa, L. Grotta, A. D'Onofrio, and G. Martino. 2020. Chemical-nutritional characteristics and aromatic profile of milk and related dairy products obtained from goats fed with extruded linseed. Asian-Australas. J. Anim. Sci. 33:148–156. https://doi.org/10.5713/ajas.18.0868.

Caponio, F, V. Alloggio, and C. Pallavicini. 1998. Modification of goat milk fat triglycerides by immobilized lipase. Eur. J. Lipid Sci. Technol. 100:74–78.

Chilliard, Y., A. Ferlay, J. Rouel, and G. Lamberet. 2003. A review of nutritional and physiological factors affecting goat milk lipid synthesis and lipolysis. J. Dairy Sci. 86:1751–1770. https://doi.org/10.3168/jds.S0022-0302(03)73761-8.

Chilliard, Y., C. Martin, J. Rouel, and M. Doreau. 2009. Milk fatty acids in dairy cows fed whole crude linseed, extruded linseed, or linseed oil, and their relationship with methane output. J. Dairy Sci. 92:5199–5211. https://doi.org/10.3168/jds.2009-2375.

Christie, W. W. 1982. Lipid Analysis-Isolation, Separation, Identification and Structural Analysis of Lipids. Pergamon Press, Oxford, UK.

Colonna, M. A., F. Giannico, A. Coluccia, G. Di Bello, G. Vonghia, and A. C. Jambrenghi. 2011. Dietary supplementation with extruded linseed and linseed oil in lamb feeding: Productive performances and meat quality traits. Prog. Nutr. 13:111–124.

Cosentino, C., C. D'adamo, S. Naturali, G. Pecora, R. Paolino, M. Musto, F. Adduci, and P. Freschi. 2018. Podolian cattle: Reproductive activity, milk and future prospects. Ital. J. Agron. 18:982. https://doi.org/10.4081/ija.2018.982.

Cosentino, C., D. Faraone, R. Paolino, P. Freschi, and M. Musto. 2016. Short communication: Sensory profile and acceptability of a cow milk cheese manufactured by adding jenny milk. J. Dairy Sci. 99:228–233. https://doi.org/10.3168/jds.2015-10107.

Devle, H., I. Vetti, C. F. Naess-Andresen, E. O. Rukke, G. Vegarud, and D. Ekeberg. 2012. A comparative study of fatty acid profiles in ruminant and non-ruminant milk. Eur. J. Lipid Sci. Technol. 114:1036–1043. https://doi.org/10.1002/ejlt.201100333.

Facciolongo, A. M., A. Lestingi, M. A. Colonna, F. Nicastro, D. De Marzo, and F. Toteda. 2018. Effect of diet lipid source (linseed vs. soybean) and gender on performance, meat quality and intramuscular fatty acid composition in fattening lambs. Small Rumin. Res. 159:11–17. https://doi.org/10.1016/j.smallrumres.2017.11.015.

Folch, J., M. Lees, and G. H. S. Sloane Stanley. 1957. A simple method for isolation and purification of total lipids from animal tissues. J. Biol. Chem. 226:497–509.

Forte, C., R. Branciari, D. Pacetti, D. Miraglia, D. Ranucci, G. Acuti, M. Balzano, N. G. Frega, and M. Trabalza-Marinucci. 2018. Dietary oregano (*Origanum vulgare* L.) aqueous extract improves oxidative stability and consumer acceptance of meat enriched with CLA and n-3 PUFA in broilers. Poult. Sci. 97:1774–1785. https://doi.org/10.3382/ps/pex452.

Freschi, P., S. Fascetti, M. Musto, C. Cosentino, R. Paolino, and V. Valentini. 2016. Seasonal variation in food habits of the Italian hare in a south Apennine semi-natural landscape. Ethol. Ecol. Evol. 28:148–162. https://doi.org/10.1080/03949370.2015.1022906.

Freschi, P., S. Fascetti, M. Musto, E. Mallia, C. Cosentino, and R. Paolino. 2015. Diet of the Italian hare (*Lepus corsicanus*) in a semi-natural landscape of southern Italy. Mammalia 79:51–59. https://doi.org/10.1515/mammalia-2013-0117.

Freschi, P., S. Fascetti, F. Riga, C. Cosentino, G. Rizzardini, and M. Musto. 2017. Diet composition of the Italian roe deer (*Capreolus capreolus italicus*) (Mammalia: Cervidae) from two protected areas. Eur. Zool. J. 84:34–42. https://doi.org/10.1080/11250003.2016.1268655.

Giannico, F., M. A. Colonna, A. Coluccia, D. Crocco, G. Vonghia, and C. Cocca. 2009. Extruded linseed and linseed oil as alternative to soybean meal and soybean oil in diets for fattening lambs. Ital. J. Anim. Sci. 8(sup2):495–497. https://doi.org/10.4081/ijas.2009.s2.495.

INRA. 1988. Alimentation des bovines, ovins et caprins. INRA, Paris, France.

IUPAC. 1987. Standard methods for the analysis of oil, fats and derivates. Oxford, UK: IUPAC method 2.301 Report of IUPAC Working Group WG 2/87. 7th ed. Blackwell Scientific Publications, Oxford, UK.

Kholif, S. M., T. A. Morsy, O. H. Matloup, H. M. Ebeid, and A. E. M. Kholif. 2015. Effects of crushed linseed or linseed oil supplementation on performance of dairy goats and fatty acid profile in milk. Page 19 in Proc. Book of the 5th Int. Sci. Conf. on Small Ruminant Prod.

Luna, P., A. Bach, M. Juarez, and M. A. de la Fuente. 2008. Effect of a diet enriched in whole linseed and sunflower oil on goat milk fatty acid composition and conjugated linoleic acid isomer profile. J. Dairy Sci. 91:20–28. https://doi.org/10.3168/jds.2007-0447.

Martínez Marín, A. L., P. Gómez-Cortés, G. Gómez Castro, M. Juárez, L. Pérez Alba, M. Pérez Hernández, and M. A. de la Fuente. 2012. Effects of feeding increasing dietary levels of high oleic or regular sunflower or linseed oil on fatty acid profile of goat milk. J. Dairy Sci. 95:1942–1955. https://doi.org/10.3168/jds.2011-4303.

Mohamed, A. G., T. A. Morsy, S. M. Kholif, and F. A. M. Hassan. 2013. Nutritive value of processed cheese manufactured from goat's milk fed diet supplemented with essential plant oils. World Appl. Sci. J. 26:1400–1406.

Morand-Fehr, P., V. Fedele, M. Decandia, and Y. Le Frileux. 2007. Influence of farming and feeding systems on composition and quality of goat and sheep milk. Small Rumin. Res. 68:20–34. https://doi.org/10.1016/j.smallrumres.2006.09.019.

Morsy, T. A., S. M. Kholif, E. Kholif, O. H. Matloup, A. Z. M. Salem, and A. Abu Elella. 2015b. Influence of sunflower whole seeds or oil on ruminal fermentation, milk production, composition, and fatty acid profile in lactating goats. Asian-Australas. J. Anim. Sci. 28:1116–1122. https://doi.org/10.5713/ajas.14.0850.

Morsy, T. A., A. G. Mohamed, S. M. Kholif, and W. A. Gafour. 2014. Nutritional properties of the processed cheese produced by milk from goats supplemented with flaxseeds or flaxseeds oil. Int. J. Dairy Sci. 9:74–81. https://doi.org/10.3923/ijds.2014.74.81.

Morsy, T. A., A. G. Mohamed, A. F. Zayan, and A. F. Sayed. 2015a. Physicochemical and Sensory Characteristics of Processed Cheese Manufactured from the Milk of Goats Supplemented with Sunflower Seed or Sunflower Oil. Int. J. Dairy Sci. 10:198–205. https://doi.org/10.3923/ijds.2015.198.205.

Nudda, A., G. Battacone, O. B. Neto, A. Cannas, A. H. Dias Francesconi, A. St. Atzori, and G. Pulina. 2014. Feeding strategies to design the fatty acid profile of sheep milk and cheese. Rev. Bras. Zootec. 43:445–456. https://doi.org/10.1590/S1516-35982014000800008.

Nudda, A., G. Battacone, M. G. Usai, S. Fancellu, and G. Pulina. 2006. Supplementation with extruded linseed cake affects concentrations of conjugated linoleic acid and vaccenic acid in goat milk. J. Dairy Sci. 89:277–282. https://doi.org/10.3168/jds.S0022-0302(06)72092-6.

Renna, M., P. Cornale, C. Lussiana, V. Malfatto, A. Mimosi, and L. M. Battaglini. 2012. Fatty acid profile of milk from goats fed diets with different levels of conserved and fresh forages. Int. J. Dairy Technol. 65:201–207. https://doi.org/10.1111/j.1471-0307.2011.00754.x.

Renna, M., C. Lussiana, M. D'Agostino, A. Mimosi, and R. Fortina. 2013. Extruded linseed supplementation in dairy goat diet: effects on productive performance and fatty acid profile of bulk milk, fresh and ripened cheese. J. Anim. Vet. Adv. 12:1550–1564.

Rizzardini, G., S. Fascetti, C. Pietri, F. Riga, C. Cosentino, and P. Freschi. 2019. Feeding preferences in dry season of the Italian hare (Lepus corsicanus) in two sites of Corsica. Eur. J. Wildlife Res. 65:43.

Rotondi, P., M. A. Colonna, G. Marsico, F. Giannico, M. Ragni, and A. M. Facciolongo. 2018. Dietary supplementation with oregano and linseed in Garganica suckling kids: effects on growth performances and meat quality. Pak. J. Zool. 50:1421–1433. https://doi.org/10.17582/journal.pjz/2018.50.4.1421.1433.

Saturino, C., M. V. Calvo, C. Gòmez-Candela, and J. Fontecha. 2017. Characterization of naturally goat cheese enriched in conjugated linoleic acid and omega-3 fatty acids for human clinical trial in overweight and obese subjects. PharmaNutrition 5:8–17. https://doi.org/10.1016/j.phanu.2016.12.001.

Spiel, J. A., K. Ząbek, J. Pomianowski, and L. Kurp. 2016. Nutritional and consumer characteristics of Polish regional goat cheese from Warmia. Probl. Hig. Epidemiol. 97:129–133.

Tekippe, J. A., A. N. Hristov, K. S. Heyler, T. W. Cassidy, V. D. Zheljazkov, J. F. S. Ferreira, S. K. Karnati, and G. A. Varga. 2011. Rumen fermentation and production effects of *Origanum vulgare* L. leaves in lactating dairy cows. J. Dairy Sci. 94:5065–5079. https://doi.org/10.3168/jds.2010-4095.

Ulbricht, T. L. V., and D. A. T. Southgate. 1991. Coronary heart disease: Seven dietary factors. Lancet 338:985–992. https://doi.org/10.1016/0140-6736(91)91846-M.

Valentini, V., A. Allegra, F. Adduci, C. Labella, R. Paolino, and C. Cosentino. 2018. Effect of cactus pear (*Opuntia ficus-indica* (L.) Miller) on the antioxidant capacity of donkey milk. Int. J. Dairy Technol. 71:579–584. https://doi.org/10.1111/1471-0307.12477.

ORCIDS

C. Cosentino https://orcid.org/0000-0001-5599-8187
M. A. Colonna https://orcid.org/0000-0002-2222-2902
M. Musto https://orcid.org/0000-0002-7337-5204
A. Dimotta https://orcid.org/0000-0002-8360-375X
P. Freschi https://orcid.org/0000-0003-4462-9153
S. Tarricone https://orcid.org/0000-0003-4490-491X
M. Ragni https://orcid.org/0000-0002-5117-7960
R. Paolino https://orcid.org/0000-0002-9404-1553