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Fatty acids, health indices and sensory properties of ricotta cheese from sheep fed three different diets

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Supplemented ricotta health and acceptability

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ABSTRACT

The study evaluates the healthy fatty acids profile and sensorial characteristics of ricotta obtained from ewes fed three different diets: diet enriched with linseed (L), un-supplemented diet (F) and pasture (P). Omega−3 fatty acids (N-3 FAs) levels in ricotta from grazing sheep and from animals that received the supplemented diet were notably higher than those that received un-supplemented feed. The L and P groups had lower levels of saturated fatty acids (SFAs), higher levels of conjugated linoleic acid (CLA) and more favourable health indices. Sensorial tests

showed that among the diet groups, the ricotta obtained from the supplementation group scored the highest with respect to greasiness, spreadability and acceptability

Keywords: extruded linseed, naturally enriched products, ricotta, fatty acid composition, sensorial test, acceptability

INTRODUCTION

Dairy products are an important part of a balanced Mediterranean diet, which is generally considered among the healthiest diets available. Ricotta is one such product, a particular type of Italian whey cheese with few analogies in other countries and cultures. Sheep ricotta is obtained by whey coagulation after the bulk milk has been used for the production of other types of cheese products, such as pecorino. A particular technique in ricotta production is direct acidification of the whey, which increases the protein coagulation; when the product surfaces, it is harvested and left to drain in plastic baskets. Composed of whey, ricotta is considered a secondary product of the dairy industry and has therefore received less attention as a study or market value subject in comparison to other cheeses. However, the nutritional characteristics of ricotta include high-value proteins and a relatively low fat content. Ricotta obtained during the pasture period (spring–autumn in central Italy) from grazing animals is usually characterised by a lower total fat content, which results in a denser and less acceptable product. In contrast, farm-fed ewes (winter in central Italy) tend to produce greasier ricotta with a higher total lipid content and a high percentage of saturated fatty acids (SFAs) (Bergamaschi *et al.* 2016). Such high levels of SFAs are discouraged by the Academy of Nutrition and Dietetics, which promotes the reduction of SFAs in dairy products and encourages an increase in unsaturated fatty acids (UFAs) (Vannice and Rasmussen, 2014). One method for increasing the dietary UFAs is to

naturally enrich the product by controlling the animal's diet. Human studies have shown the benefits of naturally enriched products on atherosclerotic markers and low-density lipoprotein (LDL) levels in various studies such as (Wang *et al.* 2012; Pintus *et al.* 2013). Yoshimura *et al*. (2018) performed a lab experiment to evaluate their effect on patients suffering from diabetes. Implementing oilseed as a natural enrichment to the typical diet of dairy ewes is a common method for improving milk quality by increasing the UFAs content, both for pasture-based and farm-rationed diets (Cabiddu *et al.* 2017). Improving the composition and quality of milk inherently improves various dairy product qualities because processing techniques do not cause a substantial change in fatty acids (FAs) composition. Compared to other oilseed supplements, linseed has a beneficial effect on the FAs composition of dairy ewes (Cabiddu *et al.* 2017). Linseed integration in the diet appears to stimulate the production of conjugated linoleic acid (CLA) isomers called rumenic acid (CLA c9 t11), an isomer that benefits consumers by reducing the cholesterol LDL/HDL ratio in the blood and exerting anti-inflammatory, anti-atherogenic, anti-carcinogenic, and anti-diabetic/anti-obesity effects (Wang *et al.* 2012). Future goals include increasing the ratio of n-3/n-6 FAs in dairy products by reducing the n-6 FAs levels and increasing the n-3 FAs levels. While n-3 FAs mediator precursors such as eicosapentanoic acid (EPA) and docosahexaenoic acid (DHA) exert an anti-inflammatory effect, n-6 mediators (e.g., arachidonic acid) exhibit a pro-inflammatory effect (Schmitz and Ecker 2008).

Taking the above discussion into account, there is substantial interest in obtaining ricotta cheese with healthy characteristics when a pasture diet is not available, for example, in the winter. To the best of our knowledge, there have been no studies comparing the ricotta obtained from grazing sheep and that from sheep fed indoors with a supplemented or un-supplemented diet. The aim of this study is to evaluate the FAs profile, health indices and sensorial characteristics of

ricotta cheese from sheep fed a diet supplemented with linseed or an un-supplemented diet (farm ration) and from grazing animals.

MATERIALS AND METHODS

Animals, experimental diets and feeding routine

The present study was conducted in accordance with the guidelines provided by the Animal Welfare Committee of the University of Teramo, Italy. The trial was conducted at a farm located in the Latium region, province of Viterbo (Italy), during the spring of 2015 over a period of approximately 80 days. The 80-day period was considered suitable for the duration of the experiment because oilseed supplementation in dairy animals is a two-stage process that requires a period of at least 20 days for the diet change to exert an effect (Harvatine *et al.* 2009).

Three weeks before the expected date of parturition, 54 Comisana ewes were randomly divided into three groups of equal size. The groups were balanced for age (32±2 months), body weight (47.5±1.2 kg), body condition score (2.65±0.05); and number of lactations (2.3±0.5).

The selected ewes were randomly allocated to the following three experimental treatment groups (18 sheep per group):

1) P – pasture group; the ewes had daily access to pasture for 22 h/d without supplementation (average stocking rate: 15 ewes/ha). The pasture primarily consisted of *Sulla* (*S, Hedysarum coronarium L.*) as well as oats (*Avena sativa*) and clover (*Trifolium incarnatum*) seeded the previous fall. This composition is typical for pastures in the Latium region. No modification was applied to the present pasture in order to improve its grazing quality, leaving the pasture in the traditional condition for this area.

2) F – farm group; the ewes had no access to pasture but were housed in straw-bedded pens and received a winter ration as practised in central Italy. The ingredients of the TMR-F were grass

hay at 1100 g/d and 800 g/d of concentrate-based meal (oat, barley and soybean) without added fats or supplements.

3) L – linseed-enriched group; the ewes had no access to pasture but were housed in straw-bedded pens and received a winter ration as practised in central Italy with added of extruded linseed. The ingredients of the TMR-L were grass hay at 1100 g/d and 800 g/d of concentrate-based meal with the addition of 0.190 kg of extruded linseed. The extrusion of linseed, ground to pass a 4-mm screen, was performed in a single screw extruder with a throughput of 1600 kg/h (barrel length: 3.2 m; die diameter: 7 mm; screw speed: 300 rpm; temperature at the end of the barrel: 130–138°C; duration: 1 min). After extrusion, the product was dried in a counter flow cooler for 12 min.

The ingredients and chemical compositions of the 3 diets are presented in Table 1.

Milking and ricotta sampling

After lamb removal at 4 weeks of age, the ewes were machine-milked twice a day at 6 a.m. and 6 p.m. From weeks 5 to 8, milk was collected daily from the ewes in each treatment group and refrigerated for pecorino and ricotta production. The milk was processed three times a week for both products. Pecorino is a semi-cooked hard cheese made from fresh whole sheep milk and is prised as a cheese product. Its production leaves only the milk whey to be used for ricotta production. Pecorino, being a completely different product, was not considered as a subject of the current research.

Ricotta samples (16 for each experimental group per week) were obtained from the whole whey after the curd had been extracted. The whey was heated to 80°C (8°C per minute) to induce the coagulation of proteins, which then floated to the surface; coagulation was enhanced by adding

citric acid, and the coagulum was skimmed from the surface and loaded into perforated moulds to drain for 4 to 6 h at a temperature below 8°C.

Chemical analysis

During the trial, samples of pasture, alfalfa hay and concentrates were collected and analysed for dry matter (DM) content, ash, crude protein (CP), and ether extract (EE), following the official methods of the AOAC (1990). Neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin (ADL) were analysed as described by Van Soest (Van Soest *et al.* 1991). All feed samples were also analysed for FA composition as described by Lock (Lock *et al.* 2006).

The FA composition of the ricotta was analysed (four ricotta samples per group). Fat extraction was performed according to the Röse-Gottlieb method. The standards polyunsaturated fatty acid (PUFA)-2, non-conjugated 18:2 isomer mixture, individual *cis*-5, 8, 11, 14, 17 C20:5, *cis*-4, 7, 10, 13, 16, 19 C22:6 (Supelco), *cis*-6, 9, 12 C18:3, and *cis*-9, 12, 15 C18:3 (Matreya Inc., Pleasant Gap, PA, USA) were used to identify PUFAs. High-purity individual CLA c9, t11 and t10, c12 (Matreya Inc.) were used to identify the CLA isomers of interest. Individual t9 C18:1 and t11 C18:1 and published isomeric profiles were used to identify trans C18:1 isomers of interest. The content of each FAME was expressed as a percentage of the total FAME present.

Sensorial analysis

The ricotta sensory panel was modified from that described by Pizzillo *et al.* 2005. Six ricotta samples were used per group to determine the sensory profile, assessed by a sensory panel. Three of these ricotta samples were used in pre-testing sessions, where the panellists were selected based on preliminary tests of their ability to recognise the intensity of basic qualities such as odour, colour, flavour and texture. A group of 15 panellists who qualified based on the sensorial

criteria described above evaluated ricotta cheese samples at room temperature. All assessments were conducted in a sensory laboratory in individual booths designed according to the international standard ISO 8589 (ISO, 2007). Three other ricotta samples were used for test evaluations. The ricotta samples were cut into 3-cm slices, coded with a random three-digit number, and served at room temperature (18 ± 1°C) in a balanced order across judges. Each panellist was also provided with unsalted crackers and a glass of water.

The descriptive terms (supplementary Table 1 and supplementary Table 2) for each major sensory attribute category were as follows:

(1) texture: gritty, granular, soft, creamy, greasy, adhesive, spreadable;

(2) taste: sweet, salted, bitter, acidic;

(3) odour: butter, fresh curd, fresh milk, acidified milk, cooked, stall, sheep, smoked, straw, fresh grass, wet hay, hay;

(4) aroma: smoke, milk acid, fresh grass, cooked, wet hay, floral;

(5) colour: white, pale, beige.

Each attribute was evaluated on a 0–9 point graduated scale.

Acceptability test

Further sensorial evaluation was performed at the University of Teramo, including an acceptability evaluation. The six remaining ricotta samples of each group were used for this purpose. Modified from the panel described by Borba *et al.* 2014, the evaluation included a group of untrained, randomly selected consumers. Their evaluation included the acceptability of the product on a scale of 0-9 with no other descriptions (0=unacceptable, 9=highly acceptable). The ricotta samples were cut into 3-cm slices, coded with a random three-digit number, and

served at room temperature (18 ± 1°C). Each panellist was also provided with unsalted crackers and a glass of water. In total, 98 consumers participated in this panel, with the ages ranging from 20 and 48 and equally distributed for men and women.

Statistical analysis:

Before analysis, the atherogenic index (AI) was calculated according to Ulbricht and Southgate (1991) as follows: (C12:0 + 4×C14:0 + C16:0)/ (monounsaturated + polyunsaturated FAs), and the I-Harris index was taken as the sum of EPA and DHA (Harris *et al.* 2006).

All data regarding the chemical and FAs composition of ricotta cheese were analysed according to the repeated-measures GLM of the SPSS version 13.0 statistical package (SPSS, 2006), including the fixed effects of dietary treatment and sampling time. The effect of sampling time is not reported because it was not significant. The significance of the fixed effects is presented for each parameter evaluated, and the variance is expressed as the standard error.

The sensory and acceptability data were normalised, standardising each assessor by his or her standard deviation (Naes, 1991) to reduce the effect of different uses of the scale. The normalised data were subjected to analysis of variance for repeated measures, with diet as the sole factor. Duncan's test was used to determine significant differences between the groups.

RESULTS

Chemical analysis

The chemical composition of the ricotta is shown in Table 2. The protein percentage of the ricotta was 8.38% in the L group, 9.10% in the F-group, and 9.51% in the P-group. The total fat percentage of the ricotta was affected ($P < 0.05$) by the dietary treatment; ricotta made from milk

of the L-group had a higher fat content (17.81%) than ricotta from the P (14.39%) and F-groups (15.24%). The moisture content of the ricotta, which was approximately 70%, showed no difference among the groups.

Fatty acids composition:

The results of the principal FAs composition and health indicators are presented in Table 3.

The proportion of total SFAs was higher in the ricotta ($P < 0.05$) of the F (74.79%) group than in the products obtained from sheep fed pasture (65.04%) or extruded linseed diets (65.99%). A significantly higher PUFA concentration ($P < 0.05$) was observed in the ricotta from the L-group(4.05%) than in the ricotta from the F-group(3.65%), whereas the P treatment yielded an intermediate value (3.6%). Overall, the ratio of SFAs/UFAs was the most favourable in the L and P-groups, being almost identical (2.00 and 1.98, respectively), with the F group having a notably higher SFA level and a ratio of 3.20. The content of n-3 FAs was significantly higher in the ricotta from the L-group than in the ricotta from the F and P-groups ($P < 0.001$); in the latter group, the n-3 FAs content was at an intermediate level. The sum of C14:0 + C16:0/SFA was higher in the ricotta made with milk from the F-group than in that from the L or P-group.

Higher levels of vaccenic acid (VA) and CLA were observed in the ricotta from the P-group than in the ricotta from the L-group ($P < 0.05$); the concentration of these FAs was lowest in the F group. The I-Harris index, as a sum of EPA+DHA (C20:5 + C22:6), was substantially higher in the ricotta of the P and L-groups than in the F-group ($P < 0.05$). The AI was lower ($P < 0.05$) in the L group than in the F-group, whereas the P-group showed a value slightly higher than that of the L-group. Cholesterol was found at a much higher concentration in the F-group ricotta (50.31 mg/100 g) followed by the L- and P-group samples, with the P-group having the lowest content

(37.96 mg/100 g). We registered the highest value of cholesterol ($P < 0.001$) in ricotta made of milk from the F-group compared to that from the other two groups.

Sensory test

The results of the sensory test are presented in Table 4.

The extruded linseed supplementation and pasture diet affected the softness of the ricotta; ricotta from ewes fed these diets received higher scores than ricotta from sheep that received the farm diet ($P < 0.05$). The diet also influenced the greasiness ($P < 0.05$), granulosity ($P < 0.05$) and spreadability ($P < 0.05$) of the product. The ricotta from the L-group received higher scores for greasiness and spreadability than the ricotta from the F-group. The ricotta from the L-group displayed less granulosity than the ricotta from the F-group, while the ricotta from the P-group received an intermediate score between those of the F and L-groups.

The pasture diet influenced the whiteness of the ricotta; the ricotta from the P-group received a lower score than the ricotta from the L and F-groups. In contrast, the ricotta made from milk of the three groups showed similar characteristics with respect to sheep flavour, sweetness, bitterness and cooked sensory properties.

Acceptability test

Even though the characteristic scores were similar for flavour, in the acceptability trial, the L group obtained the highest score, with an acceptability level of 6.1 ± 0.3. The P-group ricotta scored the lowest at 4.6 ± 0.2, and the value for the F-group was intermediate at 5.1 ± 0.2.

DISCUSSION

Fatty acids composition

The ricotta N3/N6 FA ratio was five-fold lower in the F-group and approximately two-fold higher in the P-group than in the L-group. This result occurred for two reasons. In the case of the L-group, although the n-6 Fas content was only slightly lower than that of the F-group, the higher content of n-3 FAs originating from extruded linseed integration was sufficient to significantly reduce the n-3/n-6 ratio in the ricotta. This result is in line with previous work demonstrating similar results in other cheese types (Addis *et al.* 2009). While the P diet was lower in overall fat intake with less n-6 FAs than the other two diets, the n-3 FAs content was not as high as that of the L-group, resulting in a lower ratio. The presence of green grass and primarily *Sulla* on the pasture contributed to the n-3 FAs intake, as supported by previous work showing similar effects on raw milk and cheese (Bonanno *et al.* 2016). Thus, although the L-group had a high n-6 FAs content, the ratio for this group was the most favourable. For the F-group, the animals were fed only cereals and grass hay and had little access to feed containing n-3 FAs. The high intake of cereals such as oat, barley and soybean inevitably increased the n-6 FAs content of the final product.

In evaluation of SFAs/UFAs, the proportion of total SFAs in the three groups caused the F-group to have a significantly higher level than the other groups. This result occurred because of the energy-rich diet of the F-group, which lacked substantial PUFAs. In the case of the L-group, the integration of extruded linseed in the diet increased the UFAs intake of the ewes and therefore resulted in ricotta with a lower percentage of SFAs. Regarding the P-group, the ricotta had the lowest SFAs content because of the generally lower fat content, the lower energy intake of the grazing animals and the presence of *Sulla* in the pasture. *Sulla* is known to have a beneficial

effect on the FAs profile of milk and dairy products by lowering the SFAs content, increasing the UFAs level and improving the n-3/n-6 ratio (Bonanno *et al.* 2016). It could be argued that further improvement of the pasture or a more suitable composition of grazing area would have resulted in an even better FAs profile for the P-group (Mierlita *et al.* 2018). However, our work was based on existing and traditionally managed pastures in the Lazio region rather than potential FAs profile improvement.

The concentration of PUFAs observed in the various ricotta samples followed similar trends. The F-group had the lowest percentage of PUFAs because they lacked fresh grass in their diet and had no alternative source for FAs. The percentage of PUFAs in the other two groups was higher, with the L-group having the highest value. In this case, extruded linseed had a greater influence than the available green grass of the pasture. Various studies have shown that PUFA-enriched dairy products with a low SFAs content are beneficial to hypercholesterolaemic individuals as well as healthy individuals; therefore, improvement of this parameter in ricotta is an objective for the production of healthier products.

The level of C18:1 trans-11 (VA) was significantly higher in the ricotta of the P-group, which was fed fresh grass with a lower total fat content; this result is not surprising because specific C18 chains are found in higher concentrations in this diet. This result demonstrates that pastures can be used as an FAs modulator; even a typical pasture in central Italy that was not considered as an FAs enrichment source has benefits in terms of FAs quality. Pastures, however, are not a stable source of FAs, and ricotta FAs quality tends to vary during the year, following the seasonal grazing quality and availability. Among the samples from the barn-held ewes, the L-group ricotta had a higher content of VA, which is not surprising considering the positive effect of linseed on C:18 FA isomers in the milk of dairy animals (Cabiddu *et al.* 2017). However, the

supplementation resulted in a lower percentage of VA in comparison to the grazing animals. Similarly, the levels of rumenic acid (C18:2 cis-9, trans-11), the principal isomer of CLA, were significantly higher in ricotta from the P-group ($P < 0.001$) (0.93 g/100 g of total FAs) than in ricotta from the F-group (0.31 g/100 g of total FAs) and the L-group (0.63 g/100 g of total FAs) even though the latter group had the higher composition among the two barn-held groups. Oleic acid levels were significantly higher in ricotta from the L-group than in ricotta from the P-group ($P < 0.005$), and the content was lowest in ricotta from the group of sheep fed a typical milking ration. This result is valuable because CLA is recognised as beneficial for human health, by combating oxidative stress (Matin *et al.* 2018).

The Harris index, which is the sum of DHA and EPA was the highest for the L-group and still moderately high for the P-group, while the value for the F-group was much lower. This finding is consistent with other results in this work; the higher percentage of n-3 FAs due to linseed integration results in higher concentrations of DHA and EPA (Stachowska *et al.* 2004),, similar to the green grass pasture diet. The AI exhibits similar trends, with the F-group having the highest ratio, closely followed by the P-group, and the L-group having the lowest value. Both indices are a clear indication of product quality from the viewpoint of human health. In our study, a reduction in the (C14:0 + C16:0)/SFA ratio was observed in the ricotta of the P and L-groups compared to that of the group that received a typical farm diet.

Sensorial test

Several trials were conducted to compare the effects of forage type on the sensorial properties of cheeses and ricotta (Araque *et al.* 2018). Our results showed that ricotta produced from the L-group ewes was greasier and more spreadable than the F- and P-groups ricotta. The higher fat

content of the L-group influenced the greasiness of the ricotta, as reported in previous studies (Pizzillo *et al.* 2005), and as the fat content of the ricotta decreased, the greasiness was reduced. The higher spreadability of the ricotta from the L-group was also most likely related to the higher fat content of the ricotta for this group. A higher granulosity was observed for the ricotta from the P and F-groups, which may be linked to the lower level of total fat and the higher protein content of these products. This result is particularly true for the P-group product, which was the lowest in fat and the highest in protein in comparison to the other two groups.

The difference in colour perception for the ricotta from grazing ewes and from the indoor groups (groups L and F) was notable ($P < 0.001$). The P-group products displayed less whiteness, in agreement with previous studies on cow cheese textures (Coppa *et al.* 2011) in which a similar difference was observed between the products of grazing animals and hay-fed cows. In general, the consumption of green forage increases β-carotene levels in the milk, which is responsible for much of the colour variation in cheese products. According to Carpino *et al.* 2004, the intense colour of cheese obtained from pasture-grazed cows and sheep is most likely due to the carotenoids that are widely present in grazing areas. In our study, the ricotta from the different groups showed similar characteristics with respect to flavour, sweetness and bitterness.

Naturally enriched dairy products are becoming an ever-growing reality, and studies have been reported on some products, such as kefir and cheese (Pawlos *et al.* 2016). Ricotta, however, has received less attention and has not been evaluated in profiling studies. Sensory evaluations of ricotta are usually focused on its preservation or on specific approaches such as fat reduction with respect to taste (Araque *et al.* 2018).

Acceptability trial

An acceptability trial was conducted with untrained evaluators to assess the public perception of various types of ricotta. The P-group ricotta had a good FAs composition from a nutritional viewpoint but scored the lowest in acceptability. The lower total fat content and low greasiness are the most likely causes for the low score. Similar results were obtained by Raque *et al*. (Araque *et al.* 2018) in a recent work on reduced-fat ricotta. The lower score may also be partially caused by the reduced whiteness of the product, as a consumer visual bias. This assumption could not be confirmed, even though sensory and acceptability trials have reported correlations between cheese colour and acceptability (Cosentino *et al.* 2016).

The ricotta from the L-group scored the highest in terms of acceptability. This result was not surprising since this ricotta also scored the highest in terms of greasiness, spreadability and softness, which are all desirable traits from a consumer's point of view. The higher bitterness and lower sweetness values scored by professional panellists did not hinder potential consumers. This trend could be related to the personal preferences of consumer cluster groups, as reported by Braghieri *et al.* 2015) for cow cheese products.

The F-group ricotta had an intermediate acceptability and a mixed evaluation for the sensory panel. Some parameters such as whiteness, sweetness or cooked flavour may have contributed to the consumers' assessment, although the scores were close to the P-group acceptability levels and far from the L-group results.

CONCLUSIONS

The supplementation of extruded linseed in the diet of dairy ewes is shown to be effective in increasing the levels of PUFAs, particularly n-3 FAs. However, this approach was less efficient

in increasing the levels of CLA in ricotta compared to a grazing diet. Our results indicate that extruded linseed supplementation in dairy sheep may be a useful nutritional solution when pasture is not available, as occurs in some regions of Italy during the winter. The supplementation helps to maintain a high level of beneficial FAs in an otherwise lower-quality diet.

In contrast to extruded linseed supplementation, when possible, pasture seems to be a viable option, combining a good product quality and low feeding costs. The FAs composition in ricotta obtained from grazing animals was superior to that of farm-held ewes, and in many parameters, the quality was similar to that of the L-group. In the sensory evaluation, the naturally enriched ricotta scored high in the professional panel and was well received by potential consumers in the acceptability trial. The ricotta obtained from grazing animals, however, was not received as well by potential consumers.

In conclusion, the use of extruded linseed as a supplement can be used to maintain the content of healthy FAs in sheep ricotta year-round. A preferred model should include the use of pasture primarily during spring and autumn, when the pasture is abundant with green grass, and the use of extruded linseed as supplementation when grazing availability and quality decline.

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Table 1 Ingredients (% DM), chemical composition and FA composition of the farm ration (F), extruded linseed diet (L) and pasture (P).

		Dietary Treatment		
Diets		**F**	**L**	**P**
Ingredients				
Grass hay	% DM	56.79	56.79	….
Oatmeal	% DM	12.91	10.33	….
Barley meal	% DM	12.91	10.33	….
Soybean meal	% DM	15.85	11.20	….
Extruded linseed	% DM	….	9.81	….
Mineral and vitamin mix	% DM	1.55	1.55	….
Chemical composition				
DM	%	89.12	90.56	16.72
CP	% DM	20.71	19.97	19.57
EE	% DM	2.86	4.83	2.50
NDF	% DM	39.24	44.75	29.77
ADF	% DM	25.48	25.2	21.91
ADL	% DM	3.68	3.93	1.41
Fatty acid profile (% of total FAs)				
C12:0		nd	nd	0.17
C14:0		0.6	0.2	0.30
C16:0		18.8	8.8	12.7
C16:1		nd	nd	1.1
C16:1c9		0.3	0.1	nd
C18:0		2.6	4.1	1.11
C18:1c9		23.8	21.1	1.81
C18:2c9, c12		40.0	13.3	11.5
C18:3c9, c12, c15		9.1	42.9	71.2
C18:1c11		1.0	0.6	nd

nd: not netectable

1:F:un supplemented diet; L:diet supplemented with extruded linseed; P:pasture based diet

Table 2 Chemical composition of ricotta made with raw milk from ewes fed a diet supplemented with extruded linseed (L), a typical milking ration (F) and grazing pasture (P).

	Dietary Treatment			*P-value*
Parameters	**F**	**L**	**P**	
Moisture	68.13±0.36	69.25±0.58	70.03±0.69	0.120
Protein	9.10±058	8.38±0.45	9.51±0.23	0.981
Fat	15.24^{b}±039	17.81^{a}±0.12	14.39^{b}±0.48	0.049

Means with different letters on the same row differ significantly (a, b, c, $P < 0.05$; A, B, C, $P < 0.01$)

Table 3 Profile of FAs and health indices (g/100 g of total FA) of ricotta made with raw milk from ewes fed a diet supplemented with extruded linseed (L), a typical milking ration (F) and grazing pasture (P).

		Dietary Treatment		*P-value*
Parameters	**F**	**L**	**P**	
N-3	0.49^{c}±0.17	2.83^{a}±0.14	1.1^{b}±0.15	0.010
N-6	2.07^{a}±0.22	1.99^{a}±0.21	1.57^{b}±0.65	0.050
N-3/N-6	4.22^{A}±0.54	0.70^{C}±0.11	1.42^{B}±0.21	0.001
SFAs	74.79^{c}±1.23	65.99^{a}±1.01	65.04^{b}±1.99	0.020
MUFAs	20.49^{A}±1.56	28.84^{B}±1.65	29.09^{B}±1.45	0.001
PUFAs	2.85^{a}±0.14	4.05^{c}±0.22	3.6^{b}±0.89	0.010
UFAs	23.34^{a}±1.98	32.89^{b}±1.56	32.69^{b} ±1.12	0.010
SFAs/UFAs	3.20^{B}±0.22	2.00^{A}±0.45	1.98^{A}±0.65	0.001
VA	1.02^{a}±0.73	2.25^{b}±0.56	3.19^{c}±0.45	0.010
CLA	0.31^{a}±0.01	0.63^{b}±0.01	0.93^{c}±0.05	0.020
I-Harris	0.03^{a}±0.02	0.13^{b}±0.02	0.11^{b}±0.02	0.040
AI	3.74^{c}±0.21	1.8^{a}±0.21	1.9^{b}±0.21	0.010

The data correspond to the analysis of fresh ricotta from bulk tank milk. SFA = saturated fatty acid; MUFA = monounsaturated fatty acid; PUFA = polyunsaturated fatty acid; UFA: unsaturated fatty acid; VA: vaccenic acid; CLA: conjugated linoleic acid; I-Harris (EPA+DHA); AI: atherogenic index (C12:0 + 4 × C14:0 + C16:0)/(MUFA + PUFA). Means with different letters on the same row differ significantly (a, b, c, $P < 0.05$; A, B, C, $P < 0.01$)

Table 4 Sensory attribute ratings of ricotta made from ewes fed a diet supplemented with extruded linseed (L), a typical milking ration (F) and grazing pasture (P).

	Dietary Treatment			*P-value*
Attribute	**F**	**L**	**P**	
Softness	6.5^{b}±0.21	7.8^{a}±0.13	7.6^{a}±0.32	0.049
Greasiness	4.6^{b}±0.36	5.7^{a}±0.21	4.9^{b}±0.12	0.049
Granulosity	6.5^{c}±0.25	4.1^{a}±0.41	6.2^{b}±0.14	0.030
Spreadability	4.9^{c}±0.89	7.1^{a}±0.23	6.3^{b}±0.22	0.040
Sweetness	5.5±0.14	5.3±0.15	5.9±0.65	0.890
Bitterness	5.3±0.36	5.7±0.32	5.5±0.41	0.780
Sheep milk odour	5.7±0.22	5.6±0.12	5.3±0.21	0.701
Cooked	4.2±0.14	4±0.11	3.9±0.32	0.705
Whiteness	7.2^{A}±0.57	6.9^{A}±0.21	3.5^{B}±0.41	0.001
Acceptability	5.1^{b}±0.17	6.1^{a}±0.23	4.6^{c}±0.54	0.049

Means with different letters on the same row differ significantly (a, b, c, $P < 0.05$; A, B, C, $P < 0.01$)