Sesame meal as substitute to soybean meal in Sicilo-Sarde ewes' diet: Effects on milk yield and composition, cheese yield and sensory attributes

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ABSTRACT

This study evaluated the effects of substituting soybean meal with sesame meal in the concentrate offered to Sicilo-Sarde ewes on feed intake, milk production and composition as well as cheese yield and sensory properties. For that, thirty multiparous ewes were assigned to three homogeneous groups based on their initial milk production. All ewes received individually 2 kg of oat hay and 700 g of concentrate. Three types of concentrate were offered: a control concentrate (C) and two experimental concentrates containing sesame meal (SM) that substituted soybean meal (SBM) at rates of 50 (SM50) and 100% (SM100). During the trial which lasted 60 days, all ewes had free access to water throughout the day. Ewes' milk yield was recorded weekly. Milk composition, cheese yield and quality were also determined.

Total dry matter intake was similar across groups. Also, milk production was unaffected ($p>0.05$) by the type of concentrate, averaging 285, 298 and 278 ml/ day for C, SM50, and SM100, respectively. The higher milk fat content was observed in SM50 group (8.1%; $p<0.05$) compared to the control (7.5%) and SM100 (7.4%). However, protein content, lactose and pH remained stable across all diets. Individual cheese yield was not significantly affected by dietary treatment but increased over time. Cheese chemical composition was affected by the diet and the highest dry matter and protein contents occurred for C group (51.86% and 17.57%, respectively). Substituting soybean meal with sesame meal had no significant effect on cheese firmness, elasticity, texture, color, or bitterness ($p>0.05$). Nevertheless, the substitution rate of 50% increased aroma intensity and saltiness. These results suggest that substituting soybean meal with sesame meal could improve milk composition without adversely affecting milk or cheese yield, offering a promising alternative for enhancing dairy sheep nutrition.

KEY WORDS

Sesame meal, Milk yield, Cheese, sensory quality, Sicilo-Sarde.

INTRODUCTION

In Tunisia, the dairy sheep farming is composed of the Sicilo-Sarde which is the only specialized dairy sheep breed (1) playing a crucial role in the local livestock sector. Since the introduction of this farming system, sheep's milk has been predominantly used for industrial cheese production and artisanal cheesemaking, including Sicilian cheese and Ricotta (2). However, the productivity of Sicilo-Sarde ewes is highly dependent on nutritional management, as their diet primarily consists of grass grazing, roughage and concentrates throughout the year which price increased dramatically (3). In fact, the increasing price volatility of soybean meal (SBM), the primary protein source in livestock diets worldwide, have presented significant challenges to the economic sustainability of dairy sheep farming. These rising costs have led livestock producers to seek more affordable, locally available and relatively cheap alternatives such as agro-industrial by products and aromatic and medicinal residues (4,5). These non-conventional feed resources offer a promising solution to reduce reliance on imported raw materials while maintaining or even improving animal performance. Among others, sesame meal (SM), a by-product of sesame seed oil extraction, with a crude protein content of approximately 46%, presents a strong potential to partially or fully replace SBM in livestock feed (6). Due to its local availability and high protein content, sesame meal could offer a cost-effective and sustainable solution to the growing demand for livestock feed. Omar (7) reported that the addition of sesame oil cake at 10% and 20% improved digestibility of protein and fiber, average daily gain, feed conversion ratio, and cost of feed/kg gain in growing Awassi lambs when compared to a commercially fed ration.

Despite its nutritional potential, there is a lack of research on the specific effects of sesame meal on dairy sheep performances. Therefore, this study aims to evaluate the impact of substituting soybean meal with sesame meal in the diet of Sicilo-Sarde ewes on feed intake, milk yield and composition as well as cheese yield and quality.

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MATERIAL AND METHODS

Experimental design, animals and feeding

The experiment was carried out at the experimental farm Lafareg (Beja) located in the subhumid region of Tunisia. The trial was conducted on 30 lactating multiparous Sicilo-Sarde ewes, which were assigned to three homogeneous groups of 10 animals each, based on initial milk production. The ewes were housed in individual pens measuring 1.5 m × 2.5 m with continuous access to fresh water. After an adaptation period (15 days), all groups received individually 2 kg of oat hay and 700 g of concentrate. Three types of concentrate were offered: a control concentrate (C) and two experimental concentrates containing sesame meal (SM) that substituted soybean meal (SBM) at rates of 50 (SM50) and 100% (SM100). The ingredients and the chemical composition of all types of concentrate used are presented in Table 1. Throughout this period, the amounts of feed offered and refused were daily recorded and then the intake was calculated.

Milk control and analysis

Individual milk yield was determined weekly throughout 8 weeks. During each control, ewes were hand-milked twice a day (at 9:00 AM and at 2:00 PM) and the amount of milk produced by each ewe was measured using a beaker and a graduated cylinder. At each milking, representative samples (50 ml) were taken from the whole individual milk for subsequent chemical analyses with the addition of potassium dichromate as a preservative for storage. Milk samples were evaluated for fat, protein, lactose and pH using a Lactoscan device (Milkotronic, serial no. I-18-844, Bulgaria).

Cheese making
Individual laboratory cheese yield

Cheese yield was individually determined for each ewe at each control point (8, 9). The individual laboratory cheese yield (ILCY) was measured from individual milk samples (10 mL), following the method described by Othmane (10) and Bousselmi and Othmane (11). Milk samples were preheated, homogenized, and coagulated at 37°C for 1 hour. To ensure uniform rennet distribution in the milk, rennet was diluted 10-fold with bi-distilled water prior to its addition. After coagulation, the curd (cottage cheese and whey) was centrifuged for 15 minutes at 2,500 rpm following longitudinal cutting. Then, the whey was removed by draining the test tube in an inverted position for 45 minutes, leaving the curd undisturbed at the bottom of the tube. ILCY was defined as the weight of the centrifuged curd (obtained after whey expulsion and air draining), expressed in kg per 100 L of milk. The tubes were initially weighed to determine the weight of the tube containing milk (P1). After whey expulsion and air draining, the tubes containing only the coagulum were weighed again to determine the final curd weight (P2). Cheese yield was subsequently calculated as the weight of the centrifuged curd, expressed in kg per 100 L of milk.

$$ILCY\ (\%) = 100 * \frac{(P1 - P2)}{10}$$

Sicilian Cheese-Making Process

The sicilian cheese processing was carried out under artisanal conditions. After reception and filtration, the milk was heated to 34 °C. After the addition of rennet at a rate of 5 ml/10 L, the milk was homogenized. The resulting curd was separated from the whey by cutting and filtering through a cloth. Then, the content was manually filled into perforated plastic molds and subjected to pressing to remove as much whey as possible. The resulting cheese was stored at +7 °C to allow for better drainage. Cheese yield, mathematically expressed as the amount of cheese obtained from a given quantity of milk as follow:

$$\text{Cheese Yield } \% = (\text{Total amount of cheese} / \text{Amount of milk used in production}) \times 100$$

Chemical and sensory analyses of cheese

The chemical analyses of cheese (DM, ash, protein) were determined according to Association of Official Analytical Chemists (12). A panel of 10 assessors, took part in the descriptive sensory analysis. Cheese samples from each group, along with a tasting sheet, were presented to the assessors who provided their opinions on the pleasantness of the samples by

Table 1 - Ingredients (%) and chemical composition of feeds.

	CC	SM50	SM100	Oat hay
	Ingredients of concentrate (%)			
Soybean meal	10	5	0	-
Sesame meal	0	11	25	-
Corn	12	8	0	-
barley	61	59	52	-
Wheat bran	14	14	20	-
Mineral Vitamin Supplement	3	3	3	-
	Chemical composition			
Dry matter (DM, %)	91.8	92.8	92.3	94.4
Crude Protein (%DM)	15.16	14.46	16.03	4.7
Ash (%DM)	7.8	8.7	10.9	3.1

CC: commercial concentrate; **SM50:** concentrate containing 50% of soybean meal and 50% of sesame meal; **SM100:** concentrate containing 100% of soybean meal as substitute to soybean meal.

rating them according to the intensity of these characteristics on a numerical scale from 1 to 9. To ensure the success of this analysis, a common agreement was reached on the date and time of the test. The panel were instructed not to eat or drink (except water) and not to smoke for at least one hour before the test. Although it was a hedonic test, the tasters can be considered trained, as they had previously participated in several sensory analyses. Then cheese samples were analyzed for color, texture, odor, aroma intensity, firmness, elasticity, acidity, bitterness, taste appreciation and overall appreciation.

Feed chemical Analyses

The analyses of DM, ash and crude protein content were performed on representative samples of forage (oat hay) and concentrate. Ground samples of feeds were analyzed for DM (105°C until constant weight), crude protein according to Kjeldahl method and ash by combustion at 600°C for 8 hours according to Association of Official Analytical Chemists (13).

Statistical Analysis

Milk yield and composition as well as cheese yield, chemical and sensory attributes were analyzed using the mixed procedure of SAS (14) for repeated measures. The model included the diet, time (weeks of control), and the diet × time interaction as fixed effects, and the animal within each diet as a random effect. The differences between means were compared using the Duncan's Multiple Range Test (DMRT) and the statistical significance was defined at $P < 0.05$.

RESULTS AND DISCUSSION

Feed intake, Milk yield and composition

Regardless of the concentrate type, hay and concentrate intakes were similar among groups averaging approximately 1888 and 646 g of DM, respectively. This finding is consistent with the results of Selmi et al. (15), who reported that the nature of the concentrate does not influence ewe intake levels. Throughout the trial, intake gradually increased from the beginning, reaching a peak from the fourth week onward. This increase can be attributed to the animals' adaptation to the different diets, favourable ruminal fermentation conditions, the high quality of the hay, and the diet's elevated nitrogen content.

Milk production for all groups and for all weeks of control is presented in Table 2. The milk production it was not affected by the substitution of soybean meal by sesame meal ($P>0.05$) and averaged 285, 298 and 278 ml for C, SM50 and SM100, respectively. This similarity could be explained by the fact that all diets were iso-nitrogenous. During all the trial, the milk production was significantly affected by the time. In fact, this production decreased from 334 ml at the beginning of the experiment to reach 256 ml at the end. The inclusion of sesame by-products in the diet of Awassi ewes at two levels of 7.5 and 15% improved significantly the milk production of ewes, which increased from 1001 to 1250 g/day compared to the control diet (6). The authors attributed the increase in milk production and composition in the groups supplemented with sesame by-products to the higher energy levels provided by these diets compared to the control group. However, this explanation does not apply to the present study, as the diets were iso-nitrogenous and iso-energetic. Similar results were reported by Hejazi and Abo Omar (16), who found that milk production increased more in goats fed diets containing 10 and 15% sesame cake compared to those fed a diet with 5% sesame cake. However, Jafari and al. (17) reported that the incorporation of sesame by-products at levels of 10 and 15% in the diet of dairy cows affected negatively milk production; with the lowest yield observed in cows fed a diet containing 15% sesame by-products. They attributed this decline to a reduction in dry matter intake at high inclusion rates.

In dairy sheep farming, milk composition is of considerable importance since the majority of the production is intended for cheese making (18). The parameters for the milk quality of Sicilo-Sarde ewes during the lactation period are shown in Table 2. The highest milk fat content was observed in the SM50 group (8.1%), followed by the control (7.5%) and SM100 (7.4%). These levels are higher than those reported by Hammami et al. (19), who found that the average milk fat content for Sicilo-Sarde ewes was 5.58%. At 50% of SBM substitution by SM, ewes showed the highest fat content. In the same context, Jafari and al. (17) reported that incorporating sesame by-products at a rate of 10 % into the diet of dairy cows was richer in fat. They attributed this difference to the overfeeding of cereals, which leads to a decrease in milk fat percentage and alters the milk's fatty acid profile. Conversely, milk fat concentration showed a significant increase throughout the experimental period ($p<0.001$) which can be attributed to the mobilization of the ewes' body fat reserves to meet their energy demands at the beginning of lactation, resulting in higher fatty acid levels in the blood and, consequently, an increase in milk fat content (18). The milk protein content was similar among groups and was about 6.9% for control and SM50 groups slightly higher than that of SM100 (6.4%), but without significant difference. The

Table 2 - Milk yield (ml/day) and chemical composition (%) of Sicilo-Sarde sheep fed sesame meal as substitute to soybean meal in concentrate.

	Diet (D)			Week of control (W)								P (D)	P (W)	P D*W
	C	SM50	SM100	W1	W2	W3	W4	W5	W6	W7	W8			
Milk yield (ml/day)	285	298	278	334^{a}	300^{ab}	259^{c}	283^{bc}	300^{ab}	264^{bc}	301^{ab}	256^{c}	0.16	0.0001	0.96
Fat (%)	7.5^{y}	8.1^{x}	7.4^{y}	6.39^{e}	6.77^{ed}	9.14^{a}	8.38^{b}	7.34^{dc}	7.54^{c}	7.48^{c}	8.27^{b}	0.001	0.001	0.18
Protein (%)	6.9	6.9	6.4	5.98^{e}	6.39^{d}	7.48^{a}	7.08^{b}	6.64^{dc}	6.84^{bc}	6.54^{dc}	6.89^{bc}	0.31	0.001	0.03
Lactose (%)	4.8	4.9	4.9	4.83^{b}	5.02^{a}	4.90^{ab}	4.95^{ab}	4.84^{b}	5.04^{a}	4.83^{b}	4.55^{c}	0.53	0.001	0.64
pH	6.35	6.37	6.36	6.37^{ab}	6.36^{b}	6.39^{a}	6.34^{bc}	6.35^{bc}	6.34^{bc}	6.35^{bc}	6.32^{c}	0.11	0.087	0.83

x, y, z: different letters in the same row indicate significant differences based on the diet ($p<0.05$);
a, b, c: different letters in the same row indicate significant differences based on the control week ($p<0.05$).

similar protein content in the milk for all groups could be related to similar energy intake and microbial protein synthesis in the rumen. This hypothesis is consistent with the statement by Bocquier and Caja (18), who showed that protein content is positively correlated with energy balance, as energy intake stimulates microbial protein synthesis in the rumen. However, Jafari and al. (17) reported that cows receiving a concentrate feed based on 5% and 15% sesame by-products had the highest and lowest milk protein percentages, respectively. And they explained this result by the fact that the decrease in milk protein density could be related to a high fat intake, which induces insulin resistance in amino acid absorption. On the other hand, Obeidat and al. (6) reported negative effects of energy balance on milk fat but positive effect on milk protein in Awassi ewes fed diets containing sesame by-products at levels of 0%, 7.5%, and 15%. They also found that a higher nutritional level generally led to a reduction in milk fat and a slight increase in milk protein in most dairy ewes.

The results concerning the average lactose content in the milk are shown in Table 2. Statistical analysis revealed that lactose content was affected ($P<0.05$) by the diet. It was significantly higher in the milk of ewes receiving the SM100 concentrate (4.97%) compared to the other groups, with 4.8% and 4.76% for the SM50 and C groups, respectively. This result can be explained by the fact that sesame is rich in carbohydrates. Furthermore, the higher lactose content in the milk of ewes receiving this concentrate was associated with the lowest fat content. This result is consistent with those of Alessio et al. (20), who found that milk lactose is negatively correlated with its fat content. However, the present study showed no significant influence of lactose over time ($P>0.05$; Table 2). This result could be attributed to the relatively slow degradation rate of the forage pea starch. Such a characteristic could be useful to compensate for the lack of rapidly available dietary energy from low-quality feed (21). The results concerning the pH of the milk are shown in Table 2. It was approximately 6.35, 6.37, and 6.36 for the milk of ewes receiving the C, SM50, and SM100 groups respectively. The pH values were similar among groups and in line with the results of Selmi and al. (22), who showed that the pH value for sheep milk is around 6.6. The pH provides precise information on the freshness of the milk. It depends not only on the content of casein, minerals, and ions but also on the hygiene conditions of milking, the total microbial flora, and their metabolic activity (23).

Individual laboratory Cheese yield (ILCY) and composition

The ILCY was similar among groups (Table 3). These values are higher than those observed in dairy cows where the yield was approximately 34%, whereas cow milk typically yields around 16.5%. This difference can be attributed to the higher average butyric and protein content in sheep milk compared to cow milk (24). The cheese yield increased significantly over time ($p<0.05$; Table 3). An important increase in this yield was observed at the end of the experiment for all groups. It has been shown that this evolution is proportional to the quantitative milk production and inversely proportional to the milk's butyric content (25). Indeed, the absence of the dietary effect is likely due to the very similar butyric and protein content between the three groups, knowing that these two parameters play a very important role in determining cheese yield (26).

The artisanal production of «Sicilian» cheese from Sicilo-Sarde sheep milk has been practiced for about a hundred years in the northwestern region of Tunisia. The content of dry matter (DM), ash and protein were affected by the dietary treatments (Table 4). This is in agreement with Martin and Coulon (27), who showed that the chemical composition of cheese depends on the nature of the offered feed. According to St-Gelais et al. (28), in cheese production, it is mainly casein that constitutes the cheese, while soluble proteins remain in the whey. The transformation of milk into cheese (using rennet or other enzymes) does not alter the nutritional quality of the proteins. However, the ash content decreased for the cheese derived from SM groups compared to control one. These differences are expected for traditional cheeses produced in small-scale dairies (29).

Cheeses Sensory Analysis

Table 5 presents the results of the sensory evaluation conducted on cheeses from all groups. No significant differences were observed among groups for cheeses firmness, elasticity, color, texture, or bitterness ($P > 0.05$), indicating a comparable sensory profile for these attributes across treatments. In terms of taste appreciation, the sensory panel assigned a numerically higher score to the cheese produced from ewes fed concentrates containing sesame cake (5.5) compared to the control group (4.3). Likewise, cheeses from the experimental groups (SM50 and SM100) received more favorable ratings from the panelists than the control cheese (5.5 vs. 4.4), suggesting a positive influence of sesame cake inclusion on overall taste perception. This finding is consistent with the results of Buchin et al. (30), who investigated the influence of different pastures on the organoleptic properties of cheese and reported that aroma intensity varies depending on the botanical composition of the pasture. These differences were attributed to variations in volatile compounds, some of microbial origin and others derived directly from the forage. In the present study, a distinctive sesame-related aromatic note was detected and positively perceived by the tasting panel, suggesting that the inclusion of sesame cake in the ewe's diet may have contributed to the development of specific volatile compounds enhancing the cheese's olfactory profile.

This result aligns also with the findings of Ruiz Pérez-Cacho et al. (31), who observed that goat cheeses from Andalusian goats fed a diet based on citrus by-products had a higher olfactory intensity than those fed the control diet. Regarding acidity, a numerical difference ($P>0.05$) in favor of the SM50 group (4.3)

Table 3 - Individual laboratory cheese yield of Sicilo-Sarde sheep fed sesame meal as substitute to soybean meal in concentrate.

	Diet (D)			Week of control (W)								P (D)	P (W)	P D*W
	C	SM50	SM100	W1	W2	W3	W4	W5	W6	W7	W8			
ILCY (%)	34.9	33	34.7	27.9^{c}	30.2^{c}	34.6^{b}	33^{bc}	33.4^{b}	34.4^{b}	39.4^{a}	40.9^{a}	0.07	0.0001	0.001

a, b, c: different letters on the same line indicate significant differences ($p<0.05$); CY = Cheese Yield, C = Control diet, SM50 and SM100 = Experimental diets with different levels of sesame cake substitution.

Table 4 - Cheese chemical composition (%) of Sicilo-Sarde sheep fed sesame meal as substitute to soybean meal in concentrate.

	Diets			Statistics	
	C	SM50	SM100	SEM	P-value
DM	51.86^{a}	51.04^{b}	49.03^{c}	2.23	0.04
Ash	5.01^{a}	4.73^{b}	4.79^{b}	1.07	0.02
Protein	17.57^{a}	11.85^{b}	10.42^{b}	3.26	0.001

Table 5 - Sensory attributes of Sicilo-Sarde sheep fed sesame meal as substitute to soybean meal in concentrate.

	Diets			Statistics	
	C	SM50	SM100	SEM	P-value
Color	1.9	2.1	1.8	0.51	0.78
Texture	6.2	5.9	5.9	1.03	0.93
Odor	2.4	2.9	2.3	0.92	0.63
Aroma intensity	2.7	4.7	3.5	1.15	0.06
Firmness	5.8	5.6	5.4	1.17	0.92
Elasticity	3.5	3.3	3.4	1.71	0.98
Acidity	2.5	4.3	2.4	1.28	0.08
Bitterness	2	2.7	1.9	0.99	0.51
Taste appreciation	4.3	5.1	6	1.24	0.15
Overall appreciation	4.4	5.3	5.8	1.21	0.26

SEM: standard error of the mean; **a, b:** Different letters in the same row indicate significant differences ($p<0.05$) between treatments.

was recorded compared to the T and SM100 groups (2.5). However, the increase in acidity in cheese is generally proportional to the increase in lactose content. This result does not support the present study, where the highest lactose content was recorded in the SM100 group. For overall appreciation, a numerical difference ($P>0.05$) in favor of the SM100 group (5.8) was recorded compared to the T and SM50 groups, which suggests that the cheese from ewes in the SM100 group was the most appreciated by the tasters.

CONCLUSION

This study highlights the potential of sesame meal as a sustainable alternative to soybean meal in dairy sheep nutrition, providing a locally available, protein-rich feed resource. The results show that substituting soybean meal with sesame meal maintains milk yield, improves milk protein content, and preserves cheese yield. Furthermore, the sensory quality of the cheese was enhanced, with greater aroma intensity and improved taste appreciation observed in the sesame-fed groups. Overall, these findings support the incorporation of sesame by-products into ruminant diets as part of a resource-efficient and locally adapted feeding strategy.

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Author's contribution

YY: contributed in the laboratory analyses, analysed the data statistically and wrote the first draft manuscript; **IM:** contributed in the laboratory and statistical analyses**; TJ:** conducted the experiment, contributed in the laboratory and statistical analyses; **SBS:** contributed in the writing of the manuscript; **MM:** conceived and designed the experiment contributed in the laboratory analyses; **NA**: conceived and designed the experiment, **SS:** conceived and designed the experiment and revised the manuscript. All authors read and approved the manuscript.

Conflict of interest

The authors declare that they have no conflict of interest.

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