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A survey of the commercial traits and antioxidant status of goat milk in Mediterranean pastoral farms

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Abstract

Aim of study: To enhance the viability of goat farms in Mediterranean mountain areas, studies have proposed strategies to improve the marketing of their animal products. The primary aim of this work was to provide an overview of the commercial traits and antioxidant composition of milk produced on Payoya farms. A second aim was to assess the relationships between the antioxidant capacity (TAC) and the hygiene-sanitary parameters in milk.

Area of study: Sierra de Grazalema Natural Park (Southern Spain).

Material and methods: The commercial traits (total solids, fat, protein, lactose, bacterial and somatic cell counts) and TAC of milk were determined monthly throughout the year. Milk samples were collected from sixteen Payoya farms under grazing-based management systems classified into three clusters (Low-productivity grazing farms; More intensive grazing farms; High-productivity grazing farms).

Main results: No significant differences were found between clusters in the milk quality. Principal changes were observed in the milk composition in different months due to the variation in the lactation stage and differences in feeding regimens. The negative correlation between the TAC and the somatic cell count contributes to the important role of antioxidants in maintaining optimal udder health. Vitamin A could be involved in this antioxidant mechanism due to the positive correlation between the TAC and retinol determined in a previous study.

Research highlights: The information generated on the quality of goat milk would contribute to establishing the records of the traceability system to guarantee that the animal products obtained are of the Payoya native breed.

Keywords: Payoya breed; feeding management; milk quality; somatic cell and bacterial counts; product commercialization.

Características comerciales y estado antioxidante de la leche de cabra en granjas pastorales mediterráneas

Resumen

Objetivo del estudio: Para mejorar la viabilidad de las explotaciones caprinas en las zonas mediterráneas de montaña, se han propuesto estrategias para mejorar la comercialización de sus productos. El objetivo principal de este trabajo fue proporcionar una visión general de las características comerciales y la composición antioxidante de la leche producida en explotaciones caprinas de raza Payoya. Un segundo objetivo fue evaluar las relaciones entre la capacidad antioxidante (TAC) y los parámetros higiénico-sanitarios de la leche.

Área de estudio: Parque Natural Sierra de Grazalema (Sur de España).

Material y métodos: Mensualmente y a lo largo de un año, se han determinado parámetros comerciales (sólidos totales, grasa, proteína, lactosa, recuentos totales de bacterias y de células somáticas) y la TAC de la leche. Se recogieron muestras de leche de dieciséis granjas de raza Payoya con sistemas de manejo basados en el pastoreo y clasificadas en tres grupos (Granjas de pastoreo de baja productividad; Granjas de pastoreo más intensivas; Granjas de pastoreo de alta productividad).

Resultados principales: No se encontraron diferencias significativas entre los grupos en relación con la calidad de la leche. Los principales cambios en la composición de la leche se observaron en los diferentes meses debido a la variación en la fase de la lactación y a las diferencias en la alimentación. La correlación negativa entre la TAC y el recuento de células somáticas pondría de relieve el importante papel de los antioxidantes en el mantenimiento de la salud óptima de la ubre. La vitamina A podría estar involucrada en este mecanismo antioxidante debido a la correlación positiva entre la TAC y el retinol determinada en un estudio previo.

Aspectos destacados de la inestigación: La información generada sobre la calidad de la leche de cabra contribuiría a establecer el sistema de trazabilidad que garantice la autenticidad de los productos de raza autóctona Payoya.

Palabras clave: raza Payoya; manejo de la alimentación; calidad de la leche; recuentos de bacterias y células somáticas; comercialización de los productos.

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Introduction

Dairy goats in Europe are most common around the Mediterranean basin, and the main use of the milk is for cheese making (Ruiz-Morales et al., 2019). The quality of the milk required for cheese making depends on its physical, proximate chemical, and hygienic-sanitary characteristics; for example, total bacterial count (BC) and somatic cell count (SCC) Pirisi et al., 2007). Traditionally, quality assessment systems consider several parameters, such as cheese extract (protein and fat percentages) and hygienic and bacteriological quality (Pirisi et al., 2007).

In recent years, foods containing natural antioxidants in general, and milk and dairy products in particular, have been demanded by consumers for their beneficial health effects in both humans and animals (McGrath et al., 2018; Khan et al., 2019). In animals, important roles for antioxidant compounds in maintaining optimum udder health have been identified (O`Rourke, 2009; McGrath et al., 2018). In this regard, the total antioxidant status in milk has been correlated with udder health, as reflected by the number of somatic cells present in milk. The total antioxidant capacity (TAC) is lower in mastitis milk samples compared with normal milk in cows (Atakisi et al., 2010) and in goats (Silanikove et al., 2014). However, studies on milk production, commercial traits, and total antioxidant status in dairy goat farms are scarce and incomplete (Delgado-Pertíñez et al., 2013). Thus, the applicability of the results obtained from commercial flocks to modify milk composition and quality is not well established.

The autochthonous Payoya breed is a dairy goat raised in pastoral systems. At the time of the study, 28 flocks, and 8,178 Payoya goats were registered in the correspondent herd-book (Association of Payoya breeders; unpublished data). The average milk production of the breed is 440 kg in 219-days lactation (ARCA, 2011). Produced milk is mainly oriented towards the production of pure goat cheeses. As in other small ruminant farming, their economic efficiency is mainly conditioned by productivity and feeding management (Milan et al., 2003; Ripoll-Bosh et al., 2012¸ Mena et al., 2017). The researchers' previous work (Gutiérrez-Peña et al., 2016; Mena et al., 2017), in which the profitability and social data of Payoya goat systems have studied, has suggested actions to enhance the viability of farms, such as commercial strategies to improve the sales of their products, for example, through specific certification. In this regard, a national regulation for commercializing native-bred animal products (Royal Decree-Law RD 505/2013) with a logo ("*100% Raza Autóctona*") has been published. This logo affects many products, including those fresh or processed from animals of autochthonous breeds (meat, milk, eggs, derivatives, and even non-food products such as wool).

Currently, consumers demand more information about the quality and origin of the products they purchase, making it necessary to establish specific identification by labeling products from autochthonous breeds. Therefore, using the above-mentioned national regulation will require assessing the quality of a farm's products. Based on previous work, milk samples from three grazing-based management groups were analyzed for fatty acid profile and vitamin A and E contents. There were few differences between groups, but important differences were found according to the season (Gutiérrez-Peña et al., 2018). However, there is a lack of information comparing the effect of Payoya management systems on commercial milk quality parameters.

Mena et al. (2017) conducted a multivariate analysis of the economic and social parameters of sixteen Payoya goat farms under conventional grazing-based management systems in southwestern Spain and identified three clusters. The primary aim of the present work was to provide an overview of the commercial traits and antioxidant composition of milk produced on those farms. These results would contribute significantly to the national regulation for the commercialization of native-bred animal products. A second aim of the current work was to assess the relationships between the antioxidant content and the hygiene-sanitary parameters in milk.

Material and methods

Farms involved in the study

Sixteen commercial farms raising to the autochthonous Andalusian breed Payoya, which represent 61% of the total number registered in the herd-book of the breed, were selected to provide a comprehensive representation of the different grazing goat production systems in the Sierra de Grazalema Natural Park and surrounding area (36° 35' N, 5° 26' W, southern Spain). The selection was based on the following criteria according to previous experience and knowledge of the area (Gutiérrez-Peña et al., 2016; Mena et al., 2017): i) variety of management practices; ii) data gathering and registration routine; iii) training of the farm's manager; and iv) willingness and collaborative spirit. These grazing goat farms were classified by Mena et al. (2017) into three groups according to their productivity and level of grazing: i) Low-productivity grazing farms (LPG, n = 4), characterized by small herds (174 goats), low production (177 kg of milk sold/goat/year), and minimal dependence on external inputs for animal feed due to high grazing intensity (273 and 39 kg/goat and year of concentrates and forages purchased, respectively); ii) More intensive grazing farms (MIG, n = 5), with medium-sized herds (251 goats), relatively high productivity (333 kg of milk sold/goat/year), mainly dependent on external inputs for feed with low grazing intensity (438 and 156 kg/goat and year of concentrates and forages purchased, respectively); and iii) High-productivity grazing farms (HPG, n = 7), characterized by large herds (572 goats), relatively high productivity (336 kg of milk sold/goat/year), medium dependence on external inputs for feed, and high grazing intensity (300 and 16 kg/goat and year of concentrates and forages purchased, respectively). More details about feed management and composition are reported in the previous studies of Gutiérrez-Peña et al. (2016) and Mena et al. (2017).

In those systems, goats generally lactate once a year, with an average lactation period of 6–8 months. Most births are in October–November and January–February, and lactation usually ends during the summer, resulting in a high seasonality of milk production; that is, more milk is sold in the first half of the year (Gutiérrez-Peña et al., 2016). Raw milk is the main product sold by farms, reaching a mean value of 76% of the total income from product sales (Mena et al., 2017). The main criteria for payment by cheese industry is the milk fat and protein contents and, the BC and SCC.

The study area has a Mediterranean climate, with cool and wet winters with an average temperature of 8°C and warm, dry summers with low rainfall and an average temperature of 25°C. Annual rainfall ranges from 960 to 2,220 mm. The landscape is diverse, including a mosaic of dehesa (open forest) and dense forests composed of *Quercus ilex* L., *Q. suber*, and *Q. faginea*. The dominant plant communities are characterized by sclerophyllous woody plants, often accompanied by an herbaceous or shrubby understory, as described by Costa et al. (2006). In this area, grazing is an important part of the diet. *Cistus salviifolius* L., *C. albidus*, *Myrtus communis*, *Pistacea lentiscus* L., and *Q. coccifera* are some grazed species (Scheneider, 1991).

Data collection and laboratory analyses

The farms were visited monthly for the collection of whole milk samples, following a repeated measures design, with samples taken from the bulk tank of each farm (n = 48, 60, and 84 for LPG, MIG and, HPG groups, respectively) as reported in the study by Gutiérrez-Peña et al. (2018). Duplicate aliquots of milk from the bulk tank were placed in 50 ml plastic bottles. One of the samples, in which azidiol was added as a preservative, was used to analyze milk composition. This sample was kept immediately at 4 ºC, transported refrigerated to the laboratory, and the analysis was always done within 24 h from sampling. The other sample was used for TAC analyses, placed in iceboxes, sent to the laboratory, and frozen at −20 ºC until analysis.

The information necessary for the calculation of economic and feeding indicators (Feed supply per milking goat; Net Energy Requirements obtained from Grazing (NERG); Daily goat marketable milk; Milk goat income) was collected according to the methodology described in previous studies (Gutiérrez-Peña et al., 2016; Mena et al., 2017). The price of milk was collected monthly by the purchase invoice given to the farmers. The indicator "Daily goat marketable milk" (L d^{-1}) was obtained by dividing the total milk production of bulk tank in each month by the average daily milking goats (those producing milk) each month and number of days in the month. In the same way, the indicator "Goat income" (€ d^{-1}) was calculated dividing the sales milk monthly income by the average daily milking goats each month and number of days in the month.

The *Laboratorio Interprofesional Lechero de Cantabria* (LILC) analyzed the commercial characteristics of the milk samples. The chemical composition, including total solids, fat, protein, and lactose, was determined using an FT120 instrument (Foss Electric, Hillerød, Denmark). These measurements were subjected to strict quality controls and validated by inter-comparison trials. The SCC was determined by flow cytometry (Foss Electric, Hillerød, Denmark). The BC was analyzed using a BactoScan FC (Foss Electric, Hillerød, Denmark), and the results are expressed in colony forming units (cfu).

The analysis of the TAC was performed by the *Servicio General de Investigación Agraria* (SGIA, University of Seville). The TAC was evaluated using the 2,2′-azinobis-3-ethylenebenzothiazoline-6-sulphonic acid (ABTS) method, which was conducted according to the procedure described by Gutiérrez-Peña et al. (2021). The ability to scavenge the radical cation ABTS-+ was compared with that of the vitamin E analogue Trolox®, which was used as a reference water-soluble standard antioxidant.

Statistical analyses

The data collected, including indicators related to feed management and milk quality parameters, were subjected to repeated-measures analysis. Logarithms (base 10) were taken to normalize the SCC and BC frequency distributions. The statistical model included the following components: i) a fixed-between-subjects factor (goat farms group); ii) a fixed-within-subjects factor (month, treated as a repeated measure); and iii) interactions between these factors (goat farms group × month). Tukey's honestly significant difference or least significant difference tests were used where appropriate for pairwise comparisons of means. Finally, Pearson correlation coefficients were also calculated for the variables used in the analysis. A significance level of $p \leq 0.05$ was considered statistically significant for these tests. All analyses were performed using IBM SPSS Statistics v. 26.0 for Windows (IBM Corp., Armonk, New York, USA).

a)

b)

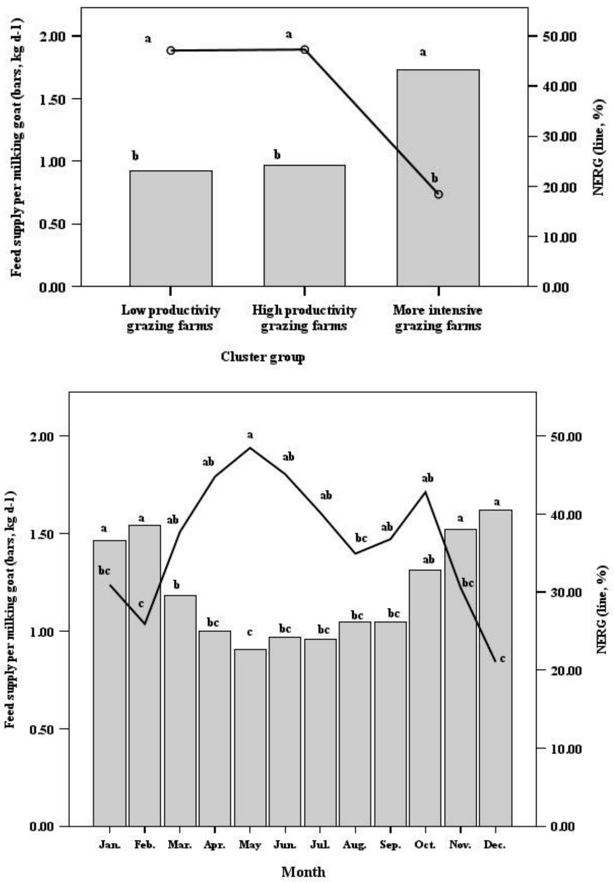

Figure 1. Indicators (mean values) related to feeding management (Feed supply, bars; Net Energy Requirements obtained from Grazing (NERG), line) of Mediterranean pastoral goat farms according to (a) cluster group and (b) sampling month. The feed supply per milking goat is the sum of the concentrate and fodder supplied in the manger by the farmers. The mean values for each parameter and factor levels were compared, and those with the same letter (a, b, c) do not differ ($p>0.05$).

Results

The indicators of feeding management are shown in Figure 1. The NERG was not statistically different between the more pastoral farms (LPG and HPG clusters; average 47%), but these values were higher ($p<0.001$) than that obtained for the MIG farms (19%; Figure 1a). Moreover, the MIG farms showed a higher ($p<0.001$) goat feed supply based mainly on concentrates (1.3 and 0.4 kg d^{-1} for concentrate and forage supply, respectively), and no differences were found between the LPG and HPG farms (averages of 0.8 and 0.1 kg d^{-1} for concentrate and forage supply, respectively). The amount of feed provided also changed with the month (Figure 1b). In winter (December, January, and February) and autumn (September, October, and November) months, goats received the highest amounts of concentrate (average of 1.2 kg d^{-1}; $p<0.05$) because the intensity of grazing was lower, and births were concentrated in those seasons of the year. The forage contribution followed an analogous pattern, supplying maximum amounts when the animals grazed less.

The yield, chemical and hygiene-sanitary compositions, and economic parameters of the milk according to the goat grazing group are shown in Table 1. No statistical differences in the percentages of chemical parameters were observed between the groups studied. Nevertheless, daily yields of milk and milk components were not different ($p>0.05$) between the MIG and HPG groups (averages of 1.34 L d^{-1} and 65.5, 49.8, and 61.8 g d^{-1} of fat, protein, and lactose, respectively), but were higher ($p<0.05$) than those obtained in the LPG group (0.77 L d^{-1} and 39.5, 28.7, and 37.1 g d^{-1} of fat, protein, and lactose, respectively). Consequently, and although the price of milk was similar for all farms (0.52€ L^{-1}), the final milk income was higher ($p<0.01$) for MIG and HPG farms (average of 0.70€ per goat d^{-1}) than for LPG farms (0.40€ goat d^{-1}) (Table 1).

The yield, chemical composition, and economic parameters of the milk were affected by the sampling month (Tables 1 and 2; Figure 2). The highest milk yield was obtained in the spring (March, April, May) months, followed by the winter months of January and February, and the lowest values were found in autumn and at the end of summer. The patterns throughout the lactation months of the lactose percentage and yield were similar, while the fat and protein percentages had an inverse relationship (higher during the autumn and, secondarily, in winter), to milk yield. The price of goat milk behaves seasonally, reaching a maximum at the end of summer and during the autumn, when there is a production deficit on farms (Figure 2). Considering the price and yields of milk (Figure

Table 1. Marketable yield, chemical composition, and hygiene-sanitary and economic parameters (mean annual values) of the goat milk in Mediterranean pastoral farms according to cluster group.

Parameters recorded	Cluster group (CG)			SEM[a]	P[b]	
	Low-productivity grazing farms (n=4)	More intensive grazing farms (n=5)	High-productivity grazing farms (n=7)		CG	Month
Daily goat marketable milk (L d^{-1})	0.77[b]	1.39[a]	1.28[a]	0.039	**	***
Total solids (%)	14.1	13.9	13.7	0.10	ns	***
Fat (%)	5.19	4.96	4.86	0.062	ns	***
Fat (g d^{-1})	39.5[b]	68.9[a]	62.1[a]	1.80	**	**
Protein (%)	3.69	3.72	3.67	0.030	ns	***
Protein (g d^{-1})	28.7[b]	52.0[a]	47.6[a]	1.39	**	**
Lactose (%)	4.39	4.49	4.43	0.020	ns	***
Lactose (g d^{-1})	37.1[b]	64.5[a]	59.1[a]	1.82	**	***
SCC (× 10^3 mL^{-1})[c] (geometric mean)	2260 (1878)	1966 (1758)	2376 (2215)	77.09	ns	***
BC (× 10^3 cfu mL^{-1})[c] (geometric mean)	173 (102)	114 (59)	109 (68)	10.2	ns	***
TAC (μmol Trolox equivalents mL^{-1})[d]	5.26	5.16	5.03	0.113	ns	***
Milk goat income (€ d^{-1})	0.40[b]	0.72[a]	0.67[a]	0.019	**	*

Means with different letters (a and b) between columns differ significantly (p<0.05).
a Standard error of mean.
b Statistical probability of treatment: ns (not significant), p>0.05; *, p≤0.05; **, p<0.01; ***, p<0.001. No significant interactions between these factors were noted (p>0.05).
c SCC, Somatic cell count; BC, Bacterial count. For the statistical analysis, a logarithmic (base 10) transformation was applied.
d TAC, Total antioxidant capacity.

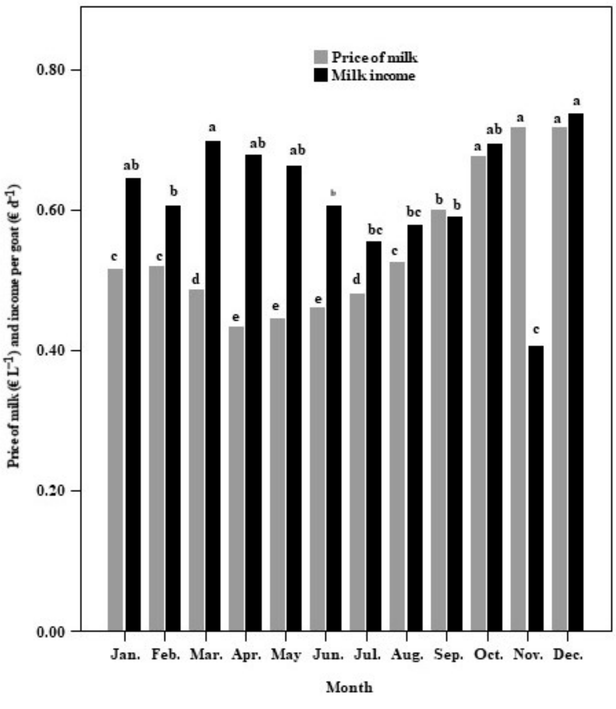

Figure 2. Mean values of economic parameters of the goat milk in Mediterranean pastoral farms according to sampling month. The mean values for each parameter were compared, and those with the same letter (a, b, c, d) did not differ (p>0.05).

2 and Table 2), the lowest milk income was obtained in the summer months and in November (Figure 2).

The BC and SCC of the milk showed no significant differences (p>0.05) with respect to the groups studied (Table 1) but were affected by the sampling month (p<0.001, Table 2). The highest SCC and BC were obtained at the end of summer and autumn, while the remaining months had the lowest counts.

Regarding the relationship of milk yield and chemical parameters with the hygiene-sanitary composition, as the SCC increased, milk yield (r = −0.23, p<0.01) and lactose (r = −0.40, p<0.001) decreased, whereas fat (r = 0.29, p<0.001) and protein (r = 0.50, p<0.001) contents increased. A positive correlation was obtained between SCC and BC (r = 0.26, p<0.001).

The TAC did not vary significantly (p>0.05) between the groups studied (Table 1). Nevertheless, it was significantly higher (p<0.001) in winter and spring milk than in milk samples taken during other seasons (Table 2). Regarding the relationship between the hygiene-sanitary parameters and the TAC, a negative correlation (r = −0.30, p<0.001) between TAC and SCC was found.

Table 2. Marketable yield, chemical composition, and hygiene-sanitary parameters (mean values) of the goat milk by month in Mediterranean pastoral farms.

Parameters recorded	Month											
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
Daily marketable goat milk (L d^{-1})	1.27^{bc}	1.19^{bc}	1.47^{ba}	1.57^{a}	1.52^{a}	1.33^{b}	1.16^{c}	1.12^{c}	0.99^{c}	1.04^{c}	0.58^{d}	1.05^{c}
Total solids (%)	14.8^{b}	13.9^{c}	13.0^{d}	12.8^{de}	12.9^{d}	12.4^{e}	12.6^{de}	14.1^{c}	14.6^{b}	16.3^{a}	15.1^{b}	14.4^{bc}
Fat (%)	5.09^{c}	5.11^{c}	4.72^{d}	4.34^{ef}	4.37^{ef}	4.30^{f}	4.27^{f}	4.59^{de}	5.44^{bc}	6.08^{a}	6.10^{a}	5.65^{ab}
Fat (g d^{-1})	65.2^{ab}	60.9^{b}	70.5^{a}	69.2^{a}	67.2^{a}	58.7^{bc}	50.9^{c}	52.9^{bc}	54.8^{bc}	63.6^{ab}	35.3^{d}	57.5^{bc}
Protein (%)	3.69^{c}	3.61^{c}	3.50^{d}	3.38^{e}	3.38^{e}	3.41^{de}	3.41^{de}	3.62^{c}	3.93^{b}	4.21^{a}	4.52^{a}	3.93^{b}
Protein (g d^{-1})	47.8^{ab}	43.9^{b}	52.5^{a}	54.4^{a}	52.7^{a}	46.6^{b}	41.0^{b}	42.0^{b}	40.2^{b}	44.9^{b}	26.2^{c}	41.3^{b}
Lactose (%)	4.79^{a}	4.76^{a}	4.62^{b}	4.56^{bc}	4.34^{cd}	4.27^{cd}	4.25^{cd}	4.18^{d}	4.19^{d}	4.26^{cd}	4.52^{bc}	4.49^{c}
Lactose (g d^{-1})	62.7^{ab}	58.5^{b}	70.1^{ab}	73.9^{a}	67.8^{ab}	58.6^{b}	51.3^{bc}	48.8b^{c}	43.4^{c}	45.3^{bc}	26.9^{d}	54.6^{bc}
SCC ($\times 10^3$ mL^{-1})^{a}	1720^{d}	1562^{d}	1595^{d}	1642^{d}	1777^{d}	2099^{c}	1917^{cd}	2734^{ab}	3286^{a}	3211^{ab}	3513^{a}	2179^{c}
BC ($\times 10^3$ cfu mL^{-1})^{a}	116^{b}	73^{bc}	80^{c}	96^{c}	104^{bc}	100^{bc}	100^{bc}	127^{bc}	175^{a}	150^{a}	182^{a}	222^{ab}
TAC (μmol Trolox equivalent mL^{-1})^{b}	5.99^{b}	6.10^{b}	5.73^{bc}	6.21^{ab}	6.90^{a}	4.59^{cd}	4.26^{cd}	3.48^{d}	4.09^{cd}	2.64^{e}	5.89^{bc}	5.51^{c}

Means with different letters (a, b, c, d, e, and f) between columns differ significantly ($p<0.05$).
a SCC, Somatic cell count; BC, Bacterial count. For the statistical analysis, a logarithmic (base 10) transformation was applied.
b TAC, Total antioxidant capacity.

Discussion

Although all animals in the study were fed by grazing, the contribution of grass differs between groups. Mena et al. (2017) have observed that the HPG farms have similar milk production per goat to the MIG farms and greater productivity than the LPG farms, with similar NERG and concentrate and forage inputs. According to milk production and chemical composition, the levels of energy and protein provided by grazing and supplemental feeds would be similar in the HPG and MIG groups and higher than in the LPG group (Morand-Fehr et al., 2007). In the present study, milk sales are the main income (Mena et al., 2017), and according to the current pricing system (including prevailing penalties), the differences between the groups are due to the milk productivity (L d^{-1}) because there were no differences in either the cheese extract (protein and fat percentages) or in the SCC and BC (Table 1).

Milk yield (1.20 L d^{-1}) was smaller, and the percentages of basic chemical components (5.00%, 3.69%, and 4.44% for fat, protein, and lactose, respectively) were within the range of individual test-day data from Murciano–Granadina goats (Pleguezuelos et al., 2015), the most important Spanish dairy goat breed, reared under a semi-intensive system, and of the bulk tank milk from dairy goat farms (de la Vara-Martínez et al., 2018). The reduced yield in the study area may be due to the characteristics of the farming systems, specifically to the autochthonous Payoya breed, which are well adapted to grazing but farmed less intensively and, consequently, have lower milk productivity. Stage of lactation and feeding (mainly due to ingestion and nutritive value of the feedstuff) differences can explain the milk yield and composition results in the months analyzed (Delgado-Pertíñez et al., 2013). Regarding the physiological factor of lactation, in the farms of this study, lactation finished toward summer, and the main kidding period was in autumn. Together with the lower temperatures, this would partially explain the reduced milk production and enriched chemical composition at the end of summer and autumn. The reproduction pattern of those farming systems (births are concentrated in October–November and January–February) is made to graze the most in spring and reduce the number of lactating animals in summer, when pasturage is scarce in the Mediterranean region (Mena et al., 2017).

Bulk tank SCC and BC have been used as indicators to evaluate udder health, as well as the efficiency of production processes and cleaning and hygiene-sanitary practices (Delgado-Pertíñez et al., 2003; Gonzalo et al., 2010; de la Vara-Martínez et al., 2018). In this study, geometric means for SCC (1950 $\times$ 10^3 cells/mL) and BC (77 $\times$ 10^3 cfu/mL) were similar to values reported for bulk tank milk from the same breed (Delgado-Pertíñez et al., 2003) and other Spanish breeds (de la Vara-Martínez et al., 2018). Significant differences in the hygiene-sanitary quality of the milk were observed for different months, in agreement with a previous study of the same breed (Delgado-Pertíñez et al., 2003). However, no significant differences were found by de la Vara-Martínez et al. (2018) in other Spanish breeds, indicating that the results are more related to good farming practices.

The seasonal variation of the SCC in our study could be related to the lactation phase, increasing toward the end of lactation (Zeng et al., 1997; Raynal-Ljutovac et al., 2007), and other non-infectious factors (Raynal-Ljutovac et al. 2007). Higher counts due to physiological causes are common because several breeding females are present in the goat herds throughout the year, and postpartum and lactation periods occur successively (Raynal-Ljutovac et al., 2007; Gutiérrez-Peña et al., 2016). Furthermore, this indicator has been associated with intra-mammary infections and milk yield losses in dairy goats (Baudry et al., 1997; Pleguezuelos et al., 2015). Nevertheless, SCC levels in small ruminants have still not been included in European legislation (EC No. 853/2004) because their significance is still debatable. Unlike the milk yield in the present study, fat and protein percentages have been shown to rise as SCC increases, in agreement with previous studies in the same breeds (Delgado-Pertíñez et al., 2003) and other Spanish breeds (Pleguezuelos et al., 2015). Although a decrease in fat and protein is expected during intramammary infection due to the reduced synthetic and secretory capacity of the mammary glands (Raynal-Ljutovac et al., 2007), no studies have rigorously evidenced this phenomenon in goats (Pleguezuelos et al., 2015). The increases in these parameters observed in our study have also been reported by other authors (Barrón-Bravo et al., 2013; Pleguezuelos et al., 2015), who attributed it to a concentration effect associated with the reduction in milk yield in infected goats as inflammatory response increased. In the case of protein, a higher soluble protein concentration in milk from blood associated with a mammary infection or SCC (Leitner et al., 2004a,b) together with a concentration effect (due to decreased milk yield) could explain the higher correlation found for protein content compared to that for fat content as SCC increases.

Unlike SCC, BC is covered by EU legislation (EC No. 853/2004), with different thresholds set according to the species and the intended use of the milk. The limits for milk from species other than cow are $\leq 500\times10^3$ cfu/mL when the destination of milk does not include heat treatment or $\leq 1500\times10^3$ cfu/mL for heat-treated milk before processing. In our study, the BC was lower in the months with the highest environmental temperatures; this requires the implementation of good hygiene-sanitary practices on farms, including maintaining the refrigeration tank at the correct temperature. The higher counts in some months (mostly autumn) may be associated with rainfall and, consequently, dirtier animals (Delgado-Pertíñez et al., 2003). The mean bacteriological values obtained in this study were lower than the maximum levels permitted by EC Regulation for products made with raw milk, which shows that the appropriate conditions of hygiene-sanitary management are being maintained at the study farms.

Dairy products contain natural antioxidants, such as vitamins, oligosaccharides, peptides, and minerals (Khan et al., 2019) and appreciable amounts of phenolic compounds (Di Trana et al., 2015; Chávez-Servín et al., 2018; Delgado-Pertíñez et al., 2021). The TAC did not vary significantly between the groups studied, in agreement with previous work (Delgado-Pertíñez et al., 2013), probably due to the similar management of animals on all farms based on the use of pastures. According to several studies in cows (Clausen et al., 2009) and sheep (Virto et al., 2012), the main water-soluble antioxidants of milk are derived from the caseins and other low molecular weight compounds, which could explain the differences between results obtained in different months in this study (i.e., higher values in winter and spring milk than in the other milk samples). With respect to the latter compounds, a positive correlation ($r = 0.31$, $p<0.001$) was observed between the TAC and retinol in our previous study (Gutiérrez-Peña et al., 2018), in agreement with the higher content of vitamin A in winter milk in our work and the findings of Revilla et al. (2016) in cheeses. However, no significant correlations have been found by other authors (Lucas et al., 2008). Some vitamins, such as vitamin A, play an important role in supporting the immune system (Spears and Weiss, 2008), and this could be associated, at least partially, with the lower SCC observed in the present study, in which a negative correlation ($r = -0.22$, $p<0.01$) between SCC and retinol was also observed. Indeed, vitamin A content in blood has been associated with the udder health of dairy cows (Chew et al., 1982; LeBlanc et al., 2004), and dairy cows supplemented with that vitamin at the end of the prepartum period had lower SCC in postpartum milk (Agustinho et al., 2021). There are few studies in goats; therefore, further research is necessary to better understand how these parameters are affected by the hygiene-sanitary components and affect inflammatory markers, especially in individual animals.

Conclusion

No significant differences were found between clusters in the composition, hygiene-sanitary parameters, and antioxidant capacity of the milk studied, as the animals in all farms were similarly managed based on the use of natural pastures. However, significant changes were observed in the milk composition by calendar month because of lactation effects and differences in feeding regimens. The percentage of lactose and the milk component yields (g d^{-1}) patterns throughout the lactation months were similar, while the relationship between the fat and protein percentages was inverse to milk yield. During the end of summer and autumn months, the highest number of bacteria and somatic cells in the milk were observed, but the bacteriological count levels were below the legal limit set by EC regulations. The TAC was significantly higher in winter and spring milks than in the other milk samples.

The negative correlation between the antioxidant capacity and the somatic cells shows the important role of antioxidants in maintaining optimal udder health. One of the compounds involved in this antioxidant mechanism could be vitamin A due to the positive correlation between the antioxidant capacity and retinol determined in a previous study.

Finally, the information generated in this and previous studies on the quality of goat milk from the autochthonous Payoya breed will contribute to establishing the records of the traceability system to guarantee that the animal products obtained are of the native breed. All of this will help the consumer to easily identify these products and increase their demand, which will result in the conservation and promotion of the genetic heritage of these breeds and the foods derived from them.

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