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Milk-related performances of Murciano-Granadina goats reared in Italy compared to cosmopolitan breeds

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ABSTRACT

The Murciano-Granadina (MG) goat breed was introduced in 2016 in northern Italy and it has become the third most widespread breed after Saanen (SA) and Alpine (AL). The study aimed to compare milk yield and composition of MG with SA and AL reared under the same farming system. A total of 11,682 milk test-day records from 1947 goats reared in 7 single- and 7 multi-breeds herds were evaluated. All breeds included out off-season kiddings: MG is a permanent polyestric breed whereas specific strategies are commonly adopted to induce oestrus across the year in SA and AL. The mixed model included breed, parity, stage of lactation, kidding season and first-order interactions as fixed effects; goat, herd-test-date and residual were random effects. All the effects were significant in explaining the variability of the traits ($p < 0.01$). The MG yielded 0.93 and 0.50 kg/d less milk ($p \leq 0.05$) than SA and AL, respectively, and showed the greatest fat, protein, casein and lactose content and the lowest SCS ($p \leq 0.05$). Oppositely to SA, the fat-to-protein ratio (F/P) of MG was always ≥ 1.00 regardless of lactation stage, parity and kidding season. In conclusion, MG can yield high-quality milk despite being less productive than SA and AL. Moreover, this recently introduced breed, whose reproductive behaviour is less sensitive to season compared to SA and AL, performs efficiently under the Veneto region farming system and can be a genetic resource of interest for the current Italian context.

HIGHLIGHTS

- Milk composition differed among all three breeds: Murciano-Granadina (MG) milk had the greatest lactose and fat content and the lowest SCS.
- MG goats milk was characterised by greater protein and casein content than Saanen (SA) and was similar to Alpine (AL).
- The fat-to-protein ratio (F/P) was always >1.00 in MG, while in SA was usually <1.00.

Introduction

In Italy, there are more than 1 million goats of which 77.5% are females (ISTAT 2020). However, less than 56 thousand spread in 633 herds were officially registered in 2020 in the Italian Breeders Association (AIA 2021). Despite being Saanen (SA) and Camosciata delle Alpi or Alpine (AL) the main goat breeds reared for milk production in Italy, Murciano-Granadina (MG) was introduced in the Veneto region in 2016 due its milk quality and less pronounced reproductive seasonality which allows less fluctuations in milk production across the year (Delgado et al. 2017). Moreover, MG presents a high rusticity and adaptability letting to be raised under harsh conditions – such as the ones in the Mediterranean area – while maintaining milk quality and production (León et al. 2012; Delgado et al.

2017). Nowadays, the Veneto region account for more than 50% of MG goats and herds in Italy (AIA 2021).

MG breed is a Spanish native breed originated in 1975 from crossing goats of Murciana and Granadina breeds (MAPA 2021), which had been introduced in semi-intensive farming systems in Europe, Africa and South America due to its high adaptability. According to Guan et al. (2021), genetic selection in the MG population has focussed on milk yield for a long time. Currently, the national association 'Asociación Nacional de Caprino de Raza Murciano-Granadina' (CAPRIGRAN 2022) is in charge of its official routine evaluation, and a comprehensive overview of traits under selection, including the casein genotype, is publicly available (https://caprigran.com/en/breeding-program/). Morphologically, MG is characterised by black or brown coats with or

without presence of horns and animals are smaller (50 kg of live bodyweight) than cosmopolitan dairy breeds such as SA and AL (MAPA 2021). Moreover, MG is considered a permanent polyestric breed due to its less pronounced seasonal reproductive behaviour and its reproductive management is based on the 'male effect' without applying artificial photoperiod or hormones (Delgado et al. 2017). It should be noted that these management practices need to be applied in SA and AL goats when a farmer want to keep its milk production all the year. Although MG is less productive , milk quality characteristics are more favourable than SA and AL for cheese manufacturing (Vacca et al. 2018; Guan et al. 2021).

Therefore, the aim of this study was to evaluate the performance in terms of milk yield and composition of MG compared to SA and AL breeds in the Veneto region using large-scale milk data collected in commercial farms during a complete year.

Materials and methods

Data editing

Information on individual goat milk samples was retrieved from the official routine milk testing of the Veneto Regional Breeders Association (Veneto, Italy). In goats milk sampling is performed every 4 weeks in Italy and in the present study the period from January to December 2020 was considered. In the Veneto region, goats feeding is mainly based on forage or hay plus concentrates. The MG herds included in the study kidded all-round year. Moreover, some SA and AL herds applied reproductive practices to also allow out-of-season kidding. However, as dealing with large-scale milk data collected from the official routine milk testing, there was no access to more detailed information on the specific practices that farmers applied.

Milk chemical composition (fat, protein, casein and lactose content) was assessed through mid-infrared spectroscopy using goat-specific models implemented in MilkoScan FT6000 (FOSS Analytical A/S, Hillerød, Denmark). Fat-corrected milk at 3.5% (FCM 3.5%) was estimated according to Pulina et al. (1991) as: FCM 3.5% = milk yield × (0.634 + 0.1046 × fat%). Moreover, fat-to-protein ratio (F/P) was calculated. Somatic cell count (SCC, cells/μL) was determined using a Fossomatic 7 DC (FOSS Analytical A/S) and transformed into SCS through the formula of Wiggans and Shook (1987): SCS = 3 + $\log_2$ (SCC/100).

The original dataset ($n = 14{,}561$) was edited to retain herds which included at least 75 lactating goats from SA, AL and/or MG dairy breed. Records not

belonging to purebred SA, AL or MG goats between 5 and 300 d in milk (DIM) and from parity $1 - 11$, and goats with less than 3 observations within lactation were discarded. For milk yield (kg/d) and fat, protein, casein and lactose content (%), values that deviated more than 3 SD from the mean were treated as missing data.

The final dataset included 11,682 test-day records from 1947 goats located in 7 single- and 7 multi-breed herds. The frequency for each breed was: 10 herds, 705 goats and 4,145 observations (AL); 8 herds, 830 goats and 5,382 observations (SA); 4 herds, 412 goats and 2,155 observations (MG). Single-breed herds were 4, 1 and 2 for AL, SA and MG, respectively. For multi-breed herds, three breed combinations were available in the dataset: SA + AL (5 herds), SA + MG (1 herd) and SA + AL + MG (1 herd). The average number of lactations and DIM were 3.10 ± 2.00 and 150.12 ± 73.18 for AL, 2.64 ± 1.64 and 141.00 ± 70.60 for SA, and 2.30 ± 1.41 and 150.70 ± 67.97 for MG.

Statistical analysis

Data editing and statistical analyses were carried out in R software version 4.1.2 (R Core Team 2022). Pearson's correlations were calculated using the package 'Hmisc' version 4.7 (Frank and Harrell 2022) and were considered weak if equal or below0.30, moderate if between 0.31 and 0.70 and strong if equal or above 0.71.

Before the analysis of variance, the normality distribution of the data was verified based on the visual inspection of datapoints, skewness and kurtosis through the 'moments' package version 0.14.1 (Komsta and Novomestky 2022). The homoscedasticity of the data was verified by the Barlett test of homogeneity of variance using the 'Stats' package version 0.1.0.

Daily milk yield, composition traits, and SCS were analysed through the following mixed model:

$$y_{ijklmno} = \mu + B_i + S_j + P_k + K_l + (B \times S)_{ij} + (B \times P)_{ik} \\ + (B \times K)_{il} + (S \times P)_{jk} + (P \times K)_{kl} + G_m \\ + H_n + e_{ijklmno}$$

where $y_{ijklmno}$ is the dependent variable; μ is the overall intercept of the model; B_i is the fixed effect of the ith breed (i = SA, AL and MG); S_j is the fixed effect of the jth stage of lactation ($j = 1 - 10$; the first being a class from 5 to 30 DIM, followed by 8 classes of 30 DIM each, and the last being a class from 271 to 300 DIM); P_k is the fixed effect of the kth parity ($k = 1-5$,

with the last including parity from 5 to 11); K_l is the fixed effect of the lth kidding season ($l = 4$; Winter, Spring, Summer, Autumn); $(B \times S)_{ij}$ is the fixed interaction effect between breed and stage of lactation; $(B \times P)_{ik}$ is the fixed interaction effect between breed and parity; $(B \times K)_{il}$ is the fixed interaction effect between breed and kidding season; $(S \times P)_{jk}$ is the fixed interaction effect between stage of lactation and parity; $(P \times K)_{kl}$ is the fixed interaction effect between parity and the kidding season; G_m is the random effect of the mth animal (1,947 goats) $\sim N(0, \sigma^2_G)$, where σ^2_{Goat} is the goat variance; H_n is the random effect of the lth herd-test-date (104 levels) $\sim N(0, \sigma^2_H)$ where σ^2_H is the herd-test-date variance; $e_{ijklmno}$ is the random residual $\sim N(0, \sigma^2_e)$, where σ^2_e is the residual variance. The random effects were assumed to be independent.

The analysis was conducted using the 'lme4' package version 1.1–29 (Bates et al. 2015) and multiple comparisons of least-squares mean were performed for the main effect of breed, parity class, stage of lactation, kidding season and their interaction using the Bonferroni adjustment. Significance was set at $p \leq 0.05$ unless otherwise stated.

Results

Breed-specific correlations

Phenotypic correlations were always significant ($p \leq 0.05$) with only few exceptions (Table 1). For instance, F/P ratio was not correlated to protein content in SA and MG breed and to casein content in MG. Milk yield was inversely correlated with fat, protein, casein, F/P ratio and SCS, and positive correlated with lactose ($p < 0.01$). A stronger correlation was observed in MG than in SA and AL between milk yield, and fat, F/P ratio and SCS, whereas a weaker correlation was observed with protein or casein. However, FCM 3.5% was also weakly correlated with fat content in MG. Protein and casein content was moderately correlated with fat content, being that correlation stronger in MG than in SA breed (Table 1). Fat was weakly positive correlated to lactose and SCS ($p < 0.01$). Protein and casein were weakly positively correlated with SCS ($p < 0.001$), being stronger in SA and AL than in MG breed. The F/P was weakly correlated with lactose and SCS. Lactose was moderately negative correlated ($p < 0.001$) with SCS, being the correlation slightly weaker in AL.

Analysis of variance

Breed, stage of lactation, parity and kidding season significantly explained the variability of milk production, gross composition and SCS ($p < 0.01$). Breed was the most important factor influencing all the investigated traits (F value, 479.94 for casein to 1,774.29 for lactose), except for SCS, which was mostly affected by parity (F value, 289.91).

Effect of breed

Results related to the breed effect are displayed in Table 2. The three breeds differed in milk yield ($p \leq$

Table 1. Pearson's correlations[a] ($p \leq 0.05$) of milk yield and quality traits calculated within Saanen (SA), Alpine (AL) and Murciano-Granadina breed (MG).

Trait[b]	Breed	Milk yield, kg/d	FCM 3.5%, kg/d	Fat, %	Protein, %	Casein, %	Fat-to-protein	Lactose, %
FCM 3.5%, kg/d	SA	0.97						
	AL	0.97						
	MG	0.96						
Fat, %	SA	−0.26	−0.04					
	AL	−0.17	0.05					
	MG	−0.41	−0.19					
Protein, %	SA	−0.37	−0.29	0.39				
	AL	−0.25	−0.15	0.51				
	MG	−0.14	−0.06	0.54				
Casein, %	SA	−0.36	−0.27	0.42	0.99			
	AL	−0.24	−0.13	0.54	1.00			
	MG	−0.13	−0.04	0.54	1.00			
Fat-to-protein	SA	−0.13	0.08	0.91	ns	0.02		
	AL	−0.04	0.16	0.84	−0.02	0.02		
	MG	−0.40	−0.20	0.83	ns	ns		
Lactose, %	SA	0.10	0.13	0.13	0.06	0.12	0.10	
	AL	0.08	0.10	0.08	0.10	0.15	0.03	
	MG	0.09	0.10	0.09	ns	0.08	0.09	
SCS	SA	−0.23	−0.22	0.06	0.23	0.20	−0.02	−0.41
	AL	−0.21	−0.17	0.17	0.22	0.21	0.07	−0.33
	MG	−0.32	−0.28	0.24	0.15	0.13	0.18	−0.39

[a]ns: not significant
[b]FCM 3.5%: fat-corrected milk at 3.5%; SCS: somatic cell score

Table 2. Number of records (*n*) and least squares means (LSM) with their standard error (SE) of milk yield and quality traits.

Trait[d]	Saanen		Alpine		Murciano-Granadina	
	n	LSM ± SE	*n*	LSM ± SE	*n*	LSM ± SE
Milk yield, kg/d	5360	2.89 ± 0.04[a]	4127	2.46 ± 0.05[b]	2144	1.96 ± 0.04[c]
FCM 3.5%, kg/d	4902	2.74 ± 0.04 [a]	3536	2.53 ± 0.05[b]	1965	2.08 ± 0.04[c]
Fat, %	5331	3.03 ± 0.03[c]	4103	3.77 ± 0.04[b]	2135	4.32 ± 0.03[a]
Protein, %	5325	3.33 ± 0.02[b]	4102	3.56 ± 0.02[a]	2120	3.56 ± 0.02[a]
Casein, %	4592	2.50 ± 0.01[b]	3321	2.67 ± 0.02[a]	1754	2.70 ± 0.01[a]
Fat-to-protein	5281	0.91 ± 0.01[c]	4068	1.00 ± 0.01[b]	2108	1.20 ± 0.01[a]
Lactose, %	5340	4.40 ± 0.01[b]	4098	4.41 ± 0.01[b]	2136	4.74 ± 0.01[a]
SCS	5281	6.28 ± 0.07[a]	4145	6.02 ± 0.08[b]	2155	5.64 ± 0.07[c]

[a,b,c]Values with different superscripts within a row are significantly different ($p \leq 0.05$).
[d]FCM 3.5%: fat-corrected milk at 3.5%; SCS: somatic cell score.

0.05), with the lowest and greatest productivity in MG (milk yield, 1.96 ± 0.04 kg/d; FCM 3.5%, 2.08 ± 0.04 kg/d) and SA (milk yield, 2.89 ± 0.04 kg/d; FCM 3.5%, 2.74 ± 0.04 kg/d), respectively. On the other hand, fat content and F/P showed the opposite pattern ($p < 0.0001$). However, protein and casein content of MG was similar to AL breed ($p < 0.001$) and greater than SA breed. The greatest lactose content (4.74 ± 0.01%) and the lowest SCS (5.64 ± 0.07) were observed in MG ($p < 0.001$); whereas SA presented the greatest SCS (6.28 ± 0.07; $p < 0.001$).

Effect of stage of lactation within breed
Variations of milk production, gross composition and SCS are depicted in Figure 1. Milk yield peaked at 31–60 DIM in MG (2.35 ± 0.12 kg/d) and AL (2.80 ± 0.07 kg/d) goats, whereas SA goats peaked in the following DIM class (4.43 ± 0.06 kg/d). However, when considering FCM 3.5%, all breeds peaked at 5–30 DIM. After the peak, milk yield gradually decreased until the end of lactation. Overall, SA breed showed greater productivity across lactation compared to MG ($p \leq 0.05$), whereas AL showed intermediate performance.

Fat content was stable until 151–180 DIM in MG, then it steadily increased until reaching 4.91 ± 0.09% at the end of lactation. On the other hand, fat content reaches the lowest point at 121–150 DIM in SA (2.60 ± 0.04%) and AL (3.28 ± 0.05%) breeds. Protein and casein content showed a similar pattern throughout the lactation. Despite the fact that SA and AL breeds behaved similarly, MG goats slightly differ showing a greater persistency in early- and mid-lactation compared to other breeds. The lactation curve of F/P ratio was similar across breeds, with better and less favourable ratio for MG (always >1.00) and SA (always <1.00), respectively.

Lactose content lactation curve was also similar among breeds but, as reported previously, milk of MG goats presented a greater ($p \leq 0.05$) content compared

to the other breeds. The greatest values were observed at the beginning of the lactation (5–30 DIM), followed by a steadily decrease towards the end of lactation (271–300 DIM). The SCS generally increased across lactation in all breeds, with small differences in early lactation (Figure 1).

Effect of parity within breed
Variations in milk production, gross composition and SCS are depicted in Figure 2. In MG, primiparous yielded (Milk production, 2.52 ± 0.07 kg/d; FCM 3.5%, 2.60 ± 0.07 kg/d; $p < 0.001$) more milk compared to the older goats, i.e. those in the last parity class (Milk production, 1.54 ± 0.10 kg/d; FCM 3.5%, 1.70 ± 0.09 kg/d; $p < 0.001$). On the contrary, SA and AL goats milk production and FCM 3.5% steadily increased until reaching the greatest yield in goats at their fourth lactation. In particular, milk production and FCM 3.5% were 3.13 ± 0.07 and 2.95 ± 0.07 kg/d, respectively, in SA and 2.76 ± 0.07 and 2.86 ± 0.07 kg/d, respectively, in AL. Although SA yielded more milk than the other breeds ($p \leq 0.05$), productivity of the first and second parity was similar to MG. Milk fat content of MG and AL increased with parity, reaching the greatest content in the last parity class, i.e. from fifth lactation onwards (4.72 ± 0.08 and 3.97 ± 0.05% for MG and AL). Also, the SA breed presented the greatest content at the fifth parity onwards (3.25 ± 0.06%), however, such estimate did not significantly differ from that referred to first parity goats (3.10 ± 0.07%). Protein and casein content were greater on the first and the last parity for all three breeds. However, the variability between parities was larger in MG goats. Moreover, SA usually showed the lowest fat, protein and casein content. While lactose content decreased linearly with parity in SA breed, moving from 4.50 ± 0.02% (first parity) to 4.33 ± 0.01% in the last parity class ($p < 0.001$), these milk components did not linearly reduce across parities in MG and AL breeds (Figure 2). The estimated lactose content was in fact the lowest in parity 4.
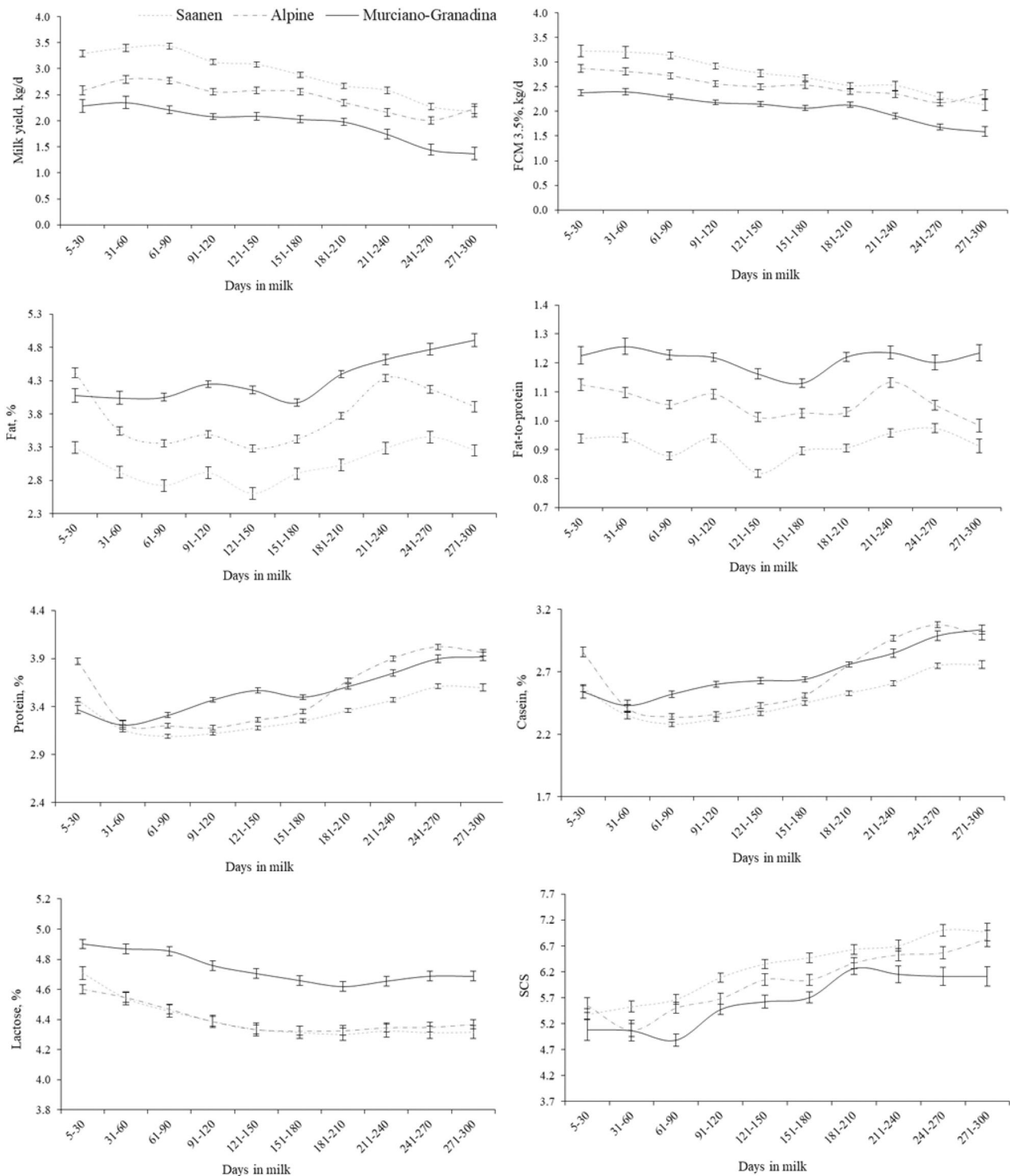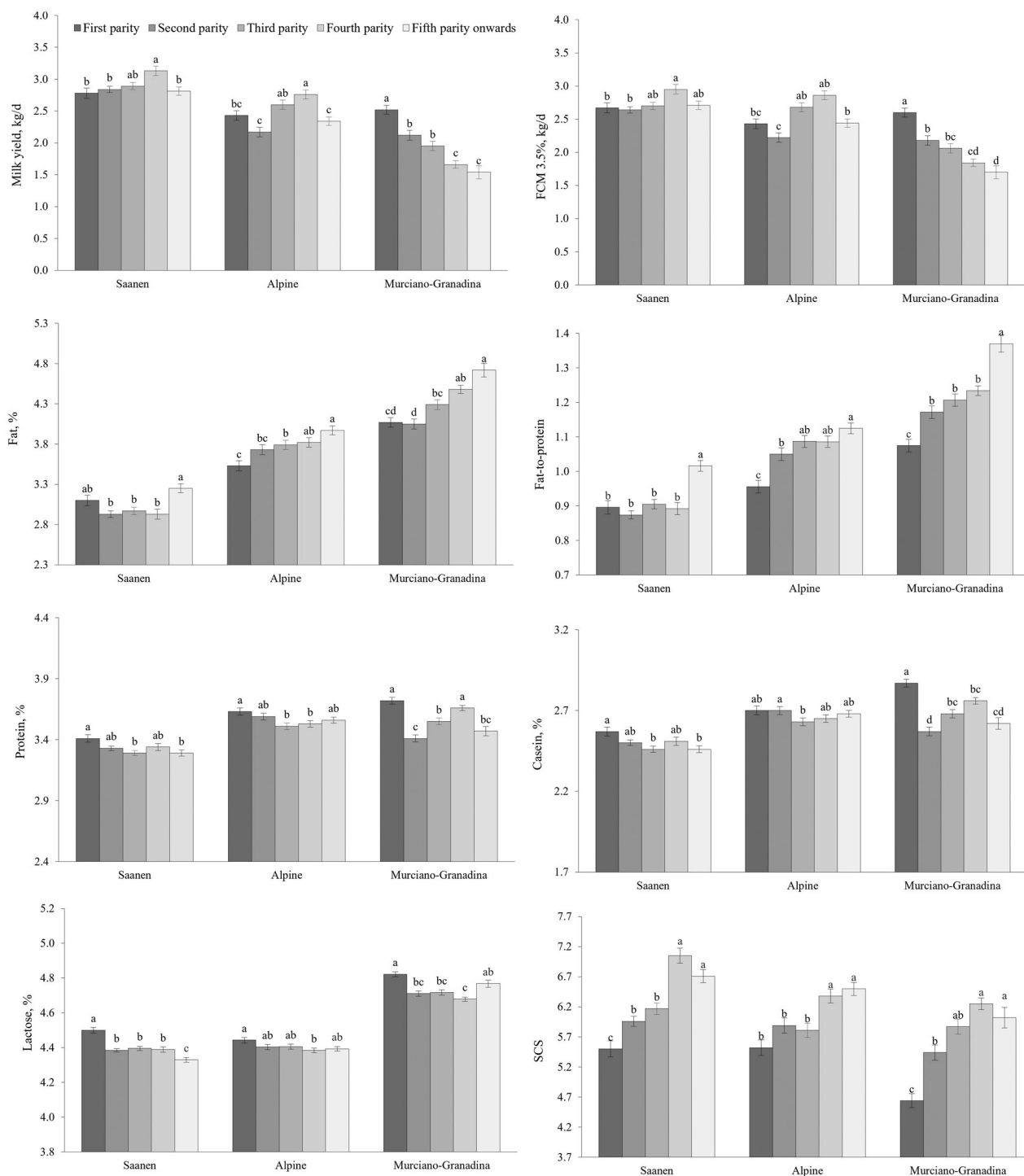
Figure 1. Least-squares means of milk yield, fat-corrected milk at 3.5% (FCM 3.5%), gross composition and somatic cell score (SCS) across lactation. The standard error is indicated with a bar.

Overall, MG breed showed at the same time the greatest lactose content and the lowest SCS ($p \leq 0.05$). The SCS increased with parity regardless of the breed; within each parity SCS of MG breed was usually lower compared to SA.

Effect of kidding season within breed

Breed-specific least-squares means of milk yield and quality traits for the fixed effect of season are depicted in Figure 3. Although MG was the only breed with no seasonal reproductive behaviour included in this
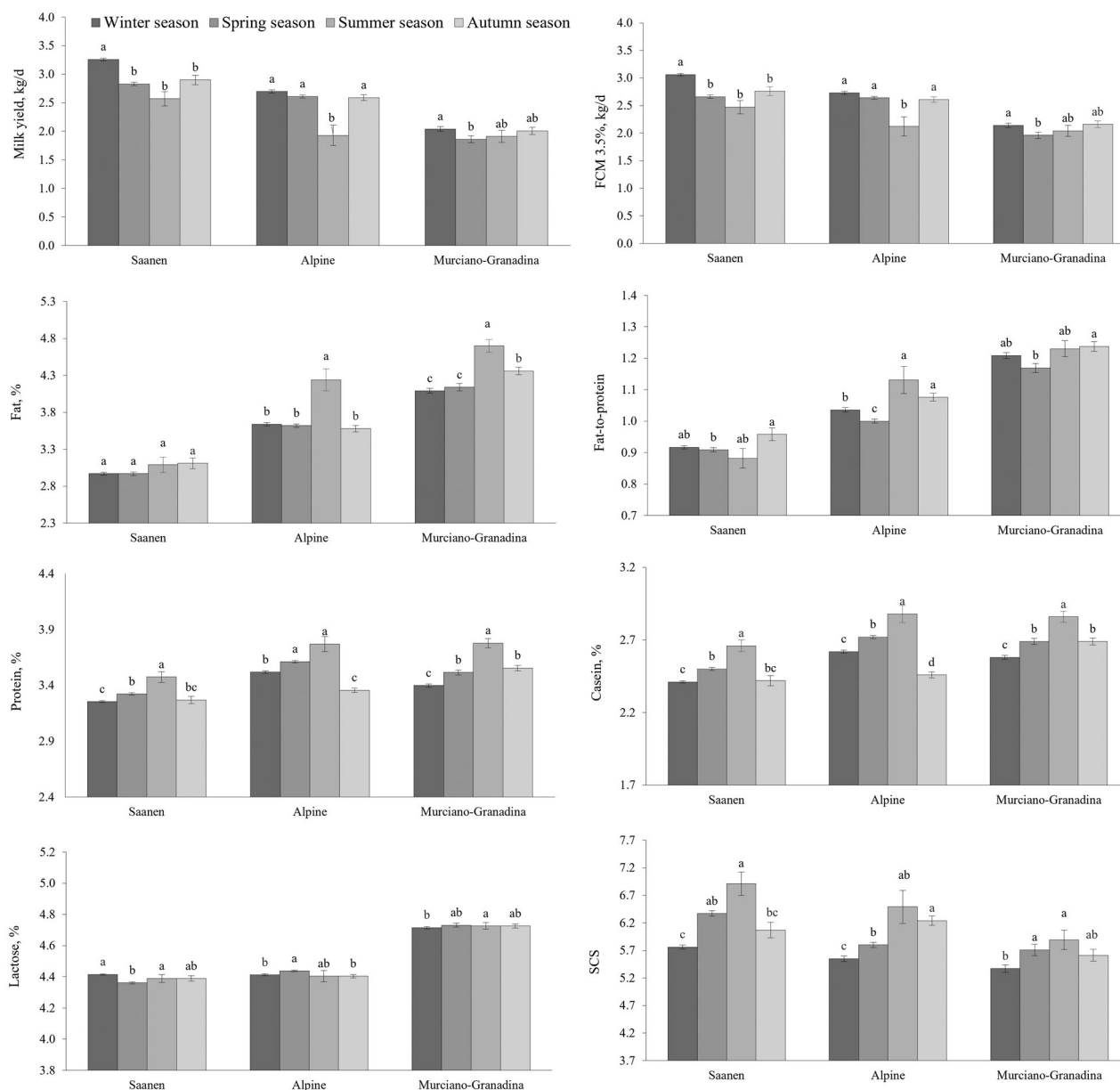
Figure 2. Least-squares means of milk yield, fat-corrected milk at 3.5% (FCM 3.5%), gross composition and somatic cell score (SCS) across parities. The standard error is indicated with a bar. Values with different superscripts within each breed are significantly different ($p \leq 0.05$).

study, herds with out-of-season kiddings for SA and AL beeds were also included. However, results should be considered carefully as the number of SA and AL goats giving birth in summer was lower compared to other seasons, increasing the standard error of estimates.

The greatest milk yield and FCM 3.5% were observed when kidding took place in winter, especially in SA. Despite the fact that the differences with the other seasons were less evident in AL and MG goats, MG goats usually had the lowest milk yield and FCM 3.5% ($p \leq 0.05$).

Figure 3. Least-squares means of milk yield, fat-corrected milk at 3.5% (FCM 3.5%), gross composition and somatic cell score (SCS) across kidding seasons. The standard error is indicated with a bar. Values with different superscripts within each breed are significantly different ($p \leq 0.05$).

Fat content and F/P ratio behaved similarly, being differences among parities more evident in the F/P ratio. A similar pattern across kidding seasons was observed in MG and AL goats, with the greatest ($p < 0.01$) fat content in goats giving birth in summer (MG, $4.70 \pm 0.09\%$; AL, $4.24 \pm 0.15\%$). In addition, the greatest fat content among breeds was obtained in MG breed.

Protein and casein content followed a similar pattern in all three breeds, increasing from winter to summer ($p \leq 0.05$). Moreover, SA showed a lower protein content in all kidding seasons compared to the other breeds ($p \leq 0.05$).

Lactose content increased from winter ($4.72 \pm 0.01\%$) to summer kidding season ($4.79 \pm 0.02\%$; $p < 0.05$) in MG breed; was lower in goats kidding in winter ($4.41 \pm 0.01\%$) and autumn ($4.40 \pm 0.01\%$) and higher in those kidding in spring ($4.44 \pm 0.01\%$; $p \leq 0.05$) in AL breed; and lower in goats kidding in spring ($4.36 \pm 0.01\%$) than summer ($4.44 \pm 0.01\%$) and winter ($4.42 \pm 0.01\%$; $p \leq 0.05$) in SA. In addition, MG always presented the greatest lactose content among all breeds ($p \leq 0.05$).

The SCS seasonal trend was similar among the three breeds, with the greatest and the lowest SCS in

summer and in winter, respectively ($p \leq 0.05$). The SA milk was characterised by the greatest levels of SCS regardless of the kidding season, whereas AL presented intermediate values without significant differences compared to SA and MG goats.

Discussion

Effect of breed

Although goat milk is mainly used as a beverage worldwide (Pulina et al. 2008), in Italy it is mostly processed into cheese. Cheese yield in goats mainly depends on fat and protein content of milk, which are inversely related to daily milk production (Pulina et al. 2008), as observed in Table 1. However, Pulina et al. (2008) reported a stronger correlation between milk yield and fat and protein content in MG than in AL and SA breeds. In this study, the weaker correlation in MG than in AL and SA breeds suggested that the dilution effect is more evident in the latter than in the former. However, there are only few studies that compared MG with cosmopolitan breeds in terms of milk production and chemical composition.

Although Vacca et al. (2018) did not find difference in milk production and composition between SA and AL goats, they only analysed over a thousand records and their experimental design did not consider repeated measures. However, in agreement with this study, they reported a significant difference between Alpine breeds (SA and AL) and Mediterranean breeds (MG, Maltese and Sarda) for milk yield and gross composition content, i.e. fat, protein and lactose.

The F/P ratio is an indicator of the titres reversion syndrome, i.e. when fat content drops below the protein content (Sandrucci et al. 2019). In normal conditions, this ratio should be >1.00 and values ≤ 1 indicate a reduction in the milk fat content rather than an increase in milk protein content. Sandrucci et al. (2019) reported that about half of the herds –mainly SA and AL breeds – presented F/P reversion syndrome in northern Italy, which impacts on the cheese quality (e.g. granular paste and lack of nice goat taste) and it is more frequent in intensive selected breeds (Morand-Fehr et al. 2007). The results of this study regarding SA and AL are therefore in agreement with Sandrucci et al. (2019).

The results obtained for the association of SCS with milk yield and lactose content are in line with other studies conducted in species like cattle and buffaloes (Costa, Visentin, et al. 2019, 2020). While milk lactose content drops due to the impaired alveolar permeability in animals with high SCC (Costa, Lopez-Villalobos,

et al. 2019), the total protein content in this study apparently increases. It has been demonstrated that in dairy species the casein fraction rather than the total protein content tends to diminish in affected quarters. This leaves space to whey proteins and impairs technological traits of milk (Forsbäck et al. 2010; Summer et al. 2012). In goats, Leitner et al. (2004) did not observe a significant reduction in casein content in affected than in unaffected quarters. Instead, albumin and whey proteins significantly increased in presence of infection, with a negative impact on both curd yield and coagulation time (Leitner et al. 2004).

Milk from healthy goats is characterised by a greater physiological amount of SCC than cow's milk. This higher baseline level has to be attributed to the apocrine secretion of goats which leads to greater cytoplasmic particles and epithelial cells into milk (Paape and Capuco 1997; Boutinaud and Jammes 2002). In other words, the contribution of epithelial cells due to exfoliation to the total SCC (mostly leukocytes and epithelial cells) is larger in goats than in cattle (Boutinaud and Jammes 2002). Nevertheless, Barrón-Bravo et al. (2013) found a reduction in goat milk synthesis with increasing levels of SCS. In addition, Ying et al. (2002) reported a greater concentration of protein with higher SCC in AL and SA goats, highlighting the superior milk quality of MG compared to SA and AL. Because MG was originated from two pure bred lines, it is expected that it will show better fitness, higher genetic variability and heterosis than pure bred lines of Murciana and Granadina breeds (Martínez et al. 2010; Deroide et al. 2016). In fact, Deroide et al. (2016) found that just 1.18% of MG animals were inbred, suggesting that there is no risk of homozygosity. On the other hand, cosmopolitan breeds inbreeding, like SA, has increased rapidly from the seventies to the nineties leading to the inbreeding depression (Teissier et al. 2022) which is reported to impair productive and reproductive performance (Gipson 2002). These considerations partly explain the superiority of MG in terms of rusticity and adaptability compared to SA and AL.

Effect of stage of lactation within breed

The pattern for milk yield lactation curve in this study agreed with Ibrahim and Tajuddin (2021), who evaluated over 2 billion test-day records in SA and AL breeds, and León et al. (2012), who evaluated approximately 500 thousand test-day records in MG breed. These authors divided the lactation curve in 3 phases, with the first one being characterised by an initial

rapid increase until the 45th–50th DIM, followed by a stabilisation and a subsequent slow decrease through to the end of lactation (Ibrahim and Tajuddin 2021; León et al. 2012).

The increase in milk components (except lactose content) and SCS from the peak towards the end of the lactation (Figure 1) is known as the concentration effect of milk components and well described in the literature (Goetsch et al. 2011; Leitner et al. 2011; Jiménez-Granado et al. 2014). Other than the dilution effect, the greater SCS levels observed at the end of lactation may denote a pre-adaptive response to the involution stage of the mammary gland where an acute inflammatory response will help prevent the transmission of infection from one lactation to another (Leitner et al. 2011). The progressive reduction of lactose content (Figure 1) towards the end of lactation is in agreement with findings reported in the literature for goats and other dairy species. Results regarding the F/P ration partially agreed with Sandrucci et al. (2019), who found F/P ratio <1.00 from the DIM 100 onwards in AL and SA breeds.

Effect of parity within breed

In contrast with the results in this study, Pizarro et al. (2020) and León et al. (2012) reported an increase in milk yield with parity in MG raised in Spain. This disagreement with the results of Pizarro et al. (2020) and León et al. (2012) could be related to the recently introduced MG breed in northern Italy. In fact, MG has been introduced in the Veneto region since 2016. Currently, MG goats in late productive life farmed in the Veneto region are those imported from Spain that were forced to adapt to the Italian farming system. Moreover, the greater milk yield of MG primiparous than multiparous observed in this study supports the adaptability of this Spanish goat to a new environment (Delgado et al. 2017). In contrast with the results in Figure 2 for fat and protein content, Vacca et al. (2018) did not observe a significant effect of the parity class in SA, AL and MG and other Mediterranean Italian breeds. In agreement with several authors (Vacca et al. 2018; Costa, Visentin, et al. 2019, Costa, Lopez-Villalobos, et al. 2019; Pizarro et al. 2020), for all three breeds lactose content decreased across parity, while value of SCS increased.

Effect of kidding season within breed

Reproductive behaviour of goat breeds from temperate areas, such as the SA and AL, are deeply affected by seasonality and need artificial photoperiod or hormones to keep milk production constant across the year. Meanwhile, MG has a less pronounced seasonal reproductive behaviour and reproduction can be managed using the 'male effect' to maintained milk production constant through the year (Arrebola et al. 2010; Zarazaga et al. 2012). The kidding season affects the sampling season and thus influences milk-related traits, including productivity. In line with several previous studies (Crepaldi et al. 1999; Sandrucci et al. 2019; Pizarro et al. 2020), all breed showed a greater milk yield when goats kidded in winter. The reduction in daily milk production observed in goats that kidded in spring and summer can be linked to the rising temperatures in early lactation, which decreases the feed intake (Salama et al. 2014). The greater fat and protein content observed in those goats that kidded in summer agreed with Bermejo et al. (2020) results in MG goats. The greater fat and protein content along with SCS in goats that kidded in summer could also be partially explained by the concentration effect previously discussed, as milk yield is lower in goats that kidded in summer than in winter as observed in Figure 3. Moreover, the lower F/P ratio observed in spring or in summer (Figure 3) was in line with Sandrucci et al. (2019) results who reported that AL and SA goats that kidded in spring showed across lactation a F/P ratio <1 earlier than goats that kidded in winter.

Conclusions

This study demonstrates that the newly introduced MG was able to adapt very well to the dairy goat management practices and conditions in northern Italy, showing a superior milk quality compared to SA and AL commonly present in this area. Findings suggested that MG, whose reproductive behaviour is less sensitive to season compared to SA and AL, performs efficiently under farming system of Veneto region and can be a genetic resource of interest for the current Italian context. Therefore, the introduction of MG may guarantee a more stable milk and cheese production across the year due to their less pronounced seasonality, which may allow farmers to ensure constant milk supplies throughout the year.

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Ethical approval

Procedures adopted in this study do not fall into the scope of an animal ethics evaluation, as they do not reach the thresholds established in Art. 1 of the 'Directive 2010/63/EU of the European Parliament and of the council of 22 September 2010 on the protection of animals used for scientific purposes'.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

None of the data were deposited in an official repository. The data that support the findings presented in this study are available from the first author or corresponding author upon reasonable request.

References

AIA (Associazione Italiana Allevatori). 2021. Statistiche ufficiali. [accessed 20 Jun 2022]. http://bollettino.aia.it/Contenuti.aspx?CD_GruppoStampe=RS&CD_Specie=C4.

Arrebola F, Pérez-Marín CC, Santiago-Moreno J. 2010. Limitation of seasonality in reproductive parameters of Mediterranean bucks, using photoperiod treatment. Small Rum Res. 89(1):31–35.

Barrón-Bravo OG, Gutiérrez-Chávez AJ, Ángel-Sahagún CA, Montaldo HH, Shepard L, Valencia-Posadas M. 2013. Losses in milk yield, fat and protein contents according to different levels of somatic cell count in dairy goats. Small Rum Res. 113(2–3):421–431.

Bates D, Maechler M, Bolker B, Walker S. 2015. Fitting linear mixed-effects models using lme4. J Statist Softw. 67(1): 1–48.

Bermejo JVD, Pérez FAL, González FJN, León JM, Álvarez JF, Gama LT. 2020. Conditioning factors of linearized wood's function lactation curve shape parameters, milk yield, fat and protein content in Murciano-Granadina primiparous does. Animals. 10: 2115.

Boutinaud M, Jammes H. 2002. Potential uses of milk epithelial cells: a review. Reprod Nutr Dev. 42(2):133–147.

CAPRIGAN. 2022. The Murciano-Granadina goat breeding program [accessed 2022 Jun 14]. https://caprigran.com/en/breeding-program/.

Costa A, Lopez-Villalobos N, Sneddon NW, Shalloo L, Franzoi M, De Marchi M, Penasa M. 2019b. Milk lactose—current status and future challenges in dairy cattle. J Dairy Sci. 102(7):5883–5898.

Costa A, Neglia G, Campanile G, De Marchi M. 2020. Milk somatic cell count and its relationship with milk yield and quality traits in Italian water buffaloes. J Dairy Sci. 103(6): 5485–5494.

Costa A, Visentin G, De Marchi M, Cassandro M, Penasa M. 2019a. Genetic relationships of lactose and freezing point with minerals and coagulation traits predicted from milk mid-infrared spectra in Holstein cows. J Dairy Sci. 102(8): 7217–7225.

Crepaldi P, Corti M, Cicogna M. 1999. Factors affecting milk production and prolificacy of Alpine goats in Lombardy (Italy). Small Rum Res. 32(1):83–88.

Delgado JV, Landi V, Barba CJ, Fernández J, Gómez MM, Camacho ME, Martínez MA, Navas FJ, León JM. 2017. Murciano-granadina goat: a Spanish local breed ready for the challenges of the twenty-first century. Sustain Goat Prod Adv Environ. 2:205–219.

Deroide CAS, Jacopini LA, Delgado JV, Léon JM, Brasil LHA, Ribeiro MN. 2016. Inbreeding depression and environmental effect on milk traits of the Murciano-Granadina goat breed. Small RumRes. 134:44–48.

Frank E, Harrell J. 2022. Hmisc: harrell miscellaneous. R package version 4.7-0. [accessed 2022 Jan 17]. https://CRAN.R-project.org/package=Hmisc.

Forsbäck L, Lindmark-Månsson H, Andrén A, Svennersten-Sjaunja K. 2010. Evaluation of quality changes in udder quarter milk from cows with low-to-moderate somatic cell counts. Animal. 4(4):617–626.

Gipson TA. 2002. Preliminary observations: inbreeding in dairy goats and its effects on milk production. Proceedings of 17th Annual Goat Field Day; April 27. Langston, OK: Langston University; p. 51–56.

Goetsch AL, Zeng SS, Gipson TA. 2011. Factors affecting goat milk production and quality. Small Rum Res. 101(1–3):55–63.

Guan D, Martínez A, Luigi-Sierra MG, Delgado JV, Landi V, Castello A, Fernandez Alvarez J, Such X, Jordana J, Amills M. 2021. Detecting the footprint of selection on the genomes of Murciano Granadina goats. Anim Genet. 52(5):683–693.

Ibrahim NS, Tajuddin FHA. 2021. Evaluation of milk production and milk composition at different stages of Saanen dairy goats. J Agrobiotechnol. 12(1S):204–221.

ISTAT. 2020. Istituto nazionale di statistica. [accessed 2022 April 6 www.istat.it.

Jiménez-Granado R, Sánchez-Rodríguez M, Arce C, Rodríguez-Estévez V. 2014. Factors affecting somatic cell count in dairy goats: a review. Span J Agric Res. 12(1): 133–150.

Komsta L, Novomestky F. 2022. moments: Moments, cumulants, skewness, kurtosis and related tests. 2022. R package version 0.14.1. [accessed 2022 Feb 5]. https://CRAN.Rproject.org/package=moments.

Leitner G, Merin U, Silanikove N. 2004. Changes in milk composition as affected by subclinical mastitis in goats. J Dairy Sci. 87(6):1719–1726.

Leitner G, Merin U, Silanikove N. 2011. Effects of glandular bacterial infection and stage of lactation on milk clotting

parameters: comparison among cows, goats and sheep. Int Dairy J. 21(4):279–285.

León JM, Macciotta NPP, Gama LT, Barba C, Delgado JV. 2012. Characterization of the lactation curve in Murciano-Granadina dairy goats. Small Rum Res. 107(2–3):76–84.

MAPA. 2021. Ministerio de agricultura, pesca y alimentación. [accessed 2021 Dec 17]. https://www.mapa.gob.es/es/ganaderia/temas/zootecnia/razas-ganaderas/razas/catalogorazas/caprino/murciano-granadina/datos_productivos.aspx.

Martínez AM, Vega-Pla JL, León JM, Camacho ME, Delgado JV, Ribeiro MN. 2010. Is the Murciano-Granadina a single goat breed? A molecular genetics approach. Arq Bras Med Vet Zootec. 62(5):1191–1198.

Morand-Fehr P, Fedele V, Decandia M, Le Frileux Y. 2007. Influence of farming and feeding systems on composition and quality of goat and sheep milk. Small Rum Res. 68(1–2):20–34.

Paape MJ, Capuco AV. 1997. Cellular defense mechanisms in the udder and lactation of goats. J Anim Sci. 75(2): 556–565.

Pizarro MG, Landi V, Navas FJ, León JM, Martínez A, Fernández J, Delgado JV. 2020. Non-parametric analysis of the effects of nongenetic factors on milk yield, fat, protein, lactose, dry matter content and somatic cell count in Murciano-Granadina goats. Italian J Anim Sci. 19(1): 960–973.

Pulina, G. Cannas, A. Serra, A. Vallebella, R1991. Determination and estimation of the energy value in Sardinian goat milk. In Proceedings of the Congress of Società Italiana Scienze Veterinarie (SISVet), Altavilla Milicia (PA), Italy, 25–28 September 1991; pp. 1779–1781.

Pulina G, Nudda A, Battacone G, Fancellu S, Francesconi AHD. 2008. Nutrition and quality of Goat's milk. In: Cannas, A, Pulina, G, editors. Dairy goats feeding and nutrition. Wallingford: CAB International; p. 1–30.

R Core Team. 2022. R: a language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing.

Salama AAK, Caja G, Hamzaoui S, Badaoui B, Castro-Costa A, Façanha DAE, Guilhermino MM, Bozzi R. 2014. Different levels of response to heat stress in dairy goats. Small Rum Res. 121(1):73–79.

Sandrucci A, Bava L, Tamburini A, Gislon G, Zucali M. 2019. Management practices and milk quality in dairy goat farms in Northern Italy. Italian J Anim Sci. 18(1):1–12.

Summer A, Malacarne M, Sandri S, Formaggioni P, Mariani P, Franceschi P. 2012. Effects of somatic cell count on the gross composition, protein fractions and mineral content of individual ewe's milk. Afr J Biotechnol. 11(97): 16377–16381.

Teissier M, Brito LF, Schenkel FS, Bruni G, Fresi P, Bapst B, Robert-Granie C, Larroque H. 2022. Genetic characterization and population connectedness of North American and European dairy goats. Front Genet. 13:862838.

Vacca GM, Stocco G, Dettori ML, Pira E, Bittante G, Pazzola M. 2018. Milk yield, quality, and coagulation properties of 6 breeds of goats: environmental and individual variability. J Dairy Sci. 101(8):7236–7247.

Wiggans GR, Shook GE. 1987. A lactation measure of somatic cell count. J Dairy Sci. 70(12):2666–2672.

Ying C, Wang HT, Hsu JT. 2002. Relationship of somatic cell count, physical, chemical and enzymatic properties to the bacterial standard plate count in dairy goat milk. Livest Prod Sci. 74(1):63–77.

Zarazaga LA, Gatica MC, Celi I, Guzmán JL. 2012. Reproductive performance is improved during seasonal anoestrus when female and male Murciano–Granadina goats receive melatonin implants and in Payoya goats when females are thus treated. Reprod Domestic Anim. 47(3):436–442.