Cheese yield, cheesemaking efficiency, and daily production of 6 breeds of goats

INTERPRETIVE SUMMARY

Cheese yield, cheese-making efficiency, and daily production of six breeds of goats. *By Vacca et al. page 000.* Individual milk samples from 560 goats of six different breeds reared in 35 farms were collected to study the effects of farm and animal factors on cheese yield traits, milk nutrients recovery in the curd and cheese-making efficiency. Results evidenced a low effect of farm compared with individual animal factors. Parity of goats was particularly important for daily productions, while days in milk affected almost all traits. Large differences were also observed among breeds. These findings emphasized the suitability of goat milk for cheese production and suggested new possibilities and direction in breeding programs.

Cheese yield, cheese-making efficiency, and daily production of six breeds of goats

Giuseppe M. Vacca*, Giorgia Stocco*[1], Maria L. Dettori*, Andrea Summer‡, Claudio Cipolat-Gotet‡, Giovanni Bittante† and Michele Pazzola*

*Department of Veterinary Medicine, University of Sassari, via Vienna 2, 07100 Sassari, Italy

‡Department of Veterinary Science, University of Parma, Via del Taglio 10, 43126 Parma, Italy

†Department of Agronomy, Food, Natural resources, Animals and Environment (DAFNAE) University of Padova, viale dell'Università 16, 35020 Legnaro (PD), Italy

[1]Corresponding author: giorgiastocco12@gmail.com

ABSTRACT

Little is known about the complex process of cheese-making at the individual level of dairy goats because of the difficulties of producing high number of model cheeses. The objectives of this work were: i) to study the cheese-making ability of goat milk; ii) to investigate the variability of cheese-making related traits among different farms; iii) to assess the effects of stage of lactation and parity, and iv) to compare six breeds of goat (Saanen and Camosciata delle Alpi for the Alpine type; Murciano-Granadina, Maltese, Sarda and Sarda Primitiva for the Mediterranean type) for their cheese-making ability.

For each goat (N = 560) the following traits were collected: a) eight milk quality traits (fat, protein, total solids, casein, lactose, pH, somatic cell score and bacterial count); b) four milk nutrients recovery traits (fat, protein, total solids and energy) in curd; c) three actual cheese yield traits (fresh cheese, cheese solids and cheese water); d) two theoretical cheese yield values (fresh cheese and cheese solids) and the related cheese-making efficiencies; e) daily milk yield and three daily cheese yield traits (fresh cheese, cheese solids and water retained in the curd).

Respect to individual animal factors, farm was not much important for recovery traits, actual and theoretical cheese yield and estimates of efficiency, while it highly influenced daily productions. Parity of goats influenced daily cheese productions, whereas DIM slightly affected recovery, % and daily cheese yield traits. Breed was the most important source of variation for almost all cheese-making traits. Compared with those of Alpine type, the four Mediterranean breeds had, on average, lower daily milk and cheese productions, greater actual and theoretical cheese yield and higher recovery of nutrients in the curd. Among Alpine type, Camosciata delle Alpi was characterized by greater nutrients recovery than Saanen. Within the four Mediterranean, the three Italians produced much less milk per day, with much more fat and protein and greater recovery traits than the Murciano-Granadina, resulting in greater actual cheese yield. Within the Italian breeds, milk from Sarda and Sarda Primitiva was characterized by lower daily yields, higher protein and fat content and greater recoveries of nutrients than Maltese goats. These results

confirmed the potential of goat milk for cheese production and could be useful to give new possibilities and direction in breeding programs.

Key words: cheese, farm, fat recovery, protein recovery.

INTRODUCTION

World production of goat milk ranks third below cow and buffalo milk, and it is mainly used to produce cheese (FAOSTAT, 2014). The percentage ratio between milk processed and cheese manufactured (**%CY**) is considered one of the most important attribute of milk affecting the profitability of dairy farmers (Emmons, 1993). Cheese yield relies first on the fat and protein (in particular casein) content of milk, and also on the technological properties of processed milk (Law and Tamine, 2010); these characteristics can influence the proportion of individual milk components recovered in the curd (**%REC**) or lost in the whey, directly related to the overall efficiency of cheese-making process (Banks, 2007).

The increasing demand for goat cheeses during the last decades, coupled with an increment of milk price, has stimulated new interest on cheese-making ability of goat milk: formulae predicting cheese yield on the basis of milk components were proposed (Zeng et al., 2007). The main problem with those formulae as regard to goat milk is the wide range of variation of its composition in relation to different breeds and dairy systems. On the other hand, information on direct measurements of %CY in the literature is scarce for goat species, and most of the studies on cheese-making ability have used goat bulk milk (Fekadu et al., 2005; Chen et al., 2010), because collection and processing of individual samples are very time-consuming and labor-intensive.

Moreover, goat breed has been shown to have strong effects on cheese yield, but again this information comes from studies using bulk milk from few groups of a small number of animals into individual experimental farms (Soyral et al., 2005; Herrera et al., 2010), or using mixed milk from different breeds (Guo et al., 2004; Kouniba et al., 2007). Therefore, in those cases, comparison of breeds may be affected by a lack of representativeness, or by different individual factors (i.e., parity, stage of lactation), or can be influenced by farm characteristics (i.e., management and feeding).

More information is recently available from a large survey on milk coagulation, curd-firming and syneresis properties of goat milk of different breeds (Vacca et al., 2018; Pazzola et al., 2018). The suitability of lactodynamography for testing large number of individual goats relies on the small volume of milk and the possibility to test several samples in a short period. Traditionally, lactodynamography does not provide direct measurement of %CY and %REC traits, but only reproduces first steps of the cheese-making process (i.e., rennet addition, milk coagulation, curd-firming). However, recent modifications of the analysis procedures proposed by Cipolat-Gotet et al. (2016a), permits to assess also the phases during which the obtained small curds are cut, heated, and drained. That method has stimulated more interest on the use of lactodynamography, because coagulation analysis could be completed by the assessment of the efficiency of cheese-making process. As regard to sheep, Othmane et al. (2002a) proposed an individual laboratory cheese yield procedure using 10 mL of milk, allowing the simultaneous recording of %CY of several samples (Othmane et al., 2002b).

To our best knowledge, no previous studies have processed a high number of goat milk samples to mimic the complex process of cheese-making on a small-scale laboratory method, and allowing the estimation of several cheese-making traits.

For these reasons, the present study was proposed in order: 1) to study the cheese-making ability of goat milk; 2) to investigate the variability among different farms; 3) to assess the effects of stage of lactation and parity; and 4) to compare six breeds of goat for their nutrients recovery in the curd (%REC), actual (%CY) and theoretical (*Th*-%CY) cheese yields, efficiency of cheese-making (*Eff*-%CY), and daily productions of cheese (dCYs).

MATERIALS AND METHODS

Farm Characteristics and Milk Sampling

A total of 560 goats from 35 farms located in Sardinia (Italy) were sampled (16 animals per farm). Six breeds were investigated: Saanen (**Sa** = 99 goats) and Camosciata delle Alpi (**CA** = 98 goats) for the Alpine type; Murciano-Granadina (**MG** = 89 goats), Maltese (**Ma** = 104 goats), Sarda (**Sr** = 86 goats) and Sarda Primitiva (**SP** = 84 goats) for the Mediterranean type. Details of the milk sampling and analysis have been described by Vacca et al. (2018), and environmental context and farming systems involved have been reported in Vacca et al. (2016).

Analysis of Milk Traits

Immediately after collection, individual milk samples were stored at 4°C, analyzed and processed within 24 hours of sampling. All samples were analyzed for fat, protein, total solids (**TS**), casein, lactose and pH with a MilkoScan FT6000 infrared analyzer (Foss Electric A/S, Hillerød, Denmark) calibrated in accordance with the related reference methods [ISO 9622/IDF 141 (2013) for fat, protein, casein, lactose and pH; ISO 6731/IDF 21 (2010a) for total solids]. Casein index was calculated as the casein to protein ratio. Somatic cell count (**SCC**) was determined by a Fossomatic 5000 somatic cell counter (Foss Electric A/S, Hillerod, Denmark) and transformed into the logarithmic somatic cell score [**SCS** = $\log_2(\text{SCC} \times 10^{-5}) + 3$] ; total bacterial count was determined using a BactoScan FC150 analyzer (Foss Electric A/S, Hillerod, Denmark) and transformed into the logarithmic bacterial count [**LBC** = $\log_{10}$ (total bacterial count/1000)].

Individual Cheese-making Procedure

The 9-mL milk cheese-making assessment (**9-MilCA**) proposed by Cipolat-Gotet et al. (2016a) was used to measure actual %CY and %REC traits. The following procedure was performed on 560 individual goat milk samples, with two replicates per each animal (9 mL × 2), for a total of 1,120 observations.

Briefly, each milk replicate was poured into a glass tube (9 mL), inserted into the modified sample rack of the lactodynamograph instrument, heated up to 35 °C for 15 min, and mixed with 0.2 mL of a rennet solution [Hansen Standard 215, with 80 ± 5% chymosin and 20 ± 5% pepsin; 215 international milk clotting units (**IMCU**)/mL (Pacovis Amrein AG, Bern, Switzerland); diluted to 1.2% (wt/vol) in distilled water]. The sample rack was then transferred from the heater to the lactodynamograph for a 30-min duration test at 35 °C. At the end of the analysis, coagulated milk samples were manually cut using a stainless steel spatula, and the rack was moved to the heater for the 30 min curd-cooking phase (55 °C). In the middle of the cooking phase, each sample was subjected to a further manual cutting by the same operator. At the end, each glass tube was removed from the sample rack and the curd was separated from the whey. The curd was slightly pressed to facilitate the whey expulsion, and the curd was then suspended above the whey for 15 min at room temperature to favor the draining. The obtained curd and whey were weighed using a precision scale. As the volume of whey produced from a single vat (about 7.5 mL) was not sufficient for assessment of the chemical composition using an infrared spectrophotometer (MilkoScan FT2, Foss Electric), two replicates of each milk sample were analyzed in two consecutive glass tubes of the same sample rack, and the whey was pooled for chemical analysis. The weights of the milk, curd and whey (in grams) and the chemical composition of milk and whey, permitted to estimate also curd composition. The actual cheese yield (%CY) traits were: **$\%CY_{CURD}$**, **$\%CY_{SOLIDS}$** and **$\%CY_{WATER}$**, calculated as the ratio of the weight (g) of fresh curd, curd dry matter and water retained in curd, respectively, to the weight of the milk processed (g), and multiplied by 100. Daily cheese yields (**dCY_{CURD}**, **dCY_{SOLIDS}** and **dCY_{WATER}**; kg/d) were calculated by multiplying the different %CYs ($\%CY_{CURD}$, $\%CY_{SOLIDS}$ and $\%CY_{WATER}$, respectively) by the daily milk yield (**dMY**, kg/d), recorded as the total yield of morning plus afternoon milking. The nutrients recovery (%REC) traits were: **$\%REC_{PROTEIN}$**, **$\%REC_{FAT}$** and **$\%REC_{SOLIDS}$**, calculated as the ratio of the weight (g) of the curd components (protein, fat and dry matter, respectively) to the same component of milk (g), and multiplied by 100. Recovery of energy in the curd (**$\%REC_{ENERGY}$**) was calculated by estimating energy of milk and curd using an equation proposed by the NRC (2001), converted to MJ/kg and multiplied by 100.

Definition of Cheese-making Efficiency

The theoretical %CY_{CURD} (***Th*-%CY$_{CURD}$**) of the milk samples of each goat was estimated using the formula of Van Slyke and Price (1949) reported by Emmons and Modler (2010) in their review:

$$Th\%CY_{CURD} = (0.93 \times \%fat + \%casein - 0.1) \times 1.09/[(100 - \%M)/100]$$

where 1.09 represents correction for milk minerals and cheese salt and carbohydrates, and %M is the percentage moisture of cheese (100 - %total solids).

A formula for estimating the theoretical CY_{SOLIDS} (***Th*-%CY$_{SOLIDS}$**) was derived from the previous one by deleting the last part, which corrects for cheese moisture:

$$Th\ \%CY_{SOLIDS} = (0.93 \times \%fat + \%casein - 0.1) \times 1.09$$

The efficiencies of CY_{CURD} (***Eff*-%CY$_{CURD}$**) and of CY_{SOLIDS} (***Eff*-%CY$_{SOLIDS}$**) were calculated by expressing the experimental value in relation to the corresponding theoretical value for each goat:

$$Eff\text{-}\%CY_{CURD} = \%CY_{CURD} / Th\text{-}\%CY_{CURD}, \text{ and}$$

$$Eff\text{-}\%CY_{SOLIDS} = \%CY_{SOLIDS} / Th\text{-}\%CY_{SOLIDS}$$

Statistical Analysis

Experimental data from cheese-making procedure (2 replicates per goat) were analyzed using the MIXED procedure (SAS Institute Inc., Cary, NC), according to the following model:

$$y_{lmnopq} = \mu + Farm_l + Breed_m + Parity_n + DIM_o + Animal_p + Glass\ tube_q + e_{lmnopq} \quad [M1]$$

where $y_{lmnopqr}$ is the observed trait (%CY, %REC, *Eff*-%CY, dCY traits); μ is the overall intercept of the model; $Farm_l$ is the random effect of the l^{th} farm (l = 1 to 35); $Breed_m$ is the fixed effect of the m^{th} breed (m= Sa, CA, MG, Ma, Sr, and SP); $Parity_n$ is the fixed effect of the n^{th} parity (n = 1 to 3; class 1: 1^{st} and 2^{nd} (193 goats); class 2: 3^{rd} and 4^{th} (205 goats); class 3: $\geq 5^{th}$ (162 goats); DIM_o is the fixed effect of the o^{th} class of days in milk (o = 1 to 4; class 1: < 80 days (146 goats);

class 2: 81-120 d (157 goats); class 3: 121-160 d (157 goats); class 4: >160 d (100 goats); $Animal_p$ is the random effect of the p^{th} animal (p = 1 to 560); Glass $tube_q$ is the random effect of the q^{th} tube (q = 1 to 8); e_{lmnopq} is the random residual ~ N (0, σ_e^2). The effects of Breed, Parity and DIM were tested using the random animal as the error line.

The theoretical cheese yields (*Th*-%CY_{CURD}, *Th*-%CY_{SOLIDS}) daily milk yield (dMY), and chemical components (fat, protein, TS, casein, lactose, pH, SCS and LBC) of milk samples were analyzed using the same model without the random factors of the Animal and the Glass tube [M2].

Orthogonal contrasts were estimated between LSMs of traits for the breed effect: a) Alpine (Sa and CA) *vs* Mediterranean type breeds (MG, Ma, Sr and SP); b) between the two Alpine breeds (Sa *vs* CA); c) within the four Mediterranean, comparing the Spanish to Italian breeds (MG *vs* Ma, Sr and SP); d) within the three Italian breeds, comparing Ma, from Sicily, with Sr and SP, from Sardinia, and e) comparing the two breeds from Sardinia (Sr *vs* SP).

Moreover, orthogonal contrasts were estimated between LSMs of traits for parity effect: a) 1^{st} and 2^{nd} vs $\geq 3^{rd}$, and b) 3^{rd} and 4^{th} *vs* $\geq 5^{th}$; and for days in milk (DIM): linear, quadratic and cubic pattern.

A further model [M3] was then used to analyze the direct effects of breed on cheese-making traits corrected for dMY and quality traits and was obtained from the model [M1] with inclusion of linear covariates of dMY, fat, protein, TS, casein, lactose, pH, SCS, and LBC. Moreover, the breed effect was considered random to obtain a correct quantification of the breed variance. The indirect effect of breed on cheese-making traits due to breed differences in terms of dMY and quality was obtained by subtracting the breed variance estimated by the model [M3] from the breed variance resulting from the base model [M1] (with breed as random effect). Both direct and indirect breed variances were represented as percentage of their sum.

RESULTS

Effects of Farm and Animal

Table 1 summarizes descriptive statistics of milk composition, recovery of nutrients (%REC), actual cheese yields (%CY), theoretical cheese yields (*Th*-%CY), efficiency of cheese-making traits (*Eff*-%CY), and daily cheese productions (dCY). Almost all traits exhibited a normal distribution and, in the case of daily yield traits and hygienic measures, a high variability.

Variances of the random effects for milk composition, daily productions, and cheese-making traits are summarized in Table 2. Among chemical composition, the proportion of variance due to the farm was very large for LBC, followed by fat, pH and TS of milk, while the incidence of this effect on the other milk components was smaller (28.8% for SCS content to 38.3% for casein content).

In the case of cheese-making traits, farm was always lower than animal effect, varying from 19% for *Eff*-$\%CY_{CURD}$ to 46% for *Th*-$\%CY_{CURD}$ of the total variance, whereas the animal effect ranged from 49% to 83%. Glass tube of the instrument sample rack had very little or no effect on the variability of the cheese-making traits (from 0.0% to 0.13 % of the total variance), highlighting the optimum repeatability of the method (from 78.5% of $\%CY_{WATER}$ to 99.9% of $\%REC_{FAT}$, data not shown). Farm and animal affected almost equally all daily production traits.

Effect of Parity and Days in Milk

The least square means of parity and related orthogonal contrasts on milk quality and cheese-making traits are summarized in Table 3. Parity had a modest effect on the quality of milk and on cheese-making traits with the only exception of SCS and daily yields. Milk from primiparous and secondiparous goats had mainly a greater content of lactose and LBC, and much lower SCS content than milk from goats with three or more parities,. Although the differences in milk protein content across classes of parity were not significant, the recovery of protein from milk to cheese ($\%REC_{PROTEIN}$) was greater in primiparous and secondiparous goats and, in general, it was lower in goats with five or more parities. Among cheese yields traits, actual $\%CY_{CURD}$ was significantly lower in goats with five or more parities. As expected, daily production traits were lower for the first group of goats for dMY (-13%), dCY (-10%), dCY_{SOLIDS} (-7%) and dCY_{WATER} (-13%) when compared to the other groups.

The variation during lactation (reported in Table 4) was significant for all the milk components, except in the case of fat. Nutrients recovery were slightly affected by DIM (excluding $\%REC_{ENERGY}$) exhibiting a quadratic trend along lactation. It can be seen from Figure 1 that, during lactation, $\%REC_{FAT}$ was characterized by an opposite pattern respect to $\%REC_{PROTEIN}$; less marked was the pattern shown by $\%REC_{SOLIDS}$. We found greater values of actual $\%CY_{CURD}$ and $\%CY_{SOLIDS}$ at the end of lactation. Daily production traits were linearly affected by DIM, showing a decrease during lactation.

Effect of Goat Breed

Least square means and related orthogonal contrasts (*F*-values and significance) for milk quality and cheese-making traits of the six breeds are reported in Table 5. These least square means are corrected for all the other factors of variation included in the base model [M1].

Comparing LSMs of the Alpine type breeds (Saanen and Camosciata delle Alpi) with the Mediterranean (Murciano-Granadina, Maltese, Sarda and Sarda Primitiva), six out of eight milk quality traits, and nine out of 15 cheese-making traits were better for the latter group of breeds. Our findings confirmed the lower milk productivity potential of Mediterranean goats in terms of dMY (-70%), dCY_{CURD} (-54%), dCY_{SOLIDS} (-60%) and dCY_{WATER} (-62%) when compared to the two Alpine breeds, only partly compensated by greater actual $\%CY_{CURD}$, (+19%) $\%CY_{SOLIDS}$ (+21%) and $\%CY_{WATER}$ (+15%). This was due not only to higher milk fat, protein and casein contents, but also to the greater %REC showed by Mediterranean breeds. Theoretical cheese yields (both *Th*-$\%CY_{CURD}$ and *Th*-$\%CY_{SOLIDS}$), based on milk composition, showed higher values for Mediterranean over the Alpine breeds. However, it is interesting to focus on the differences between the actual and theoretical cheese-yields: their ratio provides an estimate of the global efficiency of cheese-making process. As shown in Table 5, both cheese-making efficiencies of

Mediterranean goats did not differ from that of the Alpine ones confirming that the differences in actual %CY traits are mainly due to fat and casein content of milk.

Compared with Saanen, Camosciata delle Alpi presented no differences in terms of milk components, daily production and actual cheese yields traits, but had greater recovery of nutrients in the curd (+1.4% for protein, +5.0% for solids, and +5.1% for energy). Also theoretical %CYs were not different between the two breeds of Alpine type, but *Eff*-$\%CY_{SOLIDS}$ was higher in Camosciata delle Alpi goats.

Within Mediterranean breeds, Italian goats had a lower daily milk yield (-66% dMY) and also cheese production when compared to the Murciano-Granadina (-60%, -66% and -55% for dCY_{CURD}, dCY_{SOLIDS} and dCY_{WATER}, respectively), partly compensated by greater values of all actual %CY (+10%) and %REC traits (+4.4% for fat, +1.4% for protein, +5.0% for solids, and +4.5% for energy).

The differences found among the three Italian breeds were even larger: Maltese breed produced more milk and cheese per day than the two local Sardinian breeds, but had on average lower actual %CYs, due to lower milk fat and protein contents, and to lower $\%REC_{FAT}$, $\%REC_{SOLIDS}$, and $\%REC_{ENERGY}$. The theoretical %*Th*-CY_{SOLIDS}, as expected, confirmed that the two local Sardinian breeds were superior to Maltese goats, whereas *Eff*-$\%CY_{SOLIDS}$ were, on average, lower for the two local breeds due to the lower predicted *Th*-$\%CY_{CURD}$. The only difference found between the two local breeds from Sardinia was for the *Eff*-$\%CY_{CURD}$, slightly lower in Sarda Primitiva breed.

DISCUSSION

Cheese-making Ability of Goat Milk

As far we are aware, no previous studies in the literature have processed a high number of goat milk samples to mimic the complex process of cheese-making using a laboratory small scale method that allows the estimation of four recoveries of nutrients (%REC), three actual (%CY), two theoretical (*Th*-%CY), two efficiencies of cheese-making (*Eff*-%CY), and three daily cheese productions (dCY) traits. The protocol used in this study allowed to process 560 individual milk samples with two replicates. Respect to other lab procedures based on very limited quantity of milk and separating the curd through centrifugation, 9-MilCA allows to obtain %CY and %REC traits from bovine milk very similar to those found in practice, especially in relation to efficiency of curd draining and representativeness of milk fat recovery in the curd (Cipolat-Gotet et al., 2016a).

In the present study, actual %CY_{CURD} was the same as the average value obtained by Stocco et al. (2017) from milk of six breeds of cows, slightly higher compared with Cipolat-Gotet et al. (2013) from Brown Swiss cows, and neatly lower compared with results from Sarda sheep (Cipolat-Gotet et al., 2016b). Goat %REC_{FAT} was lower when compared with both species (bovine and ovine), and was much more similar to that reported by Fekadu et al. (2005) in their study on goat milk (Alpine breed). These differences among species could be explained by the different fat globules-casein matrix interaction, besides fat globules dimension, smaller for goat milk (Attaie and Richter, 2000). The %$REC_{PROTEIN}$ in goats was superior than cow and sheep, and also compared with goat milk protein recovery found by Chen et al. (2010), but it was closer to those found for a 500 mL cheese-making procedure using individual buffalo milk samples (80.4%) by Cipolat-Gotet et al. (2015). Goat %REC_{SOLIDS} was higher compared with cows and lower compared with sheep and buffaloes. Because of these differences in the recovery of nutrients in the curd, %REC_{ENERGY} was slightly lower in goats compared with the studies on bovines and especially on buffalo and sheep milk.

Effect of Farm and Animal on Cheese-making Traits

It is recognized that %CY_{CURD} depends primarily on the TS content of the milk, its recovery in curd and the retention of water in cheese (Cecchinato and Bittante, 2016). The amount of solids retained in the curd depends largely on the fat and casein contents of the milk, because lactose and the mineral fraction are retained at very low levels. In opposite, water retention in cheese is mainly influenced by several factors, among which the processing conditions (i.e., mode and time of the cutting phase, the draining and pressing of wheels and the extent of ripening) (Remeuf et al., 1991; Janhøj and Qvist, 2010). For these reason, among %CY traits, $\%CY_{WATER}$ was less affected by animal effect (Table 2). To exclude the effect of variations in the water content of the cheese, some researchers have calculated the $\%CY_{SOLIDS}$ as the ratio between the Dry Matter (**DM**) content of the cheese and the weight of the processed milk (Fagan et al., 2007). In the case of model cheeses produced using very small amounts of milk (10 mL), Melilli et al. (2002) estimate directly $\%CY_{SOLIDS}$. However, those authors use that procedure to predict the results obtained with the formula of Van Slyke and Publow (1910), obtaining on average 6.59% of $\%CY_{SOLIDS}$, whereas the one found in the present study was 7.7% for the actual $\%CY_{SOLIDS}$ and 7.4% for estimated *Th*-$\%CY_{SOLIDS}$ with Van Slyke and Price formula (1949). The differences can be largely explained by differences in milk composition and in cheese-making protocols: the use of centrifugation instead of curd cooking and draining is known to reduce the efficiency of whey separation, to overestimate all %CY and %REC traits, and to worsen the repeatability of the measures (Cipolat-Gotet et al., 2016a). In this study, TS represented 49% of the fresh curd, so water contributed slightly more than TS to both percentage and daily cheese yields (8.0 vs. 7.7%, and 0.15 vs. 0.14 kg/d, respectively).

The $\%REC_{FAT}$ and $\%REC_{PROTEIN}$ quantify the complex phenomena through which fat and proteins are transferred from milk to cheese (Emmons et al., 2003), so the loss of fat and proteins in whey reduces the cheese yield (Hallén et al., 2010). In the past, almost all the predictive formulae for estimating cheese yield have been based on knowledge of the protein and fat contents of milk, or the sum of the fat and protein, and total solids contents (Zeng et al., 2007; Emmons and Modler, 2010). All those formulae assume that the recovery of milk protein (casein) and fat in the curd is constant. However, it has been proved that those traits are not only highly variable (Stocco et al., 2017), but have larger heritability than milk protein and fat contents (Bittante et al., 2013). Actually, the incidence of the animal effect was very high for these traits (82.7% and 80.8% respectively for $\%REC_{FAT}$ and $\%REC_{PROTEIN}$), and was the highest among all cheese-making traits

(Table 2). This suggested that the improvement of %REC and %CY traits should be based principally on individual animal factors (i.e., breed, genetics, parity, stage of lactation), while farming system (facilities, management, nutrition) played a much more important role in the level of production and hygienic conditions (LBC = 63.5%, Table 2). Similar results are found by Cipolat-Gotet et al. (2013) on bovines and, in particular, they report values of variability due to herd-date from 21 to 31% for %REC traits, from 24 to 42% for actual %CY traits, and from 51 to 53% for dCY traits. Stocco et al. (2017) find lower herd-date incidence compared to the present study: from 11 to 17% for %REC traits, from 19 to 29% for actual %CY traits, from 42 to 46% for dCY traits, 15% for both *Th*-%CYs, 10% and 17% respectively for *Eff*-%CY$_{CURD}$ and *Eff*-%CY$_{SOLIDS}$. However, it is worth noting that in their case herd-date is included in the statistical model as a random effect within class of herd productivity. While in the case of Sarda sheep (Cipolat-Gotet et al., 2016b), the effect of flock is higher compared with this study for %REC (from 13% to 56%) and actual %CY traits (from 43% to 49%), and lower for dCY productions (from 18% to 42%).

Regarding %REC$_{SOLIDS}$ and %REC$_{ENERGY}$, these have never been studied before in goat milk. Their variability was mostly under the animal control (64.1% and 71.9% respectively, Table 2), even more than the single milk components. It is important to remind that in a previous study on genetic parameters of different measures of cheese yield and milk nutrient recovery in bovine milk, from the genetic point of view %REC$_{PROTEIN}$ is not directly correlated with the cheese yield, but with %REC$_{SOLIDS}$ and %REC$_{ENERGY}$, which are strongly related to the %CY traits (Bittante et al., 2013).

Individual Animal Factors on Cheese-making Traits

No previous study examined the effect of parity on cheese yield and cheese-making traits of goat milk. It is interesting to note that, while daily production traits decreased across parities, the %REC$_{PROTEIN}$ was significantly higher for goats belonging to the first group. However, the other traits were not statistically different across classes of parity. This meant that, although the dMY increased with the age of the goat, %REC and %CY did not augment throughout parities. Among milk quality traits, only lactose, SCS and LBC changed across parities. Similar results for parity on cheese-making traits are found for buffalo (Cipolat-Gotet et al., 2015) and bovine milk (Cipolat-Gotet et al., 2013; Stocco et al., 2017), while in sheep parity affect only $\%REC_{SOLIDS}$ and daily milk and cheese productions (Cipolat-Gotet et al., 2016b).

As regard to days in milk, marked changes occur in the composition of bovine milk throughout the year, especially when milk is produced mainly from spring-calving farms fed predominantly on pasture (Fox et al., 2000), because progressing of lactation is parallel to the seasonal change in quantity and quality of herbage available. For goat species, Fekadu et al. (2005) report that the significant variation of the chemical composition of milk over six months of lactation causes the variation of $\%CY_{CURD}$, $\%REC_{FAT}$ and $\%REC_{PROTEIN}$. In particular, for hard-cheese production, the measured %CY is higher at early and late stages of lactation compared to the mid-lactation, in agreement with the quadratic trend found in the present study. They state that those findings correspond to the changes in fat, protein and TS content of milk. On the contrary, for semi-hard cheese production, only milk from the last month of lactation results in a higher %CY than milk from other stages. The same authors find that both protein and fat recovery in hard cheese vary during lactation, but without a particular discernible pattern. In fact, it appeared that %CY does not correspond to the changes of %REC. In our study, most of the milk nutrient components that were entrapped into the curd had a quadratic trend during lactation. This could explain the patterns of actual %CY and %REC (Figure 1) traits, confirming data found by Cipolat-Gotet et al. (2013). The seasonal changes in milk composition, which are most pronounced at the extremes of lactation, result in variations not only in recovery of fat and protein, cheese yield and milk quality, but also in milk coagulation properties (**MCP**) and in curd-firming over time (**CF$_t$**) parameters (Pazzola et al., 2018; Vacca et al., 2018): in those studies, the technological properties of individual goat milk samples of late lactation are superior to those of early or mid-lactation milk, and justify here the higher value of actual $\%CY_{CURD}$ at the end of the period, not because of the higher water retention in the curd (that indeed did not change throughout the lactation), but because of the increment in $\%REC_{SOLIDS}$ ($\%CY_{SOLIDS}$ increased as well). On the contrary, in sheep %CY traits, $\%REC_{SOLIDS}$ and $\%REC_{ENERGY}$ increase linearly during lactation period (Cipolat-Gotet et al., 2016b).

Effect of Breed of Goat on Cheese-making Traits

As aforementioned, no previous studies have processed milk from many animals of six breeds of goat to obtain a complete balance of their cheese-making efficiency, but information on %CY comparison of some breeds is available.

Using an experimental model cheese procedure, Damiàn et al. (2008) compare the individual laboratory cheese yield (**ILCY**), the casein fractions and major milk components of 11 Saanen and 11 Anglo-Nubian goats raised under the same semi-intensive system. The two breeds are significantly different for all the traits considered, lactose excluded. As regard to ILCY, it is 48% higher in Anglo-Nubian breed compared to Saanen goats. Also, they find that ILCY is strongly related to casein fractions, in particular to αs1-CN. Also Soyral et al. (2005) observe large differences between 12 Nubian and 12 Alpine goats in $\%CY_{CURD}$ (2.71 *vs* 1.69 kg/10 kg of milk, respectively). Those authors have not performed any cutting and pressing phase and the average values are very high, probably because of the large moisture retained in the curd.

Some other information are available from studies using bulk milk produced by experimental or commercial farms and processed in small-scale dairy plants. Kouniba et al. (2007) have studied the effect of goat breed on milk composition and $\%CY_{CURD}$ from a local breed from the North of Marocco vs. Alpine. The milk of the local breed is characterized by significantly higher DM, fat and total nitrogen than Alpine breed, like in the case of the comparison between Alpine and Mediterranean breeds in our study, so as greater actual $\%CY_{CURD}$ (28.3% *vs* 17.3%,). Herrera et al. (2010) have studied $\%CY_{CURD}$ of bulk milk samples from Anglo-Nubian, Saanen, Alpine and Toggenburg goats after draining and pressing, like in the present study. They report greater %CY_{CURD} for Anglo-Nubian breed compared with the others (17.4% *vs* 12.6%, 12.7%, and 12.9% for Anglo-Nubian, Saanen, Alpine and Toggenburg, respectively).

From those above-mentioned studies, breeds of Alpine origin always show poor results compared to the other breeds when assessed in terms of %CY_{CURD}. This study confirmed (Table 5) that Alpine breeds (Sa and CA) were characterized by lower TS and poorer overall cheese-making ability when compared to Mediterranean dairy breeds. These latter are known for their lower daily milk yield, but also for higher milk fat and protein contents, and consequently for greater actual %CY_{CURD} (Figure 2) and %REC traits (Figure 3). As the *Th*-%CY_{CURD} is based on the fat and casein contents of milk, assuming constant recovery rate for both components, the difference between the theoretical and actual yields depends mainly on their nutrients recovery. In any case, the better %REC traits in Mediterranean breeds could be explained, in part, by milk coagulation, curd-firming and syneresis properties. Previous studies on these same goats have found better traditional MCP in Mediterranean dairy goats than Alpine ones (Vacca et al., 2018), even more when the entire pattern of the curd-firming process was modeled (Pazzola et al., 2018). Rapid milk coagulation and, especially, efficient curd-firming and syneresis rates have been found to result in favorable genetic and phenotypic correlations with regard to %CY and %REC traits in bovine milk, especially for those parameters recorded at maximum curd firmness or later (Cecchinato and Bittante, 2016).

On a smaller scale, similar interpretations could be applied when comparing the two Alpine specialized dairy goats breeds (Sa *vs* CA). The superiority of Camosciata delle Alpi breed is, in fact, not based on milk composition, but on efficient curd-firming, curd firmness and syneresis (Pazzola et al., 2018), that led to an overall cheese-making process, higher recovery of fat and protein in the curd (Figure 3), so a slightly higher *Eff*-%$\text{CY}_{\text{SOLIDS}}$.

Within Mediterranean breeds, we were able to confirm that the three Italian breeds had a good technological aptitude and much greater %REC and actual %CY traits, (Pazzola et al., 2018; Vacca et al., 2018) especially due to the differences also found in protein and TS contents (Table 5).

The Spanish breed Murciano-Granadina was intermediate between the two breeds of Alpine origin and the three Italian breeds in terms of milk composition, technological properties and daily milk and cheese yields.

The differences were more accentuated within the Italians: the very good quality of the two Sardinian breeds, Sr and SP, especially in terms of fat, protein, casein and TS compared with Maltese, not only explained the higher $\%REC_{FAT}$, $\%REC_{SOLIDS}$ and $\%REC_{ENERGY}$, but also the larger values for actual $\%CY_{CURD}$ and $\%CY_{SOLIDS}$. The technological superiority of milk from Sardinian breeds only partially counterbalanced the higher daily milk yield that characterize Maltese goats. This is one of the reasons that led farmers to cross Maltese bucks with local Sardinian goats for many generations, with a consequent recombination of the original genetic traits of both breeds (Vacca et al. 2016). However, the composition of milk from Maltese goats was much more similar to that from Alpines, although gelation, curd-firming and syneresis patterns have been shown to be better in Maltese compared with breed of Alpine type (Pazzola et al., 2018). Maltese breed had greater $\%REC_{FAT}$ and, although to a smaller degree, greater $\%REC_{PROTEIN}$ compared with the Saanen and Camosciata delle Alpi. It is worth noting that, even after correcting for the effect of farm, parity and DIM, this breed had the highest overall cheese-making efficiency (both as *Eff*-$\%CY_{CURD}$ and as *Eff*-$\%CY_{SOLIDS}$) of all the six breeds examined in the present study.

Despite Sarda has undergone an intensive crossing, mainly with Maltese, this breed was not different from the ancient strain, Sarda Primitiva, except for *Eff*-$\%CY_{CURD}$. It is clearly depicted in Figure 2 and 3 that both Sarda and Sarda Primitiva had the greatest actual %CY and %REC traits. Previous studies that considered local vs. foreign breed found better performances of the former over the latter (Moatsou et al., 2004; Kouniba et al., 2007).

Direct and Indirect Effects of Breed

Since the six breeds of the present study differed considerably from each other, to distinguish and quantify the direct effects of breed (independent from yield and composition) on cheese-making traits from the indirect breed effects (depending on differences in milk yield and composition), we included dMY, fat, protein, TS, casein, lactose, pH, SCS and LBC as linear covariates in model [M3]. Then we calculated the differences in breed variances with and without covariates for each trait. Figure 4 presented very different proportions of direct and indirect effects according to each examined trait.

Milk yield and composition (indirect effect of breed) accounted for a large proportion of the total breed variance for all %REC traits, but the extent of the direct effect of breed ranged from 41% for $\%REC_{ENERGY}$ to 63% for $\%REC_{PROTEIN}$. The direct effect of breed on actual %CY traits was, as expected, much lower, because of the dependence of these traits on milk composition, in particular on available fat and protein. Nevertheless, it represented a substantial proportion of total variability, being 26% for actual $\%CY_{CURD}$ and representing 36% and 39%, respectively, for the constituent traits, $\%CY_{SOLIDS}$ and $\%CY_{WATER}$. As expected, the theoretical cheese yields were totally dependent on the indirect breed effects, as they were calculated only from milk fat and casein contents (and the moisture content of cheese). Given the ratio between the actual and the theoretical %CY, the two cheese-making efficiencies were about from half to two thirds dependent on the direct effect of breed (Figure 4).

As regard to dCY traits, the indirect effect of breed was very large, including in the model the covariates with both dMY and milk composition traits. It is worth observing that the direct effect of breed was similar to or greater than those observed for actual %CY traits (26% for dCY_{CURD}, 18% for dCY_{WATER} and 39% for dCY_{SOLIDS}).

As this is the first study to investigate the direct and indirect effects of breed on cheese-making traits of goats milk, no direct comparison is possible with other studies on the same species. However, the direct effect of breed was always higher in goat compared with bovine (Stocco et al., 2017), with the exceptions of $\%REC_{SOLIDS}$ and *Eff*-$\%CY_{CURD}$. The approach previously taken to examine milk coagulation, curd-firming and syneresis traits (Vacca et al., 2018; Pazzola et al., 2018) shows that, for these latter traits, the direct effect of breed represented a great proportion of total breed variance. These traits are important in explaining %REC and %CY traits at the phenotypic, genetic, herd and residual levels, as demonstrated in a previous paper on bovine milk (Cecchinato and Bittante, 2016). It is also important to remind that a variable fraction of the breed effect on coagulation properties is explained by genetic variants of milk proteins (Ambrosoli et al., 1988; Damiàn et al., 2008; Pazzola et al., 2014). Genetic differences between Mediterranean and Alpine breeds have been mainly evidenced at casein loci, with the prevalence of alleles associated with the highest rates of protein synthesis in breeds belonging to the Mediterranean type (Vacca et al., 2014; Clark and Mora Garcia, 2017). Both milk coagulation traits and milk protein genetic variants could be a part of the factors influencing the direct effect of breed, as defined in the present study.

Among *Eff-%*CY traits, in the case of *Eff-%*CY_{SOLIDS} about a third of breed variance is due to indirect effects of breed (dMY and composition), even though it represents the ratio between actual %CY_{SOLIDS} and theoretical *Th*-%CY_{SOLIDS} predicted on the basis of the fat and casein contents of milk. It is evident that this proportion is explained by a different relationship between %CY and milk fat and casein compared with the Van Slyke and Price (1949) formula (a greater effect of casein and slightly lower effect of fat; data not shown), and by other factors included here as covariates. In particular, the constituents that could be considered indicators of the mammary gland health status (lactose, pH, SCS, and LBC), which, need further investigations for goat species.

CONCLUSIONS

In conclusion, this study confirmed that cheese-making by using goat milk is a complex phenomenon, driven by several factors. The quality of the milk processed, mainly fat and casein, the recovery of these nutrients in the curd, the retention of water in cheese, and overall cheese-making efficiency all contributed to the percentage cheese yield.

Animal factors were responsible for the greatest part of the variability in all traits and, among these factors, the breed has proven to be the most important. The two breeds of Alpine type, Saanen and Camosciata delle Alpi, seemed to be the most productive but to have the least cheese-making efficiency, while the most efficient out of the dairy breeds appeared to be the Sarda and Sarda Primitiva, and in part also Maltese breed. In particular, the two local Sardinian breeds, despite their small daily milk production, showed the highest fat and protein contents and cheese yields, and recovery rates of their milk. This study highlighted also that the differences among these breeds were the result not only of the production potential and nutrient concentrations, but also of the differences in nutrient recovery ability and overall cheese-making efficiency. So, further studies are needed to deepen the relationships among milk components, coagulation process and cheese-making traits, and size up the role of each of them. New insights provided by this study about the differences among breeds could also give new possibilities and direction in breeding programs.

ACKNOWLEDGMENTS

Research funded by the Regional Government of Sardinia (Legge Regionale 7/2007; CUP J72I15000030007).

The authors thank the farmers for giving access to their flocks; the A.I.P.A./A.P.A.s (Provincial Farmers Associations) of Cagliari, Nuoro, Sassari, and Oristano (Italy) and the firms Sepi Formaggi (Marrubiu, Italy) and L'Armentizia Moderna (Guspini, Italy) for their support in sample collection; A.R.A. Sardegna (Regional Farmers Association of Sardinia) for support in chemical milk analysis.

REFERENCES

Ambrosoli, R., L. Di Stasio, and P. Mazzocco. 1988. Content of alphas1-casein and coagulation properties in goat milk. J. Dairy Sci. 71:24-28.

Attaie, R., and R. L. Richter. 2000. Size distribution of fat globules in goat milk. J. Dairy Sci. 83:940-944.

Banks, J. M. 2007. Cheese yield. Pages 100–114 in Cheese Problems Solved. P. L. H. McSweeney, ed. Woodhead Publishing Ltd., Cambridge, UK.

Bittante, G., C. Cipolat-Gotet, and A. Cecchinato. 2013. Genetic parameters of different measures of cheese yield and milk nutrient recovery from an individual model cheese-manufacturing process. J. Dairy Sci. 96:7966-7979.

Cecchinato, A., and G. Bittante. 2016. Genetic and environmental relationships of different measures of individual cheese yield and curd nutrients recovery with coagulation properties of bovine milk. J. Dairy Sci. 99:1975-1989.

Chen, S. X., J. Z. Wang, J. S. Van Kessel, F. Z. Ren, and S. S. Zeng. 2010. Effect of somatic cell count in goat milk on yield, sensory quality, and fatty acid profile of semisoft cheese. J. Dairy Sci. 93:1345-1354.

Cipolat-Gotet, C., A. Cecchinato, and G. Bittante. 2015. Phenotypic analysis of cheese yields and nutrient recoveries in the curd of buffalo milk, as measured with an individual model cheese-manufacturing process. J. Dairy Sci. 98:633-645.

Cipolat-Gotet, C., A. Cecchinato, M. De Marchi, and G. Bittante. 2013. Factors affecting variation of different measures of cheese yield and milk nutrients recovery from an individual model cheese manufacturing process. J. Dairy Sci. 96:7952-7965.

Cipolat-Gotet, C., A. Cecchinato, G. Stocco, and G. Bittante. 2016a. The 9-MilCA method as a rapid, partly automated protocol for simultaneously recording milk coagulation, curd firming, syneresis, cheese yield, and curd nutrients recovery or whey loss. J. Dairy Sci. 99:1065-1082.

Cipolat-Gotet, C., A. Cecchinato, M. Pazzola, M. L. Dettori, G. Bittante, and G. M. Vacca. 2016b. Potential influence of herd and animal factors on the yield of cheese and recovery of components from Sarda sheep milk, as determined by a laboratory bench-top model cheese-making. Int. Dairy J. 63:8-17.

Clark S. and Mora García M.B. 2017. A 100-Year Review: Advances in goat milk research. J. Dairy Sci. 100:10026–10044 https://doi.org/10.3168/jds.2017-13287.

Damiàn, J. P., I. Sacchi, S. Reginensi, D. De Lima, and J. Bermúdez. 2008. Cheese yield, casein fractions and major components of milk of Saanen and Anglo-Nubian dairy goats. Brazilian Journal of Veterinary and Animal Science. 60(6):1564-1569.

Emmons, D. B., C. Dube, and H. W. Modler. 2003. Transfer of protein from milk to cheese. J. Dairy Sci. 86:469-485.

Emmons, D. B., C. A. Ernstrom, C. Lacroix, P. Sauve. 1993. Further considerations in formulae for predicting cheese yield from the composition of milk. J. Dairy Sci. 76:914-920.

Emmons, D.B., and H.W. Modler. 2010. Invited review: A commentary on predictive cheese yield formulas. J. Dairy Sci. 93:5517-5537.

Fagan, C. C., M. Castillo, F. A. Payne, C. P. O'Donnell, M. Leedy, and D. J. O'Callaghan. 2007. Novel online sensor technology for continuous monitoring of milk coagulation and whey separation in cheesemaking. J. Agric. Food Chem. 55:8836-8844.

FAOSTAT, (Food and Agriculture Organization of the United Nations Statistics Division). 2014. Statistical Database of the Food and Agriculture Organization of the United Nations. Accessed December 04, 2017. http://www.fao.org/faostat.

Fekadu, B., K. Soryal, S. Zeng, D. Van Hekken, B. Bah, and M. Villaquiran. 2005. Changes in goat milk composition during lactation and their effect on yield and quality of hard and semi-hard cheeses. Small Rum. Res. 59:55-63.

Fox, P. F., T. P Guinee, T. M. Cogan, and P. L. Mc Sweeney. 2000. Fundamentals of cheese science. Aspen Publishers, Inc. Gaithersburg, Maryland.

Guo, M., Y. W. Park, P. H. Dixon, J. A. Gilmore, P. S. Kindstedt. 2004. Relationship between the yield of cheese (Chèvre) and chemical composition of goat milk. Small Rumin. Res. 52: 103-107.

Hallén, E., A. Lunden, T. Allmere, and A. Andren. 2010. Casein retention in curd and loss of casein into whey at chymosin-induced coagulation of milk. J. Dairy Res. 77:71-76.

Herrera, V., M. Chavez, M. F. Gonzáles, J. M Quinteros, M. E. Ogas, and R Páez. 2010. Milk quality and cheese yield of four European and African goat biotypes bred in a semi arid area of Argentina Northwest. Proceeding of 10th International conference of goats (ISBN 085598) Area 02, N° 99-1, pag.4.

ISO-IDF. 2010a. (International Organization for Standardization and International Dairy Federation). Milk and liquid milk products. Determination of total solids content. International Standard ISO 6731 and IDF 21:2010a. ISO, Geneva, Switzerland and IDF, Brussels, Belgium.

ISO-IDF. 2013. (International Organization for Standardization and International Dairy Federation). Milk and liquid milk products. Determination of fat, protein, casein, lactose and pH content. International Standard ISO 9622 and IDF 141:2013. ISO, Geneva, Switzerland and IDF, Brussels, Belgium.

Janhøj, T., and K. B. Qvist. 2010. The formation of cheese curd. Pages 130-165 in Technology of Cheesemaking. B. A. Law and A. Y. Tamine, ed. Wiley-Blackwell, Ames, IA.

Kouniba, A., M. Berrada, and A. El Marakchi. 2007. Étude comparative de la composition chimique du lait de chèvre de la race *locale* Marocaine et la race *alpine* et évaluation de leur aptitude fromagère. Revue Méd. Vét. 158(3):152-160.

Law, B. A., and A. Y. Tamine, eds. 2010. Technology of Cheesemaking. 2nd ed. John Wiley & Sons, Ltd., Chicester, UK.

Melilli, C., J. M. Lynch, S. Carpino, D. M. Barbano, G. Licitra, and A. Cappa. 2002. An empirical method for prediction of cheese yield. J. Dairy Sci. 85:2699-2704.

Moatsou, G., M. Samolada, P. Panagiotou, and E. Anifantakis. 2004. Casein fraction of bulk milk from different caprine breeds. Food Chemistry. 87:75-81.

NRC. 2001. Nutrient Requirements of Dairy Cattle. 7th rev. ed. Natl. Acad. Press, Washington, DC.

Othmane, M. H., L. F. De la Fuente Crespo, J. A. Carriedo, and F. San Primitivo. 2002a. Heritability and genetic correlations of test day milk yield and composition, individual laboratory cheese yield, and somatic cell count for dairy ewes. J Dairy Sci. 85:2692-2698.

Othmane, M. H., J. A. Carriedo, F. San Primitivo, and L. F. De La Fuente. 2002b. Genetic parameters for lactation traits of milking ewes: protein content and composition, fat, somatic cells and individual laboratory cheese yield. Genet. Sel. Evol. 34:581-596.

Pazzola, M., M. L. Dettori, E. Pira, A. Noce, P. Paschino, and G. M. Vacca. 2014. Effect of polymorphisms at the casein gene cluster on milk renneting properties of the Sarda goat. Small Rumin. Res. 117:124-130.

Pazzola, M., G. Stocco, M. L. Dettori, C. C. Gotet, G. Bittante, and G. M. Vacca. 2018. Modeling of coagulation, curd firming, and syneresis of goat milk. J. Dairy Sci. Submitted January 5 2018.

Remeuf, F., V. Cossin, C. Dervin, J. Lenoir, and R. Tomassone. 1991. Relationships between physicochemical characteristics of milks and their cheese-making properties. Lait 71:397-421.

Soryal, K., F. A. Beyene, S. Zeng, B. Bah, and K. Tesfai. 2005. Effect of goat breed and milk composition on yield, sensory quality, fatty acid concentration of soft cheese during lactation. Small Rum. Res. 58:275-281.

Stocco, G., C. Cipolat-Gotet, V. Gasparotto, A. Cecchinato and G. Bittante. 2017. Breed of cow and herd productivity affect milk nutrient recovery in curd, and cheese yield, efficiency and daily production. Animal. doi:10.1017/S1751731117001471

Vacca, G. M., M. L. Dettori, G. Piras, F. Manca, P. Paschino, and M. Pazzola. 2014. Goat casein genotypes are associated with milk production traits in the Sarda breed. Anim. Genet. 45:723–731. doi:10.1111/age.12188

Vacca, G.M., P. Paschino, M. L. Dettori, M. Bergamaschi, C. Cipolat-Gotet, G. Bittante, and M. Pazzola. 2016. Environmental, morphological and productive characterization of Sardinian goats and use of latent explanatory factors for population analysis. J. Anim. Sci. 94:3947-3957.

Vacca, G.M., G. Stocco, M. L. Dettori, E. Pira, G. Bittante, and M. Pazzola. 2018. Milk yield, quality and coagulation properties of six breeds of goats: environmental and individual variability. J. Dairy Sci. Submitted November 8 2017.

Van Slyke, L. L., and W. V. Price. 1949. Cheese. rev. ed. Orange Judd Publ. Co., New York, NY.

Van Slyke, L. L., and C. A. Publow. 1910. The Science and Practice of Cheese Making. Orange Judd Company, New York

Zeng, S. S., K. Soryal, B. Fekadu, B. Bah, and T. Popham. 2007. Predictive formulae for goat cheese yield based on milk composition. Small Rum. Res. 69:180-186.

Table 1. Descriptive statistics of milk composition, daily productions and cheese-making traits of goat milk samples.

Trait	N	Mean	CV[1]	Percentile	
				1st	99th
Milk composition					
Fat, %	558	4.59	32	2.23	9.28
Protein, %	558	3.59	15	2.68	4.98
Casein, %	558	2.82	18	1.96	4.20
Casein index[2]	558	0.78	4	0.70	0.86
Lactose, %	558	4.66	6	3.97	5.25
Total solids, %	558	13.74	14	10.81	19.21
pH	554	6.72	2	6.47	6.99
SCS[3]	558	5.61	35	1.44	10.09
LBC[4]	557	1.80	46	0.30	3.95
Nutrients recovery (%REC), %					
%REC$_{FAT}$	1,110	80.5	8	60.45	90.49
%REC$_{PROTEIN}$	1,110	81.5	3	74.12	86.62
%REC$_{SOLIDS}$	1,110	55.7	10	43.70	67.06
%REC$_{ENERGY}$	1,110	66.3	9	52.72	76.70
Cheese yields, %					
%CY$_{CURD}$	1,102	15.7	20	10.31	22.93
%CY$_{SOLIDS}$	1,110	7.7	23	4.93	12.63
%CY$_{WATER}$	1,102	8.0	20	4.94	12.28
Theoretical CY, %					
Th-%CY$_{CURD}$	1,116	15.5	25	9.46	27.56
Th -%CY$_{SOLIDS}$	1,116	7.6	25	4.63	13.50
Cheese-making efficiencies, %					
Eff-%CY$_{CURD}$	1,100	103	16	73	145
Eff -%CY$_{SOLIDS}$	1,114	102	6	86	120
Daily production traits, kg/d					
dMY	558	1.92	58	0.24	4.80
dCY$_{CURD}$	543	0.28	53	0.02	0.66
dCY$_{SOLIDS}$	555	0.14	50	0.02	0.32
dCY$_{WATER}$	544	0.15	57	0.02	0.37

[1]CV = coefficient of variation; [2]Casein index: casein to protein ratio; [3]SCS = $\log_2$ (SCC × 10^{-5}) + 3; [4]logarithmic total bacterial count (LBC) = $\log_{10}$ (total bacterial count/1,000).

Table 2. Variances of the random effects for milk composition, cheese-making traits and daily productions of goat milk samples.

Trait	Random effects (%): Farm	Animal	Glass tube	RMSE[1]
Milk composition				
Fat, %	54.0	-	-	0.85
Protein, %	33.1	-	-	0.34
Casein, %	38.3	-	-	0.29
Casein index[2]	47.5	-	-	0.02
Lactose, %	33.9	-	-	0.20
Total solids, %	51.6	-	-	1.03
pH	52.8	-	-	0.07
SCS[3]	28.8	-	-	1.63
LBC[4]	63.5	-	-	0.51
Nutrients recovery (%REC), %				
%REC$_{\text{FAT}}$	17.1	82.7	0.01	0.21
%REC$_{\text{PROTEIN}}$	18.5	80.8	0.04	0.20
%REC$_{\text{SOLIDS}}$	34.7	64.1	0.07	0.49
%REC$_{\text{ENERGY}}$	27.4	71.9	0.03	0.37
Cheese yields, %				
%CY$_{\text{CURD}}$	31.3	60.8	0.00	0.73
%CY$_{\text{SOLIDS}}$	44.7	55.1	0.01	0.07
%CY$_{\text{WATER}}$	29.0	49.5	0.00	0.69
Theoretical CYs, %				
Th-%CY$_{\text{CURD}}$	46.1	53.9	-	0.00
Th-%CY$_{\text{SOLIDS}}$	38.7	61.3	-	0.00
Cheese-making efficiencies, %				
Eff-%CY$_{\text{CURD}}$	19.4	69.9	0.00	5.10
Eff-%CY$_{\text{SOLIDS}}$	19.6	77.5	0.13	0.96
Daily production traits, kg/d				
dMY	53.4	47.0	-	0.58
dCY$_{\text{CURD}}$	50.1	48.5	0.00	0.01
dCY$_{\text{SOLIDS}}$	48.8	51.2	0.00	0.00
dCY$_{\text{WATER}}$	52.2	43.6	0.02	0.01

[1]RMSE = Root Mean Square Error; [2]Casein index: casein to protein ratio; [3]SCS = $\log_2 (SCC \times 10^{-5}) + 3$; [4]logarithmic total bacterial count (LBC) = $\log_{10}$ (total bacterial count/1,000).

Table 3. Effect of parity on milk composition, daily productions and cheese-making traits of individual goats.

Trait	Parity (LSM)			Parity contrast (*F*-value and significance)	
	1st and 2nd	3rd and 4th	≥5th	1st and 2nd *vs* ≥3rd	3rd and 4th *vs* ≥5rd
Milk composition					
Fat, %	4.68	4.61	4.59	1.2	0.0
Protein, %	3.63	3.63	3.62	0.1	0.1
Casein, %	2.87	2.85	2.84	0.7	0.4
Casein index[1]	0.79	0.78	0.78	7.3**	3.0
Lactose, %	4.71	4.65	4.62	20.5***	4.4*
Total solids, %	13.92	13.79	13.73	3.3	0.5
pH	6.73	6.72	6.71	6.4*	5.8*
SCS[2]	5.05	5.68	6.35	50.1***	23.6***
LBC[3]	1.89	1.74	1.80	7.2**	2.0
Nutrients recovery (%REC), %					
%REC$_{\text{FAT}}$	81.3	80.6	80.1	2.6	0.6
%REC$_{\text{PROTEIN}}$	82.1	81.5	80.9	11.8***	5.7*
%REC$_{\text{SOLIDS}}$	56.4	56.0	55.7	1.3	0.6
%REC$_{\text{ENERGY}}$	66.9	66.6	66.1	1.3	1.0
Cheese yields, %					
%CY$_{\text{CURD}}$	15.9	16.0	15.5	0.8	4.2*
%CY$_{\text{SOLIDS}}$	7.9	7.8	7.7	1.9	0.4
%CY$_{\text{WATER}}$	8.0	8.1	7.9	0.1	3.0
Theoretical CYs, %					
Th-%CY$_{\text{CURD}}$	15.8	15.6	15.6	1.3	0.1
Th-%CY$_{\text{SOLIDS}}$	7.8	7.7	7.6	1.3	0.1
Cheese-making efficiencies, %					
Eff-%CY$_{\text{CURD}}$	103	103	101	1.5	4.3
Eff-%CY$_{\text{SOLIDS}}$	103	102	102	6.7*	0.9
Daily production traits, kg/d					
dMY	1.72	1.97	1.97	25.4***	0.0
dCY$_{\text{CURD}}$	0.26	0.29	0.29	9.2**	0.2
dCY$_{\text{SOLIDS}}$	0.13	0.14	0.14	8.2**	0.1
dCY$_{\text{WATER}}$	0.13	0.15	0.15	12.4***	0.1

[1]Casein index: casein to protein ratio; [2]SCS = $\log_2(\text{SCC} \times 10^{-5}) + 3$; [3]logarithmic total bacterial count (LBC) = $\log_{10}$ (total bacterial count/1,000); **P* < 0.05; ***P* < 0.01; ****P* < 0.001.

Table 4. Effect of days in milk (DIM) and orthogonal contrast for linear, quadratic and cubic trend on milk composition, daily productions and cheese-making traits of individual goats.

	DIM (LSM)				DIM contrasts (*F*-value and significance)		
Trait	< 80	80 - 120	121 - 160	> 160	linear	quadratic	cubic
Milk composition							
Fat, %	4.68	4.68	4.50	4.64	0.6	0.8	2.7
Protein, %	3.58	3.49	3.64	3.78	24.8***	15.7***	4.0*
Casein, %	2.82	2.74	2.86	2.99	20.5***	16.4***	3.1
Casein index[1]	0.79	0.78	0.78	0.79	0.0	4.9*	0.3
Lactose, %	4.77	4.65	4.62	4.60	35.6***	8.4**	0.6
Total solids, %	13.92	13.73	13.67	13.93	0.0	6.9**	0.3
pH	6.75	6.72	6.71	6.70	26.7***	1.0	0.2
SCS[2]	5.20	5.63	5.52	6.42	24.5***	3.1	7.1**
LBC[3]	1.76	1.76	1.80	1.92	4.8*	2.2	0.1
Nutrients recovery (%REC), %							
%REC$_{\text{FAT}}$	81.5	80.4	79.8	81.0	0.4	3.9*	0.2
%REC$_{\text{PROTEIN}}$	81.1	81.9	81.7	81.4	0.4	5.2*	0.5
%REC$_{\text{SOLIDS}}$	55.4	55.5	55.5	57.6	8.8**	5.5*	1.4
%REC$_{\text{ENERGY}}$	66.5	66.3	66.1	67.1	0.3	1.7	0.4
Cheese yields, %							
%CY$_{\text{CURD}}$	15.9	15.5	15.5	16.2	0.6	4.0*	0.1
%CY$_{\text{SOLIDS}}$	7.8	7.7	7.7	8.1	2.1	5.7*	0.8
%CY$_{\text{WATER}}$	8.1	7.9	8.0	8.1	0.0	1.3	0.1
Theoretical CYs, %							
Th-%CY$_{\text{CURD}}$	15.7	15.6	15.4	16.0	0.7	4.3	0.1
Th-%CY$_{\text{SOLIDS}}$	7.7	7.6	7.6	7.8	0.7	4.3	0.6
Cheese-making efficiencies, %							
Eff-%CY$_{\text{CURD}}$	104	103	102	101	2.9	0.3	0.0
Eff-%CY$_{\text{SOLIDS}}$	102	102	102	103	1.2	1.1	1.0
Daily production traits, kg/d							
dMY	2.02	1.90	1.85	1.75	10.5**	0.0	0.3
dCY$_{\text{CURD}}$	0.30	0.28	0.27	0.27	3.9*	0.5	0.0
dCY$_{\text{SOLIDS}}$	0.15	0.14	0.13	0.13	2.8	0.8	0.1
dCY$_{\text{WATER}}$	0.16	0.15	0.14	0.14	4.8*	0.7	0.0

[1]Casein index: casein to protein ratio; [2]SCS = $\log_2$ (SCC × 10^{-5}) + 3; [3]logarithmic total bacterial count (LBC) = $\log_{10}$ (total bacterial count/1,000).

**P* < 0.05; ***P* < 0.01; ****P* < 0.001.

Table 5. Effect of breed and orthogonal contrast on milk composition, daily productions and cheese-making traits of individual goats.

Trait	Breed (LSM)						Breed contrasts (*F*-value and significance)				
	Alpine type		Mediterranean type								
	Saanen (Sa)	Camosciata delle Alpi (CA)	Murciano-Granadina (MG)	Maltese (Ma)	Sarda (Sr)	Sarda Primitiva (SP)	Alpine *vs* Mediterranean	Sa *vs* CA	MG *vs* Ma - Sr - SP	Ma *vs* Sr - SP	Sr *vs* SP
Milk composition											
Fat, %	4.05	4.27	4.71	4.08	5.25	5.38	12.1***	1.2	1.0	16.1***	1.0
Protein, %	3.34	3.48	3.56	3.41	3.96	3.99	22.4***	3.4	10.1**	32.4***	0.2
Casein, %	2.60	2.70	2.78	2.64	3.18	3.21	23.6***	2.1	12.2***	34.4***	0.4
Casein index[1]	0.77	0.77	0.78	0.77	0.80	0.81	18.7***	0.4	11.5***	22.7***	1.2
Lactose, %	4.57	4.52	4.76	4.58	4.76	4.78	20.4***	1.5	1.5	10.2**	0.3
Total solids, %	12.9	13.2	14.0	13.0	14.8	15.0	23.5***	1.7	2.0	27.1***	1.1
pH	6.69	6.71	6.75	6.74	6.72	6.72	4.0	0.9	2.3	0.8	0.2
SCS[2]	5.70	6.43	6.03	5.59	5.07	5.33	3.6	4.5*	4.7*	0.8	1.1
LBC[3]	1.95	2.04	1.58	1.74	1.79	1.75	4.7*	0.5	2.1	0.0	0.3
Nutrients recovery (%REC), %											
$\%REC_{FAT}$	75.8	77.5	80.1	81.6	84.6	84.6	40.4***	1.9	9.2**	5.1*	0.0
$\%REC_{PROTEIN}$	79.9	81.0	81.2	82.2	82.4	82.4	15.6***	4.2*	5.2*	0.2	0.0
$\%REC_{SOLIDS}$	51.7	54.3	55.6	55.5	59.4	59.6	29.4***	6.7**	7.5**	10.7**	0.3
$\%REC_{ENERGY}$	61.1	64.2	66.2	66.4	70.5	70.6	46.4***	8.0**	8.9**	11.3***	0.2
Cheese yields, %											
$\%CY_{CURD}$	13.6	14.4	15.7	15.4	17.8	17.9	33.1***	1.9	6.5*	13.0***	0.0
$\%CY_{SOLIDS}$	6.6	7.1	7.8	7.2	9.1	9.1	30.7***	2.6	5.4*	23.8***	0.2
$\%CY_{WATER}$	7.1	7.5	7.9	8.3	8.6	8.7	18.0***	1.7	4.4*	0.7	0.2
Theoretical CYs, %											

Th-%CY_{CURD}	14.0	14.7	15.8	14.2	17.6	17.7	16.6***	1.9	2.8	22.4***	0.9
Th-%CY_{SOLIDS}	6.9	7.2	7.7	6.9	8.6	8.8	16.6***	1.9	2.5	22.2***	0.9
Cheese-making efficiencies, %											
Eff-%CY_{CURD}	103	103	102	113	100	95	0.0	0.0	0.0	21.0***	5.3*
Eff-%CY_{SOLIDS}	100	102	102	106	101	101	2.8	4.2*	0.2	16.8***	0.8
Daily production traits, kg/d											
dMY	2.64	2.59	2.17	2.01	1.02	0.88	62.7***	0.1	40.7***	25.2***	2.5
dCY_{CURD}	0.36	0.37	0.33	0.29	0.17	0.16	28.3***	0.0	23.8***	12.2***	0.7
dCY_{SOLIDS}	0.17	0.19	0.16	0.13	0.08	0.08	31.3***	1.5	24.4***	8.4**	0.0
dCY_{WATER}	0.19	0.19	0.17	0.16	0.09	0.08	27.3***	0.0	20.0***	15.6***	1.1

[1]Casein index: casein to protein ratio; [2]SCS = $\log_2 (SCC \times 10^{-5}) + 3$; [3]logarithmic total bacterial count (LBC) = $\log_{10}$ (total bacterial count/1,000).

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Figure 1.

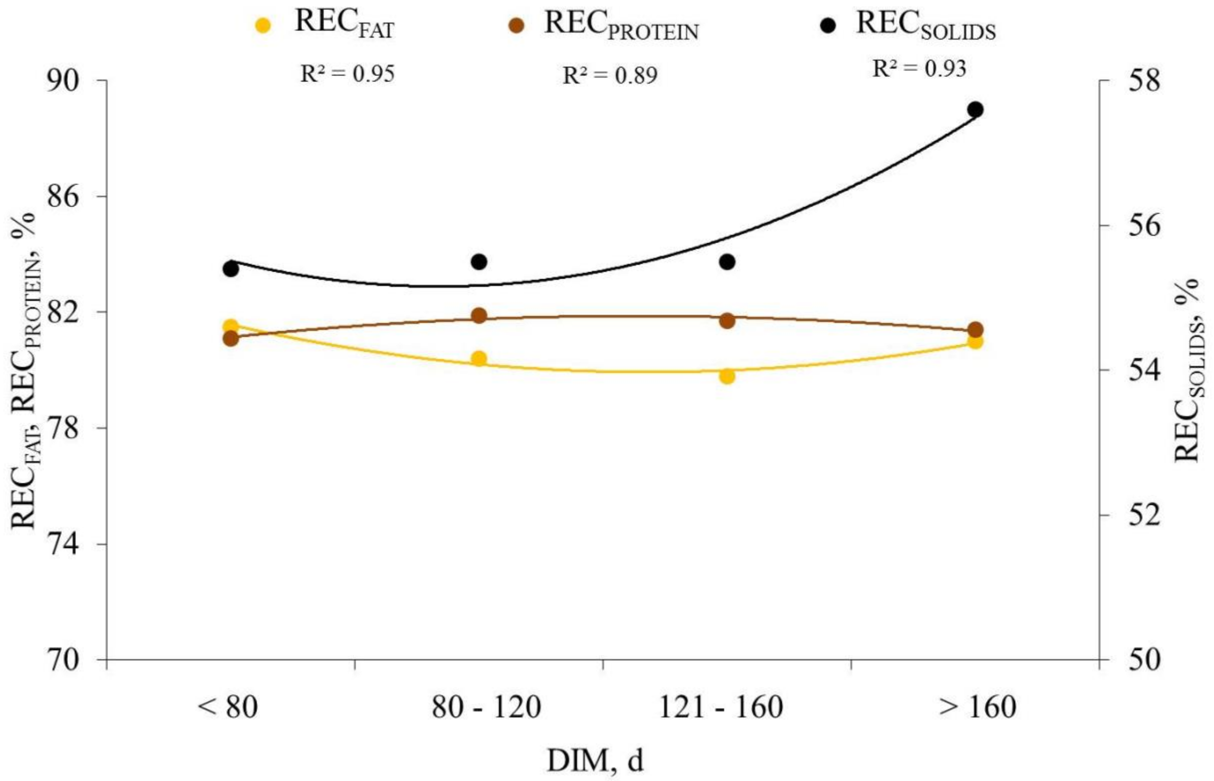

Figure 2.

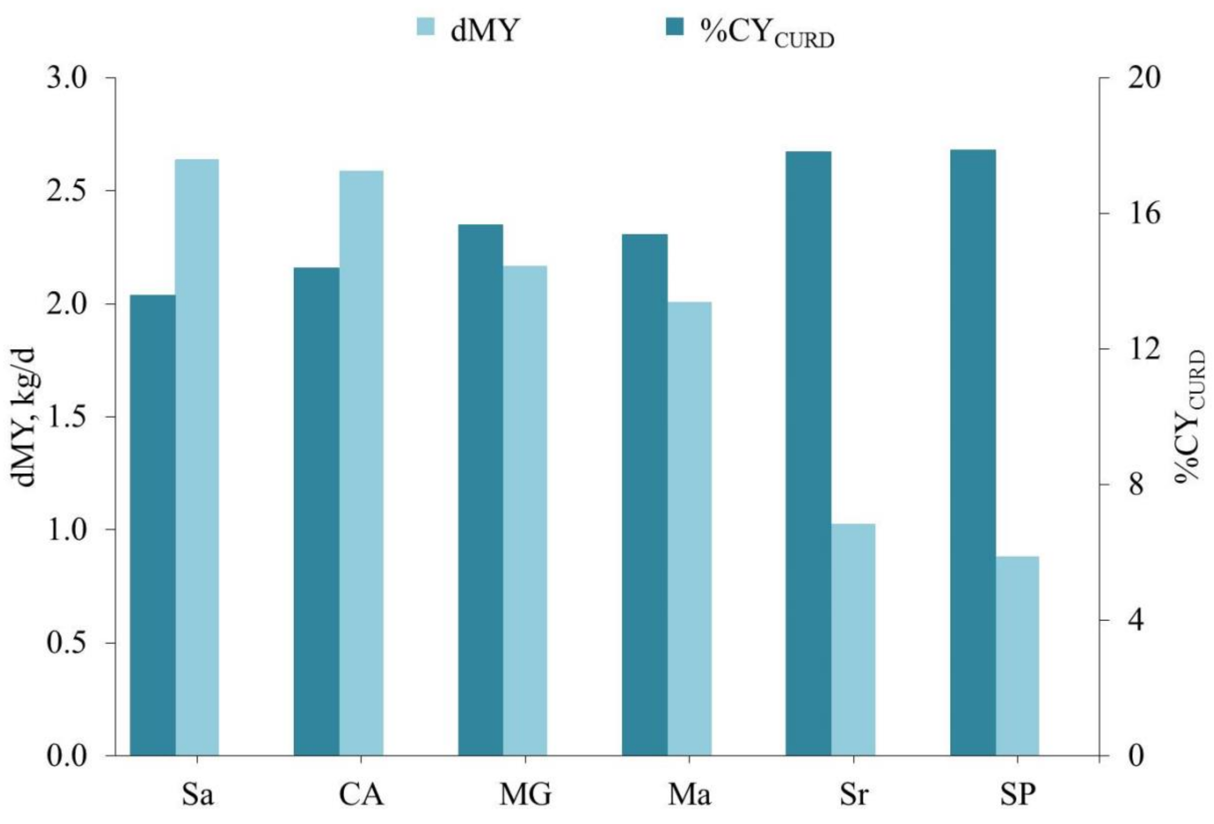

Figure 3.

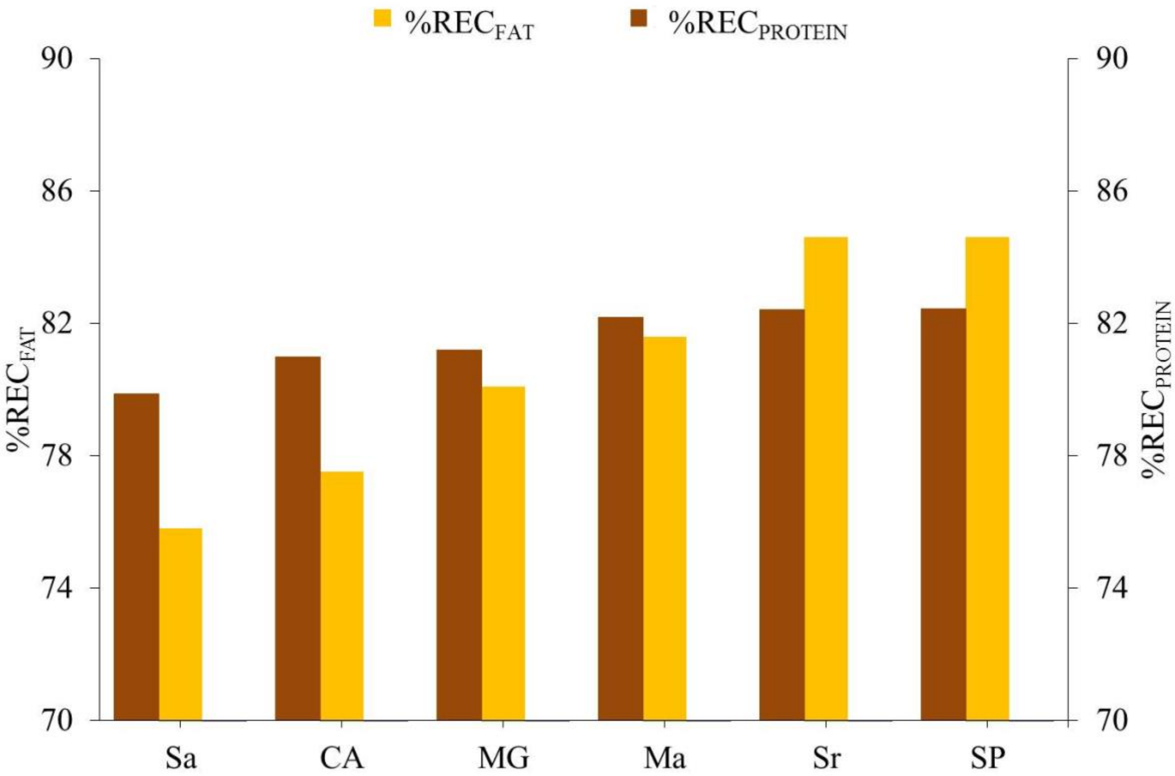

Figure 4.

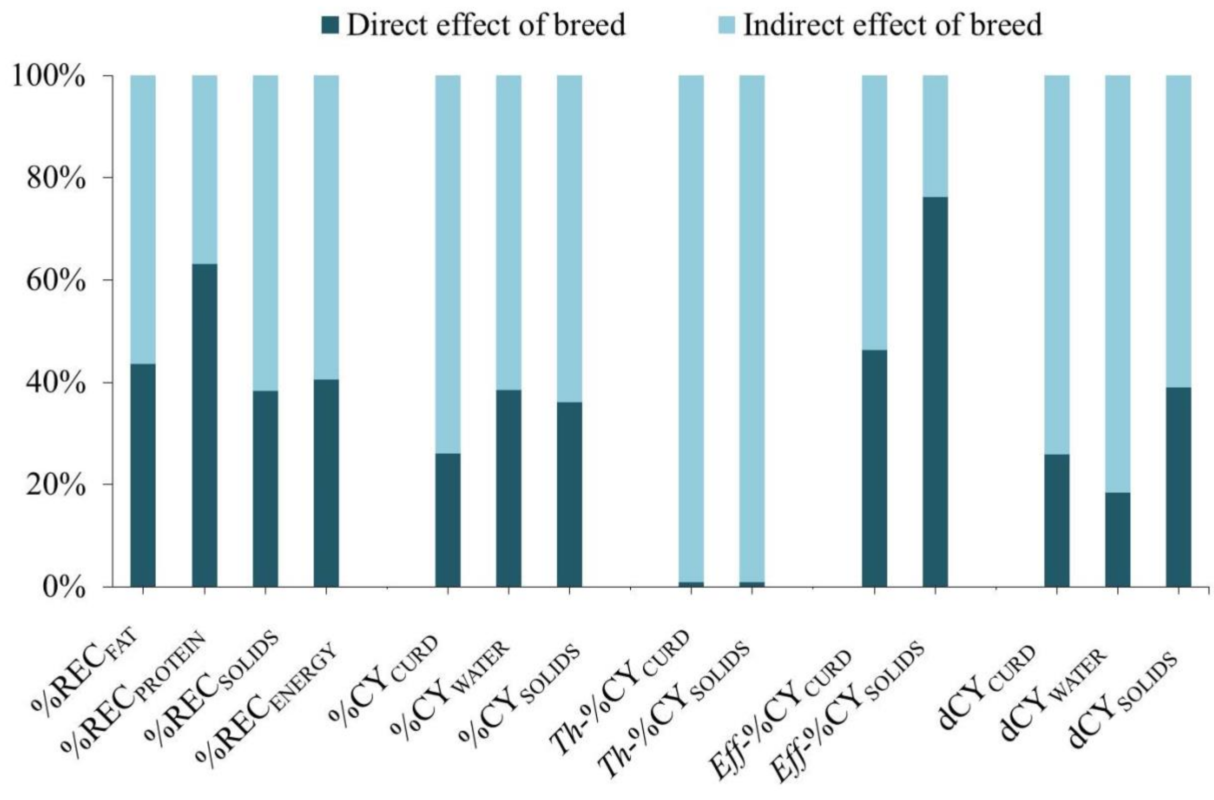

Figure captions

Figure 1. Effect of DIM for milk fat, protein and solids recovery in the curd. Results of the polynomial contrasts have been reported: the quadratic response curve of the data according to lactation, and the coefficient of determination (R^2) of the regression.

Figure 2. Effect of breed on daily milk yield (dMY) and percentage actual cheese yield ($\%CY_{CURD}$).

Figure 3. Effect of breed on fat ($\%REC_{FAT}$) and protein ($\%REC_{PROTEIN}$) recovery in the curd.

Figure 4. Proportion of total breed variance explained by direct breed effect or by indirect breed effect due to the differences in milk yield and quality traits on %RECs, actual %CY, *Th*-%CY, *Eff*-%CY and dCY traits.