

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

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note finali coverpage

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1 **INTERPRETIVE SUMMARY**

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

13 BREED OF GOATS, CHEESE YIELD AND EFFICIENCY

14

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

16

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## ABSTRACT

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

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

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

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

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

## INTRODUCTION

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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.,

92 2018). The suitability of lactodynamography for testing large number of individual goats relies on  
93 the small volume of milk and the possibility to test several samples in a short period. Traditionally,  
94 lactodynamography does not provide direct measurement of %CY and %REC traits, but only  
95 reproduces first steps of the cheese-making process (i.e., rennet addition, milk coagulation, curd-  
96 firming). However, recent modifications of the analysis procedures proposed by Cipolat-Gotet et al.  
97 (2016a), permits to assess also the phases during which the obtained small curds are cut, heated, and  
98 drained. That method has stimulated more interest on the use of lactodynamography, because  
99 coagulation analysis could be completed by the assessment of the efficiency of cheese-making  
100 process. As regard to sheep, Othmane et al. (2002a) proposed an individual laboratory cheese yield  
101 procedure using 10 mL of milk, allowing the simultaneous recording of %CY of several samples  
102 (Othmane et al., 2002b).

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

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

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## MATERIALS AND METHODS

### *Farm Characteristics and Milk Sampling*

114 A total of 560 goats from 35 farms located in Sardinia (Italy) were sampled (16 animals per  
115 farm). Six breeds were investigated: Saanen (**Sa** = 99 goats) and Camosciata delle Alpi (**CA** = 98  
116 goats) for the Alpine type; Murciano-Granadina (**MG** = 89 goats), Maltese (**Ma** = 104 goats), Sarda  
117 (**Sr** = 86 goats) and Sarda Primitiva (**SP** = 84 goats) for the Mediterranean type. Details of the milk

118 sampling and analysis have been described by Vacca et al. (2018), and environmental context and  
119 farming systems involved have been reported in Vacca et al. (2016).

120

### 121 *Analysis of Milk Traits*

122 Immediately after collection, individual milk samples were stored at 4°C, analyzed and  
123 processed within 24 hours of sampling. All samples were analyzed for fat, protein, total solids (**TS**),  
124 casein, lactose and pH with a MilkoScan FT6000 infrared analyzer (Foss Electric A/S, Hillerød,  
125 Denmark) calibrated in accordance with the related reference methods [ISO 9622/IDF 141 (2013)  
126 for fat, protein, casein, lactose and pH; ISO 6731/IDF 21 (2010a) for total solids]. **Casein index was**  
127 **calculated as the casein to protein ratio.** Somatic cell count (**SCC**) was determined by a Fossomatic  
128 5000 somatic cell counter (Foss Electric A/S, Hillerød, Denmark) and transformed into the  
129 logarithmic somatic cell score [**SCS** =  $\log_2(\text{SCC} \times 10^{-5}) + 3$ ]; total bacterial count was determined  
130 using a BactoScan FC150 analyzer (Foss Electric A/S, Hillerød, Denmark) and transformed into the  
131 logarithmic bacterial count [**LBC** =  $\log_{10}(\text{total bacterial count}/1000)$ ].

132

### 133 *Individual Cheese-making Procedure*

134 The 9-mL milk cheese-making assessment (**9-MilCA**) proposed by Cipolat-Gotet et al.  
135 (2016a) was used to measure actual %CY and %REC traits. The following procedure was  
136 performed on 560 individual goat milk samples, with two replicates per each animal (9 mL × 2), for  
137 a total of 1,120 observations.

138 Briefly, each milk replicate was poured into a glass tube (9 mL), inserted into the modified  
139 sample rack of the lactodynamograph instrument, heated up to 35 °C for 15 min, and mixed with  
140 0.2 mL of a rennet solution [Hansen Standard 215, with  $80 \pm 5\%$  chymosin and  $20 \pm 5\%$  pepsin;  
141 215 international milk clotting units (**IMCU**)/mL (Pacovis Amrein AG, Bern, Switzerland); diluted  
142 to 1.2% (wt/vol) in distilled water]. The sample rack was then transferred from the heater to the  
143 lactodynamograph for a 30-min duration test at 35 °C. At the end of the analysis, coagulated milk

144 samples were manually cut using a stainless steel spatula, and the rack was moved to the heater for  
145 the 30 min curd-cooking phase (55 °C). In the middle of the cooking phase, each sample was  
146 subjected to a further manual cutting by the same operator. At the end, each glass tube was removed  
147 from the sample rack and the curd was separated from the whey. The curd was slightly pressed to  
148 facilitate the whey expulsion, and the curd was then suspended above the whey for 15 min at room  
149 temperature to favor the draining. The obtained curd and whey were weighed using a precision  
150 scale. As the volume of whey produced from a single vat (about 7.5 mL) was not sufficient for  
151 assessment of the chemical composition using an infrared spectrophotometer (MilkoScan FT2, Foss  
152 Electric), two replicates of each milk sample were analyzed in two consecutive glass tubes of the  
153 same sample rack, and the whey was pooled for chemical analysis. The weights of the milk, curd  
154 and whey (in grams) and the chemical composition of milk and whey, permitted to estimate also  
155 curd composition. The actual cheese yield (%CY) traits were: %CY<sub>CURD</sub>, %CY<sub>SOLIDS</sub> and  
156 %CY<sub>WATER</sub>, calculated as the ratio of the weight (g) of fresh curd, curd dry matter and water  
157 retained in curd, respectively, to the weight of the milk processed (g), and multiplied by 100. Daily  
158 cheese yields (dCY<sub>CURD</sub>, dCY<sub>SOLIDS</sub> and dCY<sub>WATER</sub>; kg/d) were calculated by multiplying the  
159 different %CYs (%CY<sub>CURD</sub>, %CY<sub>SOLIDS</sub> and %CY<sub>WATER</sub>, respectively) by the daily milk yield  
160 (dMY, kg/d), recorded as the total yield of morning plus afternoon milking. The nutrients recovery  
161 (%REC) traits were: %REC<sub>PROTEIN</sub>, %REC<sub>FAT</sub> and %REC<sub>SOLIDS</sub>, calculated as the ratio of the  
162 weight (g) of the curd components (protein, fat and dry matter, respectively) to the same component  
163 of milk (g), and multiplied by 100. Recovery of energy in the curd (%REC<sub>ENERGY</sub>) was calculated  
164 by estimating energy of milk and curd using an equation proposed by the NRC (2001), converted to  
165 MJ/kg and multiplied by 100.

166

167 *Definition of Cheese-making Efficiency*

168 The theoretical %CY<sub>CURD</sub> (**Th-%CY<sub>CURD</sub>**) of the milk samples of each goat was estimated  
 169 using the formula of Van Slyke and Price (1949) reported by Emmons and Modler (2010) in their  
 170 review:

$$171 \quad Th\%CY_{CURD} = (0.93 \times \%fat + \%casein - 0.1) \times 1.09 / [(100 - \%M) / 100]$$

172 where 1.09 represents correction for milk minerals and cheese salt and carbohydrates, and  
 173 %M is the percentage moisture of cheese (100 - %total solids).

174 A formula for estimating the theoretical CY<sub>SOLIDS</sub> (**Th-%CY<sub>SOLIDS</sub>**) was derived from the  
 175 previous one by deleting the last part, which corrects for cheese moisture:

$$176 \quad Th \%CY_{SOLIDS} = (0.93 \times \%fat + \%casein - 0.1) \times 1.09$$

177 The efficiencies of CY<sub>CURD</sub> (**Eff-%CY<sub>CURD</sub>**) and of CY<sub>SOLIDS</sub> (**Eff-%CY<sub>SOLIDS</sub>**) were  
 178 calculated by expressing the experimental value in relation to the corresponding theoretical value  
 179 for each goat:

$$180 \quad Eff\%CY_{CURD} = \%CY_{CURD} / Th\%CY_{CURD}, \text{ and}$$

$$181 \quad Eff\%CY_{SOLIDS} = \%CY_{SOLIDS} / Th\%CY_{SOLIDS}$$

182

### 183 **Statistical Analysis**

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

186

$$187 \quad y_{lmnopq} = \mu + Farm_l + Breed_m + Parity_n + DIM_o + Animal_p + Glass\ tube_{q+} + e_{lmnopq} [M1]$$

188

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

194 class 2: 81-120 d (157 goats); class 3: 121-160 d (157 goats); class 4: >160 d (100 goats);  $Animal_p$   
195 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  
196 ( $q = 1$  to 8);  $e_{lmnopq}$  is the random residual  $\sim N(0, \sigma_e^2)$ . The effects of Breed, Parity and DIM were  
197 tested using the random animal as the error line.

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

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

206 Moreover, orthogonal contrasts were estimated between LSMs of traits for parity effect: a)  
207 1<sup>st</sup> and 2<sup>nd</sup> vs  $\geq 3^{rd}$ , and b) 3<sup>rd</sup> and 4<sup>th</sup> vs  $\geq 5^{th}$ ; and for days in milk (DIM): linear, quadratic and cubic  
208 pattern.

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

217

218

## RESULTS

### 219 *Effects of Farm and Animal*

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

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

229 In the case of cheese-making traits, farm was always lower than animal effect, varying from  
230 19% for *Eff*-%CY<sub>CURD</sub> to 46% for *Th*-%CY<sub>CURD</sub> of the total variance, whereas the animal effect  
231 ranged from 49% to 83%. Glass tube of the instrument sample rack had very little or no effect on  
232 the variability of the cheese-making traits (from 0.0% to 0.13 % of the total variance), highlighting  
233 the optimum repeatability of the method (from 78.5% of %CY<sub>WATER</sub> to 99.9% of %REC<sub>FAT</sub>, data  
234 not shown). Farm and animal affected almost equally all daily production traits.

235

### 236 ***Effect of Parity and Days in Milk***

237 The least square means of parity and related orthogonal contrasts on milk quality and  
238 cheese-making traits are summarized in Table 3. Parity had a modest effect on the quality of milk  
239 and on cheese-making traits with the only exception of SCS and daily yields. Milk from  
240 primiparous and secondiparous goats had mainly a greater content of lactose and LBC, and much  
241 lower SCS content than milk from goats with three or more parities,. Although the differences in  
242 milk protein content across classes of parity were not significant, the recovery of protein from milk  
243 to cheese (%REC<sub>PROTEIN</sub>) was greater in primiparous and secondiparous goats and, in general, it  
244 was lower in goats with five or more parities. Among cheese yields traits, actual %CY<sub>CURD</sub> was  
245 significantly lower in goats with five or more parities. As expected, daily production traits were

246 lower for the first group of goats for dMY (-13%), dCY (-10%), dCY<sub>SOLIDS</sub> (-7%) and dCY<sub>WATER</sub> (-  
247 13%) when compared to the other groups.

248 The variation during lactation (reported in Table 4) was significant for all the milk  
249 components, except in the case of fat. Nutrients recovery were slightly affected by DIM (excluding  
250 %REC<sub>ENERGY</sub>) exhibiting a quadratic trend along lactation. It can be seen from Figure 1 that, during  
251 lactation, %REC<sub>FAT</sub> was characterized by an opposite pattern respect to %REC<sub>PROTEIN</sub>; less marked  
252 was the pattern shown by %REC<sub>SOLIDS</sub>. We found greater values of actual %CY<sub>CURD</sub> and  
253 %CY<sub>SOLIDS</sub> at the end of lactation. Daily production traits were linearly affected by DIM, showing a  
254 decrease during lactation.

255

### 256 ***Effect of Goat Breed***

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

260 Comparing LSMs of the Alpine type breeds (Saanen and Camosciata delle Alpi) with the  
261 Mediterranean (Murciano-Granadina, Maltese, Sarda and Sarda Primitiva), six out of eight milk  
262 quality traits, and nine out of 15 cheese-making traits were better for the latter group of breeds. Our  
263 findings confirmed the lower milk productivity potential of Mediterranean goats in terms of dMY (-  
264 70%), dCY<sub>CURD</sub> (-54%), dCY<sub>SOLIDS</sub> (-60%) and dCY<sub>WATER</sub> (-62%) when compared to the two  
265 Alpine breeds, only partly compensated by greater actual %CY<sub>CURD</sub>, (+19%) %CY<sub>SOLIDS</sub> (+21%)  
266 and %CY<sub>WATER</sub> (+15%). This was due not only to higher milk fat, protein and casein contents, but  
267 also to the greater %REC showed by Mediterranean breeds. Theoretical cheese yields (both *Th*-  
268 %CY<sub>CURD</sub> and *Th*-%CY<sub>SOLIDS</sub>), based on milk composition, showed higher values for  
269 Mediterranean over the Alpine breeds. However, it is interesting to focus on the differences  
270 between the actual and theoretical cheese-yields: their ratio provides an estimate of the global  
271 efficiency of cheese-making process. As shown in Table 5, both cheese-making efficiencies of

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

274 Compared with Saanen, Camosciata delle Alpi presented no differences in terms of milk  
275 components, daily production and actual cheese yields traits, but had greater recovery of nutrients in  
276 the curd (+1.4% for protein, +5.0% for solids, and +5.1% for energy). Also theoretical %CYs were  
277 not different between the two breeds of Alpine type, but *Eff*-%CY<sub>SOLIDS</sub> was higher in Camosciata  
278 delle Alpi goats.

279 Within Mediterranean breeds, Italian goats had a lower daily milk yield (-66% dMY) and  
280 also cheese production when compared to the Murciano-Granadina (-60%, -66% and -55% for  
281 dCY<sub>CURD</sub>, dCY<sub>SOLIDS</sub> and dCY<sub>WATER</sub>, respectively), partly compensated by greater values of all  
282 actual %CY (+10%) and %REC traits (+4.4% for fat, +1.4% for protein, +5.0% for solids, and  
283 +4.5% for energy).

284 The differences found among the three Italian breeds were even larger: Maltese breed  
285 produced more milk and cheese per day than the two local Sardinian breeds, but had on average  
286 lower actual %CYs, due to lower milk fat and protein contents, and to lower %REC<sub>FAT</sub>,  
287 %REC<sub>SOLIDS</sub>, and %REC<sub>ENERGY</sub>. The theoretical %*Th*-CY<sub>SOLIDS</sub>, as expected, confirmed that the  
288 two local Sardinian breeds were superior to Maltese goats, whereas *Eff*-%CY<sub>SOLIDS</sub> were, on  
289 average, lower for the two local breeds due to the lower predicted *Th*-%CY<sub>CURD</sub>. The only  
290 difference found between the two local breeds from Sardinia was for the *Eff*-%CY<sub>CURD</sub>, slightly  
291 lower in Sarda Primitiva breed.

292

293

## DISCUSSION

### *Cheese-making Ability of Goat Milk*

295 As far we are aware, no previous studies in the literature have processed a high number of  
296 goat milk samples to mimic the complex process of cheese-making using a laboratory small scale  
297 method that allows the estimation of four recoveries of nutrients (%REC), three actual (%CY), two

298 theoretical (*Th*-%CY), two efficiencies of cheese-making (*Eff*-%CY), and three daily cheese  
299 productions (dCY) traits. The protocol used in this study allowed to process 560 individual milk  
300 samples with two replicates. Respect to other lab procedures based on very limited quantity of milk  
301 and separating the curd through centrifugation, 9-MilCA allows to obtain %CY and %REC traits  
302 from bovine milk very similar to those found in practice, especially in relation to efficiency of curd  
303 draining and representativeness of milk fat recovery in the curd (Cipolat-Gotet et al., 2016a).

304 In the present study, actual %CY<sub>CURD</sub> was the same as the average value obtained by Stocco  
305 et al. (2017) from milk of six breeds of cows, slightly higher compared with Cipolat-Gotet et al.  
306 (2013) from Brown Swiss cows, and neatly lower compared with results from Sarda sheep (Cipolat-  
307 Gotet et al., 2016b). Goat %REC<sub>FAT</sub> was lower when compared with both species (bovine and  
308 ovine), and was much more similar to that reported by Fekadu et al. (2005) in their study on goat  
309 milk (Alpine breed). These differences among species could be explained by the different fat  
310 globules-casein matrix interaction, besides fat globules dimension, smaller for goat milk (Attaie and  
311 Richter, 2000). The %REC<sub>PROTEIN</sub> in goats was superior than cow and sheep, and also compared  
312 with goat milk protein recovery found by Chen et al. (2010), but it was closer to those found for a  
313 500 mL cheese-making procedure using individual buffalo milk samples (80.4%) by Cipolat-Gotet  
314 et al. (2015). Goat %REC<sub>SOLIDS</sub> was higher compared with cows and lower compared with sheep  
315 and buffaloes. Because of these differences in the recovery of nutrients in the curd, %REC<sub>ENERGY</sub>  
316 was slightly lower in goats compared with the studies on bovines and especially on buffalo and  
317 sheep milk.

318

### 319 ***Effect of Farm and Animal on Cheese-making Traits***

320 It is recognized that %CY<sub>CURD</sub> depends primarily on the TS content of the milk, its recovery  
321 in curd and the retention of water in cheese (Cecchinato and Bittante, 2016). The amount of solids  
322 retained in the curd depends largely on the fat and casein contents of the milk, because lactose and  
323 the mineral fraction are retained at very low levels. In opposite, water retention in cheese is mainly

324 influenced by several factors, among which the processing conditions (i.e., mode and time of the  
325 cutting phase, the draining and pressing of wheels and the extent of ripening) (Remeuf et al., 1991;  
326 Janhøj and Qvist, 2010). For these reason, among %CY traits, %CY<sub>WATER</sub> was less affected by  
327 animal effect (Table 2). To exclude the effect of variations in the water content of the cheese, some  
328 researchers have calculated the %CY<sub>SOLIDS</sub> as the ratio between the Dry Matter (**DM**) content of the  
329 cheese and the weight of the processed milk (Fagan et al., 2007). In the case of model cheeses  
330 produced using very small amounts of milk (10 mL), Melilli et al. (2002) estimate directly  
331 %CY<sub>SOLIDS</sub>. However, those authors use that procedure to predict the results obtained with the  
332 formula of Van Slyke and Publow (1910), obtaining on average 6.59% of %CY<sub>SOLIDS</sub>, whereas the  
333 one found in the present study was 7.7% for the actual %CY<sub>SOLIDS</sub> and 7.4% for estimated *Th*-  
334 %CY<sub>SOLIDS</sub> with Van Slyke and Price formula (1949). The differences can be largely explained by  
335 differences in milk composition and in cheese-making protocols: the use of centrifugation instead of  
336 curd cooking and draining is known to reduce the efficiency of whey separation, to overestimate all  
337 %CY and %REC traits, and to worsen the repeatability of the measures (Cipolat-Gotet et al.,  
338 2016a). In this study, TS represented 49% of the fresh curd, so water contributed slightly more than  
339 TS to both percentage and daily cheese yields (8.0 vs. 7.7%, and 0.15 vs. 0.14 kg/d, respectively).

340         The %REC<sub>FAT</sub> and %REC<sub>PROTEIN</sub> quantify the complex phenomena through which fat and  
341 proteins are transferred from milk to cheese (Emmons et al., 2003), so the loss of fat and proteins in  
342 whey reduces the cheese yield (Hallén et al., 2010). In the past, almost all the predictive formulae  
343 for estimating cheese yield have been based on knowledge of the protein and fat contents of milk, or  
344 the sum of the fat and protein, and total solids contents (Zeng et al., 2007; Emmons and Modler,  
345 2010). All those formulae assume that the recovery of milk protein (casein) and fat in the curd is  
346 constant. However, it has been proved that those traits are not only highly variable (Stocco et al.,  
347 2017), but have larger heritability than milk protein and fat contents (Bittante et al., 2013).  
348 Actually, the incidence of the animal effect was very high for these traits (82.7% and 80.8%  
349 respectively for %REC<sub>FAT</sub> and %REC<sub>PROTEIN</sub>), and was the highest among all cheese-making traits

350 (Table 2). This suggested that the improvement of %REC and %CY traits should be based  
351 principally on individual animal factors (i.e., breed, genetics, parity, stage of lactation), while  
352 farming system (facilities, management, nutrition) played a much more important role in the level  
353 of production and hygienic conditions (LBC = 63.5%, Table 2). Similar results are found by  
354 Cipolat-Gotet et al. (2013) on bovines and, in particular, they report values of variability due to  
355 herd-date from 21 to 31% for %REC traits, from 24 to 42% for actual %CY traits, and from 51 to  
356 53% for dCY traits. Stocco et al. (2017) find lower herd-date incidence compared to the present  
357 study: from 11 to 17% for %REC traits, from 19 to 29% for actual %CY traits, from 42 to 46% for  
358 dCY traits, 15% for both *Th*-%CYs, 10% and 17% respectively for *Eff*-%CY<sub>CURD</sub> and *Eff*-  
359 %CY<sub>SOLIDS</sub>. However, it is worth noting that in their case herd-date is included in the statistical  
360 model as a random effect within class of herd productivity. While in the case of Sarda sheep  
361 (Cipolat-Gotet et al., 2016b), the effect of flock is higher compared with this study for %REC (from  
362 13% to 56%) and actual %CY traits (from 43% to 49%), and lower for dCY productions (from 18%  
363 to 42%).

364       Regarding %REC<sub>SOLIDS</sub> and %REC<sub>ENERGY</sub>, these have never been studied before in goat  
365 milk. Their variability was mostly under the animal control (64.1% and 71.9% respectively, Table  
366 2), even more than the single milk components. It is important to remind that in a previous study on  
367 genetic parameters of different measures of cheese yield and milk nutrient recovery in bovine milk,  
368 from the genetic point of view %REC<sub>PROTEIN</sub> is not directly correlated with the cheese yield, but  
369 with %REC<sub>SOLIDS</sub> and %REC<sub>ENERGY</sub>, which are strongly related to the %CY traits (Bittante et al.,  
370 2013).

371

### 372 ***Individual Animal Factors on Cheese-making Traits***

373       No previous study examined the effect of parity on cheese yield and cheese-making traits of  
374 goat milk. It is interesting to note that, while daily production traits decreased across parities, the  
375 %REC<sub>PROTEIN</sub> was significantly higher for goats belonging to the first group. However, the other

376 traits were not statistically different across classes of parity. This meant that, although the dMY  
377 increased with the age of the goat, %REC and %CY did not augment throughout parities. Among  
378 milk quality traits, only lactose, SCS and LBC changed across parities. Similar results for parity on  
379 cheese-making traits are found for buffalo (Cipolat-Gotet et al., 2015) and bovine milk (Cipolat-  
380 Gotet et al., 2013; Stocco et al., 2017), while in sheep parity affect only %REC<sub>SOLIDS</sub> and daily milk  
381 and cheese productions (Cipolat-Gotet et al., 2016b).

382 As regard to days in milk, marked changes occur in the composition of bovine milk  
383 throughout the year, especially when milk is produced mainly from spring-calving farms fed  
384 predominantly on pasture (Fox et al., 2000), because progressing of lactation is parallel to the  
385 seasonal change in quantity and quality of herbage available. For goat species, Fekadu et al. (2005)  
386 report that the significant variation of the chemical composition of milk over six months of lactation  
387 causes the variation of %CY<sub>CURD</sub>, %REC<sub>FAT</sub> and %REC<sub>PROTEIN</sub>. In particular, for hard-cheese  
388 production, the measured %CY is higher at early and late stages of lactation compared to the mid-  
389 lactation, in agreement with the quadratic trend found in the present study. They state that those  
390 findings correspond to the changes in fat, protein and TS content of milk. On the contrary, for semi-  
391 hard cheese production, only milk from the last month of lactation results in a higher %CY than  
392 milk from other stages. The same authors find that both protein and fat recovery in hard cheese vary  
393 during lactation, but without a particular discernible pattern. In fact, it appeared that %CY does not  
394 correspond to the changes of %REC. In our study, most of the milk nutrient components that were  
395 entrapped into the curd had a quadratic trend during lactation. This could explain the patterns of  
396 actual %CY and %REC (Figure 1) traits, confirming data found by Cipolat-Gotet et al. (2013). The  
397 seasonal changes in milk composition, which are most pronounced at the extremes of lactation,  
398 result in variations not only in recovery of fat and protein, cheese yield and milk quality, but also in  
399 milk coagulation properties (**MCP**) and in curd-firming over time (**CF<sub>t</sub>**) parameters (Pazzola et al.,  
400 2018; Vacca et al., 2018): in those studies, the technological properties of individual goat milk  
401 samples of late lactation are superior to those of early or mid-lactation milk, and justify here the

402 higher value of actual %CY<sub>CURD</sub> at the end of the period, not because of the higher water retention  
403 in the curd (that indeed did not change throughout the lactation), but because of the increment in  
404 %REC<sub>SOLIDS</sub> (%CY<sub>SOLIDS</sub> increased as well). On the contrary, in sheep %CY traits, %REC<sub>SOLIDS</sub>  
405 and %REC<sub>ENERGY</sub> increase linearly during lactation period (Cipolat-Gotet et al., 2016b).

406

#### 407 *Effect of Breed of Goat on Cheese-making Traits*

408 As aforementioned, no previous studies have processed milk from many animals of six  
409 breeds of goat to obtain a complete balance of their cheese-making efficiency, but information on  
410 %CY comparison of some breeds is available.

411 Using an experimental model cheese procedure, Damiàn et al. (2008) compare the  
412 individual laboratory cheese yield (**ILCY**), the casein fractions and major milk components of 11  
413 Saanen and 11 Anglo-Nubian goats raised under the same semi-intensive system. The two breeds  
414 are significantly different for all the traits considered, lactose excluded. As regard to ILCY, it is  
415 48% higher in Anglo-Nubian breed compared to Saanen goats. Also, they find that ILCY is strongly  
416 related to casein fractions, in particular to  $\alpha$ s1-CN. Also Soyral et al. (2005) observe large  
417 differences between 12 Nubian and 12 Alpine goats in %CY<sub>CURD</sub> (2.71 vs 1.69 kg/10 kg of milk,  
418 respectively). Those authors have not performed any cutting and pressing phase and the average  
419 values are very high, probably because of the large moisture retained in the curd.

420 Some other information are available from studies using bulk milk produced by  
421 experimental or commercial farms and processed in small-scale dairy plants. Kouniba et al. (2007)  
422 have studied the effect of goat breed on milk composition and %CY<sub>CURD</sub> from a local breed from  
423 the North of Marocco vs. Alpine. The milk of the local breed is characterized by significantly  
424 higher DM, fat and total nitrogen than Alpine breed, like in the case of the comparison between  
425 Alpine and Mediterranean breeds in our study, so as greater actual %CY<sub>CURD</sub> (28.3% vs 17.3%),  
426 Herrera et al. (2010) have studied %CY<sub>CURD</sub> of bulk milk samples from Anglo-Nubian, Saanen,  
427 Alpine and Toggenburg goats after draining and pressing, like in the present study. They report

428 greater %CY<sub>CURD</sub> for Anglo-Nubian breed compared with the others (17.4% vs 12.6%, 12.7%, and  
429 12.9% for Anglo-Nubian, Saanen, Alpine and Toggenburg, respectively).

430 From those above-mentioned studies, breeds of Alpine origin always show poor results  
431 compared to the other breeds when assessed in terms of %CY<sub>CURD</sub>. This study confirmed (Table 5)  
432 that Alpine breeds (Sa and CA) were characterized by lower TS and poorer overall cheese-making  
433 ability when compared to Mediterranean dairy breeds. These latter are known for their lower daily  
434 milk yield, but also for higher milk fat and protein contents, and consequently for greater actual  
435 %CY<sub>CURD</sub> (Figure 2) and %REC traits (Figure 3). As the *Th*-%CY<sub>CURD</sub> is based on the fat and  
436 casein contents of milk, assuming constant recovery rate for both components, the difference  
437 between the theoretical and actual yields depends mainly on their nutrients recovery. In any case,  
438 the better %REC traits in Mediterranean breeds could be explained, in part, by milk coagulation,  
439 curd-firming and syneresis properties. Previous studies on these same goats have found better  
440 traditional MCP in Mediterranean dairy goats than Alpine ones (Vacca et al., 2018), even more  
441 when the entire pattern of the curd-firming process was modeled (Pazzola et al., 2018). Rapid milk  
442 coagulation and, especially, efficient curd-firming and syneresis rates have been found to result in  
443 favorable genetic and phenotypic correlations with regard to %CY and %REC traits in bovine milk,  
444 especially for those parameters recorded at maximum curd firmness or later (Cecchinato and  
445 Bittante, 2016).

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

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

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

457 The differences were more accentuated within the Italians: the very good quality of the two  
458 Sardinian breeds, Sr and SP, especially in terms of fat, protein, casein and TS compared with  
459 Maltese, not only explained the higher %REC<sub>FAT</sub>, %REC<sub>SOLIDS</sub> and %REC<sub>ENERGY</sub>, but also the  
460 larger values for actual %CY<sub>CURD</sub> and %CY<sub>SOLIDS</sub>. The technological superiority of milk from  
461 Sardinian breeds only partially counterbalanced the higher daily milk yield that characterize  
462 Maltese goats. This is one of the reasons that led farmers to cross Maltese bucks with local  
463 Sardinian goats for many generations, with a consequent recombination of the original genetic traits  
464 of both breeds (Vacca et al. 2016). However, the composition of milk from Maltese goats was much  
465 more similar to that from Alpines, although gelation, curd-firming and syneresis patterns have been  
466 shown to be better in Maltese compared with breed of Alpine type (Pazzola et al., 2018). Maltese  
467 breed had greater %REC<sub>FAT</sub> and, although to a smaller degree, greater %REC<sub>PROTEIN</sub> compared with  
468 the Saanen and Camosciata delle Alpi. It is worth noting that, even after correcting for the effect of  
469 farm, parity and DIM, this breed had the highest overall cheese-making efficiency (both as *Eff*-  
470 %CY<sub>CURD</sub> and as *Eff*-%CY<sub>SOLIDS</sub>) of all the six breeds examined in the present study.

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

476

#### 477 ***Direct and Indirect Effects of Breed***

478 Since the six breeds of the present study differed considerably from each other, to  
479 distinguish and quantify the direct effects of breed (independent from yield and composition) on

480 cheese-making traits from the indirect breed effects (depending on differences in milk yield and  
481 composition), we included dMY, fat, protein, TS, casein, lactose, pH, SCS and LBC as linear  
482 covariates in model [M3]. Then we calculated the differences in breed variances with and without  
483 covariates for each trait. Figure 4 presented very different proportions of direct and indirect effects  
484 according to each examined trait.

485 Milk yield and composition (indirect effect of breed) accounted for a large proportion of the  
486 total breed variance for all %REC traits, but the extent of the direct effect of breed ranged from  
487 41% for %REC<sub>ENERGY</sub> to 63% for %REC<sub>PROTEIN</sub>. The direct effect of breed on actual %CY traits  
488 was, as expected, much lower, because of the dependence of these traits on milk composition, in  
489 particular on available fat and protein. Nevertheless, it represented a substantial proportion of total  
490 variability, being 26% for actual %CY<sub>CURD</sub> and representing 36% and 39%, respectively, for the  
491 constituent traits, %CY<sub>SOLIDS</sub> and %CY<sub>WATER</sub>. As expected, the theoretical cheese yields were  
492 totally dependent on the indirect breed effects, as they were calculated only from milk fat and  
493 casein contents (and the moisture content of cheese). Given the ratio between the actual and the  
494 theoretical %CY, the two cheese-making efficiencies were about from half to two thirds dependent  
495 on the direct effect of breed (Figure 4).

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

500 As this is the first study to investigate the direct and indirect effects of breed on cheese-  
501 making traits of goats milk, no direct comparison is possible with other studies on the same species.  
502 However, the direct effect of breed was always higher in goat compared with bovine (Stocco et al.,  
503 2017), with the exceptions of %REC<sub>SOLIDS</sub> and *Eff*-%CY<sub>CURD</sub>. The approach previously taken to  
504 examine milk coagulation, curd-firming and syneresis traits (Vacca et al., 2018; Pazzola et al.,  
505 2018) shows that, for these latter traits, the direct effect of breed represented a great proportion of

506 total breed variance. These traits are important in explaining %REC and %CY traits at the  
507 phenotypic, genetic, herd and residual levels, as demonstrated in a previous paper on bovine milk  
508 (Cecchinato and Bittante, 2016). It is also important to remind that a variable fraction of the breed  
509 effect on coagulation properties is explained by genetic variants of milk proteins (Ambrosoli et al.,  
510 1988; Damiàn et al., 2008; Pazzola et al., 2014). Genetic differences between Mediterranean and  
511 Alpine breeds have been mainly evidenced at casein loci, with the prevalence of alleles associated  
512 with the highest rates of protein synthesis in breeds belonging to the Mediterranean type (Vacca et  
513 al., 2014; Clark and Mora Garcia, 2017). Both milk coagulation traits and milk protein genetic  
514 variants could be a part of the factors influencing the direct effect of breed, as defined in the present  
515 study.

516 Among *Eff*-%CY traits, in the case of *Eff*-%CY<sub>SOLIDS</sub> about a third of breed variance is due  
517 to indirect effects of breed (dMY and composition), even though it represents the ratio between  
518 actual %CY<sub>SOLIDS</sub> and theoretical *Th*-%CY<sub>SOLIDS</sub> predicted on the basis of the fat and casein  
519 contents of milk. It is evident that this proportion is explained by a different relationship between  
520 %CY and milk fat and casein compared with the Van Slyke and Price (1949) formula (a greater  
521 effect of casein and slightly lower effect of fat; data not shown), and by other factors included here  
522 as covariates. In particular, the constituents that could be considered indicators of the mammary  
523 gland health status (lactose, pH, SCS, and LBC), which, need further investigations for goat species.

524

525

## CONCLUSIONS

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

530 Animal factors were responsible for the greatest part of the variability in all traits and,  
531 among these factors, the breed has proven to be the most important. The two breeds of Alpine type,

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

542

543

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551

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

Trait	N	Mean	CV <sup>1</sup>	Percentile	
				1 <sup>st</sup>	99 <sup>th</sup>
<b>Milk composition</b>					
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 <sup>2</sup>	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 <sup>3</sup>	558	5.61	35	1.44	10.09
LBC <sup>4</sup>	557	1.80	46	0.30	3.95
<b>Nutrients recovery (%REC), %</b>					
%REC <sub>FAT</sub>	1,110	80.5	8	60.45	90.49
%REC <sub>PROTEIN</sub>	1,110	81.5	3	74.12	86.62
%REC <sub>SOLIDS</sub>	1,110	55.7	10	43.70	67.06
%REC <sub>ENERGY</sub>	1,110	66.3	9	52.72	76.70
<b>Cheese yields, %</b>					
%CY <sub>CURD</sub>	1,102	15.7	20	10.31	22.93
%CY <sub>SOLIDS</sub>	1,110	7.7	23	4.93	12.63
%CY <sub>WATER</sub>	1,102	8.0	20	4.94	12.28
<b>Theoretical CY, %</b>					
<i>Th</i> -%CY <sub>CURD</sub>	1,116	15.5	25	9.46	27.56
<i>Th</i> -%CY <sub>SOLIDS</sub>	1,116	7.6	25	4.63	13.50
<b>Cheese-making efficiencies, %</b>					
<i>Eff</i> -%CY <sub>CURD</sub>	1,100	103	16	73	145
<i>Eff</i> -%CY <sub>SOLIDS</sub>	1,114	102	6	86	120
<b>Daily production traits, kg/d</b>					
dMY	558	1.92	58	0.24	4.80
dCY <sub>CURD</sub>	543	0.28	53	0.02	0.66
dCY <sub>SOLIDS</sub>	555	0.14	50	0.02	0.32
dCY <sub>WATER</sub>	544	0.15	57	0.02	0.37

673 <sup>1</sup>CV = coefficient of variation; <sup>2</sup>Casein index: casein to protein ratio; <sup>3</sup>SCS =  $\log_2(\text{SCC} \times 10^{-5}) + 3$ ;

674 <sup>4</sup>logarithmic total bacterial count (LBC) =  $\log_{10}(\text{total bacterial count}/1,000)$ .

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676

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

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

679 <sup>1</sup>RMSE = Root Mean Square Error; <sup>2</sup>Casein index: casein to protein ratio; <sup>3</sup>SCS =  $\log_2 (\text{SCC} \times 10^{-5})$   
680 + 3; <sup>4</sup>logarithmic total bacterial count (LBC) =  $\log_{10} (\text{total bacterial count}/1,000)$ .

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

Trait	Parity (LSM)			Parity contrast ( <i>F</i> -value and significance)	
	1 <sup>st</sup> and 2 <sup>nd</sup>	3 <sup>rd</sup> and 4 <sup>th</sup>	≥5 <sup>th</sup>	1 <sup>st</sup> and 2 <sup>nd</sup> <i>vs</i> ≥3 <sup>rd</sup>	3 <sup>rd</sup> and 4 <sup>th</sup> <i>vs</i> ≥5 <sup>rd</sup>
<b>Milk composition</b>					
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 <sup>1</sup>	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 <sup>2</sup>	5.05	5.68	6.35	50.1***	23.6***
LBC <sup>3</sup>	1.89	1.74	1.80	7.2**	2.0
<b>Nutrients recovery (%REC), %</b>					
%REC <sub>FAT</sub>	81.3	80.6	80.1	2.6	0.6
%REC <sub>PROTEIN</sub>	82.1	81.5	80.9	11.8***	5.7*
%REC <sub>SOLIDS</sub>	56.4	56.0	55.7	1.3	0.6
%REC <sub>ENERGY</sub>	66.9	66.6	66.1	1.3	1.0
<b>Cheese yields, %</b>					
%CY <sub>CURD</sub>	15.9	16.0	15.5	0.8	4.2*
%CY <sub>SOLIDS</sub>	7.9	7.8	7.7	1.9	0.4
%CY <sub>WATER</sub>	8.0	8.1	7.9	0.1	3.0
<b>Theoretical CYs, %</b>					
<i>Th</i> -%CY <sub>CURD</sub>	15.8	15.6	15.6	1.3	0.1
<i>Th</i> -%CY <sub>SOLIDS</sub>	7.8	7.7	7.6	1.3	0.1
<b>Cheese-making efficiencies, %</b>					
<i>Eff</i> -%CY <sub>CURD</sub>	103	103	101	1.5	4.3
<i>Eff</i> -%CY <sub>SOLIDS</sub>	103	102	102	6.7*	0.9
<b>Daily production traits, kg/d</b>					
dMY	1.72	1.97	1.97	25.4***	0.0
dCY <sub>CURD</sub>	0.26	0.29	0.29	9.2**	0.2
dCY <sub>SOLIDS</sub>	0.13	0.14	0.14	8.2**	0.1
dCY <sub>WATER</sub>	0.13	0.15	0.15	12.4***	0.1

686 <sup>1</sup>Casein index: casein to protein ratio; <sup>2</sup>SCS = log<sub>2</sub> (SCC × 10<sup>-5</sup>) + 3; <sup>3</sup>logarithmic total bacterial  
 687 count (LBC) = log<sub>10</sub> (total bacterial count/1,000); \**P* < 0.05; \*\**P* < 0.01; \*\*\**P* < 0.001.

688

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

Trait	DIM (LSM)				DIM contrasts ( <i>F</i> -value and significance)		
	< 80	80 - 120	121 - 160	> 160	linear	quadratic	cubic
<b>Milk composition</b>							
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 <sup>1</sup>	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 <sup>2</sup>	5.20	5.63	5.52	6.42	24.5***	3.1	7.1**
LBC <sup>3</sup>	1.76	1.76	1.80	1.92	4.8*	2.2	0.1
<b>Nutrients recovery (%REC), %</b>							
%REC <sub>FAT</sub>	81.5	80.4	79.8	81.0	0.4	3.9*	0.2
%REC <sub>PROTEIN</sub>	81.1	81.9	81.7	81.4	0.4	5.2*	0.5
%REC <sub>SOLIDS</sub>	55.4	55.5	55.5	57.6	8.8**	5.5*	1.4
%REC <sub>ENERGY</sub>	66.5	66.3	66.1	67.1	0.3	1.7	0.4
<b>Cheese yields, %</b>							
%CY <sub>CURD</sub>	15.9	15.5	15.5	16.2	0.6	4.0*	0.1
%CY <sub>SOLIDS</sub>	7.8	7.7	7.7	8.1	2.1	5.7*	0.8
%CY <sub>WATER</sub>	8.1	7.9	8.0	8.1	0.0	1.3	0.1
<b>Theoretical CYs, %</b>							
<i>Th</i> -%CY <sub>CURD</sub>	15.7	15.6	15.4	16.0	0.7	4.3	0.1
<i>Th</i> -%CY <sub>SOLIDS</sub>	7.7	7.6	7.6	7.8	0.7	4.3	0.6
<b>Cheese-making efficiencies, %</b>							
<i>Eff</i> -%CY <sub>CURD</sub>	104	103	102	101	2.9	0.3	0.0
<i>Eff</i> -%CY <sub>SOLIDS</sub>	102	102	102	103	1.2	1.1	1.0
<b>Daily production traits, kg/d</b>							
dMY	2.02	1.90	1.85	1.75	10.5**	0.0	0.3
dCY <sub>CURD</sub>	0.30	0.28	0.27	0.27	3.9*	0.5	0.0
dCY <sub>SOLIDS</sub>	0.15	0.14	0.13	0.13	2.8	0.8	0.1
dCY <sub>WATER</sub>	0.16	0.15	0.14	0.14	4.8*	0.7	0.0

691 <sup>1</sup>Casein index: casein to protein ratio; <sup>2</sup>SCS = log<sub>2</sub> (SCC × 10<sup>-5</sup>) + 3; <sup>3</sup>logarithmic total bacterial  
 692 count (LBC) = log<sub>10</sub> (total bacterial count/1,000).

693 \**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.

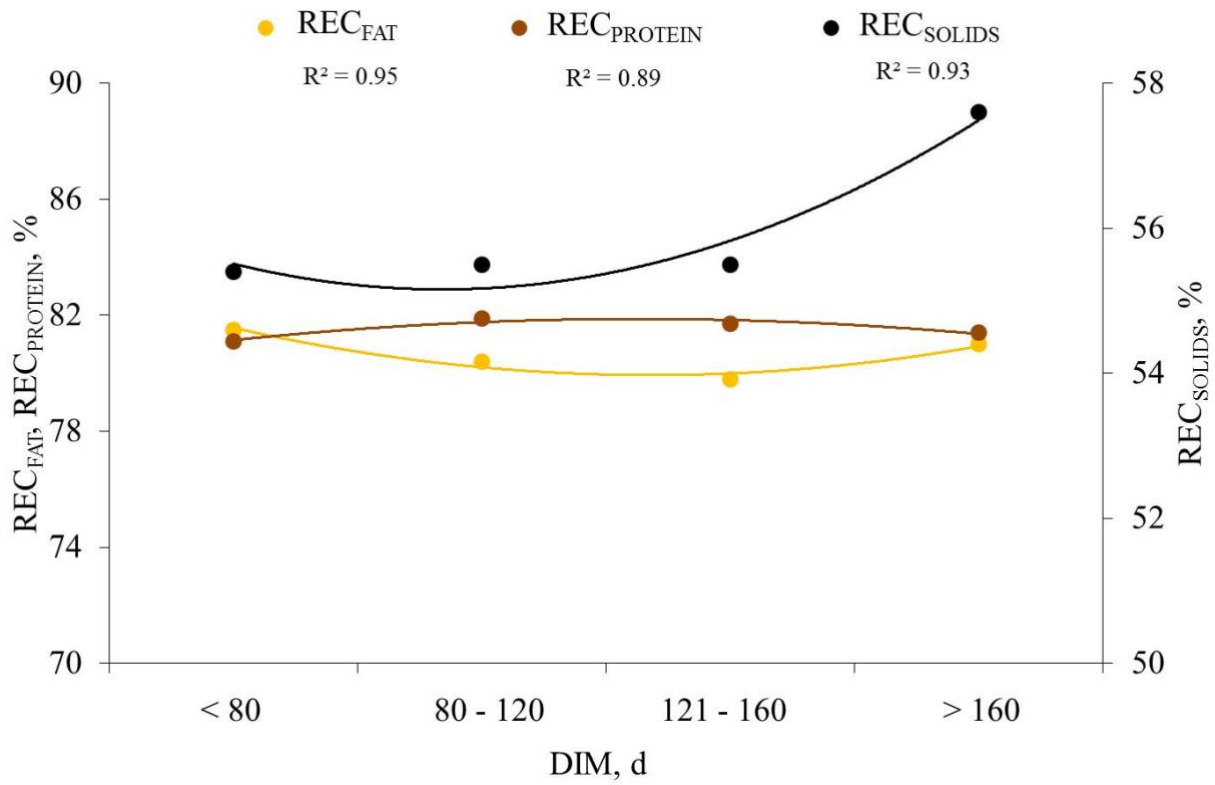
Trait	Breed (LSM)						Breed contrasts ( <i>F</i> -value and significance)				
	Alpine type		Mediterranean type				Alpine vs Mediterranean	Sa vs CA	MG vs Ma - Sr - SP	Ma vs Sr - SP	Sr vs SP
	Saanen (Sa)	Camosciata delle Alpi (CA)	Murciano- Granadina (MG)	Maltese (Ma)	Sarda (Sr)	Sarda Primitiva (SP)					
<b>Milk composition</b>											
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 <sup>1</sup>	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 <sup>2</sup>	5.70	6.43	6.03	5.59	5.07	5.33	3.6	4.5*	4.7*	0.8	1.1
LBC <sup>3</sup>	1.95	2.04	1.58	1.74	1.79	1.75	4.7*	0.5	2.1	0.0	0.3
<b>Nutrients recovery (%REC), %</b>											
%REC <sub>FAT</sub>	75.8	77.5	80.1	81.6	84.6	84.6	40.4***	1.9	9.2**	5.1*	0.0
%REC <sub>PROTEIN</sub>	79.9	81.0	81.2	82.2	82.4	82.4	15.6***	4.2*	5.2*	0.2	0.0
%REC <sub>SOLIDS</sub>	51.7	54.3	55.6	55.5	59.4	59.6	29.4***	6.7**	7.5**	10.7**	0.3
%REC <sub>ENERGY</sub>	61.1	64.2	66.2	66.4	70.5	70.6	46.4***	8.0**	8.9**	11.3***	0.2
<b>Cheese yields, %</b>											
%CY <sub>CURD</sub>	13.6	14.4	15.7	15.4	17.8	17.9	33.1***	1.9	6.5*	13.0***	0.0
%CY <sub>SOLIDS</sub>	6.6	7.1	7.8	7.2	9.1	9.1	30.7***	2.6	5.4*	23.8***	0.2
%CY <sub>WATER</sub>	7.1	7.5	7.9	8.3	8.6	8.7	18.0***	1.7	4.4*	0.7	0.2
<b>Theoretical CYs, %</b>											

<i>Th</i> -%CY <sub>CURD</sub>	14.0	14.7	15.8	14.2	17.6	17.7	16.6***	1.9	2.8	22.4***	0.9
<i>Th</i> -%CY <sub>SOLIDS</sub>	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, %											
<i>Eff</i> -%CY <sub>CURD</sub>	103	103	102	113	100	95	0.0	0.0	0.0	21.0***	5.3*
<i>Eff</i> -%CY <sub>SOLIDS</sub>	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 <sub>CURD</sub>	0.36	0.37	0.33	0.29	0.17	0.16	28.3***	0.0	23.8***	12.2***	0.7
dCY <sub>SOLIDS</sub>	0.17	0.19	0.16	0.13	0.08	0.08	31.3***	1.5	24.4***	8.4**	0.0
dCY <sub>WATER</sub>	0.19	0.19	0.17	0.16	0.09	0.08	27.3***	0.0	20.0***	15.6***	1.1

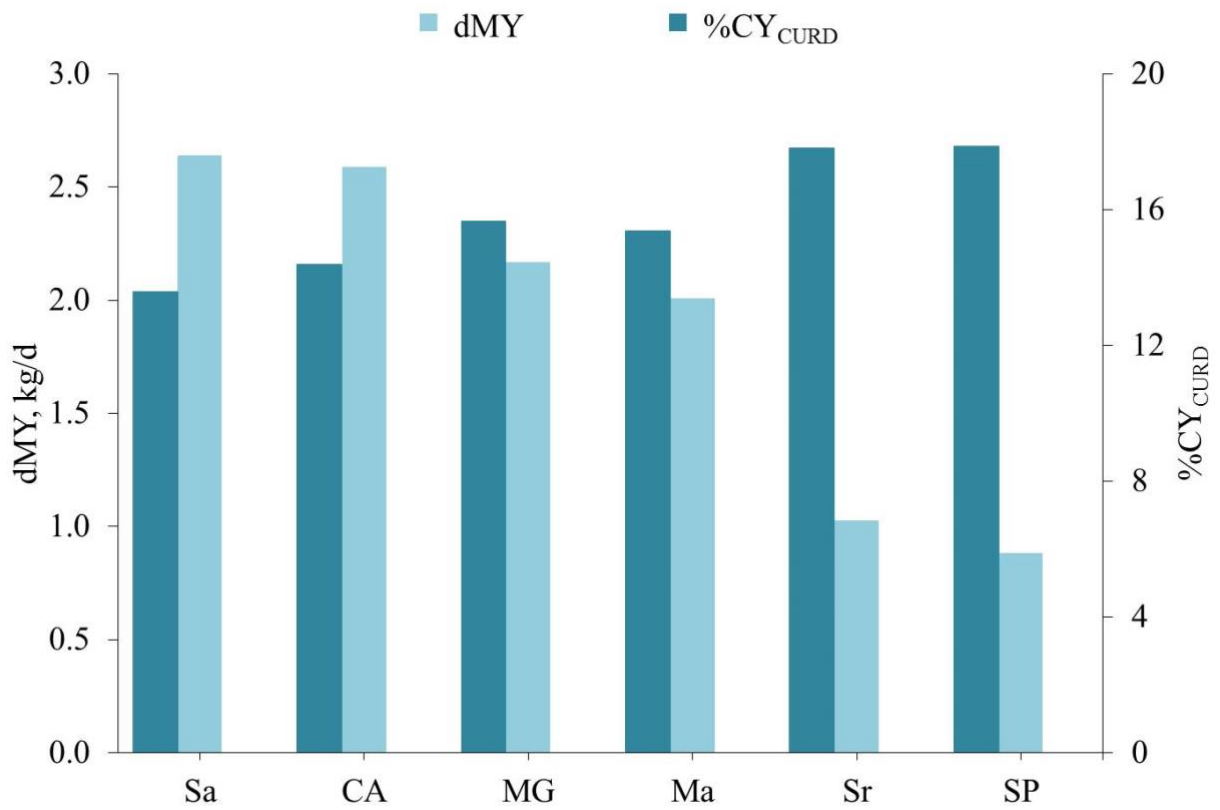
<sup>1</sup>Casein index: casein to protein ratio; <sup>2</sup>SCS =  $\log_2(\text{SCC} \times 10^{-5}) + 3$ ; <sup>3</sup>logarithmic total bacterial count (LBC) =  $\log_{10}(\text{total bacterial count}/1,000)$ .

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

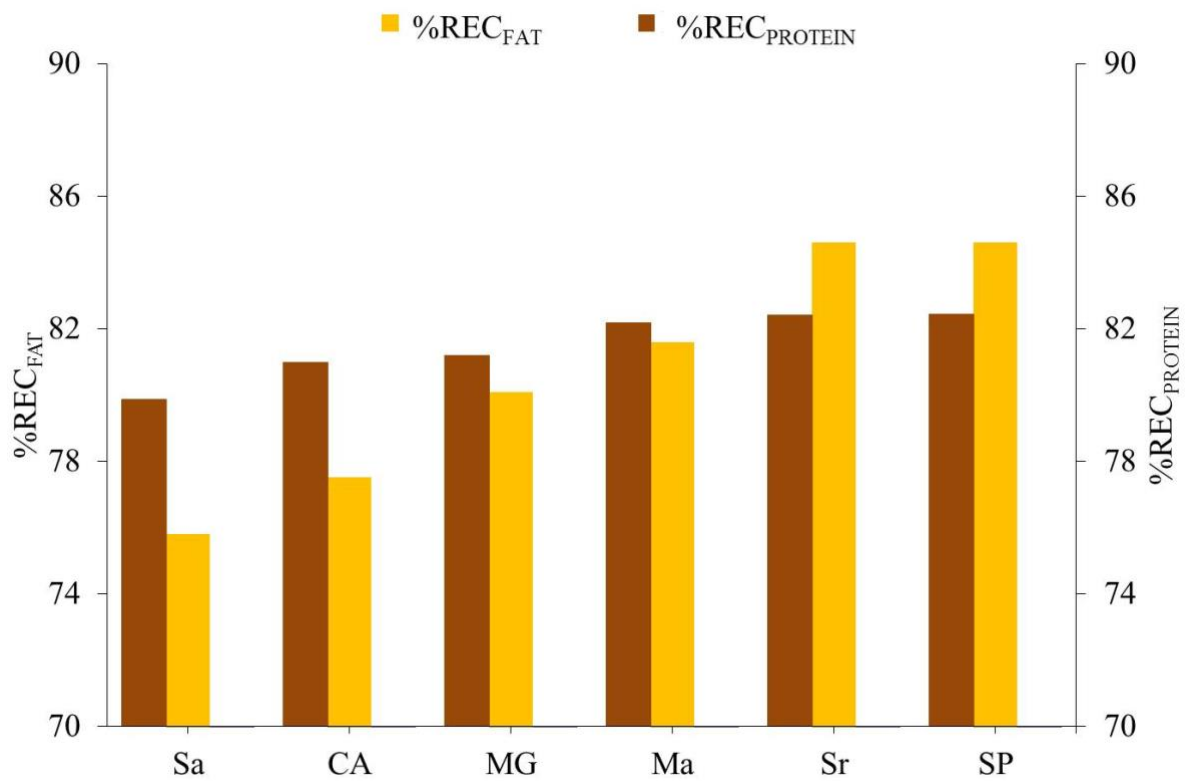
**Figure 1.**



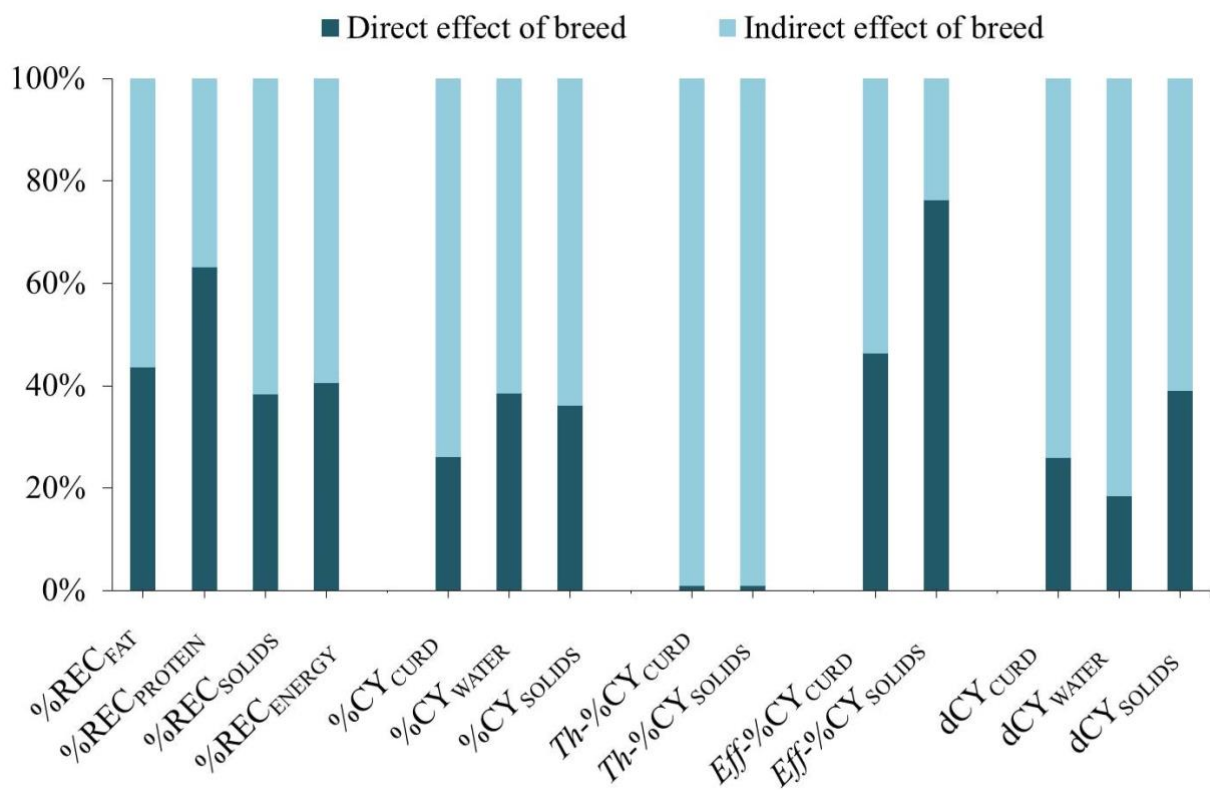
**Figure 2.**



**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<sub>CURD</sub>).

**Figure 3.** Effect of breed on fat (%REC<sub>FAT</sub>) and protein (%REC<sub>PROTEIN</sub>) 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.