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Characterization of milk composition, coagulation properties, and cheese-making ability of goats reared in extensive farms

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**Characterization of milk composition, coagulation properties
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farms**

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Manuscripts

1 **INTERPRETIVE SUMMARY**

2 **Characterization of milk composition, coagulation properties and cheese-making ability of**
3 **goats reared in extensive farms.** *By Paschino et al. page 000.* Farming of local goat breeds is an
4 important source of livelihood in many areas of the world. The aim of this study was to characterize
5 milk composition, coagulation properties and cheese-making ability of Sarda goat breed. Lactation
6 period and parity were important sources of variation for milk yield and composition. Milk energy
7 level influenced daily milk and cheese productions, while geographical area was more significant for
8 milk composition and coagulation properties. The favorable qualitative and technological
9 characteristics of milk from Sarda suggests that this breed has a high potential for cheese production
10 that needs to be preserved.

TECHNOLOGICAL QUALITY OF SARDA GOAT MILK

Characterization of milk composition, coagulation properties and cheese-making ability of goats reared in extensive farms.

Pietro Paschino*, Giorgia Stocco‡, Maria L. Dettori*, Michele Pazzola*, Maria L. Marongiu*, Carlo E. Pilo*, Claudio Cipolat-Gotet^{1‡}, and Giuseppe M. Vacca*

*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

¹Corresponding author: claudio.cipolatgotet@unipr.it

ABSTRACT

21
22 The aims of this study were to explore the variability of milk composition, coagulation
23 properties, and cheese-making traits of Sarda goat breed, and to investigate the effects of animal and
24 farm factors, and the geographical area (Central-East vs. South-West) of an insular region of Italy,
25 Sardinia. A total of 570 Sarda goats reared in 21 farms were milk-sampled during morning milking.
26 Individual milk samples were analyzed for composition, traditional coagulation properties (MCP),
27 modeled curd-firming over time (CF_t) parameters, and cheese-making (%CY: cheese yield; %REC:
28 recovery of nutrients; dCY: daily CY) traits. Farms were classified in two categories based on milk
29 energy level (ME; high and low), defined according to the average net energy of milk daily produced
30 by the lactating goats. Milk yield and composition were analyzed using a mixed model including the
31 fixed effects of ME level, geographical area, days in milk and parity, and the random effect of farm
32 within ME level and geographical area. Data about MCP, CF_t and cheese-making process were
33 analyzed using the same model, with the inclusion of the animal effect and pendulum of the
34 lactodynamograph instrument, allowing the measure of repeatability of these traits. Results showed
35 that animal had higher influence on coagulation and cheese-making traits compared with farm effect.
36 Days in milk influenced milk composition, whose changes partly reflected the modifications of %CY
37 traits. Moreover, large differences were observed between primiparous and multiparous goats:
38 primiparous goats produced less milk of better quality (higher fat, lower somatic cells and bacterial
39 count) and less cheese, but with higher recovery of fat and protein in the curd, compared with the
40 multiparous goats. The repeatability was very high, for both coagulation (84.0% to 98.8%) and
41 cheese-making traits (89.7% to 99.9%). The effect of ME level was significant for daily productions
42 of milk and cheese, coagulation time, and recovery of protein in the curd, which were better in high-
43 ME farms. As regards to geographical area, milk composition and percentage cheese yield were
44 superior in the Central-East area, while daily milk and cheese productions, and MCP were better in
45 the South-West. This result was explainable by the crossbreeding phenomenon of Sarda goats with
46 Maltese breed bucks occurred with greater intensity in the South-West compared to the Central-East

47 area of the island. The results provided by this study could be of great interest for the goat dairy
48 sector. Indeed, methods described in the present study could find a possible applicability for other
49 farming methods, goat breeds and geographical areas. The collection of a wide range of phenotypes
50 at individual animal level are fundamental for the characterization of local populations and can be
51 used to guarantee breed conservation, persistence of traditional farming system, and increase the
52 farmers' profit.

53

54 **Key words:** goat milk, coagulation, cheese making, cheese yield.

For Peer Review

INTRODUCTION

55

56 Goat farming is an important sector of agriculture in many areas of the world, representing
57 one of the main sources of livelihood (Lu and Miller, 2019). In some of those areas (i.e., Northern
58 Brazil, the Caribbean, Mediterranean and Middle East regions of Europe), goat breeding is part of
59 cultural heritage (Di Trana et al., 2015) and is based on the use of autochthonous breeds (Boyazoglu
60 et al., 2005; Sponenberg et al., 2019), whose products are usually labelled with connotation of origin
61 (i.e., Ibores, Chabichou du Poitou, Formaggella di Luinese). It is known that autochthonous goats
62 perform better than cosmopolitan goat breeds in harsh environments, because of their greater
63 physiological and anatomical adaptation (Silanikove, 2000). In this respect, it is strategic to improve
64 knowledge and support the multi-purpose local goat breeds and their genetic potential. Preservation
65 of local breeds is fundamental, as they are essential for the animal biodiversity (Di Trana et al., 2015)
66 and they can be a valuable source of economic income for dairy farmers. For example, a specific local
67 breed can be closely related to a product (dairy or meat) with particular organoleptic characteristics
68 (Di Trana et al., 2015); autochthonous breeds reared on the traditional extensive farming system can
69 be associated to the production of functional foods (Čermák et al., 2013); the traditional extensive
70 farming system can be integrated with the agro tourism activity, or with the organic farming, which
71 is still growing in the European market (Dubeuf et al., 2011). The high potential of local breeds
72 worldwide is reported in several studies aimed at characterizing milk composition and cheese-making
73 aptitude of indigenous vs. cosmopolitan goat breeds. Those studies have evidenced that, despite the
74 lower milk production, local breeds are characterized by higher milk fat, protein and total solids
75 contents (Kouniba et al., 2007), curd firmness, cheese yield (%CY) and recovery of nutrients in the
76 curd (%REC) (Vacca et al., 2018a; 2018b). The differences among breeds are explainable not only
77 by the different milk composition, but also by genetic factors, in particular milk protein variants
78 (Damián et al., 2008; Pazzola et al., 2014a).

79 Among autochthonous goat breeds reared in Sardinia, the Sarda is the most prevalent, with
80 29,000 animals recorded in the official herd book (DAD-IS, 2014). Sarda is characterized by a skillful

81 grazing behavior and is perfectly adapted to the semiarid environment. In Sardinia, those goats are
82 reared in traditional and extensive farming system methods, with grazing free pasture of the
83 Mediterranean scrubland. The Sarda breed is also characterized by excellent qualitative and
84 technological characteristics of its milk and by very favorable genetic features (Pazzola et al., 2017).
85 However, the repeated and unsupervised importation of dairy specialized goat bucks (i.e., Saanen,
86 Murciano-Grandina, Maltese) over the years, with the purpose to increase milk production, led to the
87 recombination of the original genetic characteristics of the Sarda breed. This phenomenon occurred
88 with greater intensity in South-West areas of Sardinia (Vacca et al., 2016). At research level, only
89 few previous studies have examined milk production and quality, coagulation and cheese-making
90 ability from Sarda goat breed, in most of the cases, analyzing a low number of samples. Given that
91 the characterization of local breeds' productions (i.e., milk to cheese) represents one of the most
92 important strategies for their conservation and a useful marketing instrument to raise public awareness
93 about the importance of their preservation, a large survey was carried out on the Sarda goat breed.
94 The present study aimed to: 1) quantify the contribution of the animal and farm effects (within milk
95 energy level and geographical area) on milk composition, coagulation properties, and cheese-making
96 traits; 2) study the effect of high or low class of milk energy production at farm level (defined
97 according to the milk net energy daily yielded by the goats); 3) assess the effect of the geographical
98 area; and 4) characterize the effect of different stages of lactation and parity.

100 MATERIALS AND METHODS

101 *Farm Characteristics and Milk Sampling*

102 This study involved 570 Sarda goats reared in 21 farms located in the Central and South- East
103 areas of Sardinia. Animals were selected among those officially registered in the flock books and
104 enrolled in the milk recording system of provincial associations of goat breeders on the basis of DIM
105 and parity, in order to keep a good variability of the dataset. Characteristics of sampled farms are
106 reported in Table 1. Goat farming system included the extensive techniques described by Usai et al.

107 (2006): mating was of natural type without estrus synchronization; kidding was concentrated from
108 November to March; adult goats were allowed to graze during the morning on natural pastures
109 composed of the most common plants and bush of the Mediterranean area (Vacca et al., 2010). Farms
110 were grouped as small (< 100 lactating goats), medium (100-200) or large (> 200). As regards to the
111 altitude, farms were grouped into those located in the plain (< 200 m above sea level, asl), in the hills
112 (200-500 m asl), and in the mountains (> 500 m asl). As reported in Table 1, the majority of farms in
113 the Central-East of the island were located in the mountains (8/11), and animals were hand-milked
114 (10/11), while in the South-West farms were mostly located in the hills and plains (9/10), with
115 mechanical milking (7/10). We also used the daily milk energy output (**dMEO**) of goats to define
116 farms into 2 classes of milk energy (**ME**) levels. The net energy content (**NE_L**) of milk was calculated
117 using the equation proposed by the NRC (2001):

$$118 \quad NE_L (Mcal/kg) = 0.0929 \times fat, \% + 0.0547 \times protein, \% + 0.0395 \times lactose, \%$$

119 Then **NE_L** (energy of 1 kg of milk) was converted to megajoules per kilogram and multiplied by the
120 daily milk yield (**dMY**, kg/d) of each goat (MJ/d) to obtain the individual dMEO. Individual dMEO
121 data were tested using an ANOVA (GLM procedure; SAS Institute Inc., Cary, NC) to obtain the
122 LSMeans for the selected farms after correcting for DIM and parity of the goats. After ranking the
123 dMEO LSMeans of the 21 farms, they were categorized into high ME level (high-ME: n = 10, average
124 dMEO = 5.05 MJ/d) and low ME level (low-ME: n = 11, average dMEO = 2.91 MJ/d) based on the
125 median value (3.91 MJ/d).

126

127 ***Analysis of Milk Composition***

128 Individual samples (200 mL/goat) were collected in sterile sample containers during the
129 morning milking (one sampling day for each farm) and stored at 4°C immediately after collection. In
130 mechanical milking systems, milk was sampled from the recorder jar under each stall, while in the
131 case of hand-milked systems, milk was collected from stainless steel graduated pails. Milk samples
132 were analyzed within 24 h after collection. Clinical examinations were performed at the farms by

133 veterinarians, and goats showing any clinical symptoms of mastitis (i.e., swollen, hot udder) or
134 disease were not sampled. Milk fat, protein, lactose, total solids, pH and NaCl were achieved using a
135 MilkoScan FT6000 milk analyzer (Foss Electric A/S, Hillerød, Denmark) calibrated according to
136 FIL-IDF references (ISO 9622:2013 - IDF 141:2013 for fat, protein, lactose, pH and NaCl; ISO
137 6731:2010 - IDF 21:2010a for total solids). Somatic cell count (SCC) were determined by Fossomatic
138 5000 somatic cell counter (Foss Electric A/S, Hillerød, Denmark) and transformed into the
139 logarithmic [$\log_2(\text{SCC} \times 10^{-5}) + 3$] somatic cell score (SCS), as reported by Shook (1993). Total
140 bacterial count (TBC) was measured by using a BactoScan FC150 analyzer (Foss Electric A/S,
141 Hillerød, Denmark) and transformed into the logarithmic bacterial count [$\text{LBC} = \log_{10}(\text{total bacterial}$
142 $\text{count}/1,000)$] according to ISO 21187:2004 – IDF 196:2004. Milk yield was recorded for each goat
143 by using the recorder jar in the case of mechanical milking, and by using the stainless steel graduated
144 pails in the case of manual milking. Daily milk yield was then calculated as the total yield of morning
145 plus evening milking of the same day of samples collection.

146

147 *The 9-MilCA*

148 The 9-mL milk cheese-making assessment (**9-MilCA**) proposed and described in detail by
149 Cipolat-Gotet et al. (2016a) was used to obtain traditional milk coagulation properties (**MCP**), %CY
150 and %REC traits. The procedure was performed in double per each individual milk sample (two
151 replicates of 9 mL), for a total of 1,140 observations. This procedure allowed to record the single-
152 point traditional MCP [rennet coagulation time (**RCT**, min), defined as the time interval between
153 rennet addition and gelation; curd-firming time (**k₂₀**, min), as the time between gelation and the
154 attainment of curd firmness of 20 mm; curd firmness at 30 min after rennet addition (**a₃₀**, mm)] and
155 the %CY traits, as %CY_{CURD}, %CY_{SOLIDS} and %CY_{WATER}, calculated as the ratio of the weight of
156 fresh curd, curd dry matter and water retained in curd, respectively, to the weight of the milk
157 processed, and multiplied by 100. The recorded nutrients recovery traits were: %REC_{PROTEIN},
158 %REC_{FAT} and %REC_{SOLIDS}, calculated as the ratio of the weight of the curd components (protein,

159 fat and total solids, respectively) to the weight of the same milk component, and multiplied by 100.
 160 Daily cheese yields (dCY_{CURD} , dCY_{SOLIDS} and dCY_{WATER} ; kg/d) were calculated by multiplying
 161 %CY ($\%CY_{CURD}$, $\%CY_{SOLIDS}$ and $\%CY_{WATER}$, respectively) by the individual dMY of goats.

162

163 *Modeling of Curd Firmness*

164 During the lactodynamographic analysis, the Formagraph recorded every 15 s the width (mm)
 165 of the oscillatory graph of the pendula immersed in each milk sample. Consequently, 120 curd
 166 firmness measures were recorded for each milk sample during 30 min analysis. The possibility to
 167 exploit all these values allowed to appropriately model the evolution of the coagulation process of
 168 each sample and to make the lactodynamographic analysis more informative. We used a 3-parameter
 169 model (Bittante, 2011) as follows:

$$170 \quad CF_t = CF_p \times (1 - e^{-k_{CF}(t - RCT_{eq})}),$$

171 where CF_t is curd firmness at time t (mm); CF_p is the asymptotical potential value of CF at an infinite
 172 time in absence of syneresis (mm); k_{CF} is the curd-firming instant rate constant (%/min); and RCT_{eq}
 173 (min) is RCT estimated by CF_t equation on the basis of all data points.

174

175 *Statistical Analysis*

176 For each milk sample, a curvilinear regression was fit to the 120 CF_t values available for each
 177 sample using the nonlinear procedure (PROC NLIN) of the SAS (SAS Institute Inc., Cary, NC,
 178 version 9.4). The parameters of each individual equation were estimated employing the Marquardt
 179 iterative method (350 iterations and 10^{-5} level of convergence).

180 Traditional MCP, CF_t parameters and cheese-making traits were analyzed using a MIXED
 181 procedure (SAS Institute Inc., Cary, NC, version 9.4), according to the following model:

$$182 \quad y_{mnpqrst} = \mu + DIM_m + Parity_n + Area_o + ME_p + Farm(ME_p, Area_o)_q + Animal_f + Pendulum_s +$$

$$183 \quad e_{mnpqrst} [M1]$$

184 where $y_{mnopqrst}$ is the observed trait (RCT, k_{20} , a_{30} ; RCT_{eq}, k_{CF} , CF_P ; %CY, %REC, and dCY traits); μ
 185 is the overall population mean; DIM_m is the fixed effect of the m^{th} class of days in milk [$m = 1$ to 7;
 186 class 1: ≤ 70 days (126 samples); class 2: 71-100 d (242 samples); class 3: 101-130 d (121 samples);
 187 class 4: 131-160 d (128 samples); class 5: 161-190 d (186 samples) class 6: 191-220 d (164 samples);
 188 class 7: > 220 d (82 samples)]; $Parity_n$ is the fixed effect of the n^{th} parity [$n = 1$ to 5; class 1: 1st (186
 189 samples); class 2: 2nd (270 samples); class 3: 3rd (226 samples); class 4: 4th (162 samples); class 5: \geq
 190 5th (296 samples)]; $Area_o$ is the fixed effect of the o^{th} class of area [$o = 1$ to 2; class 1: Central-East;
 191 class 2: South-West)]; ME_p is the fixed effect of the p^{th} class of milk energy level [$p = 1$ to 2; class 1:
 192 high-ME (> 3.91 MJ/d); class 2: low-ME (≤ 3.91 MJ/d)]; $Farm(ME_p, Area_o)_q$ is the random effect of
 193 the q^{th} farm ($q = 1$ to 21) within the p^{th} class of ME and the o^{th} class of area; $Animal_r$ is the random
 194 effect of the r^{th} animal ($r = 1$ to 570); $Pendulum_s$ is the random effect of the s^{th} pendulum of the
 195 lactodynamograph instrument ($s = 1$ to 8); $e_{mnopqrst}$ is the random residual $\sim N(0, \sigma_e^2)$, where σ_e^2 is the
 196 residual variance.

197 Milk composition was analyzed using a modification of model M1, without the inclusion of
 198 the random effect of the animal and pendulum of the instrument, named model [M2].

199 Orthogonal polynomial contrasts were estimated between the LSMs of classes of days in milk
 200 (linear, quadratic and cubic relationships), to observe possible significant patterns in the tested milk
 201 traits. The four degrees of freedom of parity effect were used to test the following contrasts: 1) 1st vs
 202 2nd; 2) 1st vs $\geq 2^{nd}$; 3) 2nd vs $\geq 3^{rd}$; and 4) 3rd vs $\geq 4^{th}$.

203 Repeatability (expressed in percentage) for MCP, CF_t parameters and cheese-making traits
 204 was calculated as ratio of the sum of the variances of the random effects [Farm(ME, Area), animal,
 205 pendulum] to the sum of the variances of the random effects and the random residual.

206

207

RESULTS

208 Descriptive statistics of milk yield, composition, traditional coagulation properties (MCP),
209 modeled curd-firming over time (CF_t) parameters and cheese-making traits of individual goat milk
210 samples are reported in Table 2.

211 Analysis of variance for fixed effects, variance of random effects and repeatability of MCP,
212 CF_t parameters and cheese-making traits are reported in Table 3. As regards the random effects, farm
213 variance was generally lower than 50%, excluding LBC. Animal variance was larger than that of farm
214 on coagulation (from 47 to 85%) %CY (except for %CY_{WATER}), %REC (from 68 to 75%) and dCY
215 (from 61 to 73%) traits. Percentages of repeatability were between 84.0 (a_{30}) and 99.9% (%CY_{SOLIDS}).

216 Table 4 reports least square means of milk and coagulation traits according to milk energy
217 level and geographical area. The effect of ME level was significant with higher daily productions of
218 milk and cheese, better coagulation time RCT_{eq} and greater %REC_{PROTEIN} from goats reared in high-
219 ME farms. With regard to the effect of the geographical area, goats reared in South-West area showed
220 higher dMY and NaCl, lower concentrations of milk fat, protein, lactose and Total Solids. The k_{20}
221 was shorter and a_{30} was higher in milk from goats reared in the South-West area.

222 Figure 1 summarizes the effect of days in milk. Daily milk yield and daily cheese yield
223 decreased throughout the days in milk (Figure 1a); fat and protein contents had a tendency to increase,
224 and lactose decreased, all with cubic trends (Figure 1b); NaCl increased with a cubic trend, with a
225 peak between 161 and 190 days (Figure 1d). Coagulation traits were not affected by DIM, except for
226 CF_p that showed a quadratic trend, with the lowest values between 131 and 160 days (data not shown
227 in Figure 1); cheese yield traits changed across lactation with cubic trends (Figure 1e); %REC traits
228 were not affected by DIM, except %REC_{SOLIDS}, with the lowest value between 101 and 130 days
229 (data not shown in Figure 1).

230 The effect of parity and orthogonal contrasts are reported in Table 5. Goats at first parity had
231 lower milk production compared with multiparous goats. Goats at second parity had slightly lower
232 milk production compared with goats at third and higher parities. Milk from younger goats was

233 characterized by higher fat, lactose, and Total Solids contents, and lower NaCl, SCS and LBC,
234 compared with the older ones. The LBC was lower in goats at first and second parities.

235

236

DISCUSSION

237 *Effects of Animal and Farms, and Repeatability of Coagulation and Cheese-making Traits*

238 To the best of our knowledge, this is the first study presenting a detailed description of dairy
239 production performance (from milk to cheese) of a local goat (Sarda) breed, so we could only partially
240 compare our results with those available from the literature. On average, MY and percentages of milk
241 fat and protein were similar to data reported by Pazzola et al. (2017), while curd firmness values
242 reported by this study are slightly lower, and %CY_{CURD} is higher.

243 It is acknowledged that a variable proportion of the animal effect on **coagulation** traits is due
244 to genetic aspects (i.e., casein polymorphism, whey protein genes; Damián et al., 2008; Dettori et al.,
245 2015a) and composition of milk (Vacca et al., 2018a). Large amounts of α_{s1} -casein (Clark and
246 Sherbon, 2000) are related to a delayed coagulation time but higher curd firmness values, and overall
247 high milk protein and casein contents are associated with high %CY and %REC traits (Pazzola et al.,
248 2019). Moreover, high milk fat is generally associated with better coagulation properties (Clark and
249 Sherbon, 2000), higher %CY (Guo et al., 2004), %REC traits and daily cheese productions (Pazzola
250 et al., 2019). The animal incidence on the total variability of milk and cheese traits supports that Sarda
251 goats are characterized by a large genetic component (i.e., casein polymorphism), even larger when
252 compared to other goat breeds (Moioli et al., 2007). However, this aspect needs to be better explored
253 if the preservation of the Sarda breed is considered.

254 With regard to repeatability, we compared our results with some data from bovines and ovines,
255 as this is the first study reporting individual repeatability values for coagulation traits in goat milk.
256 Bovine MCP are characterized by a lower instrumental repeatability and reproducibility than milk
257 composition traits (Tyrisevä et al., 2003; Dal Zotto et al., 2008), especially for those properties
258 recorded in the last part of the lactodynamographic analysis (i.e., curd firmness at 60 min, potential

259 curd firmness, syneresis rate). However, although MCP are highly influenced by instrument
260 (mechanical or optical devices; Cipolat-Gotet et al., 2012) and conditions of analysis (i.e., type and
261 concentration of rennet, milk temperature, acidification; Nájera et al., 2003), the individual cow
262 repeatability can be considered high (Bittante et al., 2012). Repeatability values of MCP from sheep
263 are almost similar to those from bovine milk (Ferragina et al., 2017). In this study, the individual goat
264 repeatability of RCT and k_{20} was higher than that of dairy cows, but for a_{30} it was lower (Stocco et
265 al., 2017). Moreover, if among species (Ferragina et al., 2017; Stocco et al., 2017) the repeatability
266 of modeled CF_t parameters is generally higher compared with that of traditional MCP, in goats this
267 difference was even greater. The very different coagulation patterns among species provided by the
268 modeling of data obtained during the lactodynamographic test (Pazzola et al., 2018), could explain
269 why repeatability values of these traits are also different: in sheep and goat milk the maximum
270 consistence of the curd is usually attained within 30 min from rennet addition, and after 30 min in
271 cows. Consequently, a_{30} values are usually measured in the ascending phase of the curd-firming curve
272 when bovine milk is analyzed, and in the descending phase when milk from small ruminants is tested.
273 The high individual repeatability of cheese-making traits was expected, but it was even higher
274 compared with that reported in Vacca et al. (2018a) for six breeds of goats. These results evidenced
275 that 9-MilCA can be a powerful tool, particularly compelling for the characterization of the cheese-
276 making ability of milk from local populations. Indeed, it allows the rapid, cheap, and partly automated
277 analysis of several samples per day, by using instruments commonly used in many laboratories for
278 the evaluation of MCP. The concomitant use of the modeling of the renneting data allows to a more
279 detailed description of the coagulation process. All these phenotypes are of interest for the dairy
280 sector, and the possibility to collect them at individual level could fasten the improvement and favor
281 the conservation of the genetic resources of local goat populations.

282

283 ***Effect of Milk Energy Level***

284 To our knowledge, no previous studies have investigated the effect of milk energy at farm
285 level on production, composition, coagulation traits and cheese-making ability of Sarda goat milk.
286 The average values of milk energy output (dMEO, MJ/d) of both ME levels were significantly lower
287 than those observable in bovine herds (where this factor was expressed as herd productivity level,
288 **HP**; Stocco et al., 2017), but this was expected considering the different species, and the environment
289 in which the goats are reared. It is important to remind that all the 21 farms were characterized by the
290 extensive management system, and the ME classification allowed for a balanced division of Central-
291 East and South-West farms. Even though dMEO is based on daily production of fat, protein, and
292 lactose, no difference in milk composition was observed between the two ME levels.

293 In previous studies, goat milk composition was slightly influenced by the type of farming
294 system (Van Quackebeke et al., 1996), and the effect of the feeding type has not been extensively
295 studied in goats. However, Min et al. (2005) reported that dMY, milk fat, protein and lactose were
296 the lowest for goats grazing only on mixed vegetative forages (no concentrate) compared with those
297 fed with 0.33 or 0.66 kg of concentrate per kg of milk (high producing goats: >1.5 milk kg/d).
298 Inglingstad et al. (2014) studied the effect of the diet (cultivated vs. rangeland pasture, and high vs.
299 low hay quality) on goat milk composition and coagulation properties, and evidenced that in general,
300 milk from goats on pasture was richer in protein and casein compared with milk from goats fed with
301 hay, so that RCT was significantly shorter in milk from goats fed with hay.

302 **Results of the present study are** different from those from dairy cows, in which the effect of
303 HP level was larger (Stocco et al., 2017; Stocco et al., 2018b). The faster coagulation and the higher
304 %REC_{PROTEIN} in milk samples from goats reared in high-ME farms could be related to the protein
305 and casein genetic variants, rather than their overall quantities, as no differences in milk composition
306 have been observed between ME farm levels. Two recent studies have accurately evidenced that, also
307 in goats, composition of milk can directly influence coagulation and cheese-making ability (Stocco
308 et al., 2018a; Pazzola et al., 2019), but there are also some genes of particular interest (whey protein
309 genes), especially in the Sarda breed, that influence the renneting properties (Dettori et al., 2015a;

310 2015b). Probably, those genes have also an important influence on cheese yields and on the efficiency
311 of recovery of nutrients in the curd, but this aspect is still under investigation.

312

313 *Effect of Geographical Area*

314 The idea to test the effect of geographical area was linked to the crossbreeding phenomenon
315 happened with greater intensity in the South-West area of the island (Vacca et al., 2016), where
316 farmers were used to cross their goats with the Maltese (Italian breed from Sicily) bucks, as previously
317 mentioned. This has led to the recombination of the original genetic traits of both Sarda and Maltese
318 goats. Several breeds have been imported in order to improve the productive performances of the
319 animals, and the best results have been obtained with Maltese bucks, combining both the high milk
320 yield and suitability for grazing the extensive Sardinian scrublands (Usai et al., 2006). Crossing
321 autochthonous goats with specialized dairy breeds ensures high milk production, although imported
322 animals are scarcely adaptable to local climate conditions (Lu and Miller, 2019). However, when
323 farmers rear high-yielding goats imported from areas geographically similar to those of local breeds,
324 traits from both types are successfully absorbed from the crossbred animals (i.e., Majorera goats;
325 Dickson et al., 1991; Capote et al., 2004). On the other hand, if the nutritional requirements for milk
326 production are not satisfied, the use of high-yielding goats becomes ineffective (Capote, 2002). A
327 recent study has evidenced that coagulation, curd-firming and syneresis traits are better in Maltese
328 goats compared to Alpine breeds (Pazzola et al., 2018), although the composition of milk from
329 Maltese is much more similar to that from Alpine goats and neatly worse when compared with the
330 Sarda. Indeed, milk from the Sarda is characterized by superior quality and technological aptitude
331 compared to other dairy goat breeds (i.e., Saanen, Camosciata delle Alpi, Murciano-Granadina,
332 Maltese; Vacca et al., 2018a). But the higher %CY and %REC traits from Sarda breed can only
333 partially counterbalance the higher MY characterizing Maltese goats (Vacca et al., 2018b). Thus, the
334 increase of milk production was the main objective of farmers who crossed their Sardinian goats with
335 Maltese bucks, even though description of characteristics of milk quality, coagulation process and

336 cheese-making ability of these animals have not been reported yet. In bovines it is acknowledged that
337 crossbred cows produce lower quantities (in kg) of milk, fat, and protein, but higher concentrations
338 (in %) of these components in milk, compared with purebred cows. Thus, generally crossbreeding is
339 considered a viable method for improving the technological properties of milk, particularly the
340 coagulation time and curd-firming process, but also other important traits related to fertility and
341 longevity (Malchiodi et al., 2014). The shorter k_{20} recorded in goats from the South-West area could
342 be related to the lower content of fat and lactose in milk (Stocco et al., 2019a; 2019b), but this could
343 not concurrently explain the higher curd firmness value. Possibly, differences in the proportion of
344 milk protein fractions, in the frequency of their genetic variants, or both (due to the crossbreeding
345 recombination), could explain the difference in the a_{30} trait between the two areas. It is also possible
346 that these differences in milk characteristics result from the different altitudes in which farms were
347 located, and therefore to the different pasture composition. In fact, many farms in the Central-East
348 area were located in the mountains, where trees prevail over shrubs.

349 Goats reared in the two areas produced the same %CY, but with different solids and water
350 proportion: %CY_{SOLIDS} was higher value in Central-East area (perhaps deriving from the higher Total
351 Solids in milk). Daily fresh cheese yield was higher in the South-West area, but it was higher because
352 of the higher value of water retained in the curd (dCY_{WATER}) and not because of the higher Total
353 Solids (dCY_{SOLIDS} similar between areas). High water content in the curd increases %CY values, but
354 an excess of water could be not considered a positive finding, as generally high moisture content leads
355 to a worsening of cheese quality during ripening, with a depreciation of the final product (Martin et
356 al., 1997).

357

358 *Effect of Days in Milk*

359 Many studies in the literature have investigated the effect of goat days in milk on composition
360 (Zeng et al., 1997; Fekadu et al., 2005; Idamokoro et al., 2017), but less is known about the effect on
361 coagulation and cheese-making traits. Zeng et al. (1997) reported that concentrations of milk fat,

362 protein, solids-non-fat and Total Solids from Alpine goats were higher in the first 30 DIM, then they
363 declined slightly and remained constant until drying-off. Those authors also reported that daily milk
364 production decreased gradually, in agreement with our results, together with the daily cheese
365 production. Zeng et al. (1997) observed a marked daily variations of goat SCC. In the present study,
366 the possibility to divide lactation period into many classes allowed to a better representation of the
367 trends of each component, although they were sometimes erratic. The division into early, middle and
368 late lactation can lead to curvilinear or cubic trends can become linear, as evidenced by Mioč et al.
369 (2008) and Idamokoro et al. (2017) for goat milk composition. However, Mestawet et al. (2012),
370 studying the variation of milk composition during early, middle and late lactation of four goat breeds
371 in Ethiopia, reported quadratic trends for fat, protein and Total Solids, with the lowest values at
372 middle lactation and a peak in late lactation, respectively.

373 In dairy cows both traditional MCP and modeled CF_t parameters are strongly influenced by
374 DIM, contrarily to the results of the present study, and this could be explained by the much more
375 linear trend of each milk component in cows (Stocco et al., 2017). As a consequence of this, bovine
376 cheese-making traits (especially %CY traits) greatly change (linear increase) during lactation (Stocco
377 et al., 2018b), and also in sheep it is observed the same pattern for these traits (Cipolat-Gotet et al.,
378 2016b). However, besides the differences among species, it is important to remind that the different
379 division of DIM in classes among studies could led to very different results, especially within species.

380

381 *Effect of Parity*

382 No information is available on the effect of many orders of parity on coagulation and cheese-
383 making traits of goats. In opposite, some studies are focused on the variability of milk composition
384 (Mioč et al., 2008; Lôbo et al., 2017), SCC and bacterial count (Zeng and Escobar, 1995) of goats
385 with different order of parity. Mioč et al. (2008) did not observe significant changes across parities
386 for milk fat and lactose, but only a decreased protein content moving from the 1st to the $\geq 5^{\text{th}}$ parity.
387 Zeng and Escobar (1995) did not found any significant effect of parity on goat milk composition,

388 SCC and bacterial count, but only on milk yield. That difference could be attributable to the low
389 number of parities considered (from 1st to 3rd parity). On the contrary, results by Lôbo et al. (2017),
390 regarding the effect of 7 orders of parity of dairy goats in Brazil, have evidenced the decrease of milk
391 components across parities and, in agreement with our results, the increase of SCS from the 1st to the
392 7th parity. Those authors have suggested that the increase of somatic cells could be related to the
393 growing susceptibility of the goats to mastitis (especially of subclinical type) over the different
394 lactations. That result could be further supported by the greater difference of LBC found in the present
395 study between younger (lower) and older goats (higher). The differences of milk composition found
396 among parities were not followed by great differences in coagulation traits, as only higher curd
397 firmness (a_{30}) was observed in younger goats compared to the older ones. This finding could be
398 explained by the higher fat content and lower SCS and LBC in milk from the first compared to the
399 latter (Stocco et al., 2018a). Among %CY traits, only %CY_{SOLIDS} was affected by parity, with higher
400 values in goats at 1st and 2nd parity compared with goats at $\geq 3^{\text{rd}}$ parity. This result could be attributable
401 to the different composition of milk in younger goats, as it is acknowledged that milk composition
402 affects %CY and %REC traits (Pazzola et al., 2019). Indeed, recovery of nutrients were higher in
403 younger goats, except for %REC_{SOLIDS}, while the lowest %REC values were recorded from goats
404 with $\geq 5^{\text{th}}$ parity. As expected, daily cheese productions were lower in younger goats, and this was
405 mainly due to the lower MY. In sheep, younger ewes are characterized by better MCP compared with
406 the older ones, and by higher %REC_{SOLIDS} (Cipolat-Gotet et al., 2016b).

407

408

CONCLUSIONS

409 This study provided a detailed characterization of the Sarda goat breed in terms of milk
410 quality, technological characteristics, cheese yield and milk nutrients recovery in the curd. Results
411 evidenced that the individual animal played a much more important role compared with the farm for
412 the variability of coagulation, %CY (except for %CY_{WATER}), %REC and dCY traits. The animal
413 repeatability for both traditional MCP and CF_t parameters was high and higher than other species.

414 The effect of milk energy level was limited to higher daily productions of milk and cheese, better
415 coagulation time, and higher %REC_{PROTEIN} from goats reared in high MEL-farms. The few
416 differences found between the two milk energy levels could be in part derived from the different MY
417 produced by the goats, as the farming system was similar among farms. The effect of geographical
418 area confirmed the presence of the unplanned crossbreeding, because of the higher MY in goats reared
419 in the South-West area, where Sarda goats have been crossed with Maltese bucks. However, despite
420 the lower MY, the quality of milk produced from the pure Sarda breed (Central-East area) was better
421 than the crossbred goats (South-West area). Days in milk were a valuable source of variation, in
422 particular for milk composition, that in part reflected fluctuations in %CY traits. Parity was much
423 more important in determining the differences between the primiparous vs. the multiparous goats, in
424 terms of lower production (milk and cheese) and better milk composition. However, because small
425 differences were detected for coagulation and %CY traits across parities, the technological quality of
426 milk from Sarda goats is maintained also in old animals. The recovery of fat and protein were higher
427 from younger goats, and this suggested the little better curd composition from younger goats
428 compared to that obtained from older animals. The characterization of Sarda breed provided by this
429 study could be a key point for its preservation and enhancement, and could be of great interest for the
430 goat dairy sector. **Finally, the approach, methods and statistics used for the present study could also
431 find a possible applicability for other farming methods, goat breeds and geographical areas.**

432

433

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442

REFERENCES

- 443 Bittante, G. 2011. Modeling rennet coagulation time and curd firmness of milk. *J. Dairy Sci.* 94:5821-
444 5832.
- 445 Bittante, G., M. Penasa, and A. Cecchinato. 2012. Invited review: Genetics and modeling of milk
446 coagulation properties. *J. Dairy Sci.* 95:6843–6870.
- 447 Boyazoglu, J., I. Hatziminaoglou, and P. Morand-Fehr. 2005. The role of the goat in society: Past,
448 present and perspectives for the future. *Small Rumin. Res.* 60:13-23.
- 449 Capote, J. 2002. Sistema de explotación caprina en zonas áridas. Pages 95-100 in *Actas de las XXVII*
450 *Jornadas Científicas y VI Internacionales de la SEOC.*
- 451 Capote, J., A. Tejera, M. Amills, A. Argüello, M. Fresno, and J. L. López. 2004. Influencia históri-
452 ca y actual de los genotipos canarios en la población caprina americana. *AGRI.* 35:49-60.
- 453 Čermák, B., V. Král, J. Frelich, L. Boháčová, B. Vondrášková, J. Špička, E. Samková, M.
454 Podsedníček, A. Węglarz, J. Makulska, and P. Zapletal. 2013. Quality of goat pasture in less-
455 favoured areas (LFA) of the Czech Republic and its effect on fatty acid content of goat milk
456 and cheese. *Animal Science Papers and Reports.* 31:331-346.
- 457 Cipolat-Gotet, C., A. Cecchinato, M. De Marchi, M. Penasa, and G. Bittante. 2012. Comparison
458 between mechanical and near-infrared optical methods for assessing coagulation properties of
459 bovine milk. *J. Dairy Sci.* 95:6806-6819.
- 460 Cipolat-Gotet, C., A. Cecchinato, M. Pazzola, M. L. Dettori, G. Bittante, and G. M. Vacca. 2016b.
461 Potential influence of herd and animal factors on the yield of cheese and recovery of
462 components from Sarda sheep milk, as determined by a laboratory bench-top model cheese-
463 making. *Int. Dairy J.* 63:8-17.
- 464 Cipolat-Gotet, C., A. Cecchinato, G. Stocco, and G. Bittante. 2016a. The 9-MilCA method as a rapid,
465 partly automated protocol for simultaneously recording milk coagulation, curd firming,
466 syneresis, cheese yield, and curd nutrients recovery or whey loss. *J. Dairy Sci.* 99:1065-1082.

- 467 Clark, S., J. and W. Sherbon. 2000. Alphas1-casein, milk composition and coagulation properties of
468 goat milk. *Small Rumin. Res.* 38:123-134.
- 469 DAD-IS (Domestic Animal Diversity Information System). 2014. Statistical Database of the Food
470 and Agriculture Organization of the United Nations. Accessed April 5, 2019.
471 <http://www.faostat.fao.org>.
- 472 Dal Zotto, R., M. De Marchi, A. Cecchinato, M. Penasa, M. Cassandro, P. Carnier, L. Gallo, and G.
473 Bittante. 2008. Reproducibility and repeatability of measures of milk coagulation properties
474 and predictive ability of mid-infrared reflectance spectroscopy. *J. Dairy Sci.* 91:4103-4112.
- 475 Damián, J. P., I. Sacchi, S. Reginensi, D. De Lima, and J. Bermudez. 2008. Cheese yield, casein
476 fractions and major components of milk of Saanen and Anglo-Nubian dairy goats. *Arq. Bras.*
477 *Med. Vet. Zootec.* 60:1564-1569.
- 478 Dettori, M. L., M. Pazzola, P. Paschino, M. G. Pira, and G. M. Vacca. 2015a. Variability of the
479 caprine whey protein genes and their association with milk yield, composition and renneting
480 properties in the Sarda breed. 1. The LALBA gene. *J. Dairy Res.* 82:434-441.
- 481 Dettori, M. L., M. Pazzola, E. Pira, O. Puggioni, and G. M. Vacca. 2015b. Variability of the caprine
482 whey protein genes and their association with milk yield, composition and renneting
483 properties in the Sarda breed: 2. The BLG gene. *J. Dairy Res.* 82:442-448.
- 484 Di Trana, A., L. Sepe, P. Di Gregorio, M. A. Di Napoli, D. Giorgio, A. R. Caputa, and S. Claps. 2015.
485 The role of local sheep and goat breeds and their products as a tool for sustainability and
486 safeguard of the Mediterranean environment. Pages 77-112 in *The Sustainability of Agro-*
487 *Food and Natural Resources Systems in the Mediterranean Basin.* Springer International
488 Publishing AG, Switzerland.
- 489 Dickson, L., E. Garcia, O. Garcia, and M. Arango. 1991. Comportamiento productivo y reproductivo
490 de caprinos puros Nubian y Alpino Francés bajo manejo intensivo. *Jornadas Nacionales de*
491 *Ovino y Caprino.* Venezuela.

- 492 Dubeuf, J. P. 2011. The social and environmental challenges faced by goat and small livestock local
493 activities: present contribution of research development and stakes for the future. *Small*
494 *Rumin. Res.* 98:3-8.
- 495 Fekadu, B., K. Soryal, S. Zeng, D. Van Hekken, B. Bah, and M. Villaquiran. 2005. Changes in goat
496 milk composition during lactation and their effect on yield and quality of hard and semi-hard
497 cheeses. *Small Rum. Res.* 59:55-63.
- 498 Ferragina, A., C. Cipolat-Gotet, A. Cecchinato, M. Pazzola, M. L. Dettori, G. M. Vacca, and G.
499 Bittante. 2017. Prediction and repeatability of milk coagulation properties and curd-firming
500 modeling parameters of ovine milk using Fourier-transform infrared spectroscopy and
501 Bayesian models. *J. Dairy Sci.* 100:3526-3538.
- 502 Guo, M., Y. W. Park, P. H. Dixon, J. A. Gilmore, and P. S. Kindstedt. 2004. Relationship between
503 the yield of cheese (Chevre) and chemical composition of goat milk. *Small Rumin. Res.*
504 52:103-107.
- 505 Idamokoro, E., V. Muchenje, and P. Masika. 2017. Yield and milk composition at different stages of
506 lactation from a small herd of nguni, boer, and non-descript goats raised in an extensive
507 production system. *Sustainability.* 9:1000:1-13.
- 508 Inglingstad, R. A., H. Steinshamn, B. S. Dagnachew, B. Valenti, A. Criscione, E. O. Rukke, T. G.
509 Devold, S. B. Skeie, and G. E. Vegarud. 2014. Grazing season and forage type influence goat
510 milk composition and rennet coagulation properties. *J. Dairy Sci.* 97:3800-3814.
- 511 ISO-IDF. 2004. (International Organization for Standardization and International Dairy Federation).
512 Milk. Quantitative determination of bacteriological quality. Guidance for establishing and
513 verifying a conversion relationship between routine method results and anchor method results.
514 International Standard ISO 21187 and IDF 196:2004. ISO, Geneva, Switzerland and IDF,
515 Brussels, Belgium.

- 516 ISO-IDF. 2010a. (International Organization for Standardization and International Dairy Federation).
517 Milk and liquid milk products. Determination of total solids content. International Standard
518 ISO 6731 and IDF 21:2010a. ISO, Geneva, Switzerland and IDF, Brussels, Belgium.
- 519 ISO-IDF. 2013. (International Organization for Standardization and International Dairy Federation).
520 Milk and liquid milk products. Determination of fat, protein, casein, lactose and pH content.
521 International Standard ISO 9622 and IDF 141:2013. ISO, Geneva, Switzerland and IDF,
522 Brussels, Belgium.
- 523 Kouniba, A., M. Berrada, and A. El Marakchi. 2007. Etude comparative de la composition chimique
524 du lait de chèvre de la race *locale* Marocaine et la race *alpine* et évaluation de leur aptitude
525 fromagère. Rev. Med. Vet. 158:152-160.
- 526 Lôbo, A. M. B. O., R. N. B. Lôbo, O. Facó, V. Souza, A. A. C. Alves, A. C. Costa, and M. A. M.
527 Albuquerque. 2017. Characterization of milk production and composition of four exotic goat
528 breeds in Brazil. Small Rumin. Res. 153:9-16.
- 529 Lu, C. D., and B. A. Miller. 2019. Current status, challenges and prospects for dairy goat production
530 in the Americas. Asian-Australas. J. Anim. Sci. 32:1244-1255.
- 531 Malchiodi, F., A. Cecchinato, M. Penasa, C. Cipolat-Gotet, and G. Bittante. 2014. Milk quality,
532 coagulation properties, and curd firmness modeling of purebred Holsteins and first- and
533 second generation crossbred cows from Swedish Red, Montbéliarde, and Brown Swiss bulls.
534 J. Dairy Sci. 97:4530-4541.
- 535 Martin, B., J.-F. Chamba, J.-B. Coulon, and E. Perreard. 1997. Effect of milk chemical composition
536 and clotting characteristics on chemical and sensory properties of Reblochon de Savoie
537 cheese. J. Dairy Res. 64:157-162.
- 538 Mestawet, T. A., A. Girma, T. Ådnøy, T. G. Devold, J. A. Narvhus, and G. E. Vegarud. 2012. Milk
539 production, composition and variation at different lactation stages of four goat breeds in
540 Ethiopia. Small Rumin. Res. 105:176-181.

- 541 Min, B. R., S. P. Hart, T. Sahlu, and L. D. Satter. 2005. The effect of diets on milk production and
542 composition, and on lactation curves in pastured dairy goats. *J. Dairy Sci.* 88:2604-2615.
- 543 Mioč, B., Z. Prpić, I. Vnučec, Z. Barač, V. Sušić, D. Samaržija, and V. Pavić. 2008. Factors affecting
544 goat milk yield and composition. *Mljekarstvo.* 58:305-313.
- 545 Moioli, B., M. D'Andrea, and F. Pilla. 2007. Candidate genes affecting sheep and goat milk quality.
546 *Small Rumin. Res.* 68:179-192.
- 547 Nájera, A. I., M. de Renobales, and L. I. R. Barron. 2003. Effects of pH, temperature, CaCl₂ and
548 enzyme concentrations on the rennet clotting properties of milk: A multifactorial study. *Food*
549 *Chem.* 80:345-352.
- 550 NRC. 2001 Nutrient Requirements of Dairy Cattle. 7th rev. ed. Natl. Acad. Press, Washington, DC.
- 551 Pazzola, M., M. L. Dettori, E. Pira, A. Noce, P. Paschino, and G. M. Vacca. 2014a. Effect of
552 polymorphisms at the casein gene cluster on milk renneting properties of the Sarda goat. *Small*
553 *Rumin. Res.* 117:124-130.
- 554 Pazzola, M., M. L. Dettori, and G. M. Vacca. 2017. The Sarda Goat, a Resource for the Extensive
555 Exploitation in the Mediterranean Environment. In: Simões J., Gutiérrez C. eds. *Sustainable*
556 *Goat Production in Adverse Environments: Volume II.* Springer, Cham.
- 557 Pazzola, M., G. Stocco, P. Paschino, M. L. Dettori, C. Cipolat-Gotet, G. Bittante, and G. M. Vacca.
558 2018. Modeling of coagulation, curd firming, and syneresis of goat milk from 6 breeds. *J.*
559 *Dairy Sci.* 101:7027-7039.
- 560 Pazzola, M., G. Stocco, M. L. Dettori, G. Bittante, and G. M. Vacca. 2019. Effect of goat milk
561 composition on cheesemaking traits and daily cheese production. *J. Dairy Sci.* 102:3947-
562 3955.
- 563 Shook, G. E. 1993. Genetic improvement of mastitis through selection on somatic cell count. *Vet*
564 *Clin North Am Food Anim Pract.* 9:563-581.
- 565 Silanikove, N. 2000. The physiological basis of adaptation in goats to harsh environments. *Small*
566 *Rumin. Res.* 35:181-193.

- 567 Sponenberg, D. P., A. Martin, A. Couch, and J. Beranger. 2019. Conservation Strategies for Local
568 Breed Biodiversity. *Diversity*. 11:177-191.
- 569 Stocco, G., C. Cipolat-Gotet, T. Bobbo, A. Cecchinato, and G. Bittante. 2017. Breed of cow and herd
570 productivity affect milk composition and modeling of coagulation, curd firming and syneresis.
571 *J. Dairy Sci.* 100:1-17.
- 572 Stocco, G., C. Cipolat-Gotet, V. Gasparotto, A. Cecchinato, and G. Bittante. 2018b. Breed of cow
573 and herd productivity affect milk nutrient recovery in curd, and cheese yield, efficiency and
574 daily production. *Animal*. 12:434-444.
- 575 Stocco, G., M. Pazzola, M. L. Dettori, P. Paschino, G. Bittante, and G. M. Vacca. 2018a. Effect of
576 composition on coagulation, curd-firming and syneresis of goat milk *J. Dairy Sci.* 101:9693-
577 9702.
- 578 Stocco, G., M. Pazzola, M. L. Dettori, A. Summer, C. Cipolat-Gotet, and G. M. Vacca. 2019a.
579 Variation in caprine milk composition and coagulation as affected by udder health indicators.
580 *Int. Dairy J.* 98:9-16.
- 581 Stocco, G., M. Pazzola, M. L. Dettori, P. Paschino, A. Summer, C. Cipolat-Gotet, and G. M. Vacca.
582 2019b. Effects of goat milk indirect indicators of udder health on nutrients recovery and
583 cheese yield traits. *J. Dairy Sci.* 102:8648-8657.
- 584 Tyrisevä, A.-M., T. Ikonen, and M. Ojala. 2003. Repeatability estimates for milk coagulation traits
585 and non-coagulation of milk in Finnish Ayrshire cows. *J. Dairy Res.* 70:91-98.
- 586 Usai, M. G., S. Casu, G. Molle, M. Decandia, S. Ligios, and A. Carta. 2006. Using cluster analysis
587 to characterize the goat farming system in Sardinia. *Livest. Sci.* 104:63-76.
- 588 Vacca, G. M., M. L. Dettori, V. Carcangiu, A. M. Rocchigiani, and M. Pazzola. 2010. Relationships
589 between milk characteristics and somatic cell score in milk from primiparous browsing goats.
590 *Anim. Sci. J.* 81:594-599.
- 591 Vacca, G. M., P. Paschino, M. L. Dettori, M. Bergamaschi, C. Cipolat-Gotet, G. Bittante, and M.
592 Pazzola. 2016. Environmental, morphological and productive characterization of Sardinian

- 593 goats and use of latent explanatory factors for population analysis. *J. Anim. Sci.* 94:3947-
594 3957.
- 595 Vacca, G. M., G. Stocco, M. L. Dettori, E. Pira, G. Bittante, and M. Pazzola. 2018a. Milk yield,
596 quality and coagulation properties of six breeds of goats: environmental and individual
597 variability. *J. Dairy Sci.* 101:7236-7247.
- 598 Vacca, G. M., G. Stocco, M. L. Dettori, A. Summer, C. Cipolat-Gotet, G. Bittante, and M. Pazzola.
599 2018b. Cheese yield, cheese-making efficiency, and daily production of 6 breeds of goats. *J.*
600 *Dairy Sci.* 101:7817-7832.
- 601 Van Quackebecke, E., Y. Lefrileux, A. Pommaret, and C. Audic. 1996. Comparaison de deux systèmes
602 d'alimentation des chèvres laitières. *Renc. Rech. Rum.* 3:289-292.
- 603 Zeng, S. S., and E. N. Escobar. 1995. Effect of parity and milk production on somatic cell count,
604 standard plate count and composition of goat milk. *Small Rumin. Res.* 17:269-274.
- 605 Zeng, S. S., E. N. Escobar, and T. Popham. 1997. Daily variations in somatic cell count, composition,
606 and production of Alpine goat milk. *Small Rumin. Res.* 26:253-260.

607

TABLES AND FIGURES

608 **Table 1.** Characteristics of sampled farms (N = 21).

	Geographical area	
	Central-east	South-west
Farms, no.	11	10
Goats, no.	194	376
Milk energy level, no. of farms:		
High (>3.91 MJ/d)	5	5
Low (\leq 3.91 MJ/d)	6	5
Flock size, no. of farms:		
Small (< 100 goats)	2	3
Medium (100-200 goats)	7	3
Large (> 200 goats)	2	4
Altitude, no. of farms:		
Plain (< 200 m asl ¹)	2	4
Hill (200-500 m asl)	1	5
Mountain (> 500 m asl)	8	1
Milking, no. of farms:		
Mechanical	1	7
Hand-milked	10	3

609 ¹asl = above sea level.

610 **Table 2.** Descriptive statistics of milk yield, composition, traditional coagulation properties (MCP),
 611 modeled curd-firming over time (CF_t) parameters and cheese-making traits of individual goat milk
 612 samples.

	Mean	SD	Percentile ¹	
			P5	P95
MY ² , kg/d	1.10	0.51	0.42	2.20
<i>Milk composition</i>				
Fat, %	5.28	1.22	3.41	7.47
Protein, %	3.93	0.48	3.19	4.81
Lactose, %	4.61	0.27	4.15	5.04
Total Solids, %	14.83	1.53	12.50	17.50
NaCl ³	245	50	170	327
pH	6.72	0.10	6.55	6.88
SCS ⁴	6.63	1.80	3.63	9.49
LBC ⁵	1.75	0.87	0.30	3.27
<i>Traditional MCP⁶</i>				
RCT, min	13.37	4.55	8.15	23.30
k ₂₀ , min	3.61	1.19	2.15	6.30
a ₃₀ , mm	37.14	9.90	18.42	51.04
<i>Modeled CF_t parameters⁷</i>				
RCT _{eq} , min	13.60	3.90	8.88	22.07
k _{CF} , %/min	21.21	6.92	10.22	33.67
CF _P , mm	42.22	10.25	25.12	58.52
<i>Cheese yields, %</i>				
%CY _{CURD}	19.04	3.12	14.57	24.68
%CY _{SOLIDS}	9.09	1.56	6.77	11.64
%CY _{WATER}	9.78	2.08	6.86	13.96
<i>Nutrients recovery, %</i>				
%REC _{FAT}	85.34	4.34	76.89	91.67
%REC _{PROTEIN}	81.19	2.71	76.25	85.25
%REC _{SOLIDS}	60.43	4.28	52.76	67.01
<i>Daily production traits, kg /d</i>				
dCY _{CURD}	0.208	0.096	0.079	0.392
dCY _{SOLIDS}	0.098	0.043	0.041	0.182
dCY _{WATER}	0.107	0.050	0.039	0.206

613 ¹Percentile = 5th and 95th percentiles, which indicate the upper and lower 5% limits in the 2-tailed
 614 distribution of data; ²MY = milk yield; ³NaCl = Sodium Chloride; ⁴SCS = $\log_2(\text{SCC} \times 10^{-5}) + 3$;
 615 ⁵logarithmic bacterial count (LBC) = $\log_{10}(\text{total bacterial count}/1,000)$; ⁶RCT = measured rennet
 616 gelation time; k₂₀ = time interval between gelation and attainment of curd firmness of 20 mm; a₃₀ =
 617 curd firmness 30 min after rennet addition; ⁷RCT_{eq} = rennet coagulation time estimated by CF_t
 618 modeling; k_{CF} = curd firming instant rate constant; CF_P = asymptotic potential curd firmness.

Table 3. Analysis of variance for fixed effects (F -value and significance) and variance of random effects (expressed as percentage variance on the total variance) for daily milk yield, composition, traditional coagulation properties (MCP) and modeled curd-firming over time (CF_t) parameters, and cheese-making traits, and repeatability of traditional MCP, modeled CF_t parameters and cheese-making traits.

	Fixed effects (F -value and significance)				Random effects (% on total variance)			RMSE ²	Repeatability ³ , %
	DIM	Parity	ME ¹	Area	Farm(ME, Area)	Animal	Pendulum		
MY ⁴ , kg/d	7.6***	15.2***	25.9***	8.1*	30	-	-	0.32	-
<i>Milk composition</i>									
Fat, %	3.0**	8.5***	2.1	5.1*	44	-	-	0.95	-
Protein, %	14.6***	2.5*	2.0	3.7	35	-	-	0.38	-
Lactose, %	5.1***	11.4***	1.6	9.6**	27	-	-	0.22	-
Total Solids, %	7.3***	9.5***	0.5	8.0*	41	-	-	1.20	-
NaCl ⁵	7.4***	21.0***	0.0	17.5***	37	-	-	37.70	-
pH	3.6**	7.9***	0.7	0.3	38	-	-	0.08	-
SCS ⁶	3.3**	23.5***	0.8	3.5	29	-	-	1.53	-
LBC ⁷	1.8	6.0***	2.0	0.1	60	-	-	0.54	-
<i>Traditional MCP⁸</i>									
RCT, min	0.6	1.2	2.4	3.0	24	72	0.46	0.84	96.5
k ₂₀ , min	1.9	0.4	1.4	12.8**	24	57	4.56	0.50	85.5
a ₃₀ , mm	1.3	2.5*	0.1	19.0**	6	75	3.17	3.95	84.0
<i>Modeled CF_t parameters⁹</i>									
RCT _{eq} , min	0.6	0.3	5.1*	1.0	13	85	0.39	0.43	98.8
k _{CF} , %/min	0.3	0.5	3.7	2.3	15	75	0.14	2.13	90.7
CF _p , mm	1.9	2.1	1.3	1.1	42	47	3.55	3.25	91.9
<i>Cheese yields, %</i>									
%CY _{CURD}	2.3*	3.5**	0.0	0.3	41	52	0.03	0.79	93.3
%CY _{SOLIDS}	2.9**	3.3*	0.7	5.8*	36	64	0.00	0.06	99.9
%CY _{WATER}	1.9	1.7	0.1	1.0	47	42	0.02	0.70	89.7

<i>Nutrients recovery, %</i>									
%REC _{FAT}	1.8	1.8	3.5	0.2	25	75	0.00	0.25	99.6
%REC _{PROTEIN}	0.4	5.9***	5.1*	2.7	28	70	0.01	0.29	98.8
%REC _{SOLIDS}	2.5*	2.3	0.5	1.7	31	68	0.02	0.39	99.2
<i>Daily production traits, kg /d</i>									
dCY _{CURD}	2.7*	4.1**	24.8***	5.5*	30	68	0.00	0.01	98.3
dCY _{SOLIDS}	2.7*	4.6**	36.7***	2.4	26	73	0.00	0.00	99.9
dCY _{WATER}	2.6*	4.0**	14.3***	6.6*	36	61	0.02	0.01	96.8

¹ME = milk energy level; ²RMSE = root mean square error; ³Repeatability, % = $\frac{\sigma_{Farm(HP * Area)}^2 + \sigma_{Animal}^2 + \sigma_{Pendulum}^2}{\sigma_{Farm(HP * Area)}^2 + \sigma_{Animal}^2 + \sigma_{Pendulum}^2 + \sigma_e^2} \times 100$; ⁴MY = milk yield; ⁵NaCl = Sodium Chloride; ⁶SCS = $\log_2 (SCC \times 10^{-5}) + 3$; ⁷logarithmic bacterial count (LBC) = $\log_{10} (\text{total bacterial count}/1,000)$; ⁸RCT = measured rennet gelation time; k_{20} = time interval between gelation and attainment of curd firmness of 20 mm; a_{30} = curd firmness 30 min after rennet addition; ⁹RCT_{eq} = rennet coagulation time estimated by CF_t modeling; k_{CF} = curd firming instant rate constant; CF_p = asymptotic potential curd firmness;

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

Table 4. Least square means of Milk Energy (ME) level and of geographical area for milk yield, composition, traditional coagulation properties (MCP), modeled curd-firming over time (CF_t) parameters, and cheese-making traits of individual goat milk samples. Bold numbers were used to evidence significant differences for $P < 0.05$, $P < 0.01$, and $P < 0.001$, as reported in Table 3.

	ME Level		Geographical area	
	High	Low	Central-East	South-West
MY ¹ , kg/d	1.29	0.80	0.90	1.18
<i>Milk composition</i>				
Fat, %	5.78	5.24	5.93	5.08
Protein, %	3.91	4.09	4.12	3.88
Lactose, %	4.62	4.69	4.75	4.56
Total Solids, %	15.33	15.01	15.80	14.54
NaCl ²	233	231	205	260
pH	6.70	6.73	6.71	6.73
SCS ³	6.50	6.10	5.88	6.72
LBC ⁴	1.51	1.92	1.68	1.76
<i>Traditional MCP⁵</i>				
RCT, min	12.93	14.55	14.64	12.83
k ₂₀ , min	4.63	4.15	5.24	3.54
a ₃₀ , mm	31.07	31.56	25.13	37.50
<i>Modeled CF_t parameters⁶</i>				
RCT _{eq} , min	12.94	14.56	14.12	13.38
k _{CF} , %/min	22.38	19.83	20.08	22.13
CF _P , mm	41.39	45.14	45.04	41.49
<i>Cheese yields, %</i>				
%CY _{CURD}	18.95	18.85	19.13	18.66
%CY _{SOLIDS}	9.50	9.14	9.84	8.80
%CY _{WATER}	9.44	9.59	9.18	9.84
<i>Nutrients recovery, %</i>				
%REC _{FAT}	84.33	86.17	85.46	85.03
%REC _{PROTEIN}	82.34	80.87	82.15	81.06
%REC _{SOLIDS}	61.08	60.32	61.41	59.99
<i>Daily production traits, kg /d</i>				
dCY _{CURD}	0.244	0.148	0.173	0.218
dCY _{SOLIDS}	0.120	0.071	0.089	0.102
dCY _{WATER}	0.122	0.078	0.084	0.115

¹MY = milk yield; ²NaCl = Sodium Chloride; ³SCS = $\log_2(\text{SCC} \times 10^{-5}) + 3$; ⁴logarithmic bacterial count (LBC) = $\log_{10}(\text{total bacterial count}/1,000)$; ⁵RCT = measured rennet gelation time; k₂₀ = time interval between gelation and attainment of curd firmness of 20 mm; a₃₀ = curd firmness 30 min after rennet addition; ⁶RCT_{eq} = rennet coagulation time estimated by CF_t modeling; k_{CF} = curd firming instant rate constant; CF_P = asymptotic potential curd firmness.

Table 5. Least square means of classes of parity and their orthogonal contrasts (F -value and significance) for milk yield, composition, traditional coagulation properties (MCP), modeled curd-firming over time (CF_t) parameters, and cheese-making traits of individual goat milk samples.

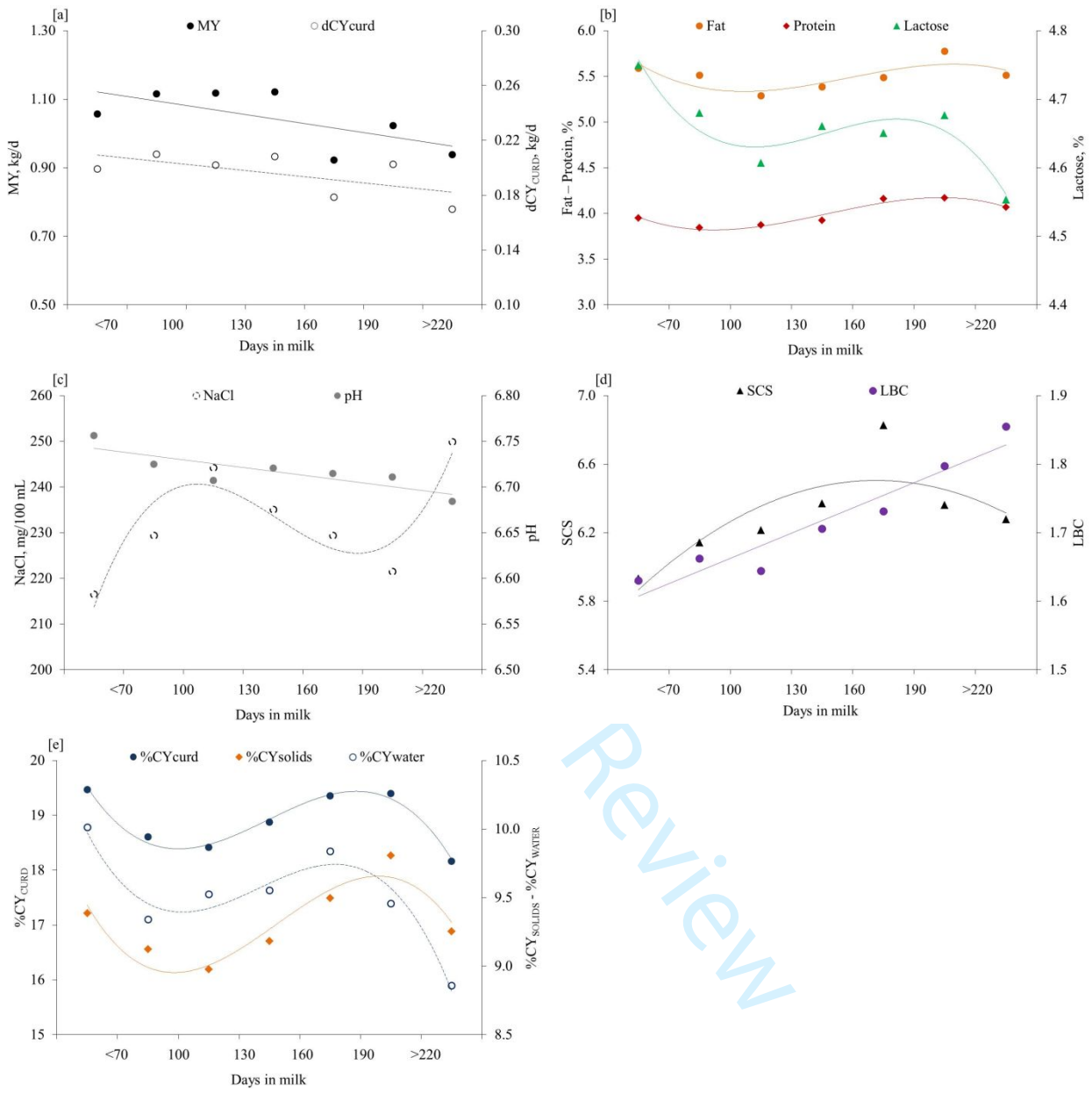
	Parity, LSMeans					Contrasts, F -value and significance			
	1 st	2 nd	3 rd	4 th	≥5 th	1 st vs 2 nd	1 st vs ≥ 2 nd	2 nd vs ≥ 3 rd	3 rd vs ≥ 4 th
MY ¹ , kd/d	0.86	1.03	1.11	1.11	1.11	25.9***	57.9***	8.2**	0.0
<i>Milk composition</i>									
Fat, %	5.82	5.57	5.53	5.41	5.21	6.9**	20.9***	5.5*	6.3*
Protein, %	3.99	4.00	3.97	4.07	3.95	0.0	0.0	0.0	1.4
Lactose, %	4.73	4.70	4.62	4.63	4.58	2.4	23.8***	21.1***	0.6
Total Solids, %	15.56	15.32	15.14	15.07	14.77	4.2*	20.7***	10.9**	4.0*
NaCl ²	213	224	237	239	249	7.5**	49.5***	33.6***	4.9*
pH	6.73	6.74	6.72	6.71	6.69	1.1	3.4	20.8***	5.5*
SCS ³	5.51	5.90	6.61	6.50	7.00	6.2*	51.6***	41.2***	1.2
LBC ⁴	1.59	1.62	1.81	1.75	1.81	0.3	10.4**	14.4***	0.4
<i>Traditional MCP⁵</i>									
RCT, min	13.13	13.35	14.00	14.38	13.83	0.2	2.3	2.6	0.1
k ₂₀ , min	4.38	4.35	4.41	4.27	4.53	0.0	0.0	0.2	0.0
a ₃₀ , mm	33.40	32.44	30.17	31.59	28.98	0.5	5.1*	3.6	0.0
<i>Modeled CF_t parameters⁶</i>									
RCT _{eq} , min	13.51	13.82	13.91	13.97	13.55	0.4	0.5	0.0	0.1
k _{CF} , %/min	20.99	21.11	21.86	20.49	21.08	0.0	0.0	0.0	1.8
CF _p , mm	44.66	43.76	41.52	43.97	42.41	0.6	2.8	1.4	2.6
<i>Cheese yields, %</i>									
%CY _{CURD}	19.34	19.15	18.95	18.91	18.15	0.4	3.6	3.3	2.2
%CY _{SOLIDS}	9.60	9.43	9.29	9.34	8.93	0.9	5.0*	2.9	1.0

%CY _{WATER}	9.63	9.62	9.51	9.63	9.16	0.0	0.6	1.1	0.4
<i>Nutrients recovery, %</i>									
%REC _{FAT}	85.89	85.76	84.86	85.07	84.66	0.1	3.0	4.5*	0.0
%REC _{PROTEIN}	82.44	82.07	81.43	81.03	81.04	1.4	13.8***	12.2***	2.0
%REC _{SOLIDS}	61.34	60.98	60.84	60.51	59.82	0.5	3.3	2.1	2.4
<i>Daily production traits, kg /d</i>									
dCY _{CURD}	0.173	0.194	0.210	0.206	0.196	5.3*	12.4***	1.8	1.3
dCY _{SOLIDS}	0.084	0.095	0.102	0.101	0.097	6.8**	15.6***	2.3	0.6
dCY _{WATER}	0.087	0.099	0.106	0.107	0.100	5.5*	12.8***	2.0	0.4

¹MY = milk yield; ²NaCl = Sodium Chloride; ³SCS = $\log_2(\text{SCC} \times 10^{-5}) + 3$; ⁴logarithmic bacterial count (LBC) = $\log_{10}(\text{total bacterial count}/1,000)$; ⁵RCT = measured rennet gelation time; k_{20} = time interval between gelation and attainment of curd firmness of 20 mm; a_{30} = curd firmness 30 min after rennet addition; ⁶RCT_{eq} = rennet coagulation time estimated by CF_t modeling; k_{CF} = curd firming instant rate constant; CF_p = asymptotic potential curd firmness;

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

Figure 1.



Review

619 **Figure 1.** Effect of days in milk on MY, dCY [a], fat, protein and lactose [b], NaCl and pH [c], SCS
620 and LBC [d], and %CY traits [e] of goats.

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