

The Role of Local Sheep and Goat Breeds and Their Products as a Tool for Sustainability and Safeguard of the Mediterranean Environment

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Abstract This chapter is a survey of recent studies on native sheep and goat breeds with special emphasis on their role as a tool of sustainability. After a short overview, strategies for adding value to the local breeds are described together with a synthesis of measures in support of animal biodiversity in marginal areas of Mediterranean environment. In this direction, three case studies are reported in which the added value of local breeds arising from a typical and/or traditional product is investigated. The first one is on native sheep breeds from Apulian region and the PDO *Canestrato Pugliese* cheese, and it indicates that *Altamura* and Apulian Merino breeds produce milk and cheese having nutritional characteristics and sensory properties distinguishable from non-native breeds. The second and third studies regard local goat breeds and local cheeses, *Caciotta* and *Ricotta* cheeses. As it appears from our discussion, *Girgentana* breed produces milk and *Caciotta* and *Ricotta* cheeses with distinguishable fatty acid profile, nutritional index and sensory properties compared to other breeds. These peculiarities add value to the *Girgentana* breed and therefore give a support in favour of this breed, amplifying its sustainable use. Finally, we point out that the high quantity of sialyloligosaccharides found in local *Garganica* breed compared to foreign breed appears as an interesting promising feature in the study of adding value to local breeds.

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1 Sheep and Goat Breeds, a Tool for Sustainability

More than two decades have passed since the principle of sustainable development received nearly universal agreement at the 1992 Earth Summit after its definition by FAO (FAO 1989).

The sustainability shows multi-dimensional structure embracing survival, resilience and efficiency, and it relies on three pillars described as the economic, environmental and social factors. The usual representation of this multi-dimensional structure is by the Venn diagram in which sustainability is represented as the set intersection of three sets, namely economic resilience, environmental integrity and social well-being. This is to be integrated with the good governance (FAO 2014), which is the fourth dimension of sustainability.

In a Mediterranean environment, the descriptors of Sustainable agriculture are numerous and interconnected. The main descriptors of the economic factor include the use of local breeds, disease resistance, forage self-sufficiency, forage quality, milk and cheese quality, typical and/or traditional products, environmental labeling, direct sales and eco-agritourism. Those of the environmental factor include biodiversity in terms of plants, animal breeds and habitat, landscape and its visual value, as well as, fire risk and the use of abandoned biomass, GHG emission and carbon sequestration. The social factor focuses on those aspects which are linked to the farmers (age, dignity, interests and future possibilities) and animal welfare (Lombardi 2005; Battaglini et al. 2014).

In this context, local breeds appear to be the major component of animal farm biodiversity, thanks to their excellent adaptation to specific environmental conditions. Furthermore, local breeds are linked to traditional products of special qualities and to several practices that are part of cultural heritage. Therefore, every effort to add value to local breeds is important, especially as a contribution to the prospects of their conservation through sustainable use.

As recently suggested by Papachristoforou et al. (2013), the available strategies to increase the value of local breeds with special attention on sheep and goats can be grouped into three interconnected categories: (1) linking local breeds to traditional products and/or to tourism/agritourism activity; (2) promoting the use of local breeds in specific farming systems like organic production, through the conservation of grazing/silvo-pastoral systems, small low-input farms and hobby farms; (3) general strategies like marketing, legislation, organisation of stakeholders and raising public awareness.

Local breeds, less frequently used in intensive systems but still preserved in situ in marginal territories, represent an important resource for maintaining animal biodiversity (Oldenbroek 2007). In marginal areas of Italy, the most important livestock activity is represented by the rearing of local breeds in connection with local tradition. In Italy, there is a population of about 7,874,108 sheep and 960,950 goats, and about 65.8 % and 69.5 % of these populations are distributed in Southern Italy, respectively (ISTAT 2009).

In Southern Italy, sheep and goat flocks are located in the marginal areas, in hilly rocky, shrub lands and mountain areas, where the production is based on the utilisation of natural pasture with a low stocking rate per hectare. In the extensive rearing system, the daily milk yield and its composition are strongly affected by annual and seasonal variation of feed availability. Especially in the mountains, herbage availability is often low but its quality is high (Rivoira 1976). At the same time, this rearing technique guarantees high ecosystem sustainability, improving the role of agriculture in the environmental preservation as well as the maintenance of rural areas, providing a means to enhance the value of family labour (Morand-Fehr and Boyazoglu 1999; Sepe et al. 2011).

The endurance of rural human population in less favoured areas assures the safeguard and survival of biodiversity, which can then be transferred to locally made “typical” products. A “typical” product is a result of several factors including raw material, transformation process and sensory characteristics. All these peculiarities are closely related to the geographical origin and to the social and cultural traditions of the production area (Scintu and Piredda 2007). In this respect, it is strategic to support the multi-purpose sheep and goat breeds still existing in the Mediterranean and marginal area of Southern Italy.

The *Altamura* and *Gentile di Puglia* (Apulian Merino) sheep breeds, native of Apulia region (Table 1), and *Jonica* and *Girgentana* goat breeds (Table 3) are maintained in nucleus form in CRA-ZOE (Consiglio per la Ricerca e la sperimentazione in Agricoltura—Unità di ricerca per la Zootecnia Estensiva), in Basilicata region, both for research purposes and preservation of these endangered breeds.

In the past, the milk from these two sheep breeds (especially *Altamura*) was used for the production of *Canestrato Pugliese* cheese. At this time, endorsed by the Status of protected Designation of Origin (PDO, CE Reg, n. 1107/96) and produced in Bari and Foggia provinces, the ripened *Canestrato Pugliese* cheese has almost entirely been made with milk of *Comisana* and *Sarda* sheep breeds both non-native of Apulian region (Table 1).

Concerning the caprino cheeses, *Caciotta* cheese is one of the several innovative products available in Southern Italy, made with goat milk and ripened for 20–30 days. On the other side, *Ricotta* cheese is a soft cheese and it appears to be the oldest and the best known whey cheese made mainly with goat milk.

The special, and often superior, characteristics of local breeds compared to non-native breeds in their native environment provide the basis for promoting their use in several production systems that guarantee the sustainability of resources and the quality of products.

In this context, we focus on the relationship between animal biodiversity and production quality, in terms of gross composition, fatty acid (FA) profile, volatile organic compounds (VOCs) and sensory properties in milk and “typical” and local cheeses obtained from native and non-native sheep and goat breeds.

Cheese characteristics and their differentiation are affected by quantitative and qualitative presence of FA in raw milk (Kim Ha and Lindsay 1993; Buchin et al. 1998). The different classes of fatty acids (saturated, unsaturated), single

Table 1 Sheep breeds

Sheep breed—L.G.	Population size (heads) ^a	Diffusion areas in Italy ^b	Prolificacy (%)	Fertility (%)	Lamb at 90 days (kg)	Wool (kg)	Lactation (days)	Lactation yield ^c (kg)	Fat ^d %	Protein ^d %
Altamura	847	Puglia	112	90	21	—	100	78 ± 21 ^e	8.10	6.78
Comisana	44,669	South, Centre, North Italy	180	95	22	—	200	159 ± 48 ^e	7.13	6.32
Gentile di Puglia (Apulian Merino)	6,800	Puglia, Molise, Basilicata, Abruzzo	120	90	22	5.5 ♀ 7.5 ♂	180	90 ± 10	8.13	7.07
Sarda	441,427	Sardegna, Centre and South Italy	110–150	96	10.5 (30 days)	—	150–200	173 ± 51 ^e	6.91	6.16

L.G. Genealogical book

^aRegistered heads, June 2014, ASSONAPA

^bIn order of population size

^cMultiparous ewe

^dClaps et al. (2008)

^eItaly: Milk recording activity, official statistics, AIA (2013)

fatty acids (conjugated linoleic acid and alpha-linolenic acid) and lipids (cholesterol) are of particular interest and may affect consumers' health (McGuire and McGuire 2000).

Milk fat is an essential prerequisite to flavour development (Marilley and Casey 2004). The triglyceride structure can affect the flavour of the cheese produced when pregastric lipases are used in cheesemaking (Kim Ha and Lindsay 1993). It is known that the development of goat milk flavour is due to volatile branched chain fatty acids but also to the structure of triglycerides and to the lipolytic action of the milk lipoprotein lipase (Chilliard et al. 2003). The volatile flavour compounds in cheese originate during ripening mainly from lipid degradation and they are determinants in the flavour of traditional sheep and goat cheeses. The flavour intensity is closely related to short- and medium-chain free FA content of products (Fernández-García et al. 2006). Large differences in texture and taste were observed among cheeses issued from milk differing by the genetic variant of α 1-casein in goats (Coulon et al. 2004). Recently, many studies have focused on the relationships among FA profile (Di Trana et al. 2004, 2005; Addis et al. 2005; Bonanno et al. 2013), volatile organic compounds (Claps et al. 2010), polyphenols content (Di Trana et al. 2014b) of milk and dairy products and different forages or natural pasture ingested by small ruminants. These studies showed that it may be possible to categorise the type of forage or feeding system (grazing or stable) utilised by sheep and goats.

Having positively tested in milk and its derivatives, the possibility of transferring, directly or indirectly, some of the constituents from diet to dairy products shows that such a transfer is an important tool of traceability. These results amplify and strengthen the mutual relationship among plant biodiversity, grazing system and nutraceutical properties of dairy products from small ruminants. Interconnection and overlapping between local know-how and scientific knowledge of all elements and/or factors related to the animal and to the environment enforce the sustainability and safeguard the Mediterranean system.

It should be stressed that the new system must be innovative and not a sort of reshuffle of old traditional systems so that the research can act as a powerful tool to add value to native breeds by creating new knowledge and providing scientific evidence on particular biological characteristics. Participation of local breeders and incorporation of scientific knowledge from several disciplines are further important tools (Dubeuf 2014).

Political strategies and European legislation can be adopted to support directly and/or indirectly local farm and native breeds. Regarding the future, the new CAP (2014–2020) draws up measures, on a European basis, supporting mountain and Mediterranean areas and environmental sustainability. In particular, in the second pillar (rural development), resources are assigned for the implementation of regional programmes in the animal biodiversity sector Reg. 1305/2013. These guidelines on a domestic basis are implemented by Mipaaf (Ministry of Agriculture and Forestry), and the regions draw up tools such as the rural development plan (RDP) on seeking their realisation.

In our discussion on the role of native sheep and goat breeds and their products, as a tool for sustainability, we have focused our attention on four sheep breeds and four goat breeds: two endangered native sheep breeds (*Altamura* and Apulian Merino) and goat breeds (*Jonica* and *Girgentana*) from Southern Italy and two non-native breeds, *Comisana* and *Sarda* sheep breeds, and *Maltese* and Red Syrian goat breeds, respectively.

2 Sheep Breeds and *Canestrato Pugliese* Cheese

In this section, we report an example that can be considered a case study. The study was carried out at the CRA-ZOE experimental farm of Foggia (41°27'N; 15°33'E), located at 76 m a.s.l in the Apulia region (Southern Italy). The maximum and minimum environmental temperatures and relative humidity during the different seasons were 23 °C, 11 °C and 68 % in spring, 30 °C, 17 °C and 64 % in summer, 19 °C, 9 °C and 76 % in autumn and 13 °C, 3 °C and 78 % in winter. The average annual rainfall was 391 mm, mainly occurred in autumn. Temperature humidity indexes were 64, 78, 68 and 57.5 in spring, summer, autumn and winter, respectively. The botanical composition of native pasture included 18.9 % *Graminaceae*, 12 % *Leguminosae*, 13.5 % *Compositae*, 11.2 % *Labiatae*, 0.3 % *Caryophyllaceae* and other botanical families being represented in lower percentage.

A flock set-up of four breeds of mature sheep was used. In order to compare local and non-native breeds, the flock was set-up with two native breeds, *Altamura* (A) and *Gentile di Puglia* (Apulian Merino) (G), and two non-native breeds, *Comisana* (C) and *Sarda* (S), the most important Mediterranean sheep breeds and native of Sicily and Sardinia regions, respectively (Table 1). All animals were homogeneous for days in milk (75 ± 11 DIM) and body condition score (2.75). The flock grazed on native pasture during the day and was housed in shaded open pens during the night. All sheep were supplemented with 0.6 kg/day of concentrate in two equal meals at milking.

2.1 *Canestrato Pugliese* Cheesemaking, Sampling and Analysis of Milk and Cheese

Three cheesemakings of *Canestrato Pugliese* were carried out for each breed in CRA-ZOE's experimental dairy for three consecutive days.

Canestrato Pugliese Cheese



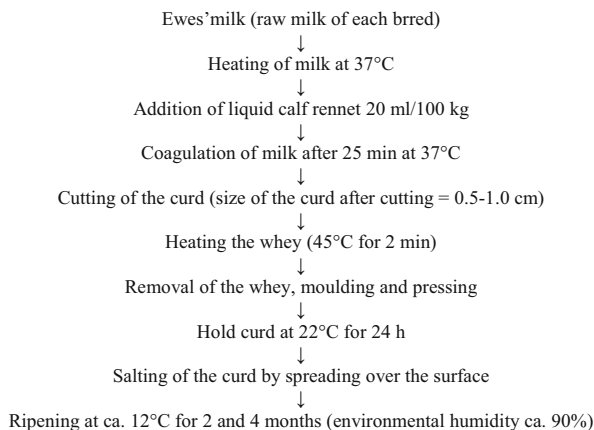
Italian Pecorino, uncooked hard cheese, recognised with Protected Designation of Origin: it is produced in Bari and Foggia provinces (Apulia region) exclusively from raw, but also thermised or pasteurised, whole sheep milk. The cheese derived its name and traditional shape from the rush basket “Canestro”, in which the curd is ripened. During ripening, usually the rind is rubbed with a mixture of oil and vinegar. The cheese has a cylindrical shape, 10–14 cm height, 25–34 cm in diameter, and weighs 7–14 kg (PDO, CE Reg. n. 1107/96). Paste is pale yellow coloured, more or less intense depending on age; compact texture, somewhat crumbly, poorly melting, not very elastic, with just visible eyes; characteristic spicy taste fairly marked.

The flowchart of *Canestrato Pugliese* cheese manufacture is shown in Fig. 1. Cheese was ripened for 6 months in a natural cave at CRA-ZOE of Bella.

Milk samples were collected at milking time, and cheese samples were obtained at the end of the ripening period. Milk and cheese samples were analysed for pH, chemical composition and fatty acid (FA) content. Volatile Organic Compounds (VOC) and sensory profile were evaluated on cheeses. Basic chemical composition was measured according to standard methods as previously reported (Pizzillo et al. 2005). FA separation and quantification was carried out using a gas chromatograph as reported by Di Trana et al. (2004). The Health-Promoting Index (HPI) was calculated as the ratio between the unsaturated FAs content and lauric acid, palmitic acid and 4 x miristic acid contents (Chen et al. 2004). VOC content was assessed by multiple dynamic headspace extraction and GC-MS (Ciccioli et al. 2004). The cheese sensory profile was evaluated, at room temperature, by ten panellists using a 0–9 point graduated scale for each attribute.

Changes in milk and cheese chemical compositions, FA profile and VOC profile were analysed by ANOVA procedure (Systat 7 1997). Analysis included the effect of sheep breed (Apulian Merino, *Altamurana*, *Comisana* and *Sarda*). Sensory profile data were normalised before submitting them to ANOVA repeated measures procedure. Significance was declared at $P < 0.05$ and tendencies at $0.05 < P \leq 0.10$; differences between means were tested using Fisher’s LSD test. In order to ascertain the discriminant effect of the sheep breed on products, milk and cheese data

Fig. 1 Flowchart of *Canestrato Pugliese* cheese



were pooled *per* breed and submitted to a multivariate approach by Stepwise Discriminant Analysis (Systat 7 1997).

2.2 Results and Discussion

Milk chemical composition was affected by sheep breed (Table 2). The native G and A breeds showed higher dry matter and fat percentage than C and S breeds. Milk from G breed was characterised by higher protein content followed by A, C and S breeds. Ash content was higher in A and C breeds than others. There were no significant differences among breeds on pH data. These results are in line with a previous study on G and A sheep breeds (Claps et al. 1999).

The *Canestrato Pugliese* cheeses from milk of G, C and S breeds were characterised by a higher content of protein and ash compared to the cheese from A breed. The breed effect on dry matter and fat reported above for milk was not observed in cheese. Breed affected chemical composition, but higher percentages of fat and ash in milk do not always lead to cheeses with a superior level of these compounds (Table 2).

A significant breed effect on milk and cheese quality was reported by Kawecka and Sosin-Bzducha (2014), using two indigenous Polish breeds, the Coloured Mountain Sheep (CMS) and the Podhale Zackel (PZ), reared under the same environmental conditions. These authors showed a higher crude protein, casein, urea, and solid non-fat contents in milk from CMS compared to PZ. Cheese obtained from CMS milk had about a 6 % lower fat content compared to cheese made from PZ milk. An effect of the month of grazing season was also found but only for milk composition. The breed x grazing season interaction affected all parameters of cheese chemical composition, while it was negligible for most of milk composition parameters.

Table 2 Effect of sheep breed on chemical composition, fatty acid content and nutritional index of milk and *Canestrato Pugliese* cheese (Claps et al. 2008; Di Trana et al. 2009)

Product	Milk				Cheese					
Breed ¹	G	A	C	S	SEM	G	A	C	S	SEM
Chemical composition (%)										
pH	6.70	6.54	6.64	6.45	0.09	5.40 ^a	5.12 ^b	5.07 ^b	5.41 ^a	0.02
Dry matter	19.85 ^a	20.32 ^a	18.38 ^b	18.42 ^b	0.43	62.56	62.88	62.78	62.48	0.56
Fat	8.13 ^a	8.10 ^a	7.13 ^b	6.91 ^b	0.06	24.87	25.29	24.67	23.41	0.59
Protein	7.07 ^a	6.78 ^b	6.32 ^c	6.16 ^c	0.09	22.4 ^a	19.15 ^b	20.28 ^{ba}	20.31 ^{ba}	0.78
Ash	0.95 ^b	0.99 ^a	0.98 ^a	0.96 ^b	0.01	6.40 ^a	5.74 ^b	6.14 ^a	6.21 ^a	0.24
Fatty acids ² (g/100 g FA)										
SFA	70.51	69.54	70.72	71.36	0.47	71.01	69.86	71.65	70.80	0.49
MUFA	24.22 ^b	25.69 ^a	24.53 ^b	24.75 ^{ab}	0.43	23.87 ^b	25.74 ^a	23.08 ^b	23.57 ^b	0.40
PUFA	5.27 ^a	4.78 ^b	5.44 ^a	5.56 ^a	0.14	5.32 ^a	4.64 ^b	5.42 ^a	5.38 ^a	0.13
omega-3	1.09 ^a	0.88 ^b	1.14 ^a	1.17 ^a	0.03	1.09 ^a	0.84 ^b	1.08 ^a	1.06 ^a	0.03
omega-6	2.05	1.83	2.04	2.06	0.08	2.12 ^a	1.87 ^b	2.19 ^b	2.18 ^b	0.07
Total <i>trans</i>	2.23 ^a	2.30 ^a	2.14 ^b	2.09 ^b	0.04	2.28 ^a	2.21 ^a	1.91 ^b	1.86 ^b	0.11
CLA	0.81 ^a	0.74 ^b	0.85 ^a	0.86 ^a	0.03	0.81 ^a	0.70 ^b	0.83 ^a	0.88 ^a	0.03
Nutritional index										
HPI	0.41 ^b	0.44 ^a	0.42 ^b	0.40 ^b	0.03	0.38&	0.40 ^{\$}	0.39&	0.39&	0.04

Means within row with different superscripts differ at^{a, b, c} $P < 0.05$; &^S $P < 0.10$

¹G Apulian Merino; A Altamura; C Comisana; S Sarda breeds

²SFA saturated fatty acids; MUFA monounsaturated fatty acids; PUFA polyunsaturated fatty acids; CLA conjugated linoleic acid; HPI health promoting index; SEM standard error mean

A negligible breed effect on milk chemical composition was observed in Boutsiko and Karamaniko, two native sheep breeds of North Western Greece (Kondyli et al. 2012).

A few studies have been published in attempt to elucidate the effect of breed on cheese chemical composition. Comparing some hard cheeses produced in various parts of Spain from different ewe breeds, Gonzalez Viñas et al. (1999) observed no significant differences in the physicochemical composition. The sheep breed effect on milk composition and coagulation properties for Niza production, a traditional Portuguese PDO cheese, was evaluated comparing two autochthonous breeds (Merino and Saloia) with the non-native Assaf breed that is commonly reared in Portugal (Martins et al. 2009). The milk composition showed higher solid content in Merino and Saloia breeds resulting in higher potential cheese making yield as far as 75 % and 27% , respectively, when compared to the corresponding value of that of Assaf milk. The lower solid content of Assaf milk led to lower curd firmness while the milk from Merino and Saloia breeds showed superior firming rates and reached higher final curd firmness in agreement with physical and chemical characteristics of milk. The results emphasise the different cheese making aptitude of the milk from the two Portuguese autochthonous breeds.

Some studies have showed that FA profile of cheese was very similar to that of milk (Addis et al. 2005; Nudda et al. 2005). In our investigation, the sheep breed affected milk and cheese FA profile, and both showed a similar trend (Table 2). In milk and cheese, G and C breeds showed a higher content of polyunsaturated FA (PUFA) and omega-3 compared to A breed, which instead increased the content of monounsaturated FA (MUFA). No differences were found in saturated FA (SFA) content, and slight differences were detected for milk omega-6 contents. Total *trans* FAs were higher in milk and cheese from native G and A breeds compared to the others.

Comparing three Italian sheep breeds (*Massese*, *Sarda* and *Comisana*), Duranti and Casoli (1988) detected breed effect on milk FA profile, in particular, on short-chain FA percentages and on unsaturated/saturated FA ratio. Later on, study about *Altamurana*, Apulian Merino and *Sarda* breed confirmed the breed effect on the majority FA of milk (Signorelli et al. 2008). As regards CLA (conjugated linoleic acid *cis*-9, *trans*-11), the higher content was found in milk and cheese from G, C and S breeds compared to A breed. Comparing three dairy sheep breeds (*Garfagnina*, *Massese* and *Sarda*), Secchiari et al. (2001) observed the breed effect on milk's total CLA isomers content, with a higher CLA content in local *Garfagnina* and *Massese* breeds compared to *Sarda* breed. In contrast with our results, other authors have not found a sheep breed effect on milk CLA content, probably due to the wide variation in milk CLA level among individuals consuming the same diet (Tsiplakou et al. 2006; Signorelli et al. 2008). Evaluating CLA isomer content in milk from Polish *Żelazneńska* and *Wrzosówka* sheep, Rozbicka-Wieczorek et al. (2013) detected a higher but not significant level of CLA in milk from *Żelazneńska* ewes. Talpur et al. (2009) found different FA profiles in milk from indigenous Pakistani sheep breeds (Kachi and Kooka) reared under the same feeding and housing conditions. Kooka breed showed a better profile with lower

SFA and higher CLA contents than Kachi breed. The variability among breeds might be useful in the improvement on milk and derived products' quality.

From the human health point of view, when comparing the autochthonous A breed with the C and S breeds, we observed health-promoting properties of milk and cheese from A endangered breed. The milk HPI from A breed was higher than that observed in the other breeds. This result was confirmed in the cheese, though the difference was slight. In our further investigation, we observed a higher HPI in *Canestrato Pugliese* cheese, 4 months ripened, produced with A breed milk than the same product obtained from *Sarda* breed milk (Claps et al. 2011).

In North Western Greece, a study was carried out in farms located in the semi-mountainous (600–800 m a.s.l.) region of Ioannina, using two small sized native breeds, Boutsiko and Karamaniko, which are endurable and adaptable to the environmental conditions, frugal in eating and having the same yearly milk production as other indigenous breeds (Voutsinas et al. 1988). The sheep breeds grazed in semi-mountainous and mountainous pastures, so as to eliminate any differences due to different feeding. The breed effect was observed for butyric, stearic, CLA and vitamin A contents, with Boutsiko breed having higher levels than Karamaniko one, while the breed effect was negligible for the major FAs (Kondyli et al. 2012).

Some studies on local sheep breeds were performed in Romania to evaluate their effect on milk FA profile (Mierlita et al. 2011a, b). Merino of Transylvania, Tsigay and Turcana are three Romanian sheep breeds on the verge of extinction for their low productivity. Turcana and Tsigay milk are used to produce some high quality traditional cheeses ("cas", "telemea" and "branza de burduf") due to their fat and protein content. Mierlita et al. (2011a) reported that Turcana sheep produced more milk than Merino of Transylvania, Tsigay breeds. In addition, Turcana milk was richer in fat and protein content and had a better HPI value, due to its lower SFA level and higher PUFA content, especially in CLA, than other milk. The healthiest FA profile of Turcana milk was also found when comparing Turcana with Spanca, another indigenous Romanian breed (Mierlita et al. 2011b). The higher concentrations of *trans*-11 C18:1 (VA), C18:1 n9c and *cis*-9 *trans*-11 CLA in Turcana milk were related to its more intense VA desaturation and conversion into *cis*-9, *trans*-11 CLA. These results support the sustainable use of animal genetic resources to improve ewe milk fat quality.

The study conducted in Poland by Kawęcka and Sosin-Bzducha (2014) is one of the few studies carried out simultaneously on milk and cheese made from different breeds of sheep: the Coloured Mountain Sheep (CMS) and Podhale Zackel (PZ). "Oscypek" cheese manufactured from PZ breed showed lower SFA, atherogenic index values and higher MUFA and omega-3 FA contents than cheese from CMS breed. The differences in the FA profile of products observed in response to breeding and grazing season may represent the basis for producing different flavoured niche cheeses. The authors indicate that these local sheep breeds have a high potential for sustainable use.

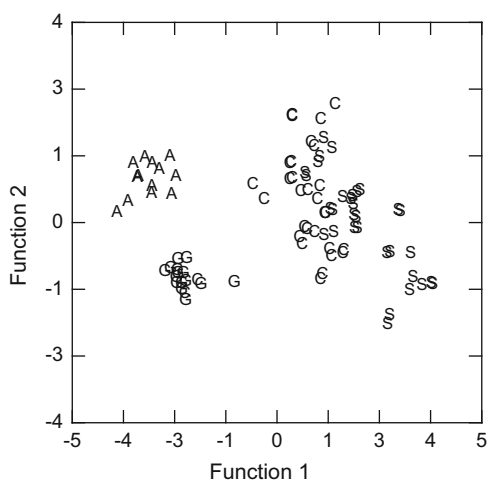
Also, the study by Esposito et al. (2014) was aimed at recovering the dairy aptitude in *Appenninica* sheep, a native breed in Central Italy. The characterization of the Apennine Pecorino cheese made from raw milk was performed using as test

pecorino made from raw milk of *Sarda* breed. These sheep breeds were maintained in the same rearing conditions. The breed effect was evident for some FAs and aromatic compounds, while it was negligible for cheese chemical composition. Cheese of *Apennine* breed showed greater content of *cis*-10 pentadecenoic acid and lower content in α -linolenic acid and γ -linolenic acid compared to cheese of *Sarda* breed.

In our study, the discriminant analysis performed on FA composition of milk and *Canestrato Pugliese* cheese highlight that A and G autochthonous breeds were well discriminated from *Comisana* and *Sarda* breeds. Canonical scores plot (Fig. 2) show on the left A and G breeds and on the right C and S breeds not well separated. The variables contributing to discriminant analysis were the main classes of FAs (SFA, MUFA, PUFA, omega-3, omega-6 and total *trans*) and single FA (oleic acid, *trans* vaccenic acid and CLA). These results suggest that local breeds, independently from diet, possess the potential to link a specific product to a breed. With a multivariate approach by Principal Components Analysis, Ighina et al. (2007) on four Alpine sheep breeds (*Frabosana*, *Delle Langhe*, *Savoiarda* and *Lacaune*) showed and confirmed that the breed has an influence on milk FA composition and CLA content when animals are fed the same diet.

Milk volatile compounds originate from the feed and/or from microbial metabolism. Some compounds present in plants, such as terpenes, can be transferred to the milk through inspiratory lung or feeding. Most of the volatile compounds are microbially produced from the catabolism of milk component and depend on the composition of the endogenous microflora in the raw milk and/or from starters (McSweeney 2004). The physicochemical characteristics of cheeses from different breeds are linked to the development of volatile flavour compounds, particularly from lipid degradation during ripening (McSweeney 2004). As suggested by Engels et al. (1997), the FAs are important components in the flavour of many cheese types; the Volatile Organic Compounds (VOC) in cheese, such as esters, methyl

Fig. 2 Distribution plot of milk and *Canestrato Pugliese* cheese using two canonical discriminant functions (Claps et al. 2008; Di Trana et al. 2009). (G) *Apulian Merinos*, (A) *Altamurana*, (C) *Comisana* and (S) *Sarda* breeds



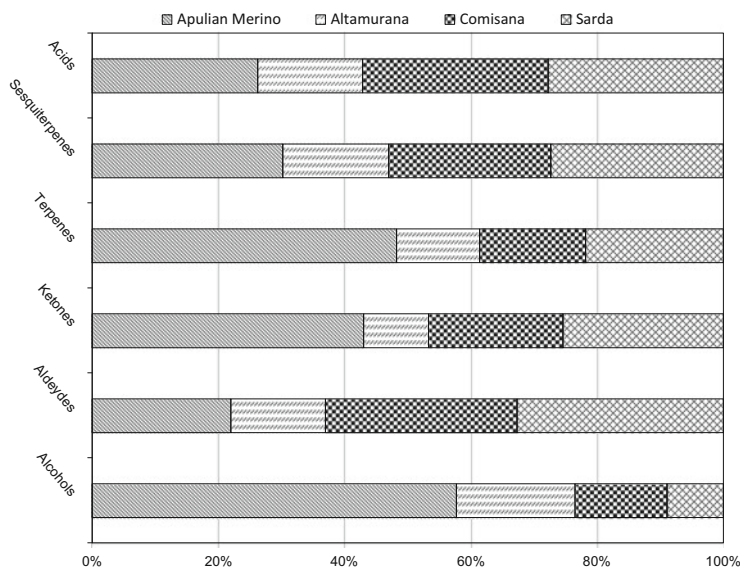


Fig. 3 Effect of sheep breed on percentage of volatile organic compounds in *Canestrato Pugliese* cheese (Claps et al. 2008; Di Trana et al. 2009)

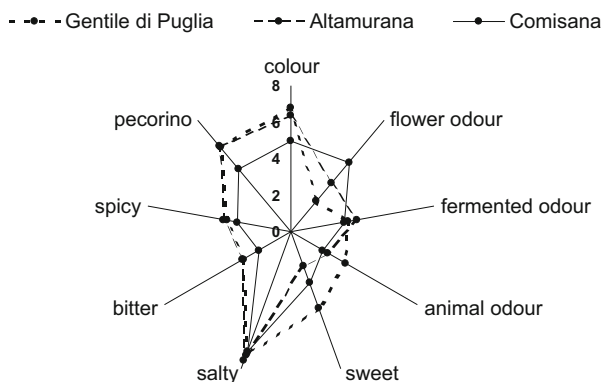
ketones and secondary alcohols, arise from the lipolysis of myristic and palmitic acids.

In our study, the sheep breed affected VOC profile of cheese (Fig. 3). In the cheese from G breed, aldehydes and acids excluded, a higher content of alcohols, ketones, terpenes and sesquiterpenes than A and C breed was detected. The highest content of the acid class of VOC found in *Canestrato Pugliese* cheese does not agree with a previous study performed on the same cheese (Di Cagno et al. 2003). These differences may be due to the use of non-starter lactic acid bacteria culture and different procedure to measure VOC profile.

A different VOC profile was found in Pecorino produced by two different breeds, *Apennine* and *Sarda*. Cheese from *Apennine* breed showed a greater level of 8-nonen-2-one and a smaller quantity of diacetyl, 1-butanol, 3-methyl-2-buten-1-ol and 2,3-butanediol than other breed (Esposito et al. 2014). The breed effect on VOC profile was also detected by Ferreira et al. (2009) on Portuguese “Castelo Branco” PDO cheeses manufactured with milk from different sheep breeds (Merino da Beira Baixa, Assaf, and Crusade). The same authors reported that the discriminant analysis of volatile fraction of PDO Castelo Branco cheese can be used to evaluate breed origin.

The sensory profile of *Canestrato Pugliese* cheese showed that the breed affected some parameters of cheese sensory properties (Fig. 4). G and A cheeses had higher scores of “pecorino”, “bitter”, “spicy” tastes and “colour” than C breed. No differences were found among breeds for “salty” and “fermented odour” tastes.

Fig. 4 Effect of sheep breed on sensory profile of *Canestrato Pugliese* cheese (Claps et al. 2008; Di Trana et al. 2009)



The relationship between ovine breeds and sensory characteristics of *Canestrato Pugliese* cheese was reported in our previous studies (Claps et al. 1999; Taibi et al. 2000). The present study suggests that the panel test could discriminate between cheese made from *Comisana* breed and cheeses from native breeds (*Altamurana* and Apulian Merino) by the colour and smell.

Regarding sheep, few studies have been conducted about the influence of breed on cheese sensory profile. Comparing cheeses produced in various parts of Spain from different ewe breeds, Gonzalez Viñas et al. (1999) indicated that the diversity of cheese sensory profile arises from their chemical composition and indirectly by animal breed. The breed effect on cheese sensory analysis was highlighted by Ferreira et al. (2009) in a study on “Castelo Branco” cheeses manufactured with milk from different breeds (Merino da Beira Baixa, Assaf, and Crusade). The results from descriptive analysis and triangle tests confirmed that these cheeses showed significantly different sensory characteristics.

2.3 Conclusion

The results indicate that chemical composition and FA profile of milk and cheese and VOC compounds and sensory properties of *Canestrato Pugliese* cheese vary according to sheep breed. Milk and cheese from Apulian Merino and *Altamurana* breeds have nutritional characteristics and sensorial properties distinguishable from other breeds. The Discriminant Analysis of FAs, the VOC profile and sensory attributes are interconnected tools able to discriminate the origin of the cheese. The differences among breeds for milk FA profiles, according to the reviewed literature on cheese characteristics, are likely to affect cheese quality and could be an indicator of typicality in order to adding value to local and endangered *Altamurana* and *Gentile di Puglia* (Apulian Merino) breeds.

3 Goat Breeds and *Caciotta* Cheese

In this paragraph, we report an example that can be considered a case study. The study was carried out at the CRA-ZOE experimental farm of Bella-Muro (40°38'N; 15°49'E), located at 360 m a.s.l in the Basilicata region (Southern Italy), during spring. The maximum and minimum environmental temperatures and relative humidity were 13 °C, 5 °C and 70 % in spring, 24 °C, 14 °C and 64 % in summer, 16 °C, 8 °C and 71 % in autumn and 7 °C, 1.3 °C and 77 % in winter. Average annual rainfall was 752 mm, mainly distributed in autumn. Temperature humidity index was 57, 72, 62 and 50 in spring, summer, autumn and winter, respectively. In autumn–winter, the contribution of botanical families in the native pasture was 92 % *Graminaceae*, 1 % *Leguminosae*, 7 % *Forbs* and the main species present were *Lolium perenne* (60 %), *Dactylis glomerata* (25 %), *Phleum pratense* (5 %). In spring–early summer, the botanical composition was 28 % *Graminaceae*, 3 % *Leguminosae*, 68 % *Forbs* and the main species were *Cichorium intybus* (15 %), *Asperula odorosa* (12 %), *Phleum pratense* (10 %), *Crepis* sp. (9 %), *Galium verum* (9 %), *Convolvulus arvensis* (8 %), *Lolium perenne* (8 %) and *Daucus carota* (7 %).

A flock set-up of four goat breeds, *Girgentana* (G), *Jonica* (I), *Maltese* (M) and Red Syrian (R) breeds (Table 3), were used. *Girgentana* breed, native of Sicily, and *Jonica*, native of Apulian and Basilicata regions, were compared with two non-native breeds: *Maltese* and Red Syrian.

Mature goats from each breed were selected on the basis of homogeneous days in milk (110 ± 10) and body condition score (2.60 ± 0.25). All goats grazed on native pasture and they received hay *ad libitum* plus a small amount of mixed grain in two equal meals at morning and evening milking.

This diet reflects the common feeding regimen of grazing goats in Mediterranean environments according to the herbage allowance at pasture.

3.1 *Caciotta* Cheesemaking, Sampling and Analysis of Milk and Cheese

Three cheesemakings of *Caciotta* cheese for each goat breed were carried out for three consecutive days in CRA-ZOE experimental dairy.

Table 3 Goat breeds

Goat breed	Population size (heads) ^a	Diffusion areas in Italy ^b	Prolificacy %	Fertility %	Kid at 40 days (kg)	Lactation (days)	Lactation yield ^c (kg)	Fat %	Protein %
Girgentana—L.G.	1,776	Sicilia, Umbria, Basilicata	180	90	8.0	210	252 ± 126 ^d	3.9 ^e	3.5 ^e
Jonica—L.G.	836	Puglia, Basilicata	170	95	13.2	210	290 ± 112 ^f	5.3 ^f	4.0 ^f
Local—R.A. (Cilentana Grigia)	129	Campania	150	90	9.0	180	200 ± 20	3.6 ^g	3.3 ^g
Maltese—L.G.	3,487	Sicilia, Sardegna, Basilicata, Lazio, Calabria	80	96	11.0	210	292 ± 102 ^d	4.3 ^f	3.6 ^f
Rossa di Siria (<i>Red Syrian</i>) R.A.	2,138	Sicilia, Basilicata, Calabria	210	95	11.0	210	178 ± 69 ^d (570 in Sicily) ^f	4.1 ^f	3.6 ^f

L.G. genealogical book; R.A anagraphic logbook

^aRegistered heads, June 2014, ASSONAPA

^bIn order of population size

^cMultiparous doe

^dItaly: Milk recording activity, official statistics, AIA (2013)

^eTodaro et al. (2005)

^fNoè et al. (2005)

^gPizzillo et al. (2005)

Goat Caciotta Cheese



Caciotta cheese (from the *left*): Pure, thyme-spiced and wine-ripened cheese

Whole goat milk cheese. It weighs 500–600 g, and it is ripened for 20–30 days; the shape is cylindrical, 15 cm in diameter and 11 cm high; the rind is ivory coloured, the texture is compact, the paste is semi-soft, with rare eyes or eyeless, and white-ivory coloured. The odour is pleasantly acidic-fermented, the taste is sweet, typical and slightly goaty. This cheese can be flavoured with various ingredients. For example, with thyme (Thyme-spiced Goat Caciotta cheese): the rind is barely formed and covered by thyme leaves, which give the typical aroma to the cheese. Moreover, with wine: in this case (Wine-ripened Goat Caciotta cheese¹), the rind is dark-red coloured because of the ripening in Aglianico del Vulture grape vinasse, which gives the typical red plonk colour and aroma to the cheese. When correctly ripened, the flavoured rinds are edible and enrich the taste and nutritional value of the cheeses with the aromas, the antioxidant compounds and vitamins contained into the leaves and vinasse.

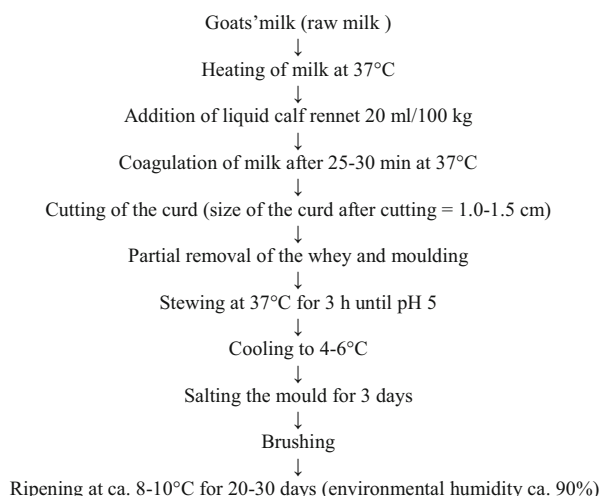
The flowchart of cheese-making process is shown in Fig. 5. *Caciotta* cheese was ripened for 1 month in a natural cave at CRA-ZOE of Bella.

Milk samples were collected during the morning and evening milking, and cheeses were sampled at the end of the ripening period. Chemical composition, pH, FA content and C14:1/C14:0 ratio were measured both in milk and cheese samples. VOC and sensory profile of *Caciotta* cheese were evaluated. Methods used for analytical assessments are given in previous section (see Sect. 2.1).

Changes in chemical composition, FA profile, VOC profile and textural properties of milk and *Caciotta* cheese were analysed by ANOVA procedure (Systat 7 1997) including the breed effect (*Girgentana*, *Jonica*, *Maltese* and Red Syrian). Data of sensory profile were normalised before submitting them to ANOVA repeated measures procedure. Significance was declared at $P < 0.05$, and tendencies were declared at $0.05 < P \leq 0.10$; differences between means were tested using Fisher's LSD test. In order to ascertain the discriminant effect of the breed on

¹ Goat cheese type pointed out by CRA-ZOE with Aglianico del Vulture, a Lucanian red wine (www.entecra.it).

Fig. 5 Flowchart of *Caciotta* cheese



products, FA data of milk and cheese were pooled *per* breed and submitted to a multivariate approach by Stepwise Discriminant Analysis (Systat 7 1997).

3.2 Results and Discussion

Goat breed affected the chemical composition of milk (Table 4). Milk from *Maltese* breed was characterised by higher contents of dry matter, fat and protein compared to the milk from the other breeds. Milk from *Jonica* goats showed higher contents of dry matter, fat, protein and ash than milk from R and G breeds. There were no significant differences among breeds on pH data. In the same study, the goat breeds affected also caseinic nitrogen (CN) and non-proteic nitrogen (NPN) fractions, M goats showing a CN content 30 %, 14 % and 16 % higher than in the milk from R, I and G goats, respectively (Claps et al. 2007). Milk dry matter from the non-native R breed did not differ significantly from milk dry matter of G breed.

A negligible breed effect on chemical composition of *Caciotta* cheese was observed (Table 4). Cheese made from milk of M breed was characterised by higher dry matter and fat contents compared to cheese from the other breeds, though the differences are not significant. The pH and ash values were statistically higher in cheese from M breed.

As FA profile is concerned, some studies in sheep (Addis et al. 2005; Claps et al. 2007) and cow (Sinclair et al. 2007) have shown that the FA profile of cheese reflects that of milk. In our study, breed had an effect on FA profile of milk and *Caciotta* cheese and both showed a similar trend. The levels of PUFA, omega-3, CLA and total *trans* FA were higher in milk from G breed than in that from the other breeds. SFA, MUFA and omega-6 contents in milk did not change among

Table 4 Effect of goat breed on chemical composition (%), fatty acid content (g/100 g FA) and index of milk and *Caciotta* cheese (Claps et al. 2007; Di Trana et al. 2009)

Product	Milk			Cheese						
Breed ¹	M	R	I	G	SEM	M	R	I	G	SEM
Chemical composition										
pH	6.57	6.61	6.51	6.66	0.02	4.78 ^a	4.43 ^b	4.27 ^b	4.40 ^b	0.06
Dry matter	13.83 ^a	12.17 ^c	12.90 ^b	11.10 ^c	0.18	53.69	53.27	51.75	50.06	1.46
Fat	4.70 ^a	3.47 ^c	4.30 ^b	3.97 ^b	0.15	27.25	24.00	26.00	24.38	1.12
Protein	3.91 ^a	3.34 ^c	3.66 ^b	3.13 ^d	0.05	18.07	21.00	18.56	18.95	0.98
Ash	0.74 ^b	0.73 ^b	0.84 ^a	0.73 ^b	0.001	5.56 ^a	4.07 ^{cb}	3.37 ^b	4.81 ^{ca}	0.28
Fatty acids ²										
SFA	70.61	71.35	70.66	70.18	0.40	70.26	71.28	71.11	70.69	0.43
MUFA	24.90	24.12	24.83	24.54	0.33	25.18	24.54	24.61	24.00	0.39
PUFA	4.48 ^b	4.53 ^b	4.52 ^b	5.28 ^a	0.09	4.56 ^b	4.18 ^c	4.28 ^{abc}	5.31 ^a	0.08
Omega-3	0.94 ^b	1.02 ^b	0.096 ^b	1.15 ^a	0.02	1.08 ^a	0.91 ^b	0.94 ^b	1.18 ^a	0.03
Omega-6	2.04	2.18	2.12	2.02	0.05	2.00 ^a	1.74 ^b	1.91 ^{ab}	1.96 ^a	0.05
CLA	0.56 ^c	0.61 ^{bc}	0.65 ^b	0.71 ^a	0.01	0.54 ^c	0.62 ^b	0.64 ^b	0.74 ^a	0.01
Total <i>trans</i>	1.34 ^b	1.32 ^b	1.38 ^b	1.74 ^a	0.03	1.43 ^a	1.42 ^a	1.42 ^a	0.79 ^b	0.05
Index										
Δ ⁹ desaturase activity	0.037 ^b	0.038 ^a	0.036 ^c	0.033 ^d	0.00	0.037 ^b	0.038 ^a	0.036 ^c	0.033 ^d	0.00
Health promoting index	0.43	0.43	0.41	0.44	0.01	0.45 ^a	0.42 ^c	0.40 ^{bc}	0.43 ^{ac}	0.01

Means within row with different superscripts differ at ^a, ^b, ^c, ^d $P < 0.05$

¹M Maltese; R Red Syrian; I Jonica; G Girgentana breeds

²SFA saturated fatty acids; MUFA monounsaturated fatty acids; PUFA polyunsaturated fatty acids; CLA conjugated linoleic acid; SEM standard error mean

breeds. Indeed, the *Caciotta* cheese made from milk of *Girgentana* breed contained more PUFA, omega-3, omega-6 and CLA and less total *trans* FA. The different FA profile among breeds might be a useful tool in quality improvement of milk and derived products. These results agree with our previous study (Di Trana et al. 2006a, b) in which we found significant differences in FA profile of milk from *Girgentana*, Cashmere, Red Syrian and *Maltese* breeds.

The Δ^9 -desaturase activity index (calculated as C14:1/C14:0 ratio) was significantly affected by goat breed in both milk and cheese. This index was higher in R breed compared to M, I and G breeds. The results suggest the breed effect in expression of Δ^9 -desaturase enzyme in the mammary gland as observed in our previous study (Di Trana et al. 2006a, b) in addition to the effect of animal species observed by Addis et al. (2005).

In the Canary Islands, Fresno et al. (2001) found significant differences between soft cheeses made from Majorera and Tinerfeña goats; chemical composition only affected the soft cheese. Later studies (Alvarez et al. 2008; Fresno and Alvarez 2007), considering other Canary goat breeds (Majorera and Palmera), demonstrated significant gross chemical differences. Cheeses from Majorero milk presented better values for fat and protein parameters but less moisture content and pH. The FA profile was very similar between breeds although sensorial features had many differences. Fresh cheeses made with Majorera goat milk presented higher roughness, firmness and friability values than cheeses from the other breeds but lower elasticity and solubility. Hard cheeses from Palmero breed were more elastic and rough than others, although firmness, friability and solubility values were lower.

In a Pakistani study, a significant effect of breed was reported in cow (Talpur et al. 2006) and goat (Talpur et al. 2009) milk. Comparing Kamori and Pateri goats kept under the same feeding and housing condition, authors reported a better FA profile with lower SFA and higher CLA content in Kamori milk. As regards cow breeds with identical dietary intake, the milk of Red Sindhi breed showed a higher content of MUFA, PUFA and CLA compared to White Thari milk.

Soryal et al. (2005), comparing the milk of Egypt Nubian and Alpine breeds, reported significant differences in fat, total protein, casein and total solids, with Nubian goat having higher contents. This gross milk composition affected cheese yield, but it did not change cheese composition and sensorial scores. Moreover, only oleic acid and unsaturated fatty acids were affected by breeds, with Alpine milk having higher content.

In Portugal, goat milk is mainly used for traditional cheesemaking, sometimes also mixed with ewe milk, or for direct household consumption but on a very limited scale. Trancoso et al. (2010) undertook a study with the main Portuguese indigenous breeds (Serrana Transmontana, Serrana Ribatejana, Serpentina, Charnequeira and Algarvia) and a foreign breed reared in Portugal (Saanen) in order to compare their milk composition, particularly concerning the micronutrients. The results showed that the Serrana breed could be distinguished from the others and there was a significant difference between both ecotypes (Serrana Transmontana SRT, Serrana Ribatejana SRR). SRT and SRR milk showed higher and lower levels of milk chemical constituents, respectively, compared to

milk of the other breeds. Milk from the foreign breed Saanen (SA) did not differ significantly from milk of the indigenous breeds, leading to suggestion that breed might not be as important for milk composition as geographical region and production system.

In Ethiopia, Mestawet et al. (2012) evaluated the cheese production potential and suitability of indigenous breeds by comparing four goat breeds, two indigenous (Somali and Arsi-Bale), one non-native (Boer) and one crossbreed (Toggenburg \times Arsi-Bale). They observed a breed effect on milk characteristics. In fact, the indigenous goats had a lower milk yield than the improved European goat breeds. However, they showed higher values in major milk components than most of the non-native breeds. In particular, Arsi-Bale goats had significantly higher protein content (4.8 %) than the others. Superior chemical composition observed in milk from indigenous Ethiopian goats revealed their potential for cheese production.

Due to a large number of FA in milk and *Caciotta* cheese, data were pooled *per* breed and analysed using a multivariate approach. Discriminant analysis, performed simultaneously on FA profile of milk and *Caciotta* cheese, clearly separates the goat products obtained from different breeds. A canonical scores plot of the two canonical discriminant functions showed M at the bottom, G on the left, I on the right and R in the centre (Fig. 6). However, R and I breeds did not show a strong distance. The most important FAs that contributed to the separation among breeds were short-chain FAs, medium-chain FAs, saturated FAs, monounsaturated FAs, omega-3, omega-6 and CLA. Under our experimental conditions, these results support the differences of milk and cheese among breeds consuming the same diet.

During cheese ripening, biochemical reactions lead to the formation of cheese aroma. Flavour compounds are produced from three major milk constituents: lactose, lipids and proteins. Aroma development in cheese products results from the metabolic activities of cheese bacteria, by glycolysis, lipolysis and proteolysis

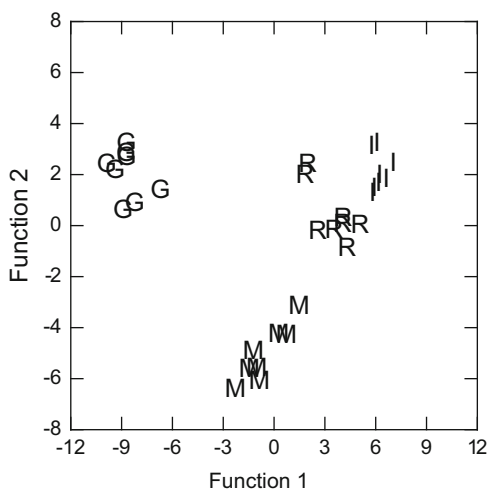


Fig. 6 Distribution plot of milk and *Caciotta* cheese using two canonical discriminant functions (Claps et al. 2007; Di Trana et al. 2009). (G) *Girgentana*, (I) *Jonica*, (M) *Maltese* and (R) *Red Syrian* breeds

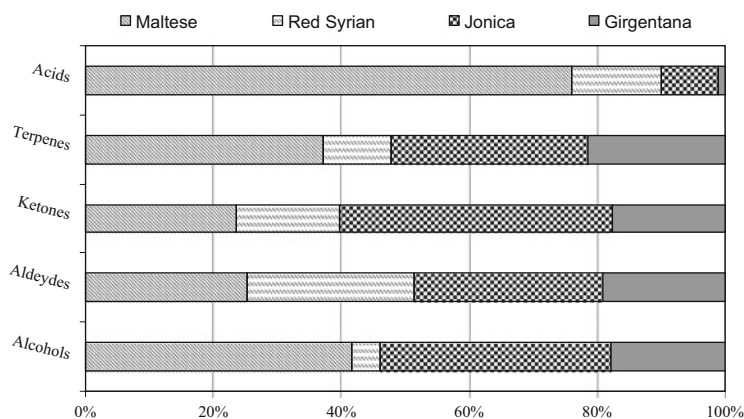


Fig. 7 Effect of goat breed on percentage of volatile organic compounds in *Caciotta* cheese (Claps et al. 2007; Di Trana et al. 2009)

(Marilley and Casey 2004). The Volatile Organic Compounds (VOCs) profile provides a “fingerprint” (Mariaca and Bosset 1997) of what happens during ripening.

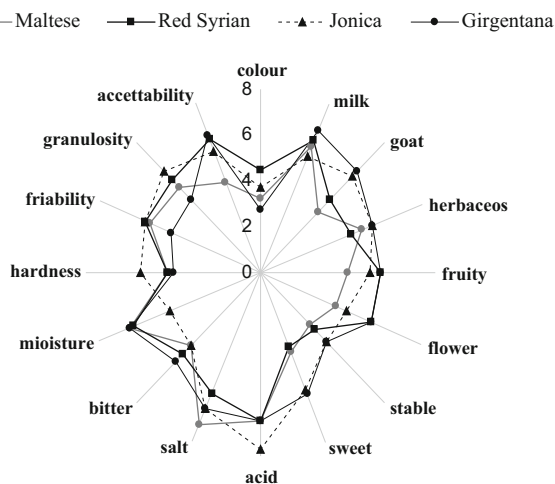
In our study, goat breed affected the VOC profile of *Caciotta* cheese. Detected headspace compounds were grouped according to their nature in acids, alcohols, aldehydes, ketones and terpenes. Significant differences were found among individual classes of aromatic compounds whose higher values were observed in M cheese, with the exception of ketones (Fig. 7). The acid class was wider in cheeses from M and R breeds compared to I and G ones.

The main source of this class is lypolysis, but it can also be the result of the lactose metabolism, directly from acetyl-CoA or formed from amino acid conversion (Tavaria et al. 2004). This class is involved in cheese aroma like “sweet” and “goaty” flavour note or in a rancidity defect when it is present in very large amounts (Tavaria et al. 2004). As alcohol class is concerned, the butan-1-ol compound is linked to “sweet, fruity” flavour note (Ferreira et al. 2009). In our study G and I cheeses showed low and high incidence of acids and alcohols compounds, respectively. Both compounds seem connected to the high “sweet” taste observed in G and I cheese and “flower” taste in cheese from G breed (Fig. 8).

The terpene class in cheeses is of plant origin and not of microbial origin (Belitz and Grosch 1986). The greater incidence of terpenes in the M, I and G cheeses than R ones suggests different grazing behaviour of goat breeds. The differences of the VOC content among breeds seem to be linked to the different grazing behaviour and intake of botanic species of goat breeds at pasture (Fedele et al. 2005; Claps et al. 2010) as well as to their genetic characteristics (see Sect. 3.3) such as wide casein polymorphism (Coulon et al. 2004).

The characteristic “goat” flavour, and its link with animal breed, was shown many years ago by Ronningen (1965). A subsequent study (Skjeldal 1979) showed a stronger taste in cheese made with Norwegian goat milk than Saanen milk. Cheese volatile fraction and consequently sensory characteristics are affected by climatic

Fig. 8 Effect of goat breed on sensory profile in *Caciotta* cheese (Claps et al. 2007; Di Trana et al. 2009)



conditions and raw milk quality, which depends on the animal species, breed, feed, farming and adventitious microflora of the raw milk (Collomb et al. 1999; Tavaría et al. 2002). In our study, the breed affected all parameters of *Caciotta* cheese sensory properties (Fig. 8). *Girgentana* cheese showed a significantly higher value of “milk odour”, “bitter”, “sweet”, “fruity” and “herbaceous” taste than others. *Girgentana* cheese had a lower value of granulosity and friability than the other breeds, probably due to its fat and protein content, as observed for ricotta cheese (see Sect 4.2). The higher value of “herbaceous” taste for G and I cheeses might be explained by the greater incidence of terpenes in these cheeses compared to R ones.

3.3 Goats and Genetic Variants of Casein Fractions

Goat casein genes show a high level of polymorphism due to the presence of several alleles in different loci in some populations. In particular, the α s1-casein (CSN1S1) locus shows 17 alleles (Grosclaude and Martin 1997; Martin et al. 2002), the β -casein (CSN2) and α s2-casein (CSN1S2) loci 8 alleles each (Marletta et al. 2007; Ramunno et al. 2001) and the κ -casein (CSN3) locus shows 21 alleles (Prinzenberg et al. 2005; Gupta et al. 2009). Except for the CSN3 gene, the polymorphism is not only due to qualitative differences but also to quantitative differences since some alleles affect the level of expression of the gene itself.

According to the level of synthesised α s1-casein, the CSN1S1 alleles have been divided into strong (A, B1, B2, B3, B4, C, H, L and M), medium (E and I), low (D, F and G) and null (O1, O2 and N), producing about 3.6 g/l; 1.6 g/l; 0.6 g/l; 0 g/l of casein, respectively. The CSN1S1 alleles have also a different influence on cheese flavour. In fact, Grosclaude and Martin (1997) report a less pronounced goat flavour in cheese obtained from AA milk compared to cheese obtained from FF milk.

Table 5 Allelic frequencies at the α s1-casein (CSN1S1), β -casein (CSN2) and α s2-casein (CSN1S2) loci in goat populations reared in southern Italy. Data were obtained from different authors

	Red Syrian	<i>Girgentana</i>	<i>Jonica</i>	<i>Maltese</i>
CSN1S1				
A	0.303 ^a	0.590 ^b –0.351 ^a	0.350 ^c	0.249 ^a –0.414 ^c
B	0.096 ^a	0.065 ^b –0.129 ^a	0.305 ^c	0.108 ^a –0.157 ^c
E	–	–	0.064 ^c	0.004 ^a –0.057 ^c
F	0.325 ^a	0.290 ^b –0.186 ^a	0.282 ^c	0.327 ^a –0.371 ^c
N		0.047 ^b –0.040 ^a	–	0.011 ^b
CSN2				
A	0.111 ^a	0.071 ^a	0.207 ^d	0.142 ^a –0.129 ^d
C	0.547 ^a	0.556 ^a	0.700 ^d	0.464 ^a –0.819 ^d
0'	0.053 ^a	0.096 ^a	0.093 ^d	0.088 ^a –0.052 ^d
CSN1S2				
A	0.243 ^a	0.535 ^a –0.722 ^c	0.291 ^c	0.153 ^a –0.286 ^c
B	–	0.023 ^a	0.014 ^c	0.086 ^c
C	0.186 ^a	0.055 ^a –0.051 ^c	0.355 ^c	0.130 ^a –0.264 ^c
E	0.012 ^a	0.002 ^c	0.005 ^c	0.038 ^a –0.107 ^c
F	0.254 ^a	0.101 ^a –0.225 ^c	0.332 ^c	0.382 ^a –0.250 ^c
D	–	0.006 ^a	–	–
0	–	–	0.005 ^c	0.004 ^a –0.007 ^c

^aGigli et al. (2008)

^bMastrangelo et al. (2013)

^cSacchi et al. (2005)

^dChessa et al. (2005)

^ePalmeri et al. (2014)

The CSN2 alleles are divided in normal alleles (A, A1, B, C, D and E), producing a normal quantity of α -casein (about 5 g/l), and 0 and 01 alleles characterised by the absence of synthesis of α -casein.

The CSN1S2 alleles are characterised by a normal (A, B, C, E, F and G) (2.5 g/l), weak (D) (1.5 g/l) and null (0) (0.0 g/l) production of α s2-casein.

The level of total milk casein is important both for its impact on cheese-making properties (strong alleles are associated with better technological properties of milk, fat percentage and fatty acid composition (Remeuf 1993; Valenti et al. 2010; Zullo et al. 2005)) and for particular dietary requirements (El-Agamy 2007). As a consequence, particular attention must be paid to casein polymorphism in breeding programmes to obtain a milk rich in casein suitable for cheesemaking or a milk deprived of a casein fraction to be used for hypoallergenic diets. In this context, local goat populations, characterised by a high genetic variability at the casein loci (Table 5), could be the start point of both selection programmes in order to reach different destinations of the final product.

The genotyping of CSN1S1, CSN2 and CSN1S2 loci in *Maltese* and Red Syrian populations reared in Basilicata showed results characterised by a good, though slightly different from those shown in Table 6, genetic variability: CSN1S1 A (0.571) F (0.212) B(0.125) E (0.038) N (0.054) and CSN1S2 “strong alleles” (0.958), 0 (0.022) in Red Syrian; CSN1S1 A (0.659) F (0.305) B(0.012) E (0.012)

Table 6 Haplotype frequencies at casein loci in goat populations reared in southern Italy. Data were obtained from different authors

	Red Syrian	<i>Girgentana</i>	<i>Jonica</i>	<i>Maltese</i>
I ^a (10.5 g/l)	0.320 ^b	0.530 ^b	0.539 ^c	0.240 ^b –0.400 ^c
II (5.5 g/l)	–	0.005 ^b	–	0.007 ^b
III (8.1 g/l)	–	–	0.044 ^c	0.024 ^c
IV (7.5 g/l)	0.321 ^b	0.250 ^b	0.250 ^c	0.380 ^b –0.368 ^c

^aRando et al. (2000) Quantitative haplotypes observed at the goat calcium-sensitive casein loci

^bGigli et al. (2008)

^cSacchi et al. (2005)

N (0.012) and CSN1S2 “strong alleles” (0.989) 0 (0.011) in *Maltese* (our unpublished results).

Test for casein haplotype could be more useful as the four casein genes are closely linked in a 250 kb DNA segment on chromosome 6. Association of strong alleles at the calcium-sensitive casein loci will lead to milk rich in total casein (10.5 g/l), while association of strong and weak allele should decrease the total casein content (Rando et al. 2000).

The analyses of casein haplotypes showed that haplotype I (Rando et al. 2000) which should produce the maximum level of total casein (10.5 g/l) had higher frequencies in *Girgentana* and *Jonica* breeds than in Red Syrian and *Maltese* breeds. So, Gigli et al. (2008) suggest that although their milk should be more suitable for cheesemaking, the largest number of haplotypes has been found in *Maltese* breed. Interestingly, in *Maltese* breed Sacchi et al. (2005) found a specimen heterozygote for a haplotype that should produce only 2.5 g/l of total casein.

3.4 Goat Breeds and Oligosaccharide Fraction

All the special characteristics and qualities that add value to local breeds should be exploited in order to find new roles for the breeds. The oligosaccharide fraction appears to be an interesting and promising feature.

Goat milk contains smaller casein micelles and fat globules, higher concentration of some whey proteins and oligosaccharides than bovine milk (Silanikove et al. 2010). The fraction of oligosaccharides (OS) in goat milk is becoming increasingly important for its known bio-functional role in consumers. Oligosaccharides, 3–10 monosaccharide residues, are either acid containing N acetylneuraminic acid (sialic acid) or neutral. OS promote bifidobacteria growth in the neonate and play a role as intestinal mucosal cell protectors against pathogens. In addition, they play an essential role in neonatal brain development (Gopal and Gill 2000). Goat colostrum and milk have shown an OS profile similar to that of human milk and a highest content of sialyloligosaccharides (SOS) in comparison to milk from other ruminants; Puente et al. (1996) found four times as much sialic acid in goat milk as in cow milk. In the last decade, OS were characterised (Viverge

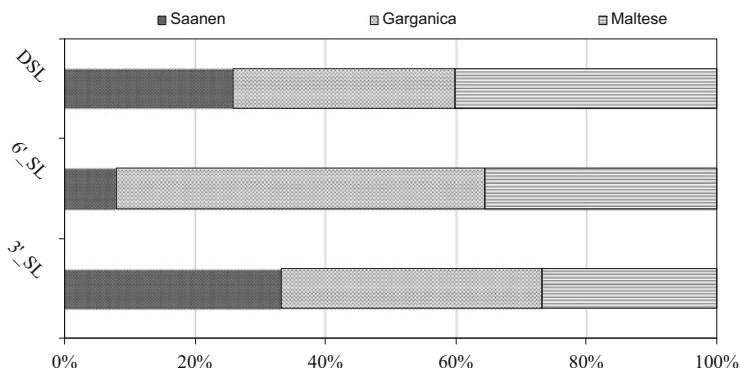


Fig. 9 Effect of goat breed on percentage of sialyloligosaccharides in milk (Claps et al. 2014)

et al. 1997) and quantified (Martinez-Ferez et al. 2006) in goat milk, and Baro Rodriguez et al. (2005) isolated and identified 25 oligosaccharides in Murciano-Granadina goat milk.

Recently, some studies have focused on the comparison of milk OS between goats with and without the genetic ability to synthesise α s1-casein (Meyrand et al. 2013), on the effect of genotype, at α s1-casein locus, and diet on SOS in goat milk (Di Trana et al. 2014a) and on the SOS content and their variation in the colostrum and milk of several goat breeds (Claps et al. 2014). In our study, the goat breed affected the content of three SOS: 3'-sialyllactose (3'-SL), 6'-sialyllactose (6'-SL) and disialyllactose (DSL). Differences in SOS compounds were found from colostrum to milk in *Garganica* and *Maltese* breeds. *Garganica* breed, a local breed of Gargano promontory in Apulian region, showed the higher values of 3'-SL and 6'-SL, while *Maltese* breed exhibited the higher content of DSL (Fig. 9). The same trend was observed comparing these data with unpublished data on Saanen breed. Although further studies are required, goat milk from native breeds appears to be an attractive natural source of human-like oligosaccharides for infant and health-promoting formulas, due to its composition and content.

3.5 Conclusion

Milk and cheese from *Girgentana* breed are distinguishable for FA profile, nutritional index and sensory properties compared to other breeds. Cheese from *Girgentana* breed shows a VOC profile that is confirmed by the corresponding sensory profile. The genetic types of goat and the genetic variants of casein fractions could have influenced the sensory profile of cheeses. The results are due to the presence in raw material of molecules produced by animals (fatty acids and casein) and also caused by grazing behaviour. These characteristics are the basis of the complex and multifactorial mechanism making the product “typical”. These

peculiarities add value to the *Girgentana* breed and therefore give a support in favour of this breed amplifying its sustainable use. The high quantity of SOS found in local breed *Garganica* compared to foreign breed appears an interesting and promising feature for adding value to local breeds.

4 Goat Breeds and *Ricotta* Cheese

In this section, we report a further example that can be considered a case study. Among products made from whey, *Ricotta* cheese is likely the earliest. It is considered as a high-moisture product, and it is essentially a co-precipitate of proteins with a mild flavour and soft texture.

Goat Ricotta Cheese



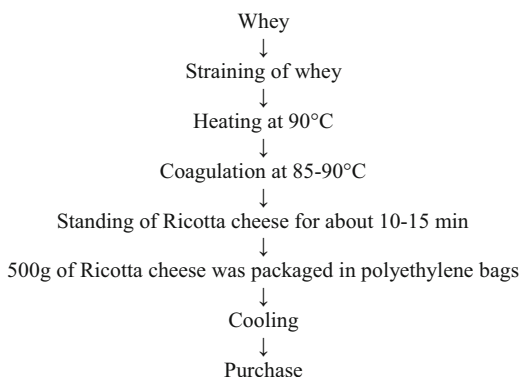
Whole goat whey cheese. It weighs 200–500 g and is consumed fresh; its shape is cylindrical, 11 cm in diameter and 8 cm high; there is no rind, the texture is compact but creamy, the paste is spreadable, eyeless and pure white coloured. Its odour is pleasantly lactic, no goaty; its taste is sweet, lactic, sapid and cloaking, slightly goaty.

This study was conducted under the same condition as for goat breed and *Caciotta* cheese case (see Sect. 3). The experimental flock was set-up with goats belonging to the *Local* (L), *Girgentana* (G), Red Syrian (R) and *Maltese* (M) goat breeds (Table 3). The flock management and feeding system are reported in the previous case (see Sect. 3) study.

4.1 *Ricotta* Cheesemaking, Sampling and Analysis of Milk and Cheese

Three *Ricotta* cheese-making trials for each breed were conducted. A simplified flowchart of cheese-making process is shown in Fig. 10. Thirty-six samples of whole milk, whey and *Ricotta* cheese were analysed for their chemical

Fig. 10 Flowchart of *Ricotta* cheese



composition, FA profile, textural properties and sensorial properties. The analytical methods and assessment procedure are previously reported (see Sect. 2.1).

Changes in milk, whey and *Ricotta* cheese of chemical composition, FA profile, textural properties and sensory profile were analysed by ANOVA procedure (Systat 7 1997). The statistical analysis evaluated the effect of *Local*, *Girgentana*, *Maltese* and Red Syrian breeds. Data about sensory profile were normalised before submitting them to ANOVA repeated measures procedure. Significance was declared at $P < 0.05$; differences between means were tested using Fisher's LSD test.

4.2 Results and Discussion

The average gross composition of milk, whey and *Ricotta* cheese for each breed is shown in Table 7. The breed effect was more evident in *Ricotta* cheese than in whey and milk.

The main effects of goat breed in *Ricotta* cheese were found in dry matter, fat and lactose contents. The milk produced by R breed showed higher fat content when compared to the M and L breeds. G milk exhibited intermediate values. As concern the whey fraction, G, R and L breed had a higher content of dry matter than M breed. *Ricotta* cheese from the *Girgentana* breed showed a higher dry matter and lactose content and an intermediate fat content than the same product from R and M breeds. The *Ricotta* cheese from *Local* breed exhibited an interesting chemical composition with high fat and dry matter content. *Ricotta* cheese did not reflect the milk gross composition in terms of fat and dry matter. According to Pintado and Malcata (1996), differences between milk and *Ricotta* cheese are related to heating time and heating temperature during *Ricotta* cheesemaking.

The FA profile of *Ricotta* cheese was significantly affected by breed (Fig. 11). The cheese made from *Girgentana* breed contained significantly lower SFA content than other breeds. Compared to the L breed, G, R and M breeds had a higher content of MUFA, because of the higher oleic acid level. A higher PUFA content was

Table 7 Effect of breed on pH and chemical composition of milk, whey and *Ricotta* cheese (Pizzillo et al. 2005)

Product	Milk %			Whey %						Ricotta cheese %DM					
	G	R	M	L	SEM	G	R	M	L	SEM	G	R	M	L	SEM
Breed ¹															
pH	6.54	6.51	6.57	6.58	0.03	6.44	6.46	6.35	6.28	0.08	6.27	6.43	6.41	6.32	0.07
DM ²	12.34	11.46	11.96	12.07	0.36	8.05 ^a	8.03 ^a	7.51 ^b	8.04 ^a	0.26	32.13 ^a	28.62 ^b	29.89 ^b	32.07 ^a	1.58
Fat	3.78 ^{ba}	4.10 ^a	3.52 ^b	3.59 ^b	0.24	1.58	1.82	1.64	1.72	0.11	64.56 ^b	61.63 ^c	66.83 ^b	71.75 ^a	3.73
Protein	3.33	3.33	3.13	3.29	0.09	1.14	1.15	1.05	1.02	0.06	20.77	24.00	21.03	19.81	1.42
Lactose	4.48	4.16	4.55	4.46	0.16	5.62	5.81	5.57	6.29	0.42	11.55 ^a	11.11 ^a	8.87 ^b	5.89 ^b	2.15

Means within row with different superscripts differ at ^{a, b, c} $P < 0.05$
¹G Girgentana; R Red Syrian; M Maltese; L Locale breeds; SEM standard error mean
²DM dry matter

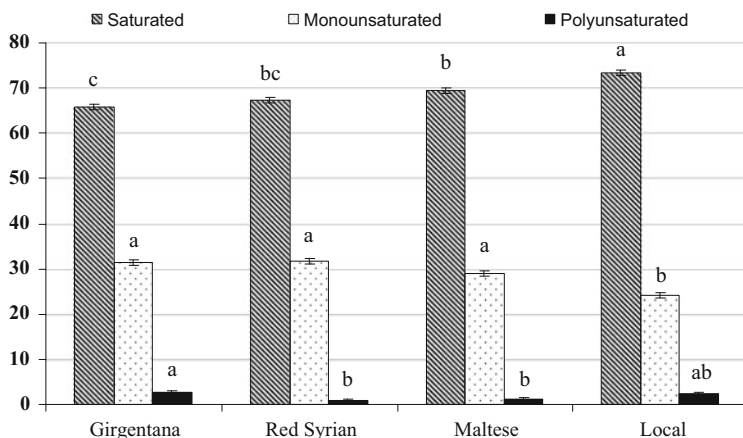


Fig. 11 Effect of goat breed on fatty acid composition (% FAME) of *Ricotta* cheese (Pizzillo et al. 2005). ^{a, b, c} $P < 0.05$

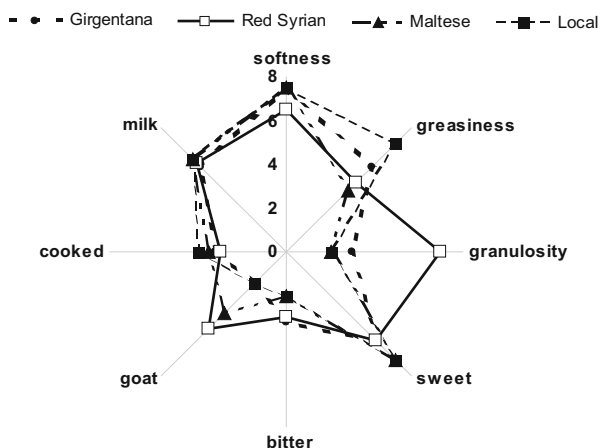
detected in *Ricotta* cheese from *Girgentana* breed compared to others because of the higher linoleic and arachidonic acid levels. Indeed, *Ricotta* cheese from G showed a level of linoleic acid 2.4, 2.7 and 1.1 times higher than R, M and L breeds, respectively, while its arachidonic acid content was 6.4, 1.6 and 1.9 times higher than the others.

As reported in previous studies (Di Trana et al. 2006a, b; Impemba et al. 2005), the breed affected the Δ^9 -desaturase activity index (ratio C18:1/C18:0), G breed having higher index value followed by R, L and M breeds. The product:substrate ratio indicates increased enzyme activity in G breed. The high level of MUFA and PUFA present in *Ricotta* cheese from *Girgentana* goat could encourage the use of this breed.

In goat dairy products, taste plays an important role in consumer acceptance (Ribeiro and Ribeiro 2010). Within the textural and colour properties of *Ricotta* cheese, the adhesiveness only was affected by breed; *Girgentana* breed exhibited a significant higher adhesiveness than *Local* breed, while no differences were detected among the others. The lower value of adhesiveness, detected in *Ricotta* cheese made from whey of *Local* breed, may be due to the higher fat/protein ratio exhibited by this product (Roland et al. 1999). The sensory attributes are shown in Fig. 12. The breed affected some sensory properties of *Ricotta* cheese such as “softness”, “greasiness” and “granulosity”. Higher “softness” and “greasiness” and lower “granulosity” and “goat” attributes were found in cheese from G and L breeds than others.

In our case, the “goat” flavour scores of *Ricotta* cheese made from R and M milk may be related to the different ratio of lipolysis and/or different frequencies of the *as1*-casein locus alleles (see Sect. 3.3). Large differences in texture and taste among cheeses issued from milk of different breeds and/or within breed are linked to the genetic variant of *as1*-casein in goats (Coulon et al. 2004). The characteristic “goat”

Fig. 12 Effect of goat breed on sensory profile of *Ricotta* cheese (Pizzillo et al. 2005)



flavour of goat milk products originates from milk fat and from the rate of fat hydrolysis; moreover, Grosclaude et al. (1994) have emphasised on the genetic dependence (see Sect. 3.3) of the variation of goat flavour intensity.

4.3 Conclusion

The results indicate that sensory properties and FA composition of *Ricotta* cheese vary according to the goat breed. The higher MUFA and PUFA levels, found in *Ricotta* cheese made from whey of *Girgentana* goats, are beneficial to human nutrition. Moreover, the greater “softness” and the lower sensor scores for “granulosity” and “goat” odour exhibited by this product could satisfy consumer demand for a cheese with adequate sensory and nutritional properties. The peculiarities of the *Girgentana* breed may motivate the use of this breed, and they are a tool for amplifying the sustainable use.

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