Journal of Dairy Research (2017) **84** 27–31. © *Proprietors of Journal of Dairy Research 2016*
doi:10.1017/S0022029916000765

Environmental and genetic factors affecting milk yield and quality in three Italian sheep breeds

Maria Selvaggi[1]*, Angela Gabriella D'Alessandro[2] and Cataldo Dario[1]

[1] Department of DETO, Section of Veterinary Science and Animal Production, University of Bari 'Aldo Moro', Valenzano, Italy
[2] Department of Agro-Environmental and Territorial Sciences, University of Bari 'Aldo Moro', Bari, Italy

Received 22 January 2016; accepted for publication 6 October 2016; first published online 23 December 2016

The aims of the study described in the Research Communication were to determine the level of influence of some environmental factors on milk yield and quality traits, including lactose, and lactation length in ewes belonging to three different Italian breeds and to estimate the heritability for the same traits. A total of 2138 lactation records obtained from 535 ewes belonging to three different Italian breeds (Comisana, Leccese, and Sarda) were used. Breed significantly affected all of the considered traits. Moreover, year of lambing affected milk yield and lactation length without influence on milk quality traits. Parity affected significantly only the milk yield, whereas type of birth showed its effect on milk yield, fat, protein, and lactose yield. On the whole, the presently reported heritability estimates are within the range of those already obtained in other dairy breeds by other authors, with values for lactation length being very low in all the investigated populations. Considering the heritability estimates for lactose content and yield, to the best of our knowledge, there is a lack of information on these parameters in ovine species and this is the first report on heritability of lactose content and yield in dairy sheep breeds. Our results suggest that genetic variability for milk traits other than lactation length is adequate for selection indicating a good response to selection in these breeds.

Keywords: Heritability, Italian dairy sheep, milk production, lactose.

Sheep milk production is very important for the economy of Mediterranean countries. Dairy sheep also help to prevent environmental degradation and land abandonment in marginal rural areas. In such difficult environmental conditions, that require a particular adaptation, sheep are able to provide high quality milk that is mainly used to produce traditional cheeses (Selvaggi et al. 2014). Following tradition, lambs are typically allowed free suckling for about 1 month and the milking period starts after weaning. As a consequence, milk production is the most important factor affecting lambs' growth rate. It is well known that milk production is significantly influenced by both genetic and environmental factors. The knowledge of the relative weight of the variance components and the estimation of heritability for milk yield and quality traits may support animal breeding strategies. Genetic parameters are characteristics of the populations and environmental conditions and may change over time due to management decisions.

*For correspondence; e-mail: maria.selvaggi@uniba.it

Local sheep breeds show many important characteristics such as rusticity, resistance and adaptability to difficult environmental conditions. Leccese is an Italian dairy sheep breed. Most researchers accept the theory of a common ancestor with the Zackel sheep, an Asiatic breed that penetrated also into South East Europe. For centuries, Leccese sheep have lived in a traditional breeding site called Salento, a narrow, flat sea level peninsula, in the southern part of Apulia, characterised by a semi-arid climate with long, dry and hot summers and mild winters. Nowadays, the Leccese sheep breed is included in the list of Italian endangered breeds drawn up by the Department for Environment, Food, and Rural Affairs. The Comisana sheep breed originated from the Maltese and Sicilian breeds in the late 19th and early 20th century in the Southeast region of Sicily. Also known as 'red head' because of its characteristic red face, the Comisana is a medium-large breed with all the morphological characteristics of a good dairy breed. This breed is well adapted to the semi-arid Mediterranean environment representing an important resource for the marginal areas of Southern Italy. The Sarda breed is a native breed of Sardinia off the coast of Italy. It originated from the local lowland sheep which were large, polled, and with white wool. Merino and Barbary sheep were also used in developing the breed. This breed is reared for milk production. Sarda and Comisana, are the most consistent dairy sheep breeds in Italy.

Estimation of heritabilities for production traits in local breeds is important both for conservation purposes and to establish appropriate breeding objectives and schemes. Moreover, the environmental effects such as year of lambing, parity number of the ewe and type of lambing play a key role in the phenotypic variation of the milk production traits. With this approach in mind, the aims of the present study were to determine the level of influence of some environmental factors on milk yield and quality traits and lactation length in ewes belonging to three different Italian breeds reared in Apulia region, and to estimate the heritability for the same traits as important and useful genetic parameters that should be considered to design breeding schemes for genetic improvement.

Material and methods

Animals

A total of 2138 lactation records obtained from 535 ewes belonging to three different breeds (Comisana, $n = 207$; Leccese, $n = 181$ and Sarda, $n = 147$), progeny of 77 unrelated rams (Comisana, $n = 30$; Leccese, $n = 26$ and Sarda, $n = 21$) were used in the present study. Data were collected over a 5-year period in three different farms (one per breed) located in the same province of Apulia region, in southern Italy. In order to reduce the variability, the dataset involved only the ewes lambing during February. Furthermore, information concerning lambing type (single or twins) and parity number (1st to 4th) were also available. The animals were reared following the traditional management practices of the area: animals are left to graze in daylight hours and return to the folds at sunset leaving the ewes with their lambs over the night. Lambs were allowed free suckling until 30 ± 3 d postpartum. Milking in these breeds is carried out twice a day, in the morning and in the afternoon. Milk test started after weaning and the milk production was recorded until individual daily milk yield dropped below 0·1 kg. Lactation records were obtained from a set of test-day records taken at fortnightly intervals and reflect the production of milk after weaning. Milk fat, protein, and lactose were analysed by near-infrared analysis (Milkoscan, Foss Electric, Hillerød, Denmark). Total fat, protein and lactose yields were obtained from milk yield and percentages for each test-day. Lactation length was calculated from weaning to drying off.

Statistical analysis

Data were analysed using the restricted maximum-likelihood method from Mixed Procedure of SAS software (1999) to identify the environmental factors affecting milk yield (MY); lactation length (LL); protein, fat and lactose yielded (PY, FY and LY, respectively), and for protein, fat and lactose content (PC, FC and LC, respectively). The model accounted for the variation due to the breed (1, …,3); the year of lambing (1,…,5); the parity number of the ewe (1,…,4) and the type of lambing (1, 2). All these effects were considered as fixed. Sires of ewes and ewe were considered as random effects. In a preliminary data analysis, the fixed effect of the flock was considered in the model; anyway, it was finally excluded since it was not found to be significant. The significant differences among sub-classes were detected using Duncan's multiple range test (Duncan, 1955). Then, a mixed model was used to estimate variance components for the same traits and one analysis per breed was made. The model accounted for the variation due to the year of lambing (1,…,5); the parity number of the ewe (1,…,4) and the type of lambing (1, 2) as fixed effects. The sire was considered as random. The error was assumed to be randomly and independently distributed, with mean of zero and a variance of σ^2e.

In matrix notation, the model can be written as:

$$y = Xb + Zs + e$$

where y is the vector of phenotypes for the considered traits; X and Z are known incidence matrices relating records to fixed and random effects, respectively; b is the vector of fixed effects; s is the vector of sire effects, and e is the vector of residual errors.

Heritability estimates were based on sire component of variance (σ^2s) as follows:

$$h^2 = 4\sigma^2\mathrm{s}/(\sigma^2\mathrm{s} + \sigma^2\mathrm{e})$$

The standard error of heritability was approximated using the method described by Becker (1968).

Results and discussion

Environmental factors

Mean squares and test of significance of factors affecting milk yield and lactation length are given in Table 1. Breed of ewes showed effect ($P < 0·001$) on both MY and LL; Leccese breed produced less milk compared with Comisana and Sarda, with a shorter duration of lactation. Differences in MY and LL among breeds were commonly reported in literature. Year of lambing was a significant effect for both MY and LL ($P < 0·001$). This may be due to variation in climate, food nutritional quality and composition from 1 year to another. Moreover, MY was affected by parity and type of birth ($P < 0·001$) with milk production increasing until the third lactation and with a greater production in ewes with twins in comparison with ewes delivering single lambs. The effect of parity on milk yield was reported in other investigations (Macciotta et al. 1999; Pollott & Gootwine, 2001), and the positive influence of birth type on MY was in accordance with a previous report (Pollott & Gootwine, 2001). Beside the positive effect of suckling stimulus on milk

Table 1. Least-square means and tests of significance of factors affecting milk yield (MY), lactation length (LL) and milk quality of ewes

	n	MY (L)	LL (d)	FC (%)	PC (%)	LC (%)
Breed		***	***	***	***	***
Comisana	828	$112{\cdot}25 \pm 2{\cdot}31^{a}$	$182 \pm 2{\cdot}27^{a}$	$7{\cdot}31 \pm 0{\cdot}04^{b}$	$4{\cdot}94 \pm 0{\cdot}03^{b}$	$4{\cdot}89 \pm 0{\cdot}02^{b}$
Leccese	723	$84{\cdot}94 \pm 2{\cdot}51^{b}$	$156 \pm 2{\cdot}46^{b}$	$7{\cdot}75 \pm 0{\cdot}04^{a}$	$5{\cdot}13 \pm 0{\cdot}03^{a}$	$5{\cdot}06 \pm 0{\cdot}03^{a}$
Sarda	587	$115{\cdot}82 \pm 2{\cdot}80^{a}$	$178 \pm 2{\cdot}64^{a}$	$7{\cdot}23 \pm 0{\cdot}05^{b}$	$4{\cdot}99 \pm 0{\cdot}03^{b}$	$4{\cdot}89 \pm 0{\cdot}03^{b}$
Year		***	***	n.s.	n.s.	n.s.
2008	403	109·90 ± 3·27	172 ± 3·10	7·41 ± 0·06	4·97 ± 0·04	4·91 ± 0·04
2009	462	97·55 ± 3·13	174 ± 3·06	7·46 ± 0·06	5·03 ± 0·04	4·99 ± 0·04
2010	439	102·93 ± 3·12	168 ± 3·10	7·41 ± 0·06	5·04 ± 0·04	5·01 ± 0·04
2011	428	104·97 ± 3·18	167 ± 3·16	7·48 ± 0·06	5·07 ± 0·04	4·92 ± 0·04
2012	406	106·84 ± 3·19	180 ± 3·10	7·39 ± 0·06	4·99 ± 0·05	4·92 ± 0·04
Parity		***	n.s.	n.s.	n.s.	n.s.
1	432	$99{\cdot}30 \pm 3{\cdot}15^{b}$	170 ± 3·09	7·49 ± 0·06	5·10 ± 0·04	4·97 ± 0·05
2	386	$102{\cdot}41 \pm 3{\cdot}35^{a,b}$	174 ± 3·19	7·42 ± 0·06	5·03 ± 0·05	4·96 ± 0·05
3	449	$110{\cdot}54 \pm 3{\cdot}08^{a}$	172 ± 3·02	7·44 ± 0·05	4·98 ± 0·04	4·94 ± 0·05
4	871	$105{\cdot}10 \pm 2{\cdot}26^{a}$	172 ± 2·21	7·38 ± 0·04	4·98 ± 0·03	4·94 ± 0·05
Type of birth		***	n.s.	n.s.	n.s.	n.s.
Single	1323	$99{\cdot}35 \pm 1{\cdot}82^{A}$	170 ± 1·81	7·44 ± 0·03	5·03 ± 0·03	4·94 ± 0·03
Twin	815	$109{\cdot}33 \pm 2{\cdot}13^{B}$	174 ± 2·37	7·42 ± 0·04	5·01 ± 0·04	4·96 ± 0·04

***$P < 0{\cdot}001$; n.s. not significant.
Means within a trait and factor followed by different letters differ significantly a, b = $P < 0{\cdot}05$; A, B = $P < 0{\cdot}01$.
FC, fat content; PC, protein content; LC, lactose content.

yield, it is well known that litter size modifies the endocrine profiles in prepartum ewes and, as a consequence, mammogenesis and lactogenesis may be positively affected by an increased fetal and placental mass. On the other hand, some investigations reported no effect of litter size on milk yield and lactation length (Hassan, 1995; Macciotta et al. 1999). In such cases the effect of litter size may be hidden by undernutrition of the dam before or after parturition. In the present study, lactation length was not influenced by parity and type of birth. These results agree with those reported by Hassan (1995) for Egyptian ewes. Similarly, Pollott & Gootwine (2001) reported no influence of litter size on lactation length, although an effect of lactation number was observed.

Least-square means for fat, protein and lactose content and the tests of significance of non-genetic factors affecting these traits are shown in Table 1. All these parameters were significantly affected by breed in accordance with results previously reported (Oravcová et al. 2007). The year and the parity of the ewes did not affect milk quality as reported by Hassan (1995) in Saidi and Ossimi breeds. Conversely, a significant effect of year on milk composition was reported by Matutinovic et al. (2011). In accordance with our results, Oravcová et al. (2007) found no significant effect of lactation number on fat and protein content in Tsigai, Improved Valachian and Lacaune sheep breeds. Furthermore, Sevi et al. (2000) reported that parity affected the quality of milk in Comisana breed, and in particular its content of fat, protein, and casein which increased with increasing parity; on the contrary, lactose content significantly decreased with increasing number of lactation.

In the present paper, birth type affected milk volume and hence yield of fat, protein and lactose but had no effect on the content of these components ($P > 0{\cdot}05$, Table 1). The number of lambs suckling did not significantly affect fat, total solids and solids-not-fat of milk obtained from Ossimi and Saidi sheep breeds (Hassan, 1995).

Heritability estimates

Estimates of sire's and environmental variance components and heritability values are given in Table 2. Heritabilities for MY were moderate, being 0·25 for Comisana and Sarda, and 0·28 for Leccese breed. These estimates fall within the range of values already published for other dairy breeds (0·10–0·38) being closer to the upper limit of the reference range (Sanna et al. 1997; Pollott & Gootwine, 2001; Gutiérrez et al. 2007). With regards to lactation length, heritability was particularly low (0·07, 0·11 and, 0·08 for Comisana, Leccese and Sarda, respectively); previous studies reported values ranging from 0·01 to 0·14 (Sanna et al. 1997; Gutiérrez et al. 2007). Heritability estimates for fat and protein content and for fat and protein yield were moderate to high, ranging from 0·20 to 0·42, and lower for lactose, ranging from 0·13 to 0·18 (Table 2). The Sarda exhibited the lowest heritabilities for fat related traits, but the lowest protein trait heritabilities were for the Comisana breed. In the literature, heritabilities for FC and PC range from 0·06 to 0·55 (Sanna et al. 1997; Hamann et al. 2004; Riggio et al. 2007). Some authors reported values of heritabilities for FY and PY slightly lower than those obtained in our breeds (Hamann et al. 2004; Riggio et al. 2007), whereas a previous investigation on Sarda breed reported slightly higher values (Sanna et al. 1997). To the best of our knowledge, only one heritability value for lactose content has been published, which was 0·28 in Merino sheep (Izquierdo et al. 2010),

Table 2. Estimates of sire (σ_s^2) and environmental (σ_e^2) variance components, heritability (h^2) and standard error (SE_h^2) for ewe lactation traits of Comisana, Leccese and Sarda breeds

Breed		MY	LL	FC	FY	PC	PY	LC	LY
Comisana	σ_s^2	903·767	308·595	0·0862	3·9085	0·0981	1·4915	0·0504	0·8324
	σ_e^2	13 556·500	17 325·405	0·8715	67·1543	0·9341	28·3377	1·3883	24·8335
	h^2	0·25	0·07	0·36	0·22	0·38	0·20	0·14	0·13
	SE_h^2	0·03	0·01	0·02	0·02	0·02	0·01	0·01	0·01
Leccese	σ_s^2	882·317	422·868	0·0877	3·8714	0·0946	1·4951	0·0564	0·8390
	σ_e^2	11 722·210	14 954·132	0·7480	58·0703	0·8060	24·5064	1·1974	21·5344
	h^2	0·28	0·11	0·42	0·25	0·42	0·23	0·18	0·15
	SE_h^2	0·03	0·01	0·02	0·02	0·02	0·02	0·01	0·01
Sarda	σ_s^2	642·127	251·240	0·0579	2·6504	0·0753	1·1652	0·0435	0·6837
	σ_e^2	9631·898	12 310·760	0·6234	47·8347	0·6591	20·0208	0·9799	17·5493
	h^2	0·25	0·08	0·34	0·21	0·41	0·22	0·17	0·15
	SE_h^2	0·03	0·01	0·02	0·02	0·03	0·02	0·02	0·01

MY, milk yield; LL, lactation length.
FC, fat content; FY, fat yield.
PC, protein content; PY, protein yield.
LC, lactose content; LY, lactose yield.

higher than we report here. In dairy cows, early studies have shown heritability estimates for lactose percentage and yield to be less or intermediate to those for fat and protein percentages; later references reported values in the range of 0·17–0·64 (Stoop et al. 2007; Ptak et al. 2012; Sneddon et al. 2015). In goat species, Brito et al. (2011) reported heritability estimates for lactose yield and percentage of 0·15 and 0·17, respectively. These values are similar to those obtained in the present investigation in sheep.

Conclusion

The wide variability of heritabilities for a certain trait reported in different studies conducted on different populations may be due to many reasons, such as differences among breeds and management factors, sampling errors, and differences in the estimation procedures adopted. Nevertheless, estimation of the heritabilities for milk yield and quality traits is necessary in order to design appropriate breeding programs. On the whole, the presently reported estimates are within the range of those already obtained in other dairy breeds by other authors, with values for lactation length being very low in all the investigated populations. The low heritabilities for lactation length may suggest low genetic gain, whereas improvements in environmental factors affecting this parameter may lead to greater gains for this phenotypic trait. On the other hand, the results obtained in the present study for milk traits other than lactation length suggest that their genetic variability is adequate for selection indicating that a good response to selection could be expected by adopting the correct breeding strategies.

References

Becker WA 1968 Estimation of variance components and heritability. In *Manual of Procedures in Quantitative Genetics*, 2nd edn, pp. 7–59. Pullman, USA: Student Book Corporation, Washington State University

Brito LF, Silva FG, Melo ALP, Caetano GC, Torres RA, Rodrigues MT & Menezes GRO 2011 Genetic and environmental factors that influence production and quality of milk of Alpine and Saanen goats. *Genetics and Molecular Research* **10** 3794–3802

Duncan DB 1955 Multiple range and multiple F tests. *Biometrics* **11** 1–42

Gutiérrez JP, Legaz E & Goyache F 2007 Genetic parameters affecting 180-days standardised milk yield, test-day milk yield and lactation length in Spanish Assaf (Assaf. E) dairy sheep. *Small Ruminant Research* **70** 233–238

Hamann H, Horstick A, Wessels A & Distl O 2004 Estimation of genetic parameters for test day milk production, somatic cell score and litter size at birth in East Friesian ewes. *Livestock Production Science* **87** 153–160

Hassan HA 1995 Effects of crossing and environmental factors on production and some constituents of milk in Ossimi and Saidi sheep and their crosses with Chios. *Small Ruminant Research* **18** 165–172

Izquierdo M, Corral JM, Padilla JA & Hernández FI 2010 Variance components and genetic correlations of milk production and composition in Merino sheep. In *Proceedings of the 9th World Congress on Genetics Applied to Livestock Production*, pp. 2–133. Leipzig, Germany

Macciotta NPP, Cappio-Borlino A & Pulina G 1999 Analysis of environmental effects on test day milk yields of Sarda dairy ewes. *Journal of Dairy Science* **82** 2212–2217

Matutinovic S, Kalit S, Salajpal K & Vrdoljak J 2011 Effects of flock, year and season on the quality of milk from an indigenous breed in the sub-Mediterranean area. *Small Ruminant Research* **100** 159–163

Oravcová M, Margetín M, Peskovicova D, Dano J, Milerski M, Hetényi L & Polák P 2007 Factors affecting ewe's milk fat and protein content and relationships between milk yield and milk components. *Czech Journal of Animal Science* **52** 189–198

Pollott GE & Gootwine E 2001 A genetic analysis of complete lactation milk production in improved Awassi sheep. *Livestock Production Science* **71** 37–47

Ptak E, Brzozowski P & Bieniek J 2012 Genetic parameters for lactose percentage in the milk of Polish Holstein-Friesians. *Journal of Animal and Feed Sciences* **21** 251–262

Riggio V, Finocchiaro R, Van Kaam JB, Portolano B & Bovenhuis H 2007 Genetic parameters for milk somatic cell score and relationships with production traits in primiparous dairy sheep. *Journal of Dairy Science* **90** 1998–2003

Sanna SR, Carta A & Casu S 1997 (Co) variance component estimates for milk composition traits in Sarda dairy sheep using a bivariate animal model. *Small Ruminant Research* **25** 77–82

SAS 1999 *SAS/STAT, User's Guide, Version 8*. Cary, NC: SAS Institute

https://doi.org/10.1017/S0022029916000765 Published online by Cambridge University Press

Selvaggi M, Laudadio V, Dario C & Tufarelli V 2014 Investigating the genetic polymorphism of sheep milk proteins: a useful tool for dairy production. *Journal of the Science of Food and Agriculture* **94** 3090–3099

Sevi A, Taibi L, Albenzio M, Muscio A & Annicchiarico G 2000 Effect of parity on milk yield, composition, somatic cell count, renneting parameters and bacteria counts of Comisana ewes. *Small Ruminant Research* **37** 99–107

Sneddon NW, Lopez-Villalobos N, Davis SR, Hickson RE & Shalloo L 2015 Genetic parameters for milk components including lactose from test day records in the New Zealand dairy herds. *New Zealand Journal of Agricultural Research* **58** 97–107

Stoop WM, Bovenhuis H & Van Arendonk JAM 2007 Genetic parameters for milk urea nitrogen in relation to milk production traits. *Journal of Dairy Science* **90** 1981–1986.