Evaluation of reference lactation length in Chios dairy sheep

Basdagianni, Z; Sinapis, E; Banos, G

Published in:
Animal

DOI:
10.1017/S1751731118000769

First published: 26/04/2018

Document Version
Peer reviewed version

Evaluation of reference lactation length in Chios dairy sheep

Z. Basdagianni[1*], E. Sinapis[1] and G. Banos[2,3]

[1] *School of Agriculture, Department of Animal production, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece*

[2] *School of Veterinary Medicine, Department of Animal Production, Ichthyology, Ecology and Environmental Protection, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece*

[3] *Scotland's Rural College and The Roslin Institute, University of Edinburgh, Easter Bush, Midlothian EH25 9RG, UK*

Corresponding author: Zoitsa Basdagianni. E-mail: basdagianni@agro.auth.gr

Abstract

Definition and establishment of a fixed reference lactation length could provide useful tools for on-farm comparison of ewes and flock management as well as genetic evaluations for the breeding programme. The objectives of this study were to (i) evaluate different reference lactation lengths for the Chios dairy sheep and (ii) define the most suitable reference length for the breed. A total of 260,042 test-day milk records from 24,474 ewes in 130 flocks collected between 2003 and 2014 were used. Fifteen (15) different lactation lengths were evaluated ranging from 120 to 260 days, defined at 10-day intervals as reference for the Chios sheep. The evaluation criteria included: **a)** heritability and repeatability of milk yield in each reference lactation, ***b***) genetic correlation of reference lactation milk yield with actual lactation milk yield and yield at first test-day record and ***c)*** correlated response in reference lactation milk yield from selection based on first test-day milk yield. The latter emulates genetic gains achieved for milk yield based on early lactation selection. Heritability and repeatability estimates of reference lactation milk yield and genetic correlation with actual lactation yield favoured long reference lactations (180-230 days). On the contrary, correlation with first test-day record milk yield was higher for short lactations (120-170 days). Moreover, selection on first test-day record milk yield would lead to a correlated response in reference yield in 220 days equal to 90% of the highest estimate achieved in the maximum reference length of 260 days (190 days when only considering first lactation milk yield). Based on the results of the present study, an overall reference lactation length for the Chios breed of 220 days post-lambing and a first lactation reference length of 190 days post-lambing are recommended.

Keywords: Standard lactation length, milk, Chios breed, Sheep management, Genetic improvement

Implications

Lactation lengths differ amongst individual dairy ewes raised in the same flock. Lactations following spring lambings tend to be shorter than those starting in the autumn, especially in the semi-extensive production systems in the Mediterranean countries. In the present study, standardised reference lactation lengths are derived and evaluated for the Chios sheep in Greece. Results can provide useful tools for on-farm management and genetic improvement programmes.

Introduction

Lactation length is one of the main factors affecting milk yield in dairy sheep. Total lactation milk yield has been traditionally used for on-farm management, on-farm selection of ewes, and genetic evaluation and selection of breeding animals at population level (Moioli and Pilla, 1994; Barillet, 1997). Although test-day genetic evaluation models are now used frequently in animal breeding instead of lactation models (Schaeffer *et al.,* 2000; Silvestre *et al.,* 2005; Lidauer *et al.,* 2003; Komprej *et al.,* 2013), lactation milk yield continues to provide useful information for management and comparison purposes.

Lactation length may be influenced by several factors, amongst which season of lambing seems to be the most important. When seasonal lambing is practiced, as is the case in most Mediterranean sheep production systems, the lactation length of ewes lambing in spring tends to be shorter compared to ewes lambing in the autumn and winter. The effect of season of lambing on lactation length has already been reported in many dairy sheep breeds such as Chios (Mavrogenis and Papachristoforou, 1990), Sarda (Carta *et al,.* 1998) and Barbaresca Siciliana (Portolano *et al.,* 2001).

Varying lactation lengths pose a problem when farmers wish to make management decisions regarding management of their stock. Definition of a fixed reference lactation length (also known as standard length) in dairy sheep could provide useful tools for on-farm comparison of animals and overall flock management as well as genetic evaluations in the breeding programme (Basdagianni *et al.,* 2004).

A reference lactation length of 305 days has been well established and accepted worldwide for dairy cattle. However, reference lactation length in dairy sheep varies according to breed and production system. In literature there are many studies that have aimed to define the best reference length definition for genetic evaluation purposes. Most studies focused on the projection and extension of part lactation (Gabina *et al.,* 1993; De La Fuente *et al.,* 1995; Carta *et al.,* 1998; Rosati and Fioretti, 2001; Portolano *et al.,* 2001; Ugarte *et al*,. 2002; Berger and Thomas, 2004; Cappelletti *et al.,* 2006; Oravcova *et al.,* 2006; Jonas *et al,.* 2011). Very few studies (El-Saied *et al.,* 1998a; El-Saied *et al.,* 1998b; Gutierrez *et al.,* 2007) have used specific criteria to evaluate the length of a reference lactation. The reference lactation length must have certain properties that make it useful and reliable in practical applications, such as being representative of the actual lactation and having a high correlation with milk yield in early lactation (Basdagianni *et al.,* 2004).

The objectives of the present study were to (i) evaluate different reference lactation lengths for the Chios dairy sheep and (ii) define the most suitable reference length for the breed. Chios is the highest milk producing sheep in Greece and one of the most productive dairy breeds worldwide.

Materials and methods

Data

Test-day records and pedigree information were obtained from the database of the Chios Sheep Breeders' Cooperative "Macedonia", which implements the genetic improvement programme for the breed in Northern Greece since 1997. Lambing is seasonal and occurs either in autumn/winter or in spring. After a suckling period of approximately 6 weeks, ewes are milked mostly twice daily. Milk recording is performed monthly by trained field officers. The first milk record is collected between 42 to 94 days after lambing and milk yield is measured using the A4 method.

Lactations with at least two monthly test-day records that took place between 2003 and 2014 were considered for the present study, following the guidelines of the International Committee for Animal Recording (ICAR, 2016). After these edits the number of remaining test-day milk yield records was 260,042. These were produced from 24,474 ewes during 46,505 lactations in 130 flocks. Ewes were daughters of 2,060 sires and 22,482 dams. These data were linked to a breed pedigree file including 87,261 animals spanning 10 generations. Two seasons of lambing (September to February and March to August; Figure 1) and four lactation classes (1st, 2nd, 3rd, 4th or higher lactation) were defined.

Actual lactation milk yield was calculated for each animal and lactation using the Fleischmann method (Barillet, 1985). Additionally, reference lactation milk yield was calculated for each animal for fifteen (15) different reference lengths ranging from 120 to 260 days post-lambing, defined in 10-day interval (i.e. 120, 130,….,250, 260). In each case, the last monthly test-day record of the ewe had to be no more than 14 days prior to the corresponding reference length end-date, as required by the Fleischmann method (Barillet, 1985). Lactations longer than 260 days were not considered in the study due to the limited number of data.

In order to evaluate the reference lactation lengths, the following criteria were considered: **a)** heritability and repeatability of reference lactation milk yield, ***b***) genetic correlation of reference lactation milk yield with actual lactation milk yield and yield at first test-day record and ***c)*** correlated response in reference lactation milk yield from selection based on the first test-day milk yield.

Data analysis

Each trait (actual lactation milk yield, lactation yield in 15 reference lengths and first test-day record milk yield) was first analysed separately using the following mixed model:

$$Y_{ikjo} = \mu + HYS_i + b{*}age + PF_k + L_j + X_o + P_o + e_{ikjo} \qquad [1]$$

where: Y_{ikjo} is the trait value for animal o; μ is the overall population mean; HYS_i is the fixed effect of herd-year-season of lambing i (i=1-3120); b is the linear regression coefficient on age at lambing (age); PF_k is the fixed effect of prolificacy class (number of lambs born alive) k (k=1-3+); L_j is the fixed effect of lactation number j (j=1-4+); X_o is the random additive genetic effect of ewe o including all available pedigree; P_o the random permanent environment of ewe o: e is the random residual.

In the analysis of actual lactation milk yield, duration of lactation i.e., actual lactation length was added as a covariate in model [1]. When the first test-day record milk yield was analysed, days in milk was also included as a covariate in model [1].

In separate analyses, the ewe effect in Model (1) was replaced by the sire of the ewe random effect, essentially rendering this a sire model.

In all analyses, variance components for each trait were estimated and used to derive heritability and repeatability estimates.

Bivariate analyses based on Model [1] were subsequently used to estimate the genetic correlations between traits.

In further separate analyses, only first lactation milk yield records were considered; in this case, the fixed lactation and the random permanent environment effects were removed from mode [1].

All the above analyses were performed with the ASReml 4.1 (Gilmour *et al.,* 2014).

Finally, the correlated response in each reference lactation milk yield from selection based on the first test-day milk yield record was estimated using the following formula (Van Vleck, 1981):

$CR_y=i_x\ a_x\ r_{xy}\ sd_y$ [2]

where: CR_y is the correlated response in response variable y (reference lactation milk yield); i_x is the selection intensity on variable x (first test-day record milk yield); a_x is the accuracy of selection on variable x; r_{xy} is the correlation between variables y and x; sd_y is the genetic standard deviation of variable y.

Since selection intensity and accuracy of selection in equation [2] pertained to the same variable (first test-day record milk yield), evaluation of different reference lactations with this criterion was performed for constant intensity and accuracy of selection; thus the evaluation was practically based on the correlation between first test-day record milk yield and reference lactation yield, and the genetic standard deviation of reference lactation yield.

Results

Table 1 summarises the descriptive statistics of all studied traits.

The sire model i.e., when sire was included as a random effect in model [1], yielded the lowest residual variance estimates and, therefore, was deemed to have the best fit. Hereafter, results shown pertain to the sire model but it should be noted that animal model (ewe as random effect in model [1]) results were very similar.

Heritability estimates of milk yield in each reference lactation ranged from 0.12 to 0.30 (standard errors 0.02-0.12) (Figure 2). Heritability estimates increased with longer reference lactation, with highest values pertaining to reference length of 200-230 days. When the analysis concerned only first lactation records the heritability estimates of reference lactation milk yield were between 0.08 and 0.37 (Figure 2). In comparison, heritability of actual lactation milk yield and first test-day milk yield were 0.15±0.02 and 0.10±0.02, respectively (0.09±0.03 and 0.11±0.03 for first lactation yield).

Repeatability estimates of milk yield in each reference lactation ranged from 0.29 to 0.48, and increased with increasing reference length (Figure 3). Repeatability estimates of actual lactation milk yield and first test-day record milk yield were 0.33± 0.01 and 0.21± 0.01, respectively.

Genetic correlation estimates between milk yield in different reference lactation lengths and actual lactation yield are shown in Figure 4. Reference lactations lengths between 180 and 220 days had the highest genetic correlation values (0.98-0.99) and are considered to be the most representative of actual lactation yield in this regard. When considering only first lactation records genetic correlations were also high, with the highest values at reference lactation length of 160 to 180 days.

Genetic correlations between reference lactation milk yield and first test-day record milk yield are shown in Figure 5. The estimates of the genetic correlation were particularly high (≥0.95) for the short lactation periods (120-170 days), with a decreasing trend for reference lactations lengths above 180 days. The trend was the same in the analysis of first lactation records only.

Correlated responses in milk yield achieved in different reference lactation lengths from selection on first test-day record milk yield were increased with increasing reference length and expressed in percentage relatively to the highest reference length of 260 days for all lactation and 230 days for first lactation record analysis (Figure 6). Correlated response (genetic progress) for the shorter reference lactations (120-200 days) were 49 - 76% of that achieved in maximum length, while for longer reference lactation this percentage was over 85%. When only first lactation records were considered, reference lactations of 120 -190 days showed genetic progress 44 - 68% of that at maximum length.

Discussion

Our goal was to evaluate candidate reference lactation lengths and define a reference lactation length suitable for Chios dairy sheep. Expressing total dairy production at a reference lactation length would facilitate the objective comparison between animals and related on-farm decisions.

The reference lactation length had to be representative of the actual lactation length and corresponding milk yield should have a high correlation with the milk yield of the first test-day record and that of the actual lactation.

Heritability estimates for actual lactation milk yield (0.15±0.02) in the present study was lower than those obtained by Mavrogenis and Papachristoforou (1990) and Ligda *et al.* (2000) in the same breed (0.23-0.33) for animals raised in experimental flocks. However, ours is the first heritability estimate of Chios sheep at population level. Data analysis from experimental flocks often yield higher heritability estimates because of better defined and controlled management conditions. Moreover, low heritability in our study might be also due to relatively low levels of genetic connectedness between flocks as a result of predominantly natural mating with own rams in the Chios ewes; this might also result in lower accuracy of heritability estimates. In other Greek dairy sheep breeds, Kominakis *et al.* (1998) reported estimated heritabilities for lactation milk yield across various models ranging between 0.18 and 0.30 for Boutsiko and Nikolaou *et al.* (2004) between 0.16 and 0.20 for Lesbos. In Spanish dairy sheep breeds Carriedo *et al.* (1995) estimated heritability of total milk yield in Churra between 0.15 and 0.29. In the improved Awassi and East Friesian breeds, reported heritabilities were 0.10 and 0.15, respectively (Pollott and Gootwine, 2001; Hamann *et al.,* 2004). In the Italian sheep breeds Comisana, Sarda and Leccese, heritabilities of milk yield were 0.25-0.28 (Selvaggi *et al.,* 2017).

Heritability estimate for first test-day record milk yield in the present study was 0.10±0.02 and was similar to those reported by Oravcova (2014) for the Tsigai breed. Heritability is generally lower at the early stages of lactation as a consequence of higher residual variance as reported in several sheep (Kominakis *et al.,* 2001; Komprej *et al.* 2013) and cattle studies (Rekaya *et al.,* 1999; Silvestre *et al.* 2005).

Heritability estimates of milk yield in different reference lactation lengths in the present study were higher (0.19 - 0.30) for longer lactations of 200-230 days. Legarra and Ugarte, (2001) reported heritability 0.20 for the Latxa breed and Serrano *et al.* (2003), 0.18 in Manchega ewes for milk yield in reference lactation length of 120 days. Gutierrez *et al.* (2007) reported heritabilities between 0.13 and 0.18 for 180-day reference milk yield. High heritability facilitates the accurate genetic evaluation and the selection; from this standpoint, our study suggests that longer reference lactations are preferable.

Repeatability estimates for different reference lactation milk yields ranged from 0.29 to 0.48 in the present study. El-Saied *et al.* (1998b) reported repeatability 0.38 in 120 day standardised milk yield. In the present study, the repeatability estimates were higher (>0.40) in longer reference lactations

(200-260 days), which render the latter more suitable for on-farm selection of ewes and flock management.

Estimates of genetic correlation between reference lactation milk yield and actual lactation yield were high and ranged from 0.98 to 0.99, for reference lactation length of 180-230 days. These estimates are higher than those reported of Mavrogenis and Papachristoforou (1990) in Chios sheep in Cyprus, for reference length of 60 and 90 days (0.91 and 0.92 respectively). In Churra breed, El-Saied *et al.* (1998b) found genetic correlation between actual lactation milk yield and 120-day standardised lactation milk yield 0.99, and Portolano *et al.* (2001) reported similar genetic correlations between total milk yield and milk yield at standard lactation length of 180 and 200 days (0.94 and 0.97) in Valle del Belice dairy sheep. Similar high estimates of genetic correlation (0.99) were also reported in the Spanish Assaf breed by Gutierrez *et al.* (2007) considering reference yield at 180 days. Reference lactations lengths with higher genetic correlation are more representative of the actual lactation, which is a desirable characteristic in the choice of the former. Based on this criterion, reference length of 180-230 days in the present study would be desirable for the Chios sheep. By the same token, reference lactation length of 160 to 190 days would be preferable for first lactation milk yield (Figure 4). This discrepancy between all and first lactation may be due to the fact that yearling have not had the opportunity to express their full genetic capacity as actual lactations were shorter due to most of them lambing in spring.

Genetic correlations between reference lactation milk yield and first test-day record milk yield favoured short reference lactation lengths in the present study (0.98 for 120 days versus 0.88 for 260 days), with higher values (>0.95) at reference lactations 120-170 days. These estimates were similar to those reported by Banos *et al.* (2005) for the same breed and suggest that more accurate predictions of the lactation milk yield from the first test-day record can be achieved for shorter reference length (120-170 days). However, even for the longer lactations lengths (180-260 days), the genetic correlation is considerably high (0.88-0.94), meaning that milk yield at first test-day record can be useful in predicting the total reference lactation milk yield of the ewes in nearly all cases.

Of the above criteria used to evaluate the reference lactation length in the Chios sheep, genetic parameters (heritability, repeatability) of reference lactation milk yield and genetic correlation with actual lactation yield would favour long reference lactations (180-230 days), whereas genetic correlation with first test-day record milk yield would advocate for short reference lactations (120-170 days). In order to combine the above criteria, correlated responses in reference lactation milk yield to selection based on the first test-day record milk yield were estimated. Selection based on early lactation yield (first test-day record the present study) can facilitate early decisions and enhance the efficiency of on-farm management (e.g. setting up mating strategies). According to our results, correlated response would favour milk yield in the maximum reference lactation length considered in the present study (260 and 230 days for all and first lactation, respectively). This is primarily due to higher genetic variance estimates associated with longer lactation milk yield. However, such long lactations are not representative of the actual length (Table 1) and may not be practical for farm management.

Furthermore, prolonged lactations of low milk production would not be beneficial to the overall profitability of the farm (Gutierrez *et al.*, 2007).

Combining all evaluation criteria, it is suggested that a reference lactation length 220 days post–lambing would be most useful for the management of the Chios breed stock. This length is close to the average actual lactation length of the breed (208 days; Table 1); therefore, it can be considered representative for the Chios sheep. Furthermore, milk yield in 220 days had one of the highest heritability estimates and the highest genetic correlation with actual lactation yield amongst all reference lactation yields. In addition, milk yield in 220 days had a reasonable genetic correlation with first test-day record milk yield which amounted to 92% of the most highly correlated reference yield (in 120 days). Finally, selection on first test-day record milk yield would lead to correlated response in reference yield in 220 days equal to 90% of the highest estimate achieved in the maximum (albeit unrealistic) reference length of 260 days.

Following the same reasoning, a reference length of 190 days would be the most suitable for first lactation ewes. These animals may require a separate reference length because they tend to have shorter lactations due to predominantly spring lambings.

Conclusions

Reference lactation length of 220 days post-lambing is recommended for the Chios sheep breed as it gives on balance the best results regarding genetic parameter estimates, genetic correlation with actual lactation and first test-day record milk yield, and correlated response to selection for increased first test-date yield. By the same token, a first lactation reference length of 190 days is recommended. Future research should asses the validity of the recommended reference length for other dairy sheep breeds.

Acknowledgments

Data for this study were made available by the Chios Sheep Breeders' Cooperative "Macedonia".

References

Banos G, Arsenos G, Abas Z and Basdagianni Z 2005. Population parameter estimation of daily milk yield of the Chios sheep using test-day random regression models and Gibbs sampling. Animal Science 81, 233-238.

Barillet F 1985. Amélioration génétique de la composition du lait des brebis: l'exemple de la race Lacaune (Genetic improvement for ewe milk composition. The case of Lacaune breed). Ph.D. Thesis, INA Paris - Grignon, France.

Barillet F 1997. Genetics of milk production. In the Genetics of sheep (ed. Piper L and Ruvinsky A), pp. 539-564. CAB International, New York, USE.

Basdagianni Z, Banos G, Abas Z, Arsenos G, Sinapis E and Zygoyiannis D 2004. Evaluation and definition of reference lactation length in Chios dairy sheep Proceedings of the 34th Biennial Session of International Committee for Animal Recording, 29 May-3 June 2004, Sousse, Tunisia, pp 121-125.

Berger YM and Thomas DL 2004. Milk testing, calculation of milk production, and adjustment factors. Proceedings of the 10th Great Lake Dairy Sheep Symposium, 4-6 November 2004, Madison, pp 55-62.

Cappelletti CA, Rozen FMB, De La Fuente LF and San Primitivo F 2006. Extension factors for part-lactation in Churra sheep breed. Small Ruminant Research 63, 282-287.

Carriedo JA, Baro JA, De La Fuente LF and San Primitivo F 1995. Genetic parameters for milk yield in dairy sheep. Journal of Animal Breeding and Genetics 112, 59- 63.

Carta A, Sanna SR, Rosati A and Casu S 1998. Milk yield adjustments for milking length and age parity lambing month interaction in Sarda dairy sheep. Annales de Zootechnie 47, 59-66.

Carta A, Casu S and Salaris S 2009. Invited review: Current state of genetic improvement in dairy sheep. Journal of Dairy Science 92, 5814-5833.

De La Fuente LF, Baro JA and San Primitivo F 1995. Breeding programme for Spanish Churra sheep breed. Cahiers Options Méditerranéennes 11, 165-172.

El-Saied UM, Carriedo JA, Baro JA, De La Fuente LF and San Primitivo F 1998a. Genetics correlations and heritabilities for milk yield and lactation length of dairy sheep. Small Ruminant Research 27, 217-221.

El-Saied UM, Carriedo JA, De La Fuente LF and San Primitivo F 1998b. Genetic and environmental estimations for test-day and standardized milk yield of dairy sheep. Small Ruminant Research 27:209-215.

Gabina D, Arrese F, Arranz J and Beltran de Heredia I 1993. Average milk yield and environmental effects on Latxa sheep. Journal of Dairy Science 76, 1191-1198.

Gilmour AR, Gogel BJ, Cullis BR, Welham SJ and Thompson R 2014. ASReml User Guide Release 41 Functional Specification, VSN International Ltd, Hemel Hempstead, HP1 1ES, UK. https://www.vsni.co.uk.

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

Hamann H, Horstick A, Wessels A and 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.

Jonas E, Thomson P, Hall E, McGill D, Lam M and Raadsma H 2011. Mapping quantitative trait loci (QTL) in sheep IV Analysis of lactation persistency and extended lactation traits in sheep. Genetics Selection Evolution 43:22.

Kominakis A, Rogdakis E and Koutsotolis K 1998. Genetic parameters for milk yield and litter size in Boutsiko dairy sheep. Canadian Journal of Animal Science 78, 525-532.

Kominakis A, Volanis M and Rogdakis E 2001. Genetic modelling of test day records in dairy sheep using orthogonal Legendre polynomials. Small Ruminant Research 39, 209-217.

Komprej A, Malovrh Š, Gorjanc G, Kompan D and Kovač M 2013. Genetic and environmental parameters estimation for milk traits in Slovenian dairy sheep using random regression model. Czech Journal of Animal Science 58 (3), 125-135.

Legarra A and Ugarte E 2001. Genetic parameters of milk traits in Latxa dairy sheep. Animal Science 73, 407-412.

Lidauer M, Mantysaari EA and Stranden I 2003. Comparison of test-day models for genetic evaluation of production traits in dairy cattle. Livestock Production Science 79, 73-86.

Ligda Ch, Gabreilidis G, Papadopoulos Th and Georgoudis, A 2000. Estimation of genetic parameters for production traits of Chios sheep using a multitrait animal model. Livestock Production Science 66, 217-221.

Macciotta NPP, Mele M, Cappio-Borlino A and Secchiari P 2005. Issues and perspectives in dairy sheep breeding. Italian Journal of Animal Science 4, 5-23.

Mavrogenis AP and Papachristoforou Ch 1990. Use of part lactation records for selection in Chios sheep and Damascus Goats. Technical Bulletin, 122 Agricultural Research Institute, Ministry of Agriculture and Natural Resources Nicosia, Cyprus, 1-7.

Moioli BM and Pilla AM 1994. Genetic evaluation of dairy sheep with an animal model for annual or partial lactation production. Journal of Dairy Science 77, 609-615.

Nikolaou M, Kominakis AP, Rogdakis E and Zampitis S 2004. Effect of mean and variance heterogeneity on genetic evaluations of Lesbos dairy sheep. Livestock Production Science 88, 107-115.

Oravcova M, Margetın M, Peskovicova D, Dano J, Milerski M, Hetenyi L and Polak P 2006. Factors affecting milk yield and ewe’s lactation curves estimated with test-day models Czech Journal of Animal Science 51, 483-490.

Oravcova M 2014. Variance components and genetic parameters estimated for daily milk yield in individual months of lactation: the case of Tsigai sheep. Veterinarija ir Zootechnika 68 (90), 55-59.

Pollott GE and Gootwine E 2001. A genetic analysis of complete lactation in improved Awassi sheep. Livestock Production Science 71, 37-47.

Portolano B, Montalbano L and Militi W 2001. Genetic and environmental sources of variation for milk yield traits in Barbaresca Siciliana breed. Small Ruminant Research 41, 195-202.

Rekaya R, Carabano MJ and Toro MA 1999. Use of test day yields for the genetic evaluation of production traits in Holstein-Friesian cattle. Livestock Production Science 57, 203-217.

Rosati A and Fioretti M 2001. Reference length milk production projection for Italian dairy sheep breeds. Proceedings of the 32nd Biennial Session of International Committee for Animal Recording, 14-19 May 2000, Bled, Slovenia, pp 91-96.

Sanna SR, Carta A and Casu S 1997. Covariance component estimates for milk composition traits in Sarda sheep using a bivariate model. Small Ruminant Research 25, 77-82.

Schaeffer LR, Jamrozik J, Kistemaker GJ and Van Doornmaal BJ 2000. Experience with a test-day model. Journal of Dairy Science 83, 1135-1144.

Selvaggi M, D’Alessandro AG and Dario C 2017. Environmental and genetic factors affecting milk yield and quality in three Italian sheep breeds. Journal of Dairy Research 84, 27-31.

Silvestre AM, Petim-Batista F and Colaco J 2005. Genetic parameter estimates of Portuguese dairy cows for milk, fat and protein using a spline test-day model. Journal of Dairy Science 88, 1225-1230.

Ugarte E, Serrano M, De La Fuente LF, Perez-Guzmam MD, Alfonso L and Gutierrez JP 2002. Situación actual de los programas de mejora genética en ovino de leche (Current state of breeding dairy sheep programs). Información Técnica Económica Agraria (ITEA) 98, 102-117.

Van Vleck 1981. Notes on the theory and application of selection principles for the genetic improvement of animal. Cornell University press, 4th edition.

Table 1 *Descriptive statistics for milk yield traits in the Chios sheep breed*.

Trait	Records	Mean	SD	CV%
Actual lactation milk yield (kg)	46,505	324	134.3	41
Lactation length (days)	46,505	208	48.2	23
First test-day record milk yield (g)	46,505	1,910	821.3	43
Yield in reference length 120 days (kg)	43,169	221	83.9	38
Yield in reference length 130 days (kg)	41,873	237	88.1	37
Yield in reference length 140 days (kg)	39,905	253	92.1	36
Yield in reference length 150 days (kg)	37,527	268	96.1	36
Yield in reference length 160 days (kg)	34,750	284	99.7	35
Yield in reference length 170 days (kg)	31,980	299	103.2	34
Yield in reference length 180 days (kg)	28,938	316	106.4	34
Yield in reference length 190 days (kg)	25,539	333	109.6	33
Yield in reference length 200 days (kg)	22,340	349	113.3	32
Yield in reference length 210 days (kg)	18,995	363	116.7	32
Yield in reference length 220 days (kg)	15,433	377	118.5	31
Yield in reference length 230 days (kg)	12,239	391	120.9	31
Yield in reference length 240 days (kg)	9,160	407	120.7	30
Yield in reference length 250 days (kg)	6,629	421	122.4	29
Yield in reference length 260 days (kg)	4,116	433	124.4	29

Figure 1 Distribution of lambings in the Chios sheep breed.

Figure 2 Heritability estimates of milk yield in different reference lactation lengths; standard errors range from 0.02 to 0.12 for all lactations (all lac)and from 0.03 to 0.18 for first lactation (1^{st} lac).

Figure 3 Repeatability estimates of milk yield in different reference lactation lengths; standard errors range from 0.01 to 0.03.

Figure 4 Genetic correlation estimates between milk yield in different reference lactation lengths and actual lactation yield; standard errors were lower than 0.02 in all cases.

Figure 5 Genetic correlation estimates between milk yield in different reference lactation lengths and first test-day record milk yield; standard errors ranged from 0.01 to 0.10 for all lactations (all lac) and from 0.00 to 0.03 for first lactation (1^{st} lac).

Figure 6 Correlated response in reference lactation milk yield to selection based on the first test-day record milk yield, expressed as a percentage relatively to response in highest reference length of 260 days (230 days for 1^{st} lactation records).