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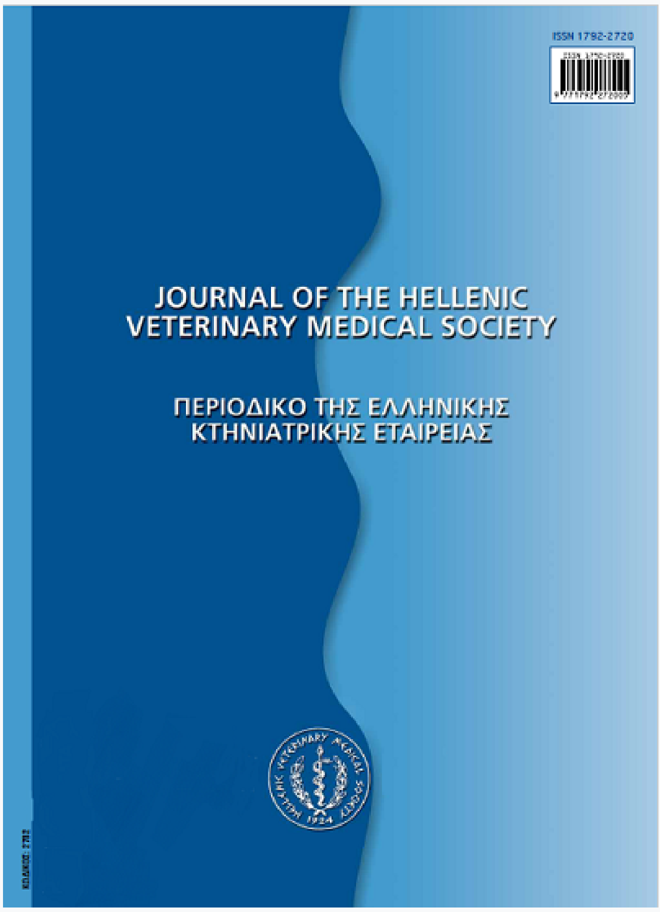

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Effect of management factors on reproductive and milk production performance of a dairy sheep breed adapted to low-input management systems

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Επίδραση παραγόντων διαχείρισης στις αναπαραγωγικές και γαλακτοπαραγωγικές αποδόσεις γαλακτοπαραγωγών προβάτων προσαρμοσμένων σε συστήματα διαχείρισης χαμηλών εισροών

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ABSTRACT. Interest on the implementation and improvisation of low-input dairy sheep farming is rising. Our study aimed to describe a) the milk productivity of the Sfakia sheep, a Mediterranean well-adapted to low-input management schemes breed ("low-input breed"), and b) the effect of management (MS) and milking system (MLS) on milk yield and quality. Monthly bulk milk samples (n=307) and reproductive data were collected from 10 extensive and 10 semi-intensive Sfakia sheep flocks in Crete Greece, over two consecutive lactations. All semi-intensive and four extensive farms were equipped with a milking parlour machine (MPM). A portable machine (PM) was used in three extensive farms; hand-milking (HM) was applied in the rest extensive farms. The effect of MS and MLS on daily milk yield/ewe (DMY), somatic cell count (SCC), total bacterial count (TBC), pH and % lactose content (LACT) of milk was explored with linear mixed-effects models. Mean DMY ($p<0.001$) as well as the seasonal variation pattern of SCC ($p=0.020$) and LACT ($p=0.018$) differed between MS. TBC was higher in extensive farms using MPM than HM ($p=0.002$); PM was related to lower SCC, compared to MPM ($p=0.044$) and HM ($p=0.012$). Concluding, mild interventions in management and milking practices could improve the productivity of "low-input" dairy sheep breeds.

Keywords: *dairy sheep, low-input system, semi-intensive management system, reproduction, udder health*

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ΠΕΡΙΛΗΨΗ. Η εκτροφή γαλακτοπαραγωγών προβάτων σε εκμεταλλεύσεις χαμηλών εισροών, αποκτά αυξανόμενο ενδιαφέρον και ευρύτερη εφαρμογή τα τελευταία χρόνια. Σκοπός της μελέτης ήταν η διερεύνηση α) της γαλακτοπαραγωγικής ικανότητας του προβάτου φυλής Σφακίων, μιας χαρακτηριστικής φυλής προσαρμοσμένης σε συστήματα διαχείρισης χαμηλών εισροών της Μεσογείου, και β) της επίδρασης του συστήματος διαχείρισης (MS) και τρόπου άμελξης (MLS) στην ποσότητα και ποιότητα του γάλακτος αυτών των προβάτων. Για τους σκοπούς της μελέτης, συλλέχθηκαν δείγματα γάλακτος από τη δεξαμενή ψύξης γάλακτος (n=307) και στοιχεία αναπαραγωγικής διαχείρισης, από 10 εκτατικές και 10 ημι-εντατικές εκμεταλλεύσεις προβάτων της φυλής Σφακίων στην Κρήτη, σε μηνιαία βάση για 2 συνεχόμενες γαλακτικές περιόδους. Το σύνολο των ημι-εντατικών και 4 από τις 10 εκτατικές μονάδες διέθεταν σταθερό αμελκτήριο (MPM), ενώ εφαρμοζόταν άμελξη με φορητή μηχανή (PM) και άμελξη στο χέρι (HM) σε 3 και 4 εκτατικές εκμεταλλεύσεις, αντίστοιχα. Η επίδραση του MS και του MLS στην ημερήσια γαλ/γη ανά προβατίνα (DMY), στον αριθμό σωματικών κυττάρων (SCC), στην ολική μικροβιακή χλωρίδα (TBC), στο pH και στην % περιεκτικότητα σε λακτόζη (LACT) του γάλακτος διερευνήθηκε με γραμμικά μοντέλα μικτών επιδράσεων. Η μέση DMY ($p<0.001$) και η εποχική διακύμανση των SCC ($p=0.020$) και LACT ($p=0.018$) επηρεάστηκαν σημαντικά από το MS. Όσον αφορά τη σύγκριση μεταξύ των μεθόδων άμελξης, ο TBC ήταν υψηλότερος στις εκτατικές εκμεταλλεύσεις με MPM σε σχέση με αυτές με HM ($p=0.002$). Η χρήση PM συσχετίστηκε με χαμηλότερα επίπεδα SCC, σε σχέση τόσο με το MPM ($p=0.044$) όσο και το HM ($p=0.012$). Συμπερασματικά, ήπιες διαχειριστικές παρεμβάσεις και η εφαρμογή ορθών πρακτικών άμελξης σε εκμεταλλεύσεις γαλακτοπαραγωγών προβάτων χαμηλών εισροών θα μπορούσαν να βελτιώσουν σημαντικά τις αποδόσεις τους.

Λέξεις ευρετηρίασης: *γαλακτοπαραγωγά πρόβατα, , σύστημα διαχείρισης χαμηλών εισροών, ημι-εντατικά συστήματα, αναπαραγωγή, υγεία μαστού*

INTRODUCTION

Dairy sheep farming is of major economical and agricultural importance, especially for South European and Mediterranean countries (de Rancourt et al., 2006). Due to the diverse microclimatic and geomorphological conditions within this area, a variety of different sheep breeds and management systems are encountered (Boyazoglu and Morand-Fehr, 2001; de Rancourt et al., 2006). The management systems applied by farmers are utilizing the local environmental resources and well-adapted dairy sheep breeds to achieve ideal productivity outputs. Under these conditions, a cost-effective output is achieved by low-input management systems. Additionally, low-input farming systems are in accordance with animal welfare rules and preservation of environmental sustainability (Vagnoni et al., 2015) and towards the general social demands for traditional dairy products.

Dairy sheep farming is usually based on extensive (low-input) and semi-intensive management systems. The main differences between these two management systems are based in a) hours per daywhere animals spend outside the farm, in pastures or grazing plains (i.e. extensively managed sheep are basically reared outdoors throughout the year, but animals are kept indoors or under shelter at least during winter nights or the lambing season), b) investment in infrastructure [i.e. semi-intensive farms invest in a larger extent infacilities and equipment such as buildings and automated milking parlours (higher inputs), whereas less or none indoor facilities, and none or a small milking parlour machine (sometimes portable) are available in extensive farms] c) nutrition (i.e. nutrition of extensively reared sheep is mostly based on grazing and concentrate feed supplement is provided rarely, while semi-intensively reared sheep are offered almost constantly concentrate feed and hay on top of grazing - higher inputs)(Stefanakis et al., 2007; Volanis et al., 2007).

The economic performance of low-input dairy sheep farms is directly related to the annual ewe milk yield, which is mainly affected by the management system applied, the udder health of ewes and the reproductive performance traits of the animals within each flock. In order to properly outline all the above, an in-depth description and analysis of i) productivity scores per flock (main milk and reproductive traits) and ii) different management strategies applied, is needed. Only then, it will be possible to thorough estimate those flock traits, one by one, and reveal management flaws allowing in a second phase specific targets and improvement methods to be set. These allocated traits could subsequently be improved by technical intervention, better management strategies and prophylactic measures. With these inexpensive methods and without gross changes in the facilities or equipment of the flocks, a beneficial improvement of the milk quantity and quality potential of dairy sheep well-adapted to low-input management schemes ("low-input breeds") should be expected.

Although older surveyshave extensively recorded milk characteristics of "low-input breeds" (Stefanakis et al., 2007; Volaniset al., 2007), there is lack of information regarding udder health parameters and repoductive performance indices. Furthermore, no exploration of the effects of different risk factors nor comparison of the available management systems or parity status of ewes has been described. Thus, the purposes of this study were to: a) characterize milk productivity, udder health parameters and reproductive performance in "low-input dairy sheep breeds" for two consecutive production years and b) describe the variation of milk/udder and reproductive traits of "low-input breeds" under different management systems and factors.

MATERIALS AND METHODS

Selection of a study area and a "low-input sheep breed"

Many sheep are bred in Mediterranean region, area which is exposed to significant environmental changes, such as climatic alterations (warming and precipitation decrease), desertification and pasture degradation (Giorgi and Lionello 2008; Lorent et al., 2009). Within this area, the island of Crete in Greece is a distinctive study scenario because on top of the specific climatic conditions the island presents a highly dense sheep population. The sheep population in Crete is approximately 2 million heads (1.82 x 106) and counts for approximately 20% of the national sheep (9.07 x 106 heads) population of Greece (National Statistical Service of Greece, 2014). It is therefore obvious that such abiotic stress factors combined with a variety of biotic stress factors (different management and breeding systems) can significantly influence dairy sheep production.

The Sfakia sheep is a "low-input dairy breed", which prevails in Crete mainly due to its successful adaptation to the semi-arid environment of the region. It is a hardy small sized breed (weight: 44kg - 64kg; height: 64cm – 74cm, for ewes-rams, respectively) with relatively high milk production of 109.8±40.8l of milk for a lactation period of 156.5±29.3 days (Kominakis et al., 2001). Mating period is in May and June (for multiparous ewes) or at the end of summer (for less than one year old – primiparous- ewes). The length of the lactation period varies and usually ranges from October to the beginning of summer, or from January to summer, for multiparous and primiparous ewes, respectively. Milk production of "low-input Sfakia sheep" is the stock for a large variety of traditional dairy products with a protected geographical indication and a protected designation of origin, contributing considerably to local agricultural income (Boyazoglu and Morand-Fehr, 2001). This breed was selected as a representative low-input model for the comparison of the management effects on output performance.

Selection of farms

For the purposes of this study, 10 semi-intensive and 10 extensive dairy sheep flocks of the Sfakia sheep breed were selected in the regions of Rethymno and Chania in Crete, Greece, where the majority of population of this breed is reared. The selection was based on previous management level description and input characteristics of these farms (Stefanakis et al., 2007; Volanis et al., 2007). So, compared to extensive farms, the semi-intensive ones had markedly more available infrastructures (shelters, buildings, milking machines), richer nutrition (increased use of concentrate feed supplements), higher labour inputs (more farmers and milkers, increased cleaning and maintenance labour), less land usage (minimum to less grazing) and higher energy inputs (power supply, fuel usage etc.). The extensive farms had importantly fewer inputs and in some cases absence of some inputs (e.g. no energy inputs), thus being representative of typical low-input management systems. Monthly bulk milk samples were collected in each flock for two consecutive lactation periods (December to August for lactation periods 2009/2010 and 2010/2011). Machine-assisted milking with a milking parlour machine (MPM) was applied in all semi-intensive flocks and in four out of ten extensive flocks. In three extensive farms a portable milking machine (PM) was used, whereas hand-milking (HM) was applied in the rest three extensive flocks. Due to the similar distribution of the the three MLS's within the extensive management system, reproductive characteristics and milk parameters were compared between MPM, PM and HM of extensive system only.

Daily milk yield per ewe measurements

In each monthly visit per farm, the number of ewes milked and their daily milk production were recorded, in order to calculate the average daily milk yield per ewe (DMY). Daily milk production and number of ewes milked once (i.e. of ewes milked once during the suckling period) was recorded separately and not used for the calculation of average DMY. Due to milking order of ewes in all farms (separate milking of multi, primiparous and suckling ewes) the calculation of DMY was made from ewes normally

Table 1. Flock composition and udder health-related characteristics (mean±SD) of 20 dairy sheep flocks (Sfakia breed) conditional on management system and year of sampling

	Year 1 & 2			Year1			Year2		
	Total	**Semi-intensive**	**Extensive**	**Total**	**Semi-intensive**	**Extensive**	**Total**	**Semi-intensive**	**Extensive**
Flock characteristics									
Total Milking Sheep	395.43±148.08	449.05±140.44	341.80±138.68	415.15±154.93	469.60±132.20	360.70±163.11	375.70±142.08	428.50±152.39	322.90±114.89
Multiparous	267.25±105.64	300.30±103.56	234.20±99.40	276.30±109.08	310.10±100.41	242.50±111.78	258.20±104.10	290.50±111.12	225.90±90.61
Primiparous	128.18±75.47	148.75±67.12	107.60±79.33	138.85±89.32	159.50±73.12	118.20±102.70	117.50±58.93	138.00±62.50	97.00±49.90
Indoor surface/ewe		2.99±1.61	1.90±0.87		2.99±1.61	1.90±0.87		2.99±1.61	1.90±0.87
Lactation period characteristics									
Duration		230.50±19.32	183.50±22.07		238±21.71	182±24.70		222±17.03	188±19.32
Daily milk yield/ewe	0.76±0.36	0.87±0.38	0.62±0.25	0.82±0.34	0.94±0.37	0.67±0.21	0.72±0.36	0.80±0.38	0.57±0.28
Weaning Day	39.35±7.61	38.20±8.47	40.50±6.67	39.35±7.71	38.20±8.70	40.50±6.85	39.35±7.71	38.20±8.70	40.50±6.85
Udder health									
Clinical Mastitis (%)	5.28±3.27	5.33±2.97	5.22±3.62	5.06±3.17	4.78±2.54	5.33±3.84	5.50±3.43	5.89±3.41	5.11±3.62
Ewes with one half -udder (%)	2.36±2.44	2.94±3.30	1.78±0.81	1.89±1.53	2.11±2.03	1.67±0.87	2.83±3.07	3.78±4.18	1.89±0.78
Slaughter due to mastitis (%)	1.69±3.17	3.11±4.01	0.28±0.58	1.11±1.68	2.11±1.90	0.11±0.33	2.28±4.14	4.11±5.33	0.44±0.73
Death due to mastitis (%)	0.72±0.88	1.33±0.84	0.11±0.32	0.72±0.90	1.33±0.87	0.11±0.33	0.72±0.90	1.33±0.87	0.11±0.33

Table 2. Reproductive traits of 20 dairy sheep flocks (Sfakia breed) conditional on management system and year of sampling

	Year 1 & 2		Year 1		Year 2	
	Semi-intensive	**Extensive**	**Semi-intensive**	**Extensive**	**Semi-intensive**	**Extensive**
Fertility traits						
Ewes:Ram	12.75±3.13	14.20±8.05	13.20±2.78	13.90±6.82	12.30±3.53	14.50±9.49
Return to oestrus (%)	6.90±4.06[a]	8.00±4.95[a]	6.50±4.38[a]	8.00±5.31[a]	7.30±3.92[a]	8.00±4.85[a]
Fertility rate (%)	97.50±2.44[a]	97.25±3.61[a]	98.10±1.20[a]	98.30±2.75[a]	96.90±3.21[a]	96.20±4.19[a]
Fecundity rate (%)	93.10±2.92[a]	92.95±4.16[a]	93.60±2.63[a]	94.10±3.70[a]	92.60±3.24[a]	91.80±4.47[a]
Miscarriages (%)	2.05±0.95[a]	3.25±2.15[a]	1.80±0.92[a]	2.90±2.00[a]	2.30±0.95[a]	3.60±2.37[a]
Parturition						
Prolificacy (lambs/ewe/delivery)	1.36±0.10[a]	1.26±0.10[b]	1.37±0.10[a]	1.26±0.10[b]	1.36±0.10[a]	1.26±0.10[b]
Dystocia (%)	1.35±1.42[a]	1.55±1.10[a]	1.10±1.00[a]	1.60±1.17[a]	1.60±1.78[a]	1.50±1.08[a]
Stillbirths (%)	0.80±0.77[a]	0.70±0.66[a]	0.70±0.68[a]	0.70±0.68[a]	0.90±0.88[a]	0.70±0.68[a]
Lamb survival						
Lambs adopted (%)	3.40±2.09[a]	4.50±2.50[a]	2.90±1.52[a]	4.00±2.16[a]	3.90±2.51[a]	5.00±2.83[a]
Lamb losses 0-48h pp (%)	1.60±1.23[a]	2.66±2.16[a]	1.10±0.74[a]	2.30±1.95[a]	2.10±1.45[a]	3.00±2.40[a]
Lamb losses 48h pp-weaning day (%)	6.10±2.69[a]	7.40±3.41[a]	5.00±2.06[a]	6.70±3.27[a]	7.20±2.90[a]	8.10±3.57[a]
Total lamb losses (%)	8.65±4.10[a]	10.60±4.30[a]	7.00±2.83[a]	9.40±4.22[a]	10.30±4.62[a]	11.80±4.24[a]

Values are expressed as mean±SD. Statistically significant differences between the two management systems within the same sampling year are flagged with different letters (a, b). pp: post parturition milked (not suckled) by dividing their daily milk production with their number. These calculations were applied in this way, so to avoid under- or over- estimation of average DMY.

Bulk milk sample collection and analysis

In each monthly visit of the two consecutive lactation periods studied, a bulk milk sample from the milk produced the specific day (pool of milk collected during morning and evening milking) was collected (n=307) and kept at 4°C until analysis. Samples were processed, after 12 to 18 hours, at the State Milk Quality Laboratory (ELOGAK) in Rethymno, Crete. The samples were heated to 25oC and pH was measured. Lactose levels % (gr/100ml) of bulk milk samples were measured by infrared methods (MilkoscanTM, FOSS®). Somatic cell count (SCC) and the number of total bacterial count (TBC) were assessed in samples with pH>6, using the FossomaticTM (Gonzalo et al., 1993) and BactoScanTM system (FOSS®, Denmark), respectively. All procedures in the present study were carried out with no physical or clinical intervention on animals and the trial was run under the supervision of veterinarians.

Questionnaire

Following thorough discussion with all the farm owners, detailed questionnaires were filled in for each of the two above mentioned lactation periods. Data regarding the composition of the flock (total flock size, number of ewes that gave parturition, number of multi- and primiparous ewes, number of rams and lambs born), the available surface per animal indoors, the availability of separate lambing, suckling and quarantine/infirmary rooms within the farm and the type of grazing (common or private pasture) were collected.

Reproductive performance traits (return to oestrus after mating, miscarriages and dystocia rates, ewe mortality at parturition, stillbirths and rates of lamb mortality: until 48h post parturition (pp), 48h pp to weaning and post-weaning) were recorded per farm. Additionally, with the use of the above data, the following parameters were calculated: fecundity, fertility, prolificacy and the ewe to ram rate (ewe/ram).

Regarding the milking process, the following data were collected: type of milking system (parlour milking machine systems, portable (bucket) milking machine, hand milking), frequency of milking, number of milking personnel, use of disposable gloves during milking, udder preparation before milking, teat dipping post milking, general percentage and time-period of most clinical mastitis cases, treatment (route of administration, duration of treatment) and the usual outcome of clinical mastitis, the percentage of ewes with one functional udder-half, the mortality rate due to clinical mastitis and the intramammary application of drying off antibiotics at the end of the lactation period. Data collected in the questionnaire also included: number of adopted lambs, the pp weaning day, the onset, the frequency and duration of milking during the suckling period (if applied) and information about administration of vaccines against clinical mastitis infectious agents.

Statistical analysis

Mean values (±SD) were used for the descriptive presentation of the continuous data collected through the questionnaire, as well as of the parameters [pH, (%) lactose content, TBC, SCC)] determined in monthly bulk milk samples. The mean values of the outcome variables were compared between different management systems, using the independent Student's t-test or the Mann Whitney test (depending on the distribution of the outcome variable).

The fixed effect of year of experimentation, MS and month of lactation on the repeated measurements of bulk milk parameters [pH, (%) lactose content, TBC, SCC)] of the 20 visited farms was analyzed with linear mixed-effects models. Using the same statistical approach, the fixed effect of year of experimentation, MLS and month of lactation on bulk milk SCC, TBC and DMY was explored for the 10 extensive farms. Given the repeated-measures design of the study, covariance structure of linear models was assumed to be a first-order autoregressive structure. The levels "semi-intensive management system", "milking parlour machine", "year 1" were set as the baseline condition for the estimation of model parameters for the fixed effect of MS (2-level factor), MLS (3-level factor) and year of experimentation (2-level factor). Between-farm variability was included as a random effect in the model structure; the intercept of the models was allowed to vary across farms. The random effect of farm (repeated over month of lactation), as well as the fixed effects of MS, MLS, month of lactation, and the interaction terms MS x month of lactation and MLS x month of lactation were stepwise added in the model structure. The subsequent improvement of model fit was evaluated by model comparisons based on the -2 log-likelihood ratio criterion (at 0.05 significance level). Estimates of model parameters and parameter-specific P-values were estimated using a normal approximation. Normality of model residuals was assessed through diagnostic Trellis plots.

Data processing, statistical analysis and graphical illustration of the results were done using nlme [20], lattice [21] and ggplot2 [22] packages in R version 3.1.3[23].

RESULTS

Data regarding the composition of the flocks (total number of sheep, number of multi- and primiparous ewes) and mastitis-related indices are presented in Table 1. According to the data collected through the questionnaire, the indoor available surface area/animal was higher in semi-intensive (2.99±1.61 m2/ewe) compared to extensive farms (1.90±0.87 m2/ewe) (Table 1). A discrete lambing, weaning and isolation room was available in most semi-intensive farms (7/10, 8/10 and 7/10 farms, respectively), while such facilities were present in less than one third of the extensive farms (1/10, 3/10 and 3/10, respectively). Half of the flocks shared a common pasture with other flock(s); the majority of the flocks applying common grazing (8/10 farms) were extensively reared, thus meaning that most semi-intensive flocks had private grazing areas.

[Table 1]

Results on the reproductive traits recorded are presented in Table 2. As demonstrated, parameters of reproductive performance exhibited no statistical differences between the two management systems, except for prolificacy ($p<0.05$). Prolificacy values were higher for semi-intensively bred ewes (1.36±0.10 lambs/delivery) compared to extensively bred ewes (1.26±0.10 lambs/delivery; Table 2).

[Table 2]

The mean duration of lactation period was 230.50±19.32 and 183.50±22.07 days for semi-intensive and extensive farms, respectively. DMY per ewe was 0.87±0.38 and 0.62±0.25 l for semi-intensively and extensively bred ewes, respectively (Table 1). In 18 out of 20 farms, ewes were subject to milking once per day during the 2nd half of the suckling period; the mean start day for semi-intensive and extensive farms was at 17 and 22 days pp, respectively. In all studied farms the time of weaning ranged from 30 to 55 days pp (38 and 41 days pp, for semi-intensive and extensive farms, respectively; Table 1).

Concerning udder handling, post milking teat-dipping was applied in only 3 (2 semi-intensive and 1 extensive) out of 20 flocks, only for a limited time period during the lactation; udder preparation before applying the milking devices was not the case in any of these dairy flocks. Milking was carried out by one (3 extensive farms), two (7 semi-intensive farms and 6 extensive farms) or three (3 semi-intensive farms and 1 extensive farm) individuals and the use of gloves during milking was reported in only 3 (extensive) farms. Milking frequency during the lactation period was twice per day in all flocks. According to farmers, mastitis problems were more frequently observed in the following stages of the lactation period (in descending order): suckling period, before the onset of dry period, the last two months of the lactation, the first or second third of the lactation. Regarding the treatment of clinical mastitis cases, a combination of intramammary and intramuscular antibiotics was used in 4 out of 20 farms (1/10 semi-intensive and 3/10 extensive farms), whereas only systemic antibiotics were administered in the rest of the farms; the usual duration of treatment was two consecutive days. Treatment with dry period antibiotics at the end of the lactation was not applied in any of the flocks visited. In only 3 (semi-intensive) out of 20 flocks a yearly vaccination against clinical mastitis agents took place. Animal losses due to clinical mastitis did not exceed 1% (0.72% ± 0.88%) of total flock population (Table 1). The frequency of mastitis-related mortality and permanent loss of one half-udder was higher in semi-intensively (1.30%±0.80% and 4.35%±5.34%, respectively) compared to extensively bred ewes (0.10%±0.31% and 2.45%±1.28%, respectively); however, this trend was not proven statistically significant ($p>0.05$ in all cases; Table 1).

Monthly variations of bulk milk traits (pH, % lactose content, SCC, TBC) and DMY were analyzed in relation to the management system applied (Figure 1). Estimated coefficients (mean value±SEM) and the respective significance levels for the fixed effects of experimentation year, MS, month of lactation and their interaction term are presented in Table 3. As illustrated in Figure 1, significant monthly fluctuations were detected for the five dependent variables [$F(7, 292)=23.760$, $p<0.001$ for DMY; $F(7, 292)=0.203$, $p<0.001$ for % lactose content; $F(7, 292)=4.440$, $p<0.01$ for SCC; $F(7, 292)=3.000$, $p<0.05$ for milk pH; $F(7, 292)=3.589$, p0.05 for TBC]. The fixed effect of the interaction term *MS x month of lactation* was proven non significant for bulk milk pH, TBC and DMY ($p>0.05$ *in all cases)*, which therefore shows that the monthly variation pattern of the above mentioned dependent variables was similar for semi-intensive and extensive systems (Figure 1). On the contrary, MS had a significant effect on the monthly variation pattern of bulk milk SCC [$F(7, 292)=2.428$, $p=0.020$)] and % lactose content [$F(7, 291)=6.391$, $p=0.018$] in the

Figure 1. Monthly variation of daily milk yield/ewe (lit), pH, lactose content (%), somatic cell count (SCC x1000 cells/ml) and total bacterial count (CFU/ml) of bulk milk throughout the lactation period, in relation to the management system (MS) applied.

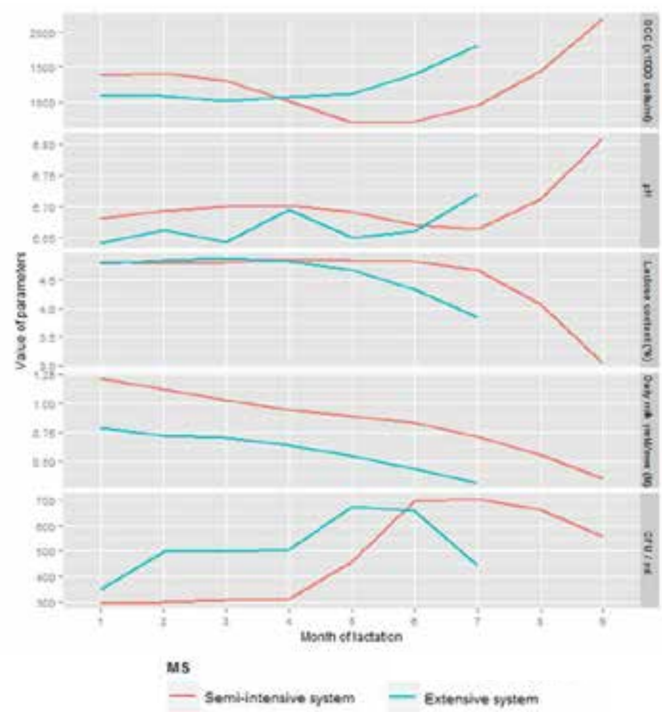
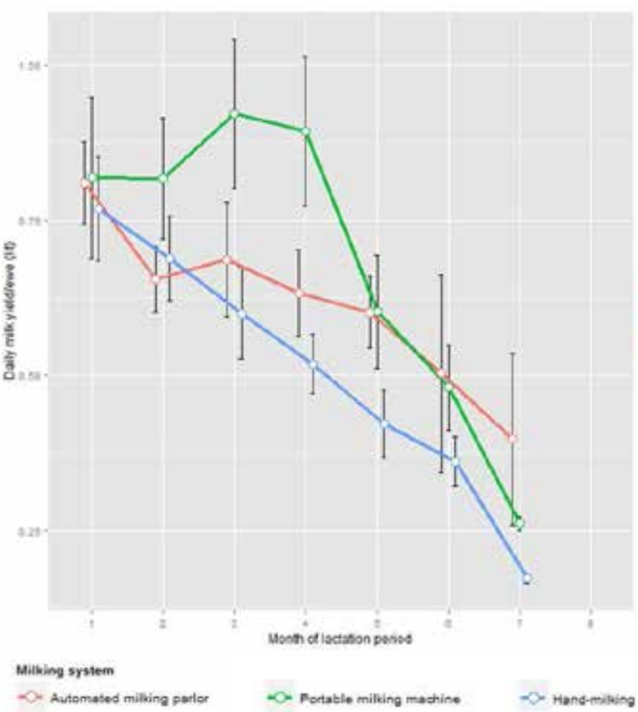


Figure 2. Monthly variation of daily milk yield/ewe (lit) of 10 extensive farms, in relation to the month of lactation and the milking system applied. Values are expressed as mean ±SE.



course of the lactation period. SCC levels were significantly ($p<0.05$) elevated in late lactation (months 9 and 7 for semi-intensive and extensive farms, respectively; Figure 1). In overall, individual daily milk yield was higher by 0.288 l in semi-intensively compared to extensively bred ewes [F(1, 292)=58.910, $p<0.001$], but lactation curve followed the same time pattern for both management systems (Figure 1). Lactose content (%) was lower by 0.062 gr/100ml of bulk milk samples collected from semi-intensive farms [F(1, 291)=5.640, $p<0.001$]. [Table 3] [Figure 1]

The effect of MLS on the fluctuations of milk traits (SCC, TBC) and DMY throughout the lactation period was assessed within extensive farms (Figures 2-4). The monthly variation pattern of SCC (Figure 3) and TBC (Figure 4) was not related to MLS in extensive farms ($p>0.05$ in both cases). Though not statistically significant, an increase of SCC of bulk milk in farms applying MPM and HM, in comparison to PM, at late lactation was observed (Figure 3). In addition, an overall effect of MLS on the levels of SCC and TBC was detected. In particular, bulk milk samples collected from farms where PM was used exhibited lower levels of SCC by 598.818 ($p=0.044<0.05$) or 677.268 x 103 cells/ml ($p=0.012<0.05$) when compared to samples collected from farms where MPM or HM was applied, respectively. Interestingly, bulk milk TBC values were higher by 498.454 units in extensive farms with MPM than in farms with HM ($p=0.002<0.01$). [Figures 2, 3, 4]

DISCUSSION

The potential effect of management systems on reproductive and productive performance of a "low-input dairy sheep breed" was explored in the present study. Different reproductive practices were followed in semi-intensive and extensive farms; oestrus synchronization schemes, scheduled mating and lower ewe/ram ratio were reported in semi-intensive farms, while were not the case in extensively bred ewes. However, no statistical differences were found in the reproductive indices recorded, apart from prolificacy. The significantly higher numbers in semi-intensively reared ewes could be attributed to better feeding and management strategies. Improvement of animal nutrition and management methods may possibly enable the preservation of multi-pregnancies, the decrease of early embryonic losses and the avoidance of metabolic diseases related to prolifica-

Figure 3. Monthly variation of somatic cell count (SCC x1000 cells/ml) of bulk milk collected from 10 extensive farms, in relation to the month of lactation and the milking system applied. Values are expressed as mean ±SE.

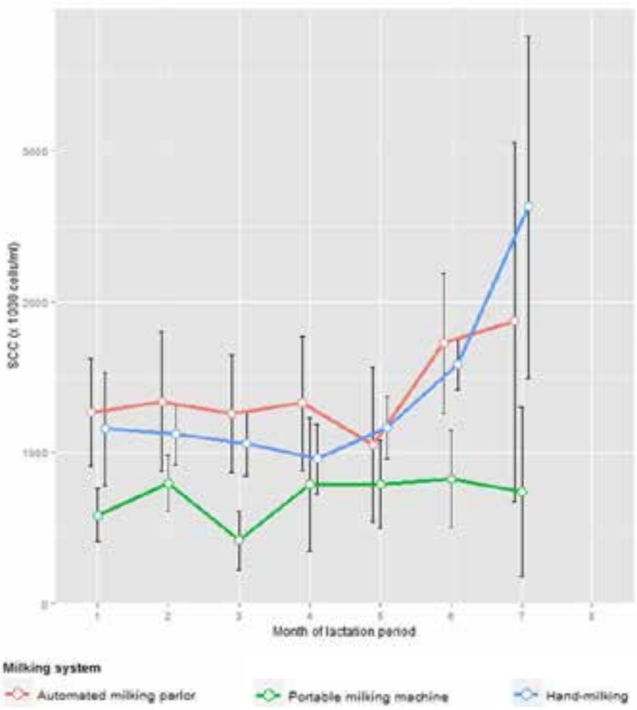
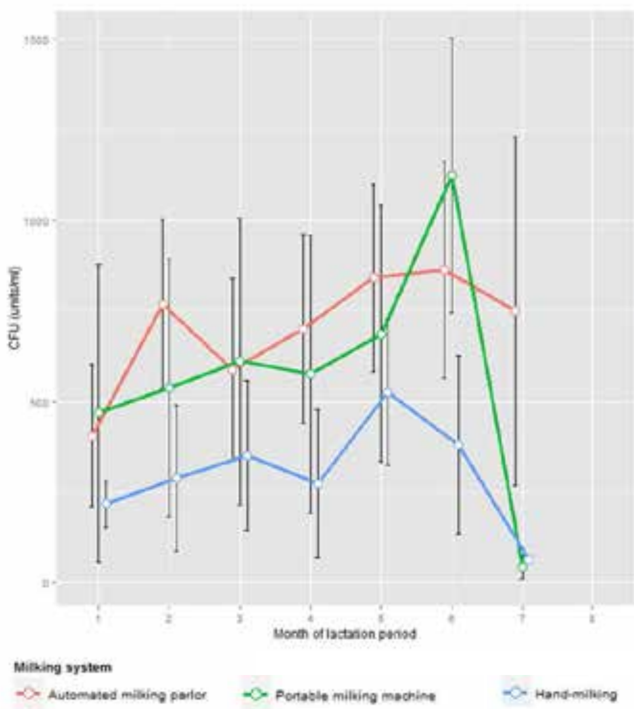


Figure 4. Monthly variation of total bacterial count (CFU/ml) of bulk milk collected from 10 extensive farms, in relation to the month of lactation and the milking system applied. Values are expressed as mean ±SE.



cy (Rhind et al., 1980; Viñoles et al., 2009; Gootwine, 2011; Fthenakis et al., 2012).

Almost half of the extensive farms (4/10) revealed a modernizing trend towards updating management practices and available equipment. In particular, 4 out of 10 extensive farms had a MPM installed, which was a common characteristic for all semi-intensive farms. This differentiation may imply a transition stage of these farms towards a more advanced and intensified management state.

As presented on Table 1, mean DMY of extensive farms was close to the levels previously recorded for Sfakia breed (0,7l mean DMY; Kominakis et al., 2001). However, mean DMY of semi-intensive farms exceeded the expected levels. Furthermore, DMY was different between the two management systems (Table 1). Semi-intensive farms had higher milk production (higher DMY by 0.288 l, $p<0.001$) and a longer lactation period (230.50±19.32 days against 183.50±22.07 days for extensive farms; Table 1). Based on the relative literature (McKusick et al., 2001; Sinapis, 2007), reasons for the degraded milk production of extensive farms could be: the later time point of weaning (on the 41st day of lactation period against the 38th day in semi-intensive farms; Table 1), the poorer ewe selection on a basis of productivity traits, the hand milking system and the lower nutritional input, namely less addition of concentrates and more grazing in uncultivated grasslands or shrublands which all have a low energy and protein value. However, in the current study only the differences regarding the daily milk production between the two management systems were explored; an integrated study also including the quality and organoleptic characteristics of milk produced by intensively and more extensively bred ewes would further add to the present knowledge.

Regarding both semi-intensive and extensive farms, a lack of advanced udder health management was observed. Only in few farms, post-dipping (in 1 extensive and 2 semi-intensive farms) and vaccination against mastitis (in 3 semi-intensive farms) were applied. “Blind” mastitis treatments, the non-usage of dry-period antibiotics and non-steroid anti-inflammatory drugs, as well as the absence of an integrated management for subclinical mastitis were the case in most farms, against the already established guidelines for udder health management (Fthenakis et al., 2012; Fragkou et al., 2014). Although good milking practice was not always the case, the frequency of clinical mastitis cases

Table 3. Estimated coefficients (mean value±SEM) for the fixed effects of year of experimentation (year 1 vs 2), management system (extensive vs semi-intensive), month of lactation (months 2 to 8 vs 1) and the interaction term of management system and month of lactation on bulk milk parameters (SCC, TBC, % lactose content, pH) and DMY. Significant coefficients are flagged.

	SCC	TBC	% lactose content	pH	DMY
(Intercept)	1132.12±248.5	183.92±153.36	5.26±1.28	6.64±0.03	310.72±29.37
Year2	399.56±100.65**	149±70.44**	-0.82±0.6	0.08±0.01*	-49.17±11.89**
Extensive	-327.71±461.09	153.87±292.1	0.34±2.64*	-0.07±0.06	-102.75±45.19**
Month2	161.44±254.22	99.75±165.06	4.26±1.7*	0.01±0.04	21.24±16.39*
Month3	83.9±262.61	71.12±174.6	-0.1±1.7	0.02±0.04	7.42±19.75
Month4	-420.09±263.21	85.58±175.79	0.04±1.7	0±0.04	28.05±21.15
Month5	-529.3±263.25**	104.34±175.94	0.01±1.7	0.04±0.04	30.97±21.7
Month6	-752.04±263.25**	530.32±175.89**	-0.09±1.7	-0.03±0.04	6.7±22.01
Month7	-263.42±263.12	496.64±177.84**	-0.05±1.7*	-0.01±0.04	-45.54±21.4**
Month8	22.54±261.37	259.37±173.45	-0.65±1.7*	0.01±0.04	-132.2±20.27**
Extensive: Month2	-52.49±473.71	-210.32±309.53	-4.66±3.12	0.02±0.07	-55.59±31.27
Extensive: Month3	84.26±483.09	8.96±320.15	-0.28±3.11	0.06±0.07	-40.49±34.83
Extensive: Month4	450.9±483.76	-40.4±321.47	-0.36±3.11	0.03±0.07	-53.42±36.24
Extensive: Month5	640.93±483.72**	-52.24±321.45	-0.37±3.11	0.06±0.07	-67.18±36.51
Extensive: Month6	781.69±482.58**	-287.94±319.94	-0.39±3.11*	0.06±0.07	-53.88±35.96
Extensive:Month7	701.41±485.59**	-152.96±321.47	-0.85±3.14**	0.05±0.07	-54.53±34.88
Extensive: Month8	860.09±543.75	-283.5±357.78	-0.62±3.47	0.12±0.08	-6.25±38.35

*: p<0.05, **: p<0.01

was close to the accepted thresholds described by Bergonier et al. (2003) for both MS (5.33%±2.97% and 5.22%±3.62% for semi-intensive and extensive farms, respectively; Table 1). Though the udder health management practice was irrelevant to the management system applied, there seemed to be a trend for semi-intensive farms to exhibit higher case frequency and clinical mastitis-related losses (death or involuntary slaughter, functionality loss of one half-udder) compared to extensive farms (Table 1); however, this trend was not proven statistically significant (p>0.05 in all cases). As indicated by the high SD values of the above mentioned variables (Table 1), this could be attributed to the high variability detected among the semi-intensive farms, regarding mastitis-related animal and udder functionality losses. Another possible cause could be the improper usage (e.g. poor maintenance or wrong adjustment of milking machine's vacuum and pulse, poor hygiene of milkers / milking machine, wrong milking order of ewes etc.) of the milking equipment in semi-intensive farms, that could adversely affect the incidence and severity of clinical mastitis cases (Bergonier et al., 2003).

The relation of clinical to subclinical mastitis frequency is often described as the "tip of the iceberg phenomenon", which suggests that a single clinical mastitis case can indicate multiple subclinical mastitis cases in a farm (Bakken and Gudding, 1982). In the present study, such a phenomenon was also implied by the relatively high SCC of bulk milk samples with a concurrent low clinical mastitis incidence in the farms visited. The levels of bulk milk SCC in MPM and PM had values over 0.5x106, while in HM they exceeded 1x106 SCC/ml of bulk milk (Figure 3). This finding suggests that machine-milked ewes were less likely to suffer from subclinical mastitis in comparison to the hand-milked ewes (Berthelot et al., 2006). However, SCC levels did not differ between farms of the two management systems (p>0.05). This is in accordance to the lack of adequate prophylactic measure (i.e. use of dry-off antibiotics, on time diagnosis and proper mastitis treatment) regarding subclinical mastitis in both management systems. When the effect of milking method within a single management system (namely the extensive management system) on SCC was explored, significantly lower levels of the later were recorded for PM (by 598.818 and 677.268 x103 cells/ml in comparison to MPM and HM, respectively; $p<0.05$ in both cases). The closer inspection of the udder by the farmer before and/or during milking and the milder interference with animal welfare achieved while milking with a portable milking machine, could potentially contribute towards the protection of the udder against subclinical mastitis and the production of low SCC milk. Targeted interventions and a careful prophylactic approach is essential against subclinical mastitis, lately reported as the primary cause of "Milk-drop syndrome of ewes" (Fthenakis et al., 2012).

In regard to TBC values, when the effect of the milking method used within the same management (extensive) system was explored, significant differences between hand- and machine-milked flocks were detected. In particular, bulk milk samples collected from extensive farms where HM was applied, exhibited significantly lower TBC (by 498.454 units, $p=0.002<0.01$), when compared to bulk milk samples of flocks with MPM (Figure 4). This finding implies that the possibly inadequate hygiene and functional status of the parlour machine, as well as the lack of good milking practice, can outweigh the risk of microbial contamination of the milk during HM, thus resulting in milk of higher bacterial burden in flocks with MPM. However, HM resulted in lower DMY (by 0.181 l, $p=0.001$) when compared to PM (Figure 2). It appears that machine-assisted milking has a beneficial effect on the milk productivity of ewes, but to ensure the quality of the produced milk, attention should be paid to the maintenance of the milking equipment. The results of our study revealed a significant increase of SCC levels of bulk milk samples collected from both semi-intensive and extensive farms at the late stage of the lactation (month 9 and 7 for semi-intensive and extensive farms, respectively; $p<0.05$ in all cases) (Figure 1). Bulk milk samples collected in months 5-7 of the lactation showed significantly higher TBC values (Figure 1). A seasonal variation of the quantity and the physicochemical properties of sheep milk has been previously described (Casoli et al., 1989; Carta et al.,1995). Similar to our results, Gonzalo et al.(1994) reported an effect of lactation stage on milk yield and SCC levels of the Churra dairy sheep. This result was expected and can be attributed to the different infective status and milk dilution/concentration effects throughout the lactation period (Carta et al., 1995). For the extensively bred ewes, the three milking methods applied (MPM, PM, HM) did not significantly affect the monthly variation patterns of SCC, TBC and DMY (Figures 2-4).

Conclusion

In conclusion, an attempt to describe the reproductive and milk productive status of "low-input dairy sheep breeds" in relation to different management systems applied has been made in this study. Crucial declinations from the established guidelines concerning udder health management and milking procedures have been identified. In the same time, strong indications implying the potential improvement of quantitative and qualitative milk traits under more intensified management conditions were presented. Mild interventions (i.e. induction of milking using a portable milking machine, adequate udder health prophylaxis) could prove beneficial towards the increase of milk production and the reduction of SCC and TBC levels. Targeted genetic selection could also contribute to the exploitation of the full productive potential of such promising breeds, reared in low- or medium- input management schemes, increasing their relative high output. Attention should be paid though to the preservation of animal welfare and the special characteristics which enable low-input sheep farms to thrive in rather challenging climatic and geomorphological conditions.

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CONFLICT OF INTEREST STATEMENT

No author of this paper has a financial or personal relationship with other people or organizations that could inappropriately influence or bias the content of the paper.

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