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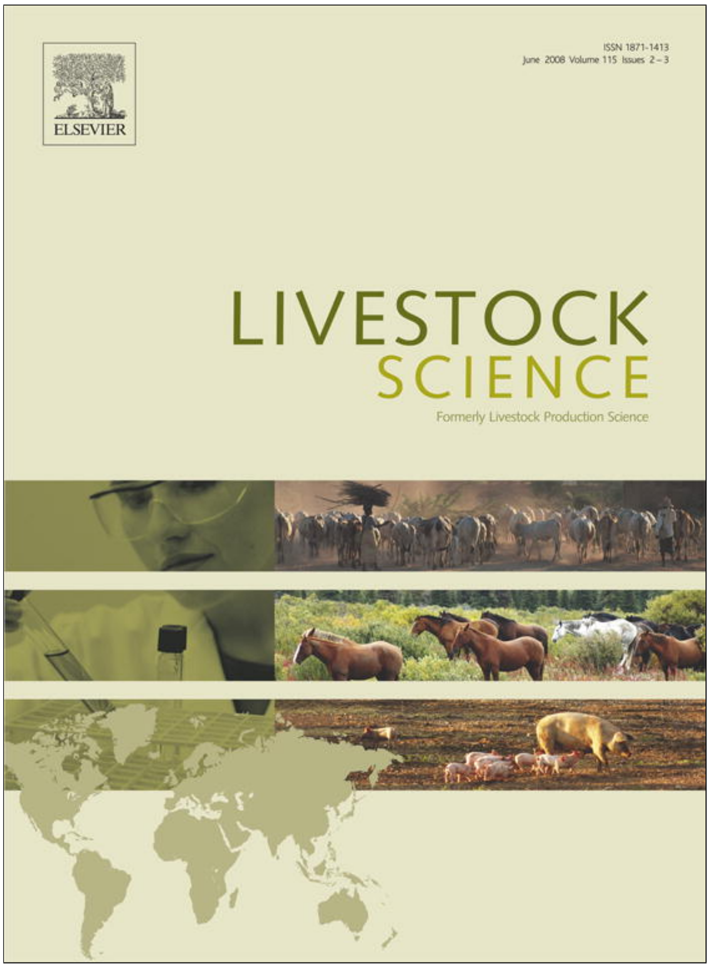
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Grouping strategies and lead factors for ration formulation in milking ewes of the Chios breed

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Abstract

The aim of this study was to develop an efficient strategy for ration formulation for milking ewes of the Chios breed in Greece. The strategy involved two and three groupings according to production level and challenge feeding using lead factors. Lead factors, that adjust upwards the average production of a flock or a group of ewes, were calculated for the 83rd and the 90th percentile, using 49,237 milk test-day records from 549 flock-test-days, referring to 64 flocks and 97 complete lactations. Lead factors were 1.25 for the single-group, 1.14 and 1.17 for the two-group, and 1.11, 1.07 and 1.15 for the three-group strategy for the 83rd percentile. Regarding the 90th percentile, these were: 1.33 for the single-group, 1.18 and 1.19 for the two-group, and 1.15, 1.09 and 1.16 for the three-group strategy. Analysis of variance was used to assess the influence of several effects on lead factors. Flock-year and mean and standard deviation milk yield were significant ($P<0.05$) in nearly all cases, leading to calculation of different lead factors for high (>250 kg of milk/ewe/year) and low (<250 kg of milk/ewe/year) producing flocks. Higher producing flocks were associated with somewhat lower than average lead factors, while the opposite was true for lower producing flocks. In order to allow the sufficient expression of the genetic potential of the best ewes and accurately estimate their genetic value under Greek conditions, the 90th percentile strategy can be adopted for the higher producing groups and the 83rd for the lower ones.

Keywords: Chios breed; Milk production; Feeding strategy; Grouping; Lead factors

1. Introduction

Due to particular social, economic and climatic conditions, sheep have always played a major role in dairy farming in Greece (deRancourt et al., 2006). According to Eurostat (2004), sheep milk production in 2002 was 667,000 tonnes and comprised 35% of total milk produced in Greece (1.9 million tonnes); cow and goat milk represented the remaining 42% and 23% of total milk, respectively. There are about 6.9 million ewes in Greece, all of the dairy type (deRancourt et al., 2006). After a suckling period that typically lasts 6 to 8 weeks, their average milk production is about 100 kg in a 5-month lactation; low genetic merit, poor management and inadequate nutrition are the main reasons for their unsatisfactory performance. Amongst the indigenous breeds, which represent more than 98% of the national flock, the Chios breed is the most productive one. Results of milk records in purebred flocks showed an average milk yield of 302 kg in 200 days after an initial 6-week

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suckling period (Chios Sheep Breeders Cooperative "Macedonia", 2004). Mean prolificacy of these ewes was 1.87 and 40% of them produced more than 300 kg of milk per lactation, whereas the potential ram dams (top 15% of the ewes) produced more than 450 kg per lactation (Chios Sheep Breeders Cooperative "Macedonia", 2004).

Currently, a genetic improvement program is being implemented in the flocks of the Chios Sheep Breeders Cooperative. Its success depends largely on the nutrition of animals implying that participating flocks must apply effective feeding strategies. The notion in ration formulation for sheep (and animals in general) is to provide sufficient nutrients, in suitable amounts and proportions, to fulfill their needs for maintenance, growth and production (Cannas, 2004). In practice, milking ewes of the Chios breed are kept in a single group within flock and are fed according to the average flock production. However, when ewes are fed on the basis of average milk yield, approximately half of the flock is expected to be overfed and half (the best ewes) underfed. If rations are adjusted for the high producing ewes, then half of the problem is partially overcome but low producing ewes would be even more overfed, leading to increased production costs.

Bocquier et al. (1995) suggested that splitting a flock in two groups, according to ewe's production level could efficiently reduce within group variability; the added benefit of forming three or four groups was small in that study. However, feeding for the average production of each group would still compromise the performance of the best ewes. An alternative option could be the proposal by Stallings and McGilliard (1984), who introduced the use of lead factors in feeding strategies for dairy cows. Lead factors, adjusting energy and protein densities of diets by adjusting upwards the average production level, can be used to minimize both the proportion of underfed animals and the extent of underfeeding. The application of such system in dairy sheep is likely to allow a higher milk production and a more accurate estimation of the genetic value of potential ram dams. Bocquier et al. (2002) demonstrated that ewes fed rations meeting less than 80% of their energy requirements reduced their milk production in a faster rate than that explained by their nutrient intake. Hence, the question that arises is whether the combination of the above two strategies, grouping animals and using lead factors for ration formulation, could give the best results not only from a nutritional but also from a financial perspective. No relevant studies have been found in the international literature available to us.

Flocks participating in milk-recording schemes can easily apply such strategies. Group production levels can be calculated from individual ewes' records. On the contrary, these are difficult to assess in flocks where milk-recording is not practiced. Factors predicting group production levels from total daily flock production might be useful in such circumstances. This would be of particular interest for the Greek sheep production since most flocks do not participate in milk-recording schemes.

The aim of this study was to develop an efficient feeding regime for the milking ewes of the Chios breed in Greece, combining different grouping strategies and lead factors.

2. Materials and methods

2.1. Data description

Data comprised test-day milk yield records of individual ewes collected by the Chios Sheep Breeders' Cooperative 'Macedonia" from 1998 to year 2000. Milk-recording stopped in 2001 and was resumed in 2004. Average milk yield, standard deviation and coefficient of variation (CV) were calculated per flock-test-day. Flocks were required to have a minimum of three valid test-days. Data regarding flock-test-days with less than 20 ewes and a CV for milk production less than 10% were removed. After edits, 49,237 milk test-day records from 549 flock-test-days, 64 flocks and 97 complete lactations were used. Flock-test-days were assigned to seven classes indicating the stage of lactation according to the average number of days since lambing (45–74, 75–104, 105–134, 135–164, 165–194, 195–224, ≥225 days). This was used to create the mean lactation curve of the ewes in the data set.

2.2. Lead factor calculation

Lead factors were calculated within each flock for single, two or three equally sized groups formed according to milk production. The latter was the only criterion considered in lead factor calculation. The equations used to calculate lead factors were: (i) [(mean milk yield + one standard deviation)/mean milk yield], which was expected to satisfy the nutritional requirements of 83% of the ewes in each group and (ii) [milk yield of the 90th percentile ewe/mean milk yield], which was expected to satisfy the nutritional requirements of 90% of the ewes in each group. The latter was considered as the feeding strategy allowing high producing ewes to better express their genetic potential under Greek conditions.

2.3. Effectiveness of ration formulation strategy

The following equation was used to determine the daily milk production of individual ewes above which less than 80% of their energy requirement would be met, if rations were formulated according to group average or according to the adjusted (using the lead factors) production level:

$$\{([ER_m + ER_p] \times 100/80) - ER_m\}/ER_{per\ kg\ of\ milk}$$

where

ER_m energy requirement for maintenance
ER_p energy requirement for milk production (average or adjusted)
$ER_{per\ kg\ of\ milk}$ energy requirement per kg of milk produced

Energy requirements for maintenance and milk production were those published by Bocquier et al. (1988) for ewes with a body weight of 60 kg, producing milk with a 6.5% fat and 5.5% protein content. The result was used to calculate the number of ewe-test-day records where the energy requirement of ewes was not adequately met (less than 80%).

2.4. Statistical analysis of lead factors

Analysis of variance was used to assess the influence of several effects on lead factors, using model [1].

$$Y_{ijk1} = \mu + FY_i + CM_j + \sum_{k=1}^{2} \alpha_k \cdot M^k + \sum_{l=1}^{2} \beta_l \cdot MS^l + \gamma \cdot D + \delta \cdot DS + e_{ijkl} \quad [1]$$

where

Y lead factor
μ population mean
FY_i fixed effects of ith flock by year interaction
CM_j fixed effect of jth calendar month
α_k fixed regression (linear and quadratic) on mean test-day milk yield (M)
β_l fixed regression (linear and quadratic) on standard deviation of test-day milk yield (MS)
γ fixed (linear) regression on mean days-in-milk (D)
δ fixed (linear) regression on standard deviation of days-in-milk (DS)
e random residual

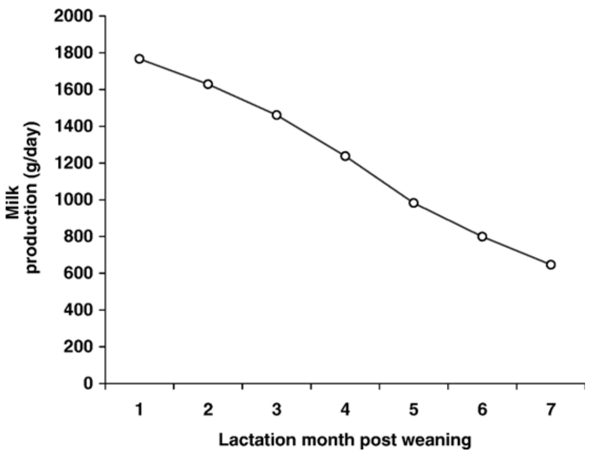

Fig. 1. Mean lactation curve of the Chios ewes.

Separate analyses were conducted for each group and grouping strategy.

2.5. Economic analysis

The economic benefit of feeding milking ewes in either two or three groups in comparison to a single group was calculated as the difference in the amounts of concentrates fed. One kg of concentrates was assumed to correspond to 1.5 kg of milk produced (0.96 UFL and 125 g of PDI per kg, Bocquier et al., 1988). Concentrate price was set at 0.24 euros per kg (current Greek market price for a formulation of the above specifications).

2.6. Group production factors calculation

Group production factors, predicting the average milk yield of each group, were calculated in relation to the average yield of each flock. For example, when two groups were formed, two such factors were calculated as the ratio of the average production of each group over the average production of the entire flock. Similar logic applied to three groups. The entire data set was then randomly split into two independent subsets consisting of 274 (49 flock-years) and 275 (48 flock-years) test-day records, respectively. These two independent data sets were created to validate results using the product moment correlation between estimated and actual mean daily milk yield.

3. Results

The average number of ewes per test-day was 90. Fig. 1 shows the mean lactation curve of the Chios ewes according to monthly intervals post-weaning. The average milk yield by stage of lactation class was 1767, 1629, 1461, 1237, 983, 799 and 646 g for the seven classes, respectively. Average milk yield of ewes was about 245 kg in 200 days.

Table 1
Lead factors for various grouping strategies

	Lead factors		
83rd percentile			
Single group	1.25		
Two groups	1.14	1.17	
Three groups	1.11	1.07	1.15
90th percentile			
Single group	1.33		
Two groups	1.18	1.19	
Three groups	1.15	1.09	1.16

Table 1 shows the lead factors (mean values) for various feeding strategies considering the 83rd and the 90th percentile. In all cases, the first group included ewes with the highest milk production. As shown in Table 1, when ewes were fed as a single group, lead factors were 1.25 and 1.33 at the 83rd and 90th percentile, respectively. The latter suggests that rations should be formulated according to a production level of 25% and 33% higher than the flock average in order to meet the energy requirements of 83% and 90% of the ewes, respectively. Smaller lead factors were associated with feeding of ewes in either two or three groups. This was expected because the within group coefficient of variation was smaller. The difference between the 83rd and the 90th percentiles was rather large when ewes were kept in a single group (1.25 and 1.33, respectively) but it became smaller when ewes were considered in two or three groups. Lead factors required by the higher producing groups were still different between the 83rd and the 90th percentiles for both the two-group (1.14 and 1.18) and the three-group strategies (1.11 and 1.15). For lower producing groups this difference was smaller (1–2%).

Table 2 shows the number of ewe-test-day records where the energy requirement of ewes was not adequately met (less than 80% per ewe), by grouping and feeding strategy. When rations were formulated for the average production of a single group there were 719 such cases out of a total of 49,237 records (1.46%). Actually, such “violations” were observed in about 57% of the flocks and the real incidence rate was 2.33% (719 out of 30,744 records in these flocks). This number may seem small but it concerns the best ewes of the population as all these cases appeared in the highest producing groups. Using both grouping and lead factors greatly reduced such incidences and the combination of the two strategies practically eliminated the problem (Table 2).

Table 2
Number of ewe-test-day records, where the energy requirement of ewes was not adequately met, by grouping and feeding strategy (total number of ewe-test-day records was 49,237)

	Feeding by		
	Average flock production	Adjusted flock production by lead factors calculated at the	
		83rd percentile	90th percentile
One group	719	159	93
Two groups	101	32	25
Three groups	54	22	13

Table 3
Model fit and influence of various effects on lead factors depending on percentile and grouping strategy

	1G	2G-A	2G-B	3G-A	3G-B	3G-C
83rd percentile						
R^2	0.96	0.95	0.94	0.96	0.92	0.94
Flock-year [a]	0.00	0.00	0.00	0.00	0.02	0.00
Calendar month [a]	0.01	0.23	0.07	0.64	0.00	0.58
Milk [a]	0.00	0.00	0.00	0.00	0.00	0.00
Milk StdDev [a]	0.00	0.00	0.00	0.00	0.00	0.00
Milk-square [a]	0.00	0.00	0.00	0.00	0.00	0.00
Milk StdDev-square [a]	0.00	0.00	0.00	0.00	0.00	0.00
DIM [a]	0.15	0.13	0.13	0.43	0.52	0.27
DIM StdDev [a]	0.05	0.02	0.88	0.03	0.19	0.68
90th percentile						
R^2	0.74	0.75	0.72	0.79	0.78	0.71
Flock-year [a]	0.11	0.00	0.00	0.00	0.06	0.12
Calendar month [a]	0.13	0.85	0.85	0.86	0.72	0.37
Milk [a]	0.00	0.00	0.00	0.00	0.00	0.00
Milk StdDev [a]	0.00	0.00	0.00	0.00	0.00	0.00
Milk-square [a]	0.00	0.00	0.00	0.13	0.00	0.00
Milk StdDev-square [a]	0.00	0.00	0.00	0.00	0.00	0.00
DIM [a]	0.57	0.72	0.35	0.81	0.37	0.30
DIM StdDev [a]	0.97	0.01	0.72	0.00	0.09	0.17

1G: single group; 2G-A: first of two groups (high production); 2G-B: second of two groups (low production); 3G-A: first of three groups (high production); 3G-B: second of three groups (intermediate production); 3G-C: third of three groups (low production).

[a] *P*-values.

Table 3 shows the results of the analysis of variance. The model used to analyze lead factors yielded R^2 values ranging from 0.92 to 0.96 for lead factors calculated for the 83rd percentile, for all grouping strategies (single, two or three groups), suggesting good fit of the model. When lead factors were calculated for the 90th percentile then R^2 values ranged from 0.71 to 0.79. Lower values were expected, as the production level of the best ewes in each flock does not follow a normal distribution. Therefore, the higher the genetic merit of ewes, the more difficult it is to predict their energy requirements. As shown in Table 3, the effect of the flock-year on lead factors was significant ($P<0.05$) in most cases. The only exception was for the second and third groups (intermediate and low production levels, respectively) in the three-group strategy when lead factors were calculated for the 90th percentile. The effect of calendar month was significant ($P<0.05$) only in the case of high producing groups when lead factors were calculated for the 83rd percentile. Linear and quadratic regressions on mean and standard deviation milk yield were significant ($P<0.05$) in nearly all cases, which implies that production level should be always considered in the definition of lead factors and feeding strategies. The average number of days-in-milk did not have a significant effect on lead factors, whereas their standard deviation had an effect in about half of the cases (Table 3).

The consistent significance of milk production level led us to the calculation of lead factors according to flock production level, using the methodology described at the Materials and methods section. Two groups were formed, high (>250 kg of milk/ewe/year) and low (<250 kg of milk/ewe/year) producing flocks. Lead factors (mean values) for these two groups are presented in Table 4. Due to smaller within-flock variation, higher producing flocks were associated with somewhat lower than average lead factors when comparisons were made with those shown in Table 1. Exactly the opposite is true for lower producing flocks.

Calculations using the two-group instead of single-group feeding strategy together with the pertinent lead factors revealed that the average flock would save 18.5 or 25 kg of concentrates per milking ewe for lead factors pertaining to the 83rd or the 90th percentile, respectively. Moreover, the adoption of the three-group strategy would save 25 or 34 kg, respectively, compared to single-group feeding. Considering current prices, savings per individual milking ewe would range from 4.5 to 8.2 euros. It should be pointed out that these results pertain to data used in the present study, where average lactation milk production was 245 kg. However, considering the latest data of milk production of the breed (302 kg per lactation, Chios Sheep Breeders Cooperative "Macedonia", 2004) savings can be 15–20% higher than those reported above.

Table 4
Lead factors for various grouping strategies, for 'high' (>250 kg milk/ewe/year) and 'low' (<250 kg milk/ewe/year) producing flocks

	Flock production level					
	'High'			'Low'		
83rd percentile						
Single group	1.20			1.28		
Two groups	1.12	1.15		1.16	1.19	
Three groups	1.10	1.06	1.14	1.12	1.08	1.16
90th percentile						
Single group	1.28			1.36		
Two groups	1.16	1.17		1.20	1.21	
Three groups	1.14	1.08	1.15	1.16	1.10	1.17

Table 5
Group production factors, coefficients of variation and product moment correlation

Group	Group production factor	Coefficient of variation (%)	Product moment correlation
Two groups			
A	1.20	7.5	0.20 ($P\leq0.01$)
B	0.80	12.0	0.13 ($P\leq0.05$)
Three groups			
A	1.28	10.4	0.18 ($P\leq0.01$)
B	0.98	4.0	0.04
C	0.73	15.8	0.21 ($P\leq0.01$)

Calculated group production factors are shown in Table 5. They were 1.20 and 0.80 for the two-group and 1.28, 0.98 and 0.73 for the three-group strategy. Table 5 also shows the respective estimates of coefficient of variation and product moment correlation between actual and calculated average group yields in independent data sets. As shown in Table 5, group production factors are relatively stable. Given the moderately low product moment correlation, their predictive capacity of average production of each group in flocks not participating in milk-recording schemes is considered to be moderate.

4. Discussion

Grouping and feeding ewes based on their production level is recognized as a strategy that supports high and economically efficient milk production (Cannas, 2004). Moreover, the need for challenge feeding of milking ewes has long been recognized as a drive for higher production (Bocquier et al., 1988). However, the available literature on the subject is rather scarce. Bocquier and Caja (2001) reported that the application of such system to the French Lacaune breed of sheep has targeted at 10% and 30% above average energy and protein needs, respectively. This energy allowance seems somewhat low for Greek conditions. Results of the present study showed that for milking ewes of the Chios breed such targets should range from 7 to 33% above the average milk yield, subject to the adopted group feeding strategy (Table 1). The test-day coefficient of variation in the present study ranged from 15 to 45%, which is in close agreement with those reported by Bocquier et al. (1995) and Barillet et al. (2002). On the other hand, the 'standard' 30% increase in protein allowance does not seem justified in all cases, especially for the lower producing groups. An exception should probably be made during the first month of lactation because of low protein reserves that can be mobilized to cover a potential deficit. Recently, Hassoun and Bocquier (2007) suggested that when individual ewe milk records are available (flocks participating in milk-recording schemes), the preferable strategy is to cover the energy requirements of 85% of the ewes (approximately one standard deviation above mean production), which supports the results of the present study. They expect that the protein concentration of rations formulated using this strategy would cover the protein requirements of almost 100% of the flock or group. Working with cows, St-Pierre and Thraen (1999) found that, for optimum economic efficiency, different lead factors were needed for net energy and crude protein; lead factors for crude protein were 4–5% lower than those for net energy.

The results of the present study suggest that when feeding was based on average flock production, only a small number of ewes were not adequately fed (i.e. meeting less than 80% of their energy needs). However, one can argue that with such a feeding strategy and after a 6-week suckling period, the available reserves would have been almost depleted and milk production of the best ewes already compromised. This implies that grouping and challenge feeding of ewes should be applied during the suckling period as well, according to previous lactation performance and number of lambs suckled per ewe. In any case, the application of a combined strategy including grouping by production level and applying lead factors for ration formulation, is expected not only to greatly reduce such incidences but also to result in higher milk production.

Although milk production level is the principal factor affecting the nutrient requirements of lactating ewes (Barillet et al., 2002), other criteria such as age, days-in-milk, body weight and, especially, body condition score can and, in some cases, should be used when groups of ewes are formed (Barillet et al., 2002; Cannas, 2004). For lactating dairy cows, various grouping strategies have been proposed (Coppock et al., 1981; McGilliard et al., 1983; Nocek et al., 1985; Schuker et al., 1988; Pecsok et al., 1992; Williams and Oltenacu, 1992; Spahr et al., 1993). Williams and Oltenacu (1992) found that the most effective grouping strategy was based on required nutrient density by kg of dry matter intake whereas an approach similar to this study was the least effective one. Unfortunately, models predicting dry matter intake of lactating dairy ewes of the Chios breed are not available and fat and protein content of milk produced is presently not recorded. This emphasizes the need of including the criteria already mentioned when forming groups of ewes.

The application of the proposed system, combining grouping and lead factors, is dynamic. Ewes should be reallocated periodically, according to milk production and body condition score, aiming at maximizing reproductive performance as well as milk production (deRancourt et al., 2006; Cannas, 2004; Rassu et al., 2004). The proposed system can also be adaptable. Flock and milk production level have a significant effect on lead factors, with higher producing flocks requiring slightly lower lead factors (Table 4) because of lower within-flock variation. This is in accordance with the findings of Stallings and McGilliard (1984). Moreover, the 90th percentile strategy can be adopted for the higher producing groups, thereby allowing a more rigorous program of breeding management and a more accurate estimation of genetic values, while the 83rd percentile

Table 6
Proposed lead factors for 'high' (>250 kg milk/ewe/year) and 'low' (<250 kg milk/ewe/year) producing flocks of the Chios ewes

	Flock production level					
	'High'			'Low'		
	Group production level					
Grouping strategy	High [a]		Low [b]	High [a]		Low [b]
Two groups	1.16		1.15	1.20		1.19
	High [a]	Intermediate [b]	Low [b]	High [a]	Intermediate [b]	Low [b]
Three groups	1.14	1.06	1.14	1.16	1.08	1.16

[a] 90th percentile lead factor.
[b] 83rd percentile lead factor.

seems sufficient for the low producing groups. Sniffen et al. (1992) suggested that cows in early lactation (high producers) should possibly be fed to a higher percentile than those in late lactation (low producers). In the case of sheep, seasonal lambing is a constraint to the application of the former system (early and late lactation groups). In dairy ewes, however, feeding higher producing ewes to a higher percentile seems a reasonable alternative. In Table 6, a system using a combination of these options is presented. It is believed to be the most effective strategy for feeding dairy ewes of the Chios breed in Greece under the present conditions where genetic improvement programs are taking their first steps and milk production of the best ewes largely exceeds that of the average ewe. No other lead factors applied to dairy sheep were found in the international literature. Information regarding group assignment and lead factors used should be recorded for the accurate genetic evaluation of each ewe.

Flocks participating in milk-recording programs can benefit the most by grouping and challenge feeding the ewes. The system can actually be customized, making specific recommendations for each flock, after the results of milk-recording of each test-day are known. The use of computers makes the task easy to implement and relevant information could be sent back to farmers within a day. Nevertheless, the application of the system proposed in Table 6 is reasonably accurate for practical purposes. Furthermore, combined with the group production factors, the system can also be used by flocks not participating in milk-recording schemes. Most sheep farmers can effectively divide their flock in two groups (higher and lower producing ewes) but the production level of each one of them is laborious or practically impossible to assess when hand- or mechanical-milking is practiced, respectively.

The comparatively small added benefit of forming three instead of two groups makes the former option less attractive, especially for smaller flocks (<200 ewes). Farmers keeping bigger flocks may find the three-group strategy more appropriate. Of course, there is always the option of forming a third group comprising of first-lactation ewes only, irrespective of milk production. Whether this is a profitable choice remains unknown. This has proved very effective for first-lactation cows though (Phelps, 1992).

Milk-recording data from other Greek dairy sheep breeds (e.g. Karagouniko, Serres) show that lead factors presented in Table 1 and group production factors presented in Table 5 can be applied with reasonable success when forming feeding strategies for them. More research is needed in order to determine whether these factors affect them in the same way and how can the system be fine-tuned. However, difficulties in applying the proposed system arise from the inherent resistance of many farmers to change. Practices followed for many years are not easily abandoned, especially if these changes seem to require more labor (grouping) and investment (challenge feeding). Admittedly, forming groups during the grazing season can be very difficult, especially in less organized farms where pastures are not fenced. On the other hand, the benefits of increased milk production and enhanced reproductive performance should out-weigh any extra effort and cost. Effective communication between the farmers and their technical advisors is the only way to overcome these problems.

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