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J. Dairy Sci. 93:3303–3309
doi:10.3168/jds.2009-2787

Economic weights for major milk constituents of Manchega dairy ewes

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ABSTRACT

The objective of this study was to estimate economic weights of major components of milk (fat and protein) for the Manchega dairy sheep breed. An economic study was carried out and the profit associated with fat and protein yields of milk was calculated as the difference between incomes and costs. Incomes were obtained from milk sales to cheese industry and a reference marked price was used. Costs were calculated considering the energy necessary to produce each of the components of milk, and the price per milk forage unit was calculated as the total expense in feedstuff divided by the total (theoretical) needs of the flock. Economic values were defined as partial derivatives of the profit function with respect to each trait. Economic weights for fat and protein yields were similar, being slightly greater for protein in all cases. For carrier, economic weights were close to zero and negative because an increase in carrier production without changes in fat and protein composition leads to an increase in energy demands, holding the sale price of milk constant. When genetic standard deviations were taken into account and standardized economic values were calculated, an increase in economic value of protein and a decrease in economic value of fat yields were observed. The consequences that different changes in production system conditions have on the estimated economic weights were also studied. In general, economic weights were relatively insensitive to changes in production levels and market prices except for changes on milk price. Given the economic importance shown for fat and protein, milk components should be taken into consideration when breeding objectives for dairy sheep are established.
Key words: economic weight, milk composition, sheep

INTRODUCTION

One of the main goals of animal breeding programs is to increase the economic output through increased production and improved quality. In dairy production systems, this means an increase in milk yield as well as in milk quality. Several genetic programs have been established with the main, and sometimes only, objective of improving total milk production in females (Barillet, 1997). However, in the last years, more attention has been focused on milk composition (Barillet, 1997; Othmane et al., 2002), either as a way to improve milk quality or because of the presence of quota systems with restrictions on milk production (Gibson, 1989a; Harris and Freeman, 1993; Wolfová et al., 2007a). Moreover, evaluation of traits other than milk yield should provide dairy producers with more useful information upon which to base their selection decisions (Abdallah and McDaniel, 2000).

Among important milk composition traits, we can consider fat and protein content and SCC, the latter also related to the health of the flock. An economic study of the importance of milk composition traits will be useful to know which trait will be more profitable to improve depending on the characteristics of the market and will help breeders to make better decisions based on economic arguments.

Economic weights are key in the definition of breeding objectives and criteria for livestock improvement programs (Groen et al., 1997). The methods have largely been discussed (see Goddard, 1998 for references and a general discussion) and economic weights have been calculated for many species and management systems.

For dairy sheep, economic weights for different production traits have been reported. Legarra et al. (2007a) presented economic weights for fertility, prolificacy, longevity, and milk yield in Latxa and Manchega dairy sheep. In relation to milk components, Fuerst-Waltl and Baumung (2009) estimated economic weights for fat and protein contents in Austrian sheep, and Legarra et al. (2007b) calculated economic weights for the SCS in dairy sheep.

The purpose of this work was to estimate economic weights for the major components of milk in Manchega dairy sheep. The Manchega breeding program was established with the aim of improving milk production (Jurado et al., 1995), achieving a genetic gain of 0.82

Received October 2, 2009.
Accepted March 18, 2010.
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Table 1. Technical and economic data from 12 herds in the study[1]

Farm indicator	1Q	2Q	3Q
Ewes in the flock (n)	495	949	1,541
Fertility (lambings/yr per ewe)	0.89	0.91	0.93
Prolificacy	1.09	1.17	1.25
Longevity (yr)	4.58	5.04	5.61
Milk yield (L/ewe in flock)	116.70	144.65	172.90
Fixed costs (€/yr)	28,444	47,628	71,930
Feeding costs (€/yr)	34,050	62,950	97,160
Milk price (€/L)	1.01	1.10	1.13
Lamb price (€/lamb)	48.55	50.01	50.36

[1]1Q: first quartile; 2Q: median; 3Q: third quartile.

L/yr (Jurado et al., 2006). In general for dairy sheep, because almost all milk produced is sold to the cheese industry, milk composition has a great importance (Othmane et al., 2003). For the Manchega case, that importance could be considered even greater because cheese production is under the mark of origin "Manchego Cheese," which makes the final product more valuable.

First, we showed how profit functions were designed and how economic weights were derived from these functions. Second, economic weights were estimated using technical and economic data obtained from field data collected at farm level and economic data from market. These data have already been presented by Legarra et al. (2007a) for Manchega sheep. The final aim of this work was thus to prepare a coherent framework to make decisions in the Manchega breeding scheme.

MATERIALS AND METHODS

Data

Economic and technical data were collected by technicians as a part of the overall management program within the Manchega sheep breeding program. Although initially these data were gathered by farmers and then collected by technicians, in the last years a routine collection program has been established as a management support.

Economic and technical data from 12 herds of Manchega dairy sheep were used. An extended explanation about how these data were collected, checked, and used to obtain several economic indicators of herds was presented by Legarra et al. (2007a). Table 1 has a summary of the main technical and economic indicators. Figure 1 shows the costs associated with milk production and the contribution of fat and protein composition to the milk sale price. In general, economic data had widely variable and skewed distributions. For this reason, economic and technical data, and economic weights obtained from these data, are presented by medians and quartiles instead of means and standard deviations because medians are a more robust and informative measure of centrality for these kinds of distributions.

Production data from ewes were also recorded: milk, fat, and protein yield (kg/lactation) and fat and protein contents (%). Table 2 presents mean (±SD) of milk data on Manchega dairy sheep. These statistics were calculated using data from the whole population.

Estimation of Economic Weights

Economic weights were calculated considering profit functions (Ponzoni, 1986; Goddard, 1998) where profit (P) is defined as the difference between incomes (I) and costs (C): $P = I - C$.

As it was pointed out before, real technical and economic data from each farm were used and a set of economic weights was obtained for each farm. Because we took into account the characteristics of each farm, it is expected that such economic weights maximize the profit of each farm. However, selection must be oriented to the whole population and a single set of economic weights should be used when breeding objectives are established. The use of a representative sample of technical, economic, and biological data that described the production system of Manchega sheep could be considered. Legarra et al. (2007a) studied the expected genetic gains if each farm used either its own economic weights or a set of weights common to all farms, finding no differences between approaches.

Incomes. Incomes were obtained from milk sales to the cheese industry. The final milk price that cheese industries pay to the farmers is established using a reference market value. This value is expressed as Euros (€) per hectograde of (milk) dry useful matter (i.e., the sum of fat and protein contents expressed as percentages and divided by 100). For this work, the reference milk price ($MilkPrice_{ref}$) was 7.95 €/hectograde of dry useful matter as it was established by the Albacete (Spain) market. Base milk price is set by cheese industries by using the following equation:

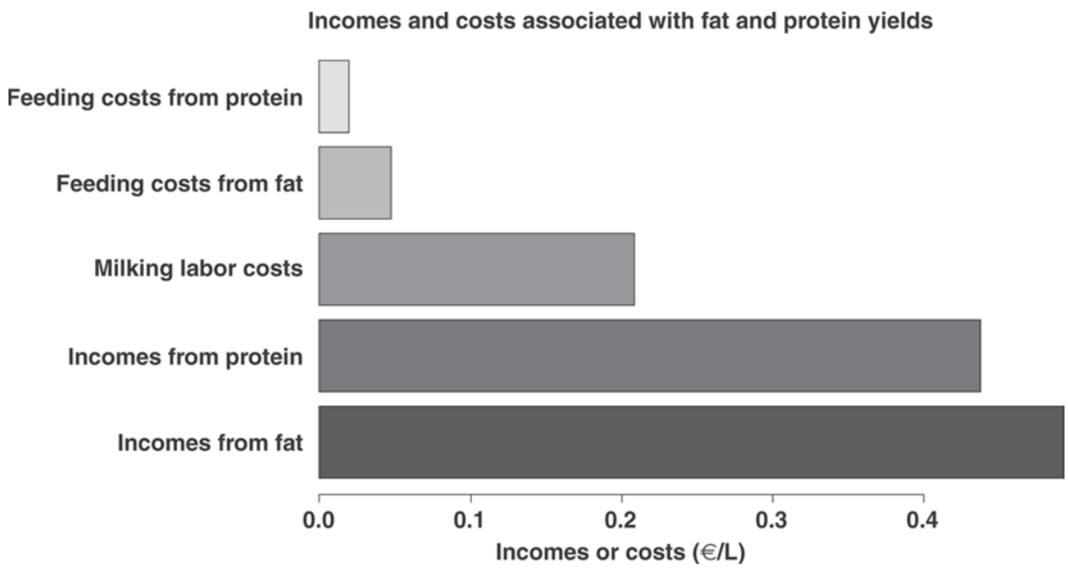

Figure 1. Contribution of fat and protein yields to the incomes and costs of milk production. Incomes and costs are expressed as Euros per liter of milk.

$$\text{MilkPrice}_{\text{base}}\left(€\right) = \text{MilkPrice}_{\text{ref}} \times \left(\frac{\text{fat content} + \text{protein content}}{100}\right). \quad [1]$$

Using equation [1] and data in Table 2, a final base milk price of 1.01 €/L was obtained.

Therefore, income from milk sales was equal to

$$\text{I}_{\text{milk}}\ (€/\text{ewe per year}) = \text{milk yield} \times \text{MilkPrice}_{\text{base}}. \quad [2]$$

When fat and protein yields were used instead of contents, equation [2] was as follows:

$$\text{I}_{\text{milk}}\ (€/\text{ewe per year}) = \text{MilkPrice}_{\text{ref}} \times (\text{fat yield} + \text{protein yield}), \quad [3]$$

because

$$\text{fat content} = \frac{\text{fat yield}}{\text{milk yield}} \times 100$$

and

$$\text{protein content} = \frac{\text{protein yield}}{\text{milk yield}} \times 100.$$

Expenses. Expenses associated with milk production were calculated considering the energy needs necessary to produce each of the components of milk: fat, protein, and carrier (Gibson, 1989a). The term carrier was used to refer to a milk volume with a fixed composition; thus, an increase in carrier implies more milk production without changes in fat and protein yields.

Reference values for fat and protein contents in the Manchega breed were 69.23 and 57.22 g/L, respectively (Table 2). Energy needs to produce milk are equal to the amount of energy present in milk (Colleau et al., 1994). In general, for sheep, the calorific value of 1 kg of milk with a known composition of 65 g of fat/L and 55 g of protein/L is equal to 0.64 milk forage units (**UFL**)/kg (INRA, 2007). Because this milk composition is quite similar to the milk composition of Manchega sheep, we decided to use the same energy value.

Energy content of milk can be split into each of its components: fat, protein, and volume. For dairy cattle, Wilmink (1988) and Colleau et al. (1994) pointed out how the energy necessary to produce 1 kg of milk is distributed in proportions of 55, 22.5, and 22.5% to produce fat, protein, and volume, respectively. No references about energy supplies for milk component in ewes were found, so we decided to use these values.

Table 2. Milk yield and composition of Manchega dairy sheep

Item	Mean	SD
Milk yield (kg/lactation)	148.57	64.98
Fat yield (kg/lactation)	9.89	4.39
Protein yield (kg/lactation)	8.42	3.55
Fat content (g/kg)	69.23	14.67
Protein content (g/kg)	57.22	5.65

The energy needs (**EN**) associated with fat, protein, and carrier production were calculated as follows:

$$EN_i\left(\text{UFL/kg}\right) = \frac{\text{energy value of milk} \times P_i}{\text{milk component content}}, \qquad [4]$$

where i represents each of the milk components (fat, protein, and carrier) and P_i is the proportion of the total energy necessary to produce each one of the components. Thus,

$$EN_{fat} = (0.64 \times 0.55)/0.06923 = 5.08 \text{ UFL/kg},$$

$$EN_{protein} = (0.64 \times 0.225)/0.05722 = 2.52 \text{ UFL/kg},$$
and

$$EN_{carrier} = (0.64 \times 0.225)/1.0 = 0.14 \text{ UFL/kg}.$$

The price per UFL was calculated as the total expense in feedstuff divided by the total (theoretical) needs of the flock in UFL, the latter estimated following the INRA (1988) and Caja (1994) recommendations. For Manchega dairy sheep, the average cost of 1 UFL was 0.13 € (Legarra et al., 2007a). Expenses associated with production of fat, protein, and carrier were 0.660, 0.328, and 0.019 €/kg, respectively. Therefore, expenses from milk sales were equal to

$$C_{milk}\left(\text{€/ewe per year}\right) = \text{milk yield} \times \left(\frac{C_{fat.ref} \times FC + C_{protein.ref} \times PC}{100} + C_{carrier.ref}\right), \qquad [5]$$

where $C_{fat.ref}$, $C_{protein.ref}$, and $C_{carrier.ref}$ are the reference expenses associated with fat, protein, and carrier production described above; FC is fat content; and PC is protein content. When fat and protein yields were used instead of contents, equation [5] was as follows:

$$C_{milk}\ (\text{€/ewe per year}) = C_{fat.ref} \times \text{fat yield} + C_{protein.ref} \times \text{protein yield} + C_{carrier.ref} \times \text{carrier yield}. \qquad [6]$$

Therefore, the total profit obtained from milk production as a function of milk fat, protein, and carrier yields can be derived from equations [3] and [6] as follows:

$$P_{milk}\ (\text{€/ewe per year}) = \text{MilkPrice}_{ref} \times (\text{fat yield} + \text{protein yield}) - (C_{fat.ref} \times \text{fat yield} + C_{protein.ref} \times \text{protein yield} + C_{carrier.ref} \times \text{carrier yield}). \qquad [7]$$

Economic Weights. Economic value of a trait expresses to what extent the economic efficiency of production is improved at the moment of expression of 1 unit of genetic superiority for a trait (Groen, 1989), that is, the contribution to change in profit per unit change of a trait, given no change in any other trait. Economic value of a trait is obtained as the partial derivative of the profit function with respect to that trait and assuming that the other traits remain unchanged. Deriving equation [7] with respect to each trait, economic weights for milk components were

$$v_{\text{fat yield}} = \frac{\partial P_{milk}}{\partial \text{fat yield}} = \text{MilkPrice}_{ref} - C_{fat.ref},$$

$$v_{\text{protein yield}} = \frac{\partial P_{milk}}{\partial \text{protein yield}} = \text{MilkPrice}_{ref} - C_{protein.ref},$$

and

$$v_{carrier} = \frac{\partial P_{milk}}{\partial \text{carrier}} = -C_{carrier.ref}.$$

Standardized economic weights were also calculated by dividing economic values of different traits by their genetic standard deviation. This allowed better comparisons of the relative economic importance of traits. Genetic standard deviations used in this work were 1.24 and 0.97 for fat and protein yield, respectively (unpublished data, estimated using the whole Manchega population). For milk carrier the genetic variance used was 19.05, the same that was used for milk yield.

Sensitivity of Economic Weights

A sensitivity study was carried out to evaluate how changes in the production system conditions could affect the resulting economic weights. Extreme situations in productions levels and market prices were simulated, changing milk yield, fat and protein contents, feeding costs, and milk market price by ±50%.

RESULTS AND DISCUSSION

A summary of the economic weights obtained for milk components in Manchega dairy sheep is given in Table 3. Economic weights for fat and protein yields had medians of 7.24 and 7.60 €, respectively. Economic weights for fat and protein yields were similar, being in all cases slightly larger for protein. As was mentioned about of the total energy necessary to produce 1 kg of milk, 50% goes to produce fat and only 25% goes to

Table 3. Economic weights for primary components of milk in Manchega sheep[1,2]

	Economic weight			Standardized economic weight[3]		
Milk component (€/kg)	1Q	2Q	3Q	1Q	2Q	3Q
Fat yield	7.04	7.24	7.27	5.68	5.84	5.86
Protein yield	7.53	7.60	7.65	7.76	7.84	7.89
Carrier	−0.02	−0.02	−0.02	−0.001	−0.001	−0.001

[1]For each trait, normal and standardized economic weights are presented.

[2]1Q: first quartile; 2Q: median; 3Q: third quartile.

[3]Standardized economic weights were calculated by dividing economic values of different traits by their genetic standard deviation.

synthesize protein, leading to production costs of 0.660 and 0.328 €/kg of fat and protein, respectively. Therefore, the production of protein was more profitable and economic weights are larger. Differences between economic weights for protein and fat obtained for different herds were low, as shown by the similarity of first and third quartiles columns in Table 3. This would allow using a unique set of economic weights for all herds, obtaining economic responses close to optimal for all of them.

Costs of producing milk components have been calculated as the sum of feeding and labor costs. The main problem was to define how the feeding cost for producing 1 kg of milk had to be divided among its components: fat, protein, and carrier. Gibson (1989a) suggested doing this by considering splitting the energy requirements to produce 1 kg of milk among volume, fat, protein, and lactose components. For fat and protein yields in dairy cattle, Gibson (1989a) showed production costs of \$1.028 (equivalent to 0.696 €) and \$0.523 (0.352 €). No references about energy supplies for milk components in ewes were found, so we decided to use those described by Wilmink (1988) and Colleau et al. (1994) for dairy cattle. Considering a calorific value of 0.64 UFL/kg of milk (INRA, 2007), production costs of 0.660, 0.328, and 0.019 €/kg of fat, protein, and volume, respectively, were obtained. Our results were quite similar to those obtained by Gibson (1989a).

Economic weights for fat and protein yields instead of contents were estimated. Gibson (1989b) pointed out that although some systems pay for volume with corrections based on various solids concentrations, all methods of payment could be expressed in terms of price per unit weight of each component; moreover, construction of selection indices based on concentrations rather than yields led to unnecessary difficulties in handling the resulting nonlinearity.

Some studies can be found in the literature about economic weight estimates for milk components on dairy cattle and sheep. For New Zealand dairy cattle, Spelman and Garrick (1997) showed economic weights of 1.36 NZ\$/kg (equivalent to 0.66 €), 5.09 NZ\$/kg (2.46 €), and −0.082 NZ\$/kg (−0.04 €) for fat and protein yield and carrier, respectively. Sölkner and Fuerst (2002), in the Brown Swiss population, obtained economic values of 1.82 and 2.83 €/kg for fat and protein, respectively. For Austrian sheep breed, Fuerst-Waltl and Baumung (2009) obtained economic weights of 2.90 and 6.40 €/kg for fat and protein, respectively. In general from the literature, differences observed between fat and protein economic values were greater than those observed in our study. As a result of the implicit assumption of same price for fat and protein in the Manchega dairy sheep market and the greater importance of incomes compared with costs in this study, the economic weights of protein and fat were very similar, with a relationship of 7.60/7.24 = 1.05. In the cited studies, protein:fat ratio were 3.73 (Spelman and Garrick, 1997), 1.55 (Sölkner and Fuerst, 2002), and 2.21 (Fuerst-Waltl and Baumung, 2009). Thus, in all of the studies the relative economic importance for protein was greater than for fat, as it can be observed from market prices. Gibson (1989a) and Wolfová et al. (2007b) pointed out that the relative economic importance of milk production traits (milk yield, fat, and protein) is very sensitive to the payment system, and this is strongly marked in markets with production quotas. A trait with a positive economic weight could change to a negative value if its production is under quota restriction. Examples of economic weights calculated for scenarios with and without quotas are presented by Groen (1989), Nielsen et al. (2004), and Wolfová et al. (2007a).

For Manchega dairy sheep, economic weights for carrier have been close to zero and negative, with a median value of −0.019 €/kg. This makes sense because milk price depends only on fat and protein contents. An increase in carrier production without changes in fat and protein composition leads to an increase in energy demands, leaving the sale price of milk constant. According to our results, most of the studies in dairy cattle have reported a negative economic value for the carrier (Colleau et al., 1994; Pieters et al., 1997; Spelman and Garrick, 1997).

After standardization to compare between traits, economic weights changed from 7.24 to 5.84 € and from 7.60 to 7.84 € for fat and protein yields, respectively

Table 4. Sensitivity of economic weights (€/kg) to changes on production system conditions[1]

Scenario	Fat yield	Protein yield
Base situation	7.24	7.60
Milk yield		
+50%	7.27	7.62
−50%	7.20	7.58
Fat content		
+50%	7.47	7.60
−50%	6.52	7.60
Protein content		
+50%	7.24	7.71
−50%	7.24	7.26
Feeding costs		
+50%	6.88	7.43
−50%	7.59	7.77
Milk price		
+50%	11.20	11.60
−50%	3.26	3.63

[1]The new scenarios have been defined as the increase/decrease of 50% on base production levels and market prices. Economic weights median values have been used.

(Table 3), indicating that because the genetic variance is larger for protein than for fat, genetic and therefore economic responses will expected to be greater for protein.

Results regarding sensitivity study are presented in Table 4. In general, economic weights for principal milk components had low sensitivity to changes in production levels and market prices, except for changes in milk price. Thus, an increase of 50% in milk price leads to an increase of 70% in economic values for fat and protein yields, whereas a decrease of 50% in milk price leads to a decrease of >50% in these economic values. Changes in the production level of 1 trait have no effects on economic weights of the other trait. If feeding costs increase, the economic importance of milk traits decreases and production costs increase. Changes in milk prices had much greater influence on estimated economic values than changes in feed costs. As shown in Figure 1, feed costs represent only a part of production costs and its magnitude is much less than income obtained from milk sales. For that reason, changes in milk price will always have more effect on the economic weights for milk composition traits.

As commented above, the Manchega dairy market is peculiar because fat and protein have the same price, although the contribution of both traits to cheese yield is not the same (Othmane et al., 2002). Several studies have examined the amount of milk required to produce a unit of cheese (Manfredini et al., 1992; Delacroix-Buchet et al., 1994; Pellegrini et al., 1997); thus, cheese yield formulae have been developed based on the fat and protein contents of milk (Pellegrini, 1995; Pirisi et al., 1996). These works reported that the contribution to cheese yield is greater for protein than for fat, with values of 1.733 and 1.257 g/100 g for protein and fat (Pirisi et al., 1996) or 0.334 and 0.056 g/L for fat and protein (Pellegrini, 1995), respectively. Therefore, it would seem logical for the market price for protein to be greater than that for fat, such as in the Austrian sheep breed market (Fuerst-Waltl and Baumung, 2009). A payment system in which fat and protein have the same value could be considered not optimal, and undesirable genetic responses with changes in the protein-fat balance could appear. A better option could be to assign prices to fat and protein according to their relative contributions to cheese yield; thus, a revision of payment systems of Manchega sheep breed could be of interest.

In this study, we focused on the economic value of principal milk components. However, it would be useful to consider other factors that are also involved in profitability as a way to have a global vision of the breeding objectives in this breed. In a previous work of our group (Legarra et al., 2007a), economic weights for fertility, prolificacy, milk yield, and longevity were estimated. Technical and economic data and market conditions were the same as those considered in this study. The median across-herd economic values were 137.66 €/lambing, 34.17 €/lamb, 0.73 €/L, and 2.16 €/yr for fertility, prolificacy, milk yield, and longevity, respectively. An increase in fertility provides a high overall increase in profit as a result of the sale of both lambs and milk. Increases in prolificacy or milk yield are also quite profitable. Economic weights for fat and protein of milk obtained in the present study were less than those estimated for fertility and prolificacy and greater than for milk yield and longevity. Economic weight in standardized units in Legarra et al. (2007a) were 15.07, 4.53, 10.45, and 0.34 € for fertility, prolificacy, milk production, and longevity, respectively; that is, when genetic variances of traits are taken into account, the relative economic importance of milk yield became the highest. Regarding milk components, protein yield had the largest weight, with a standardized economic weight of 7.84 €.

In addition to the economic importance of fat and protein yields, genetic correlations between milk yield with fat and protein contents have been estimated to be −0.29 and −0.45, respectively, for Manchega sheep (unpublished results). A selection scheme focusing only on milk yield could lead to a decrease in both fat and protein contents and to a deterioration of cheese yield and quality. This is an extra reason to consider fat and protein as breeding objectives to be included in a selection index.

CONCLUSIONS

Economic weights for fat and protein were quite similar, but slightly greater for protein than for fat. For carrier, a negative economic weight was obtained because an increase in volume leads to an increase in energy demands at a constant sale price. Differences observed in the economic weights between herds were low; thus, optimal economic responses could be obtained after using a unique set of economic weights. This could be the median economic weights across herds. Economic weights for fat and protein components were weakly sensitive to changes in production levels or market prices, except for milk price. The inclusion of fat and protein contents of milk in breeding goals will be of interest because of their economic values and their negative correlation with milk yield as a way to reduce the negative consequences that a selection scheme based only on milk yield could have on milk quality.

ACKNOWLEDGMENTS

This work was financed by project INIA RTA-02-002-C2. We thank the Breeder's Association of Manchega sheep breed (AGRAMA, Spain) for the information and discussion kindly provided. We also thank 2 anonymous reviewers for helping with manuscript editing. Referees and editor are truly acknowledged for their comments.

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