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Fernández R., Serradilla J.M.

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R. Fernández*, A.C. Herruzo and J.M. Serradilla***
*Departmento de Producción Animal, ETSIAM, Universidad de Córdoba,
Apdo. 3048, 14080 Córdoba, Spain
**Unidad de Economía, ETSIM, Universidad Politécnica de Madrid,
Ciudad Universitaria s/n, 28040 Madrid, Spain

SUMMARY – An economic evaluation of a selection programme for the main autochthonous Spanish dairy goat breeds, Murciano-Granadina and Malagueña, has been carried out. Different annual genetic progresses obtained through deterministic simulations of different selection schemes have been considered. These progresses ranged from 5.62 to 15.84 k for milk yield in 240 days, from 0.25 to 0.53 g/k for protein content and from 0.30 to 0.35 g/k for fat content. Various rates of diffusion of the breeding progress from the selected nucleus to the rest of the herds were also taken into account. The economic evaluation approach used is based on the Marshallian welfare theory. It involves computing the yearly variation of the Marshallian economic surplus induced by supply and demand shifts produced by the increments of milk yield and protein and fat contents due to selection programmes. These values, together with the cost of implementing selection programmes, were used to estimate the social internal rate of return (SIRR) of public investments. Results show that the SIRR is independent on the mode of payment of milk to producers (with a bonus only for fat or with a bonus for fat and protein) and it depends heavily on the diffusion rates of genetic improvement from the selection nuclei to the rest of the herds in the breed. In general, selection schemes based on AI have higher SIRR than those based on natural service, the latter being frequently negative or close to zero.

Key words: Goats, selection programmes, economic analysis, internal rate of return.

RESUME – *"Analyse économique des programmes de sélection caprine". Les programmes de sélection des principales races espagnoles autochtones du secteur caprin laitier, Murciano-Granadina et Malagueña, ont été évalués. Les différents progrès génétiques obtenus par simulation déterministique des différents schémas ont été considérés. Ces progrès ont varié de 5,62 kg à 15,84 kg pour la production laitière standardisée à 240 jours, de 0,25 à 0,53 g/kg pour le taux de matières azotés et de 0,30 à 0,35 g/kg pour le taux butyreux. Différents taux de diffusion du progrès génétique du noyau de sélection vers le reste de la population ont été pris en considération. Concernant l'évaluation économique, l'approche a été basée sur la théorie du bien-être marshallien. Elle consiste en le calcul de la variation annuelle du surplus économique marshallien produit par les changements de l'offre et de la demande causés par l'augmentation de la production laitière ainsi que des taux azoté et butyreux, à travers les programmes de sélection. Ces valeurs, ainsi que les coûts de mise en place des programmes de sélection, ont été utilisés pour estimer le taux social interne du revenu (TSIR) des investissements publics. Les résultats montrent que le TSIR ne dépend pas du mode du paiement du lait aux éleveurs (avec un bonus pour le taux butyreux seulement ou avec un bonus pour les taux azoté et butyreux) mais dépend en grande partie des taux de diffusion du progrès génétique du noyau de sélection vers le reste des élevages de la race. Les schémas de sélection basés sur l'insémination artificielle ont produit, généralement, un TSIR plus élevé que ceux basés sur la monte naturelle qui a été négatif ou proche de zéro.*

Mots-clés : *Caprins, programmes de sélection, analyse économique, taux interne du revenu.*

Introduction

Spain has the second largest population of goats of the EU (22%), after Greece. Most of these goats (45.91%) are in Andalusia and Murcia Regions, in the South of the country and 27.32% belong to one of the two main dairy breeds: Murciano-Granadina and Malagueña (Esteban Muñoz, 1997). These breeds have been farmed traditionally under extensive systems. However, during the last two decades, farms are evolving to more intensive systems. Their performances have increased as a consequence of environmental improvements, but they are still very heterogeneous and low productive, with respect to many of the improved European breeds. Their genetic improvement is a necessity, due to their good adaptation to the, often, harsh environmental conditions under which they are raised, which makes difficult their substitution by exotic breeds.

Since the 1950s (Murciano-Granadina) and 1970s (Malagueña), recording schemes for these breeds were established, and have been carried out more or less continuously. However, not an effective selection has been performed, apart from the low effective, and often oriented to morphological traits, within-herd selection carried out by farmers. The organisational causes of this failure are numerous: low economic and cultural level of farmers, absence of adequate extension and training programmes and an insufficient level of association of breeders. The main technical drawback has been the lack of an extensive AI programme.

In the last years, however, the number of farmers better trained, well organised and much more conscious of the necessity of applying modern selection programmes to these breeds has considerably increased and AI is starting to be implemented in farms. But, they still depend to a large extent on public funds for the development of the AI and selection programmes. In this situation, an economic analysis of these programmes is a necessary step, both for the breeders associations and for the Administration to find out the profitability of their investments.

No previous information exists on economic analysis of selection programmes for goats, but there are several previous works, which have assessed the economic returns of public investments in research leading to the improvement of other sectors of the animal production. Economic returns of increasing yields have been studied by Peterson (1967) in poultry, Wennergren and Whitaker (1977) in sheep, Haque *et al.* (1987) in laying hens, Hout *et al.* (1988) in swine, Widmer *et al.* (1988) in beef and Fox et. al. (1989) in dairy industry, among others (for a review see Echevarría, 1990). In addition, research payoff from quality improvement in several livestock have been analysed by Voon (1991, 1992a, 1992b) and by Voon and Edwards (1991). All these works are based on the Marshallian welfare theory and normally involve computing the annual changes in Marshallian consumer and producer surplus due to annual shifts in the supply and demand curves as a consequence of the adoption of processes and/or products innovations. A similar analytical framework is used in this study to compute the economic benefits derived from yield and quality improvements of goat's milk achieved through the selection programmes.

Material and methods

Two selection schemes, based on natural service (NS) and AI for the reproduction of sires and dams, applied to selection nucleus constituted by 5,000 and 10,000 goats of each breed, were simulated. Annual genetic progresses obtained for a period of 25 years of selection were calculated with the asymptotic model of Rendel and Robertson (1950) and its adaptation to the AI schemes (Lindhe, 1968).

Three traits were considered: milk yield, average protein and average fat contents in 240 days lactations. Different heritability values (Table 1), ranging from those estimated in the Murciano-Granadina breed (Analla *et al.*, 1996) to larger ones cited by other authors (see review by Ricordeau, 1981 and Jiménez-Gamero *et al.*, 1995), were considered. These different heritabilities, together with variations of the generation intervals, selection intensities, average number of daughters and proportion of AI services for testing sires, generating different values of annual genetic progresses. A reduction coefficient (75%) was applied to these values in order to take into account usual differences between expected and realised genetic progresses. Minimum and maximum values of genetic progress obtained are given in Table 2.

Table 1. Heritability values considered to calculate genetic progresses

	Milk yield	Protein content	Fat content
Low h^2	0.20	0.25	0.20
Medium h^2	0.25	0.30	0.25
High h^2	0.35	0.40	0.35

Table 2. Minimum and maximum values of annual genetic progress per goat used for the economic analysis

Selection nucleus size and reproduction system	Milk yield (kg)	Protein content (g/kg)	Fat content (g/kg)
5000 goats-NS	5.62-10.53	0.21-0.35	0.30-056
5000 goats-AI	6.46-14.87	0.23-0.50	0.35-0.80
10000 goats-AI	6.46-15.84	0.23-0.53	0.35-0.85

Diffusion of genetic improvement from the selection nucleus to the other herds of the breed was proposed to take place through the selling of young males, sons of the selected sires in the nucleus, in the case of NS and through the selling of semen from the selected sires, in the scheme with AI. Depending on the number of young males and semen doses sold yearly, different hypothesis were considered related to the rates of diffusion (Tables 3 and 4).

Table 3. Hypothesis considered for the diffusion of genetic improvement in the scheme based on NS

Diffusion hypothesis	% of herds in selection nucleus selling males	Number of males sold per herd and year
D-1	50	0.5
D-2	50	1
D-3	50	2
D-4	100	2

Table 4. Number of semen doses sold yearly from the herds in the selection nuclei to the rest of the herds of each breed

No. of sires tested	Number of goats in selection nuclei	
	5,000	10,000
10	36,000	32,000
15	56,000	
30		112,000

Semen doses sold yearly from the selection nuclei depend on the surplus existing in these nuclei after having covered their necessities. Values in Table 4 have been obtained considering that each tested male produces 750 normal doses of semen per year from ages 10 month to 4.5 years.

Diffusion rate (DR) was defined as DR = 0.5*p; being *p* the proportion of females from each breed mated with males or inseminated with semen from the selection nucleus. Values of *p* for the different diffusion hypothesis considered in Tables 3 and 4 were computed on the bases of data on herds size distribution given by SODIAN (1987) and the census of each breed.

Marshallian economic surplus changes induced by technical change, depend on the market conditions (demand and supply elasticity) and on the nature of the supply and demand shifts. In many technology assessment projects demand and supply conditions are explicitly modelled. Due to the scarce information available on the behaviour of the market of goat milk, a hypothesis less sensitive to market approach (and also more restrictive) is employed in this work. Thus, the extra production attributed to the selection programme is valued at a single market price that assumes that the supply curve is vertical and shifts against a horizontal demand curve. Economic benefits are then measure by the expected value of the extra production. Thus, although economic surplus changes may not be explicitly measured, economic surplus calculations are still implicitly being made (see Alston *et al.*, 1995, p. 54).

Two effect of the selection programme are analysed in this work: increase in production (yields) and improvement in milk quality (protein and fat).

The production effect of the selection programme is modelled as a shift to the right in the milk supply curve. Thus, the benefits to producers as a consequence of the increase in yields obtained through selection in the year t is given by:

Production effect = $h_t\ Pc_0\ qc_{t-1}\ N$,

Where, h_t the rate of shift of the milk supply in the year t, Pc_0 is the price of one litre of milk with the initial quality, qc_{t-1} is the average yearly production of a goat in a herd out of the selection nuclei in the year $t-1$ and N the number of goats of the breed. The rate of shift of the supply curve in year t is given by:

$$h_t = \frac{qn_{t-i} - qc_{t-1}}{qc_{t-1}} DR$$

where, qn_{t-i} is the average milk yield per goat in the selection nuclei in the year $t-1$, qc_{t-1} is the average milk yield per goat in the rest of the herds in the year $t-1$, DR is the diffusion rate and i is the interval in years for the diffusion of the selected males or semen from the selection nuclei to the rest the herds. It has been considered to be $i = 3$ schemes based on NS and $i = 2$ for schemes based on AI.

The milk quality effect of the selection programme (increase in fat and protein contents) is modelled as an upward shift in the milk demand curve along the vertical milk supply curve. The benefit to producers from the improvement in milk quality is given by:

Quality effect = $k_t\ Pc_{t-1}\ qc_t\ N$,

where k_t is the rate of shift of the milk demand curve, Pc_{t-1} is the price of one litre of milk in the year $t-1$ (before the increase in quality), qc_t is the average milk yield per goat in herds out of the selection nuclei in the year t, N is the number of goats of the breed. The rate of shift in the demand curve in year t is given by:

$$k_t = \frac{Pn_{t-i} - Pc_{t-1}}{Pc_{t-1}} DR$$

where, Pn_{t-i} is the price of a litre of milk paid to the herds in the selection nuclei in the year $t-i$, Pc_{t-1} is the price of one litre of milk paid to the uherds out of the selection nuclei in the year $t-1$, RD is the rate of diffusion and i has the same meaning and takes the same values as in the rate of shift in the supply curve.

Two forms for the payment of milk have been considered: (i) quantity and fat content; and (ii) quantity, fat and protein content.

In the first case, prices of milk and fat concentration were collected from the Year-books of Agricultural Statistics (Junta de Andalucía, 1986-1995) and from the accounting data bases of three large Andalusian cooperatives of goats farmers. From this information a price of 13.59 ptas for each gram of far per kilo of milk referred to 1998 was derived.

In the second case, the French formula was used: $P = b+d_1(PC-28)+d_2(FC-33)$; P being the price of one litre of milk, PC its protein content, FC its fat content and b, d_1 and d_2 coefficients that in 1995 took the following average values: b = 2.8 FF/kg, d_1 = 0.075 FF/g/kg and d_2 = 0.025 FF/g/kg. Considering average values of 36 g/kg for protein content and 49 g/kg for fat content (Serradilla *et al.*, 1995; Díaz *et al.*, 1999), having into account the relation of 1.5 between the contributions of protein and fat to the final price, the value in ptas of the FF and actualising to 1998, the price paid for milk with this formula in ptas is: $P = 9.74\ PC + 6.49\ FC$.

This price increases yearly, as a consequence of the increment of protein and fat contents of the milk obtained through the selection programme. It is also discounted at an annual rate of 3%.

The costs of selection programmes have been computed adding the investments and annual expenses directed by both breeders associations (Asociación de Criadores de la Cabra Malagueña and Asociación de Criadores de la Raza Murciano-Granadina) to the milk recording and breeding schemes, the investments and annual expenses of the three laboratories where milk is analysed and records are registered (Laboratories de Control Lechero Caprino), and the estimated cost of a centre for testing males, laboratories and the AI of goats in the herds. These costs are given in Table 5.

Table 5. Costs of selection programmes (x 1000 ptas)

		Recording and selection	Testing sires and AI	Total
Investments		26,883	71,139	98,022
Labour/year		41,596	7,400	48,996
Maintenance (per year)	5,000 goats	8,140	9,850	17,990
	10,000 goats	12,340	19,552	31,892
Annual totals	5,000 goats	49,736	17,250	66,986
	10,000 goats	53,936	26,952	80,888

Results and discussion

Social internal rates of return (SIRR) of public investments in the selection programmes, during the period of 25 years considered, are given in Table 6, for the scheme based on NS and Table 7 for the scheme based on AI.

Table 6. Social internal rates (%) of return[†] (SIRR) of the investments in Murciano-Granadina and Malagueña breeds considered during the 25 years of selection under schemes based on NS

No. of males sold out of the selection nuclei[††]	No. of goats/selection nucleus			
	5,000		10,000	
	Maximum genetic gain	Minimum genetic gain	Maximum genetic gain	Minimum genetic gain
37/74	–17.79 –18.31	–1 –1	–2.01 –2.20	–14.69 –14.84
74/148	–2.01 –2.24	–14.69 –14.84	6.46 6.28	–0.82 –0.88
148/295	6.46 6.28	–0.82 –0.88	13.90 13.73	7.54 7.49
295/590	13.90 13.73	7.54 7.49	21.61 21.43	15.22 15.17

[†]Upper values correspond to the payment for milk and fat content. Lower values correspond to the payment for fat and protein content.
[††]First value corresponds to selection nuclei with 5,000 goats. Second value corresponds to selection nuclei with 10,000 goats.

The first consideration that we can derived from the tables above is that the formula used for the payment of milk does not significantly influence the SIRR of the investments. This means that this formula should be decided through an agreement between producers and transformers in order to maximise the potentiality of milk to produce cheese and, therefore, it should be taken into account to define the selection criteria.

A second consequence of these results is that selection schemes based on NS have lower SIRR than those schemes based on AI. Most of them are negative or close to zero. The only case of a SIRR similar to those of AI schemes corresponds to the combination of a high diffusion rate with a maximum genetic gain. The latest is hardly obtained with NS schemes.

Table 7. Social internal rates (%) of return† (SIRR) of the investments in Murciano-Granadina and Malagueña breeds considered during the 25 years of selection under schemes based on AI

No. of semen doses sold out of the selection nuclei††	No. of goats/selection nucleus	
	5,000	10,000
72,000/64,000	20.47	19.11
(maximum genetic gain)	20.30	18.93
112,000/224,000	17.31	24.12
(minimum genetic gain)	17.21	24.01

†Upper values correspond to the payment for milk fat content. Lower values correspond to the payment for fat and protein content.
††First value corresponds to selection nuclei with 5,000 goats. Second value corresponds to selection nuclei with 10,000 goats.

In the NS schemes, the values of SIRR obtained are linearly related to the size of the selection nuclei, but this is due to diffusion rates being twice as large in one case than another. When similar diffusion rates are considered, SIRR values are equal in both cases. Therefore, it is actually the potentiality of producing a sufficiently large number of improved males to be sold out of the selection nuclei what determine the SIRR.

The situation is not very different, although a little more complicated, for the results shown in the case of AI schemes (Table 7). Unfortunately, no comparisons can be made between all combinations of diffusion rates and levels of genetic gain, since they are interdependent. The number of semen doses available for selling out of the selection nuclei depend on the number of tested sires, and this number depends on the selection intensity. This selection intensity is independent on the size of the selection nuclei (double number of males in one case than another) when it is low (minimum genetic gain), but it depends on the size of the selection nuclei when it is high (maximum genetic gain) because the number of sires tested can not be lower than 10 to avoid inbreeding.

However, we can say that for a given level of genetic gain, there is a relation, though not linear, between SIRR and size of selection nuclei.

In general, social internal rates of return obtained in our study are below the values obtained in other works assessing the returns of public investments on research and development in animal production systems. According to Herruzo (1995), social rate of returns to animal production research documented in the literature range between 27% and 97%, for dairy cattle; 21% and 67%, for the chickens industry, and 22% and 44% for research on sheep farming. One of the reasons explaining our lower rates of return is the smaller size of our cattle sector when compared with the size of sector analysed in similar studies.

Since almost all investments in the selection programmes are public, the incomes obtained by farmers in the selection nuclei through the selling of males or semen doses have not been considered to get former results. A further analysis was carried out considering these benefits and also imputing the expenses of the breeders association (Asociación de Criadores de la Cabra Malagueña) to breeders in the selection nuclei. (This excludes the costs derived from the public laboratories and the AI, which is a reasonable hypothesis in a first stage of the process of breeders assuming the costs of selection.) In this analysis only a single selection nucleus of 10,000 goat of the Malagueña breed has been considered. Internal rates of return of breeders investments range from 19% to 34% for the scheme based on NS and from 21% to 47% for the AI scheme.

Conclusions

The findings of this study demonstrate that the social returns to investments in goat selection schemes are high. From the point of view of the returns expected from public investments in the genetic improvement of Murciano-Granadina and Malagueña breeds, maximising the final cheese yield should be the only criterion used to define the formula used for the payment of milk and the selection criteria. Selection schemes should be based on the use of AI and they should improve reproduction techniques in order to increase the diffusion of the genetic improvement reached in the selection nuclei to the whole of the breed. In order to achieve this higher rate of diffusion of the genetic improvement, keeping a sufficiently high selection pressure to get a good annual rate of genetic gain without increasing dangerously the average inbreeding, selection nuclei should be the largest the possible.

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