BREEDING PROGRAMMES IN DAIRY SHEEP

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INTRODUCTION

Dairy sheep are traditionally bred in Mediterranean areas on a wide range of production systems. Each region has its own local breed well-adapted to that specific environment and to cope with the seasonal availability of pastures. Breeding environments and production systems may greatly differ, from a breed to another but also within breed, on orography, soil, climate, rainfall distribution, vegetation seasonality and grazing availability. Usual husbandry systems include a suckling period of at least one month, and have a dual purpose, with income from lamb's meat and ewe's milk, that is generally processed into high-quality cheese. Very often there is a complete association between a region of production, a breed and the brand name of a cheese, sometimes qualified as a PDO.

The great diversity of production systems, from extensive to intensive management is combined to a great diversity of genetic material. Under these conditions the strategy of genetic improvement of dairy traits corresponds usually to selection of the local pure-breds, because of a better adaptation to their own environments. In sheep, due to group feeding techniques, on-farm milk recording practices can be scarcely used for management and are mainly applied for selection purposes. So, the regular increase of recorded ewes of these last years can be directly associated to the development of selection programmes. However, technical and economic constraints related to the organisation of a selection programme still have a great influence, even in the EU countries, on the implementation and efficiency of dairy sheep selection schemes. In some situations those difficulties have driven farmers towards the use of some renowned high yielding breeds as purebred or crossbred animals. Crossbreeding and upgrading of local breeds with imported male lines have been used where the development of irrigation and intensive pastures have increased the available resources for dairy sheep farming. Thus, during the last 20 years Assaf, Awassi and Lacaune breeds in Spain and Sarda breed in Italy have greatly diffused and replaced to some extent the local breeds in semi-intensive and intensive farms.

Current situation and future perspectives of breeding programmes in dairy sheep are examined in this paper, paying attention on technical and economic problems that could prevent a more effective use of selection and crossbreeding plans in sheep farms.

CROSSBREEDING PROGRAMMES

Since 1960, because of practical problems related to the organization of a selection scheme, many breeders and farmers have attempted to improve local livestock production through importation of high-yielding breeds across the Mediterranean countries. East Friesian, Awassi and Chios breeds were the most imported ewes at this time. The East Friesian breed, due to a poor survival of purebred animals in southern climates, was used in a number of crossbreeding programmes that only in Israel produced a "synthetic" line of practical importance. The Assaf

genotype, obtained by crossing East Friesian and Awassi, is still reared in some Israeli farms but, as a matter of fact, in the "kibbutz" production environment, the improved Awassi purebred ewes can now give similar or even better results.
Since 1980, in the Spanish newly irrigated areas, the upgrade of native sheep populations was obtained through the massive introduction of Awassi, Assaf and Lacaune blood, so producing a large increase in numbers of crossbred ewes. Nowadays, more than 45% of Spanish dairy sheep are foreign breeds and crossbreds (Ugarte *et al*., 2001).
In other countries, the expected productive advantage of foreign breeds did not result compatible with the maintenance of the existing farming systems and revealed that the use of the upgraded genotypes can be economically sustainable only in some situations. For instance, the comparison between a "synthetic" genotype, obtained by crossing East Friesian and Sarda breeds, and Sarda native sheep, showed that in Sardinian irrigated lowlands the higher yields from "synthetic" animals did not counterbalance the higher inputs required and the organisational costs related to create and diffuse the new genotype (Sanna *et al*., 2001).

SELECTION SCHEMES

Current situation. Recently, the problems linked with a crossbreeding plan or yielding responses from imported genotypes lower than expected, resulted in a renewed interest in selection programmes and, together with the respect of the link with PDO or local products, have suggested for a number of breeds the implementation of AI-based breeding programmes.
For many years in Mediterranean countries dairy sheep farmers have tried to enhance their breeding activities moving from traditional intra-flock selection to collective plans of genetic improvement. In several countries some nucleus-flocks were created and used to classify various farms ewes coming from and to mate them with rams born from best dams. These centralised structures, built to compare yields in the same environment and especially to carry out planned matings among best animals, became obsolete during the seventies with the diffusion of milk recording, the availability of accurate genetic evaluation methods (Contemporary Comparison first and BLUP later) and the introduction of AI. Both classification of animals and planned matings could be moved to the usual environment of production. Thus, it was possible to take advantage of a wider genetic variance, to check genotypes over a range of environments and to improve the dissemination of superior genetic material with a greater number of rams born in selection flocks. Another benefit consequent to this dispersed strategy was the direct involvement of a large number of farmers in selection activities. This fact was not negligible in the usual conditions of dairy sheep breeding, rather static and conservative if compared to other animal productions.
To date, in southern Europe milk recording has been implemented for several breeds on a large scale in private flocks, combined with a BLUP genetic evaluation of animals on milk yield or in some cases on milk yield and milk composition. Table 1 reports the current situation of milk recording practices in dairy sheep breeds. According to recorded numbers of ewes France, Italy and Spain confirm a strong interest for selection programmes. This could be directly related to the annual genetic gain for milk production traits achieved in those countries by some breeding programmes, that clearly demonstrate the practical feasibility of selection in dairy sheep. Lacaune, Manech and Basco-Bearnaise breeds in France, Sarda in Italy and Latxa, Carranzana, Churra and Manchega in Spain have today well established breeding schemes.

Table 1. Official milk recording in ICAR countries with more than 1000 recorded ewes

Country	Population size	Recorded females	Recorded Flocks
Bulgaria	1,515,600	8,149	31
Cyprus	190,000	3,650	12
France	1,395,000	281,547	807
Germany	142,750	1,728	148
Greece	9,261,000	55,832	626
Israel	46,200	10,950	17
Italy	6,147,500	418,271	2,764
Slovak Republic	230,600	49,828	159
Slovenia	2,800	1,162	31
Spain	2,377,600	161,441	427

(adapted from Astruc and Barillet, 2001).

Especially the Lacaune breeding programme, by taking advantage of the strong cooperative willingness and the peculiar farming system of Roquefort area in France, clearly showed that optimal genetic gain can be achieved by coupling the standard genetic improvement tools to seasonal mating, prolificacy and generation interval of sheep flocks. Following the Lacaune experience and adapting the selection tools to each situation other breeding programmes have reached interesting levels of annual genetic gain (between 1 and 2% of the average milk yield; Arranz *et al.*, 2001). Every year, despite economic and organisational problems, about 200,000 ewes in France, 22,000 in Italy and 50,000 in Spain of the official recorded females are artificially inseminated.

Breeding objectives. In the last 30 years dairy sheep systems have kept their dual purpose and have conserved an income characterised by a 65-75% contribution from milk and 35-25% from meat. Under these conditions and considering the increase in consumption of sheep cheese recorded in EU countries increasing ewe's milk yield is still the most profitable option for a number of breeds (Gabina *et al.*, 2000 ; Natale *et al.*, 2000). As for dairy cattle, the breeding objectives for small ruminants assumed that an increase in individual milk yield would provide a progress with respect to the economic margin per animal. This usual assumption, acceptable only if dairy selection maintains or increases feed efficiency, has been positively checked on Lacaune dairy sheep by Marie *et al.* (1996).
Thus, for most breeds the selection objective is still the increase of milk yield in milking period (after the lamb weaning), and milk recording is mostly carried out through official AT and AC methods, being the A4 method very expensive for small ruminant breeding programmes. Genetic parameters for dairy traits shows the same pattern as in cattle (Barillet, 1997): heritabilities are moderate for milk, fat and protein yields (~ 0.30) and smaller than for fat and protein contents (~ 0.50). Milk and matter yields are highly related (~ 0.80 to 0.95) but their genetic correlations with contents are very different: milk yield shows a negative coefficient with fat and protein contents, while fat and protein yields exhibit correlations with contents close to zero.

The Lacaune selection scheme was re-oriented in 1987 to improve both milk yield and composition. In fact, following a decreasing trend for protein and fat content caused by the achieved genetic gain on milk yield, the sampling of milk composition was introduced for ewes at first and second lambing (Barillet, 1997). Currently, the Manchega breeding programme is also based on milk, fat and protein yield traits and others breeds are currently carrying out the recording of milk composition in order to monitor its genetic trend and study the reorientation of the main selection criterion.

Genetic evaluation. Almost all breeds involved in a breeding programme are now using a BLUP-animal model evaluation based upon a repeatability animal model, including fixed environmental effects and random additive genetic and female permanent environment effects. Main environmental effects, identified to have an influence on milk yield per lactation in dairy sheep production systems are :

- Milking length (ML) : positive phenotypic and genetic correlations have been found between ML and milk yield (Barillet and Boichard, 1987). In fact these variables are influenced by individual environmental and genetic causes and by flock management decisions (drying off date, for instance, is chosen by the farmer for the whole flock at the same time). In addition, in almost all breeds, mature ewes lamb earlier than yearlings so, for these classes milk yield differs not only for an age effect but also for a different ML. Usually, the effect of ML is taken into account *a priori* either by a standard lactation length or by applying a multiplicative adjustment.
- Flock Year (FY) : usually these factors originate the Contemporary Group in which daughters of different rams are compared, so their importance is not strictly related to the well-known effects of flock management and year of production. They are usually included in the model as a 2^{nd} or 3^{rd} order interaction with parity (P), age (A) or month of lambing (M) to take into account for the group management effects.
- Age at lambing (A) or Parity (P) : in some breeds this factor is used in the model to take into account yield variation due to the age or parity. In some cases they can further detailed considering age at first lambing or distance from the previous lambing.
- Month or Season of lambing : this factor is often introduced in the model within Year, Year-Age, or Flock-Year factors. His magnitude can be noticeable in dairy sheep grazing system because of the strong relationship between milk yield and seasonal rainfall, and then with the herbage availability.
- Interval between lambing and 1^{st} test-day : because this period is not usually negligible (15-25 days) using the usual methods of lactation computation the weight of the first test-day yield results higher than those of the others. This requires an adjustment associated to the day in milk in which the recording starts. Currently this factor is considered only for some breeds.
- Number of born or weaned lambs : the effect of this factor on lactation yield is evident only in breeds of low production level. In high producing breeds a positive effect exists only on first test-day records of two-lamb ewes but this is counterbalanced by a lower persistence of lactation than in one-lamb ewes.

For some breeds an *a priori* adjustment of yields is performed by using multiplicative coefficients for Age, Parity and Month of lambing (Carta *et al*., 1998).

If compared with cattle, data structures for genetic evaluation in dairy sheep can benefit of the larger size of contemporary groups and higher prolificacy. On the other side, although AI has recently increased its spread in the most organised breeding programmes, female replacement of flocks, with some exception, comes mostly from natural matings, usually by controlled natural service (ewes during the mating period are managed in groups with only one ram). Often only one or two rams are used for the entire flock so, the connectedness among contemporary groups is still a major problem for the genetic evaluation and estimation of variance components (Carta *et al.*, 1998). AI-born rams used under natural controlled mating conditions play an important role, in order to link different flocks. These additional relationships can be very important in dairy sheep genetic evaluation and increase the advantages of AI in terms of spreading of well-known sires, useful as a reference term for the other genetic lines. As an example, in the Sarda breeding programme in the last years 20% of primiparous are born from AI and another 30% comes from the natural matings with AI-born rams.

Another source of problems in dairy sheep genetic evaluation is related to the number of females having unknown parents that are often bred in recorded flocks: the ewes born after the controlled mating period and those that were already in the flocks at the time of breeding programme subscription. These ewes, useful for a sounder estimation of the production circumstances are commonly evaluated together with their flock-mates with pedigree record. Classical rules are routinely used to define phantom groups that could take into account for genetic value of these animals, but, if animals with unknown parents are frequent (more than 20% of the total in some cases) the accuracy of EBVs could be seriously affected.

As a consequence of the differences between production systems, usual in dairy sheep farming, group average and variability of yields may greatly differ between flocks. Thus, in order to improve the accuracy of selection a heterogeneity of variance adjustment can be used.

Use of best animals. As introduced above, in dairy sheep as in other species, AI has a primary role to increase efficiency in selection scheme, promoting an effective comparison between genotypes and the use of male selection pathways. In fact, the use of “traditional” breeding strategies in dairy sheep, strictly based upon natural controlled mating, assumed that the main emphasis was applied only on dam-son selection pathway. This was applied because within a flock it is easier and faster to choose a dam over two or three lactations rather than a ram from the yields of a group of daughters. Moreover, to avoid inbreeding, natural mating rams are used for 3 or more years only in very large flocks so, shepherds could seldom carry out planned matings between their best ewes and a “tested” ram. Thus, the use of AI has really improved the genetic gain expected by the sire-son pathway by allowing a great number of planned matings from the best proven sires.

From a technical point of view most of AI's in dairy sheep selection schemes are realised after oestrus synchronisation through a cervical insemination with fresh semen. A wide use of frozen semen by cervical insemination does not seem currently possible because of low conception rates resultant from the anatomic structure of sheep cervix. These technical limitations have heavily reduced the spreading of AI in many breeds and now only selection schemes that have early managed AI, often coupled with natural controlled mating, may show an appreciable annual genetic gain. Furthermore, in extensive and semi-extensive production systems economic reasons are limiting a wider use of AI. In such situations selection schemes need to combine at its best AI with NM to realise, at least, progeny testing for a number of reference rams and planned matings to produce young rams.

Future perspectives.
Breeding objectives. The efficiency of selection on milk traits is now whetting interest on new breeding goals, which are relevant to satisfy the consumer demand both for typical products, as labelled cheeses (PDO), and for safety and "healthy" food products. As already occurred in cattle, dairy sheep breeding programmes should in the future focus more on functional traits in order to decrease production costs, via a reduction of involuntary culling, and to reduce contaminants and zoonoses in the chain food. Under these conditions, specific attention should be given to the udder which is involved both in machine milking ability and resistance to mastitis. Many studies are currently moving on these topics in order to achieve basic knowledge about traits and their related selection criteria (Marie-Etancelin *et al*., 2001). Main results showed that: i) selection against subclinical mastitis may be achieved by using the Somatic Cell Score since heritability of this trait, on a lactation basis, was estimated in the range 0.10-0.15; ii) appraisal of elementary traits (teat position, udder attachment, udder halves separation, teat length) by linear scales seems to be the basic approach to select udder morphology, taking into account their moderate to high heritability and a moderate genetic antagonism with milk yield.
There is a well-documented evidence of genetic control of susceptibility to scrapie in sheep. A number of polymorphisms in the PrP gene, particularly those occurring at codons 136, 154 and 171 have been identified as being related to susceptibility to scrapie. Thus, in order to assure safety and "healthy" food products, dairy sheep breeding programmes have likely to introduce among their goals the improvement of resistance to scrapie disease, particularly considering the possible BSE effect on meat and milk marketing. Since 1999, this trait has been included in the selection criteria of the French breeds.
The economic effect of infections from gastrointestinal nematode parasites and *Oestrus ovis*, the costs related to treatments, and the large individual variability of resistance status in grazing sheep farms suggest that these traits could be considered as breeding goals in the next years.
The exploitation of genetic variation for body reserve mobilisation and ability to cope with temporary stress or nutritional shortages could certainly be of great interest for seasonal productions achieved on pasture-based farming systems. Thus, the relationships between live weight, body condition score variation and energy balance should be considered, also in dairy sheep breeding, as main research issues.

Genetic evaluation. A stimulating alternative for genetic evaluation is to analyse individual test day records instead of lactation yields. The use of Test-Day evaluation could improve the EBV's accuracy by better taking into account for daily variations on milk traits. In fact, in pasture-based farming system, as those for dairy sheep frequently are, climatic changes have an immediate effect on yield traits, that could be efficiently assessed through test-day models. These models could be further attractive for fat, protein content and somatic cell count if we consider the usual designs adopted to record these traits : 2-4 records per lactation, at only one milking, usually in the middle of lactation. For all the traits listed above, that could be difficult or expensive to measure at the farm level, an actual improvement for dairy sheep breeding programmes will be the exploitation of QTL information. In order to this, some QTL detection projects have been designed on dairy sheep breeds to achieve basic knowledge on the genetic determinism of the above cited traits (Barillet, 1999 ; Carta *et al*., 2002).

Use of best animals. Anatomical, physiological and economic restrictions have seriously hampered the spreading of AI and a greater diffusion of best selected animals. Nevertheless, all the results obtained in dairy sheep programmes were mainly achieved by using AI as the key factor of a breeding scheme. Unfortunately, the current knowledge in animal reproduction science can not allow, in the usual practice, an artificial insemination free from hormonal treatments of synchronisation. So, some concern about the use on a large scale of hormones in livestock production still exists, and restrictions about these tools could seriously affect both the selection accuracy and the use of best animals in dairy sheep breeding programmes.

CONCLUSION

The extensive or semi-extensive conditions of many Mediterranean areas in which dairy sheep are typically bred, have been a limiting factor for a wide use of AI and for its effectiveness as a selection tool. Although the widespread use of AI in the selection flocks can yield an annual genetic gain close to the maximum predicted (2.4% of average milk yield in Lacaune with 80% of selection flocks ewes inseminated), interesting levels of genetic gain can also be achieved with a lower percentage of inseminated ewes. A planned use of AI, combined with a sound genetic evaluation and well-established rules for ram utilisation, produced significant levels of genetic gain for milk yield even in traditional production systems. The efficiency of selection on milk yield have already shifted (or is currently shifting) the breeder's interest on milk composition traits. Current research themes in dairy sheep breeding are focusing on udder morphology and resistance to diseases. QTL's information coming from present studies (Barillet, 1999 ; Carta *et al*., 2002) could certainly accelerate the inclusion of several new traits in the selection criteria, especially those that are difficult to measure on a large scale.

The evolution of dairy sheep breeding programmes is similar, to some extent, to that occurred to cattle breeds: in order to take advantage of that experience some crucial points have to be considered. The basic goal of dairy sheep breeding programmes should be the improvement of stock performances within an environmental situation where the modifications of farming systems are difficult and costly. As a matter of fact, the generation of a selected stock that needs a specific environment to express its genetic potential, did not fully match with the current objectives of most dairy sheep breeds. Some results support the idea that genes acting on milk yield could not allow similar responses to adverse environmental conditions in different farming systems (Sanna *et al*., 2002). In fact, adaptation to climate changes and to their influences on feeding resources and management could heavily affect the expression of genes controlling milk production. Thus, in such a situation, the assessment of the average capability to perform under varying environmental conditions should be estimated, at least for the AI rams, and the use of genotypes showing the highest average and greatest homogeneity of performances could efficiently improve phenotypic stability. Then, a selection nucleus representative of the wide range of farming conditions proper to each breed could be the best guarantee for future improvement of dairy sheep productions.

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