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B. Lahoz[1], C. Jousseins[2], J.H. Calvo[1,3], J. Papuchon[4], J.L. Alabart[1], L. Pardos[5], V. Loywyck[2], M. Serrano[6], C. Soulas[7], P. Eguinoa[8], F. Tortereau[9], E. Fantova[10], E. Jouhet[11], A. Bernués[1], R. Canellas[12], J.C. Boscolo[13], J. Folch[1] and S. Fabre[9]

[1]CITA, Instituto Agroalimentario IA2 de Aragón (CITA-Universidad de Zaragoza), Unidad de Producción y Sanidad Animal, 50059, Zaragoza (Spain)
[2]Institut de l'Elevage, 31321, Castanet-Tolosan Cedex (France)
[3]ARAID, 50018, Zaragoza (Spain)
[4]ACAP, 09000, Foix (France)
[5]Universidad de Zaragoza, Escuela Politécnica Superior, 22071, Huesca (Spain)
[6]INIA, Departamento de Mejora Genética Animal, 28040, Madrid (Spain)
[7]SCA-CDEO, 64130, Ordiarp (France)
[8]INTIA, Unidad Producción Ganadera, 31610, Villava, Navarra (Spain)
[9]INRA, UMR1388 GenPhySE, 31326, Castanet-Tolosan Cedex (France)
[10]UPRA-Grupo Pastores, 50014, Zaragoza (Spain)
[11]CORAM, 31321, Castanet-Tolosan Cedex (France)
[12]Terre Ovine, 32220, Lombez (France)
[13]ACOAN, 22728, Ansó, Huesca (Spain)

Abstract. Sheep farming of local breeds in the Pyrenean region is of major significance from an economic, social and environmental viewpoint. However, this activity is in continuous recession. Common problems are found in both sides of the border, in France and in Spain: its scarce profitability and a lack of generational renewal, due in part to the lack of innovation linked to its particular geographic isolation. The PIRINNOVI project aims at establishing a network for acquisition, exchange and transfer of field knowledge but also research methodologies to improve sheep farming sustainability by the way of management and reproductive genetics. Common indicators for sustainability are being designed to perform technical-economic, social and environmental studies. Regardless of breed, increasing efficiency is a key factor to improve sustainability of sheep production. Thus, PIRINNOVI focuses on common reproductive problems like the low efficiency of selection schemes for prolificacy and maternal effects on growing lambs. For this purpose, artificial insemination protocol review, automatization of lamb weight recording, next-generation sequencing (NGS) and other genomic technologies based on SNP arrays are being used in both countries. The opinion of farmers, technicians and other users of the Pyrenean territory on these innovations and their implications for the continuity of this activity are also studied and taken into account for the future.

Keywords. Efficiency – Genetics – Indicators – Ovine – Reproduction.

L'innovation et la coopération transfrontalière multi-acteurs dans les Pyrénées centrales pour améliorer la durabilité des races de brebis locales

Résumé. *L'élevage ovin de races locales dans la région pyrénéenne revêt une importance majeure en termes économique, social et environnemental. Toutefois, cette activité est en récession. Les mêmes problèmes se retrouvent des deux côtés de la frontière, en France et en Espagne: son manque de rentabilité et le déficit de renouvellement des générations, qui résultent en partie du manque d'innovation lié à son isolement géographique. Le projet PIRINNOVI vise à établir un réseau pour l'acquisition, l'échange et le transfert sur le terrain de connaissances, mais également développer des méthodologies de recherche afin d'améliorer la durabilité de l'élevage*

ovin par une meilleure gestion et amélioration génétique de la reproduction. Des indicateurs communs pour le développement durable ont été déterminés pour réaliser des études technico-économiques, sociales et environnementales. Quelle que soit la race, améliorer l'efficacité est un facteur clé pour améliorer la durabilité de l'élevage ovin. Ainsi, PIRINNOVI s'attache à étudier les problèmes observés en reproduction comme la faible efficacité des schémas de sélection sur la prolificité et les aptitudes maternelles. Ainsi, l'examen du protocole d'insémination artificielle, de l'automatisation de la pesée des agneaux, le séquençage de nouvelle génération (NGS) et d'autres technologies génomiques basées sur des marqueurs SNP sont utilisés dans les deux pays. L'opinion des éleveurs, des techniciens et d'autres utilisateurs du territoire pyrénéen sur ces innovations et leurs implications pour la continuité de l'activité est sollicitée et étudiée pour une prise en compte à l'avenir.

Mots-clés. *Efficacité – Génétique – Indicateurs – Ovin –Reproduction.*

I – Introduction and objectives

Sheep farming is largely present on both sides of the Pyrenean border and represents a great economic, social and environmental potential for the territory. It provides an alternative for employment in rural areas, and using local breeds, it represents a unique genetic and cultural heritage. However, the steady decline in economic profitability of these activities, due in part to the lack of innovation linked to its geographic isolation, is threatening its sustainability and with it, the survival of some breeds. It affects more particularly local meat breeds, well adapted to the territory but often less productive. PIRINNOVI project includes a total area of 117,000 km², including the following territories in France: Pyrénées-Atlantiques, Hautes-Pyrénées, Haute-Garonne, Ariège, Pyrénées-Orientales; and Spain: Navarra, Huesca and Zaragoza. In this area, there are around 1,337,000* sheep animals belonging to a total of 18 local breeds, some of them in danger of extinction. In France, this concerns Tarasconnaise (152,100 ewes), Aure et Campans (9,000 ewes), Barégeoise (4,000 ewes), Castillonaise (3,000 ewes), Montagne Noire (2,000 ewes), Rouge du Rousillon (4,000 ewes), Lourdaise (400 ewes), Basco-Béarnaise (80,000 ewes), Manech Tête Noire (120,000 ewes), Manech Tête Rousse (270,000 ewes), and Lacaune meat sheep. In Spain, the project focuses on Ansotana (6,391), Churra Tensina (10,452), Xisqueta (19,700), Roya Bilbilitana (19,207), Maellana (7,200), Rasa Aragonesa (380,638) and Navarra (87,591). Multi-actor cooperation is guaranteed by the participation of 7 R&D agencies, 8 livestock associations and 4 agricultural cooperatives. The objective of PIRINNOVI is to establish a forum for acquisition and exchange of knowledge and research methodologies in the field of sheep management and reproductive genetics. This is achieved by the transfer of skills and technologies to local breed flocks of the Pyrenean region, to improve their efficiency, sustainability and visibility for society. The project is divided into five tasks, including sustainability and genetic axes.

II – Technical actions

1. Sustainability axis

In order to improve the productive efficiency of meat sheep farms, it is necessary to have relevant and reliable technical and economic information. This facilitates further decision-making, not only for farmers and technicians, but also for Administrations, companies and the sector in general. Nevertheless, it is absolutely necessary to go beyond the economic sustainability, and also to study the social and environmental context. In PIRINNOVI, common indicators for economic, social and environmental sustainability are designed for most breeds of the project, valid for both sides of the border. This information, as well as the innovations raised on the project, will be shared with different actors within the territory, to get their acceptance and opinion.

2. Genetic axis

A. Maternal ability

Common work is carried out to improve maternal abilities and prolificacy linked to major genes, due to their major impact on farm profitability. Selecting for maternal abilities will lead to obtain ewes with good maternal care behaviour and sufficient milk to rear their lambs. While more interesting for prolific flocks, it would also be worth for all kind of flocks irrespective of their prolificacy. Selecting ewes for maternal abilities is carried out by assessing the average daily gain of their progeny during the pre-weaning stage, during which lambs' growth depends mostly on their mother's dairy value and maternal behaviour. In practice, lambs are to be weighted twice before weaning, typically at birth and at weaning. While selection for maternal abilities is well stablished in France (with a single weighing at 30 days of age), it is currently starting in Spain. In this sense, a maternal capacity selection criterion in the Rasa Aragonesa breed is being included since 2015 by UPRA-Grupo Pastores within its selection program for prolificacy. In the framework of PIRINNOVI, two other Spanish breeds (Navarra and Ansotana) have started to implement maternal abilities selection programs. One of the bottlenecks for implementing such programs is the unwillingness of farmers to weigh lambs, record weights and keep and transmit weighing records. In order to increase the efficiency of the breeding schemes, activities focus on three main points:

– Electronic identification and weight recording in lambs

Two systems combining electronic identification, already mandatory in France, and automatization are being setting up. In Navarra and Rasa Aragonesa breeds, a "self-weighing" system has been designed to record static weights at about 30 days of age. In this system, lambs are weighed and identified through HD-RFID ear tags when approaching a feeder with attracting supplemental feeds. Image recognition software discards wrong measurements. A prototype has been developed and is currently tested in the Navarra breed. In Ansotana breed, a system consisting in a corridor with manual door opening and a crane implemented with HD-RFID and automatic weight recording is also being tested.

– Artificial insemination

Artificial insemination (AI) is an essential tool for the connection of flocks, the diffusion of genetic progress and to limit the increase of inbreeding. On the French side of the border, apart from the Lacaune breed for which AI is largely used, AI is performed in the 3 local dairy breeds of the Pyrenees Atlantiques region: Manech Tête Noire, Manech Tête Rousse and Basco-Bearnaise (82,550 AI in 2015)**. However in these latter breeds, fertility problems are recurrent, with an average fertility of 55.8% (2016), which threaten the selection schemes. In the meat sheep context, these problems led to the almost total drop up of AI in the Tarasconnaise breed, passing from 4,000 AI/year (1990) to 483 AI in 2015*, which weakens the breed selection scheme. In the Spanish side, AI is applied in the developed local breeds, Navarra and Rasa Aragonesa. The large variability of fertility results, with means of 52.2% in Rasa Aragonesa and 67.4% in Navarra (2015), progressively discourages breeders from using AI (12,232 *vs.* 6,195 AI in 2006 and 2015, respectively, total in both breeds)**. In the endangered sheep breeds exploited on both sides of the Pyrenees in more extensive regimes, the AI is not used or anecdotally, as in Ansotana or Roya Bilbilitana breeds in Spain. Whatever the breed, the fertility of AI has not been improved over the last 10 years, with a great variability between breeds, years and farms. This constitutes an obstacle for the development

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* Information provided by breed associations.
** Compte rendu annuel sur l'insémination artificielle ovine-Campagne 2015. L'Institut de l'Elevage (Ed.).

of the technique and therefore, for the progress of the breeding programs. PIRINNOVI project aims at improving the fertility results and the dissemination of AI in local sheep livestock. The activity will be developed at three levels: 1) Individualized analysis through surveys of AI results and ultrasound gestation diagnosis to elucidate the causes of fertility problems and final advice for farmers, 2) AI development in endangered breeds aiming at working on maternal abilities, and 3) Physiological studies on ovarian cyclicity in breeds that do not have this information.

– Genomics

The limited use of AI in the Pyrenean area is an obstacle to the progress of the breeding schemes for maternal abilities in meat sheep. In PIRINNOVI, genomic technologies based on SNP arrays are being used in both countries. In Spain, it is planned to design a common multibreed paternity test valid for all the Pyrenean breeds involved in the project. In France, the real impact of an improved paternity knowledge on the precision of genetic evaluations will be evaluated in a French pilot breed (Tarasconnaise) using an already designed paternity SNP array (developed for French sheep breeds).

B. Prolificacy

Prolificacy, defined as the number of lambs per lambing ewe, is a very interesting trait that has been selected for several decades in meat sheep. It is under a polygenic genetic determinism with very low heritability, so that a small effect and a very slow genetic progress are usually achieved. However, in some sheep breeds of the Pyrenean area considerable genetic improvements have been observed over very short periods of time, revealing the great effect of polymorphisms in major genes affecting prolificacy. In Spain, it is the case of the prolific $FecX^R$ allele in $BMP15$ gene on chromosome X (Martínez-Royo *et al*., 2008). It is segregating in Rasa Aragonesa, and has been introgressed in the Navarra breed, leading to an increase of +0.35 lambs per heterozygous lambing ewe (Lahoz *et al*., 2011). In France, the prolific $FecL^L$ allele, on chromosome 11, segregates in the Lacaune breed, with an effect on the production of +0.47 lambs per heterozygous lambing ewe (Martin et al., 2014). Techno-economic studies show the main influence of prolificacy major gene on flock profitability (+21 extra € /ewe/year; Pardos *et al*., 2010). For these reasons, the frequency of these polymorphisms in flocks was increased up by dedicated breeding schemes (27.9% and close to 10% for heterozigous $FecL^L$ and $FecX^R$ ewes, respectively; Martin *et al*., 2014; UPRA 2017*). Although management programs for these genes have been developed in both countries, little is known about the pleiotropic effect of both polymorphisms, and more particularly of the $FecL^L$, on age at puberty, fertility, seasonality, or possible interaction with hormonal treatments. It is expected that the correct management of naturally prolific sheep on farms could, in many cases, reduce the use of hormonal treatments by presenting naturally higher prolificacy and fertility. The PIRINNOVI project aims at 1) studying the pleiotropic effect of the $FecL^L$ prolific allele in French Lacaune and $FecX^R$ in Spanish Rasa Aragonesa, 2) discovering, using high density SNP array and whole genome sequencing, new prolific alleles among prolific Lacaune and Rasa Aragonesa ewes non-carrier of $FecL^L$ or $FecX^R$, and 3) identifying the possible presence of already known prolific allele worldwide (using the paternity SNP array tool) in the rest of Spanish and French endangered breeds that share the Pyrenean territory, either for their correct management or for elimination.

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