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BREEDING FOR SHEEP PARASITE RESISTANCE IN EXTENSIVE PRODUCTION SYSTEMS: FROM PHENOTYPE TO GENOTYPE

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Worldwide, gastrointestinal parasites (GIP) generate numerous productive and economic losses in sheep production and Uruguay does not escape to this problem. Due to the aggravating situation of anthelmintic resistance to all drugs available in the market, the use of non-chemical alternative strategies is essential to address the problem of GIP. For this reason, commercial producers who raise their sheep in temperate and subtropical areas under extensive systems and the breeders (that provide genetics), would like to consider genetic resistance to GIP in their selection objective. In Uruguay, genetic evaluations of wool and meat quality and production traits are routinely carried out by the Uruguayan Secretariat of Wool (SUL) and the National Institute of Agricultural Research (INIA) (www.geneticaovina.com.uy). Since the beginning in 1994, genetic evaluations of the Merino and Corriedale breeds have included Fecal Egg Count per gram (FEC) as the selection criterion. The national approach has been to contribute to the selection of genetically resistant animals within an integrated control of parasites. However, as it is a difficult characteristic to record, different strategies have been included to augment genetic improvement of resistance to GIP, which are described below.

Support for recording and new criteria

Given the reluctance of producers to collect data, different projects had been working to support the beginning of recording. As an example, we can mention INIA and Inter-American Bank financing for the development of recording for Corriedale (2002) and Australian Merino (2004). More recently, coordination and registration are being done directly on Corriedale (2018) and Merilin (2020) stud flocks, within an INIA project in conjunction with the breed societies. Currently, the genetic evaluation is consolidated in the Merino breed and growing in Corriedale. Table 1 reports the information in the national database (SULAR) within the genetic evaluation system (INIA-SUL) collected in the last four years, in Table 2 the total data within the system.

Table 1: Number of animals with FEC registration, according to birth year

Breed	**2014**	**2015**	**2016**	**2017**
Corriedale	121	1079	1301	1451
Merino	726	1298	1400	1397
Total	**882**	**2435**	**2796**	**3133**

Table 2: Total data in SULAR related to GIP resistance

Breed	**Trait***	**N**	**mean**	**sd**
Corriedale	BCS at FEC	1394	2.74	0.6
	FAMACHA	3077	2.28	0.8
	FEC	21772	1530.07	2319.66
	PCV	2495	35.27	4.75
Merino	BCS at FEC	230	2.81	0.39
	FAMACHA	1590	2.11	0.85

**FEC: Fecal egg count post weaning.*
PCV: Packed cell volume.
BCS: Body condition score

FEC	25700	1279.08	1967.7
PCV	1356	32.05	5.41

Estimated FEC heritability in lambs is moderate, with values ranging from 0.2 to 0.4 in agreement with the international studies (e.g. review by Safari et al., 2005), which would allow genetic progress for this trait. Due to the described efforts in registration, it has been possible to estimate the FEC heritability for the main breeds in production systems under natural infestations. These estimates are between 0.15 ± 0.01 for Merino (Ciappesoni et al, 2013) and 0.21 ± 0.02 for Corriedale (Castells, 2009). Studies have also been conducted to relate the nematode resistance in periparturient ewes and post-weaning lambs in Uruguayan Merino sheep (Goldberg et al., 2012). Currently, the study of the spring rise phenomenon continues in different breeds and production systems (Del Pino et al., 2019). Furthermore, different studies have been carried out looking for new, easy-to-measure or complementary selection criteria such as: FAMACHA © (Ciappesoni & Goldberg 2018), fecal occult blood test (FOB) (Rodriguez et al., 2015), control of IgA levels (Escribano et al., 2019) and dag score (RUMIAR project, INIA).

Generation of resistance selection nucleus

As a strategy for the generation of genetically resistance breeding stock and the dissemination of genetic tools (i.e. EBV), selection nuclei are in place in experimental stations: (1) Corriedale: divergent selection lines by FEC EBV (from 2000, SUL Cerro Colorado); (2) Merino: selection by FEC EBV and production (since 2015 FAgro-Udelar - San Antonio); (3) Corriedale: selection by FEC EBV and production (since 2017 INIA Glencoe).

Development and use of molecular tools

Initially, many countries aimed to use genetic markers to identify alleles associated with resistance to GIP and to select for breeding young animals carrying these alleles. Marker association studies were also carried out in Uruguay using microsatellite molecular markers (STRs) in the Corriedale (Nicolini, 2006) and Merino (Ciappesoni et al., 2010) breeds. A low-density panel of 507 SNPs associated with GIP resistance and useful for parentage testing (Peraza et al., 2019) was also developed in Uruguay. Nowadays, the genomic selection is the preferred approach, particularly for expensive or difficult to measure traits such as FEC. By using single nucleotide polymorphism (SNP) information (i.e. SNP type molecular marker panels of different density) together with phenotypic and pedigree information, it is possible to increase EBV accuracy in young animals. Currently, several countries are implementing genomic selection in sheep, such as New Zealand, Australia and France. In Uruguay, particularly in the Merino breed, the reference population is being developed with aim of publishing the first genomic EBV for FEC in 2020. Currently DNA samples of more than 8000 Merino animals with FEC phenotypes are stored in the National DNA Bank of INIA. In addition, there are currently more than 1200 animals genotyped with different arrays (15k and 50k), with 3000 animals planned to be reached in 2021.

Additionally, SNP panels of different densities have been useful for breed genetic characterization and population structure analysis. Several studies have been carried out with the Uruguayan Merino, Corriedale and Creole breeds (Grasso et al., 2014), Australian Merino and other related breeds (Vera et al., 2019; Ceccobelli et al., 2019). Likewise, mechanisms involved in genetic resistance to GIP in Corriedale were investigated using RNA sequencing (Peraza et al., 2016). We plan to include selection signature studies in Corriedale breed using divergent selection lines.

In summary, several tools to improve the genetic resistance of sheep to GIP have been developed and further research is ongoing with the aim of increasing their effectiveness and contributing to greater economic benefits and more sustainable production systems. Research and innovation initiatives have been made possible due to the coordinated work of research and knowledge transfer institutions, with the support of breeders' associations.

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