Selection tools to benefit from international cooperation in small ruminants: a comprehensive work package of the SMARTER project

J.M. Astruc[1], L. Brito[2,3], B. Bapst[4], G. Bruni[5], M. Burke[6], G. Ciappesoni[7], J. Conington[8], C. Garcia-Baccino[9], H. Larroque[9], A. Legarra[9], A. O'Brien[10], J. Posta[11], C. Robert-Granié[9], M. Teissier[9], E. Ugarte[12], C. Moreno-Romieux[9], D. Berry[10]

[1]*IDELE, Castanet-Tolosan, France*
[2]*Purdue Univ, West Lafayette, USA*
[3]*Univ of Guelph, Guelph, Canada*
[4]*Qualitas AG, Zug, Switzerland*
[5]*ARAL, Crema, Italy*
[6]ICAR, Roma, Italy
[7]INIA, Montevideo, Uruguay
[8]SRUC, Edinburgh, UK
[9]*INRAE, Castanet-Tolosan, France*
[10]TEAGASC, Fermoy, Ireland
[11]*UNIDEB, Debrecen, Hungary*
[12]NEIKER, Vitoria, Spain
Corresponding Author:Jean-Michel.Astruc@idele.fr

Abstract

SMARTER (SMAll RuminanT breeding for Efficiency and Resilience) is an H2020 EU multi-actor project, whose global objective is to develop novel and collaborative strategies to improve resilience and efficiency of the sheep and goat sectors at the animal, population/breed and system/farm levels. A dedicated work package (WP6) aims to contribute to accelerated genetic progress for resilience and efficiency (R&E) through international harmonisation and cooperation in order to deploy genomic evaluations across countries. The goal of this paper is to present the different tasks that are being undertaken to successfully meet the WP6 goals.

SMARTER will generate recommendations on the phenotyping of R&E related traits, which will enrich the ICAR guidelines in the area of small ruminants. SMARTER will also build 3 prototypes (meat and dairy sheep, dairy goat) of across country genetic and genomic evaluations. The activities under development will result in the tools to enable a future routine international evaluation whose business and practical operation model will be established during the project. SMARTER has already proposed and implemented several tools towards the development of across country genomic evaluations. For instance, the file formats to exchange pedigree, phenotype and genotype, have been established based on Interbull and Interbeef experiences. An international codification of the sheep and goat breeds has been initiated and is expected to be consolidated by ICAR. The current breeding programs and genetic evaluation systems have been described, based on a survey distributed to all the partners. A comparison of sheep genotype metrics across breeds and countries should lead to a common genotype platform suitable to all SMARTER populations. Data sharing agreements have been signed between partners to pool large set of historical phenotypic and genomic datasets. Furthermore, a deterministic model has been developed to quantify the long-term benefits and feasibility of international genetic and genomic evaluations has been evaluated. The assessment of the long-term benefit of international evaluation is crucial

to inform countries to endorse the harmonisation of their methods of phenotyping and evaluation and accept to pool together data from different countries.

Keywords: Sheep, goat, guidelines, international evaluation, genomics, harmonisation

Introduction

SMARTER stands for "SMAll RuminanTs breeding for Efficiency and Resilience ». It is an H2020 project running from November 2018 to October 2022 (initially), expanded to 2023 (due to Covid-19) and coordinated by Carole Moreno-Romieux from INRAE (SMARTER project, 2019).

This is a multi-actor project with 27 full partners from 13 countries. Half the partners are non-academic. ICAR is included in the partnership. Various stakeholders are also participating in the project. Most of the members of the Sheep, Goat and Camelid ICAR working group are from organisations which are either partners or stakeholders in SMARTER.

An entire work package (WP6) is dedicated to propose and develop practical tools to achieve the objective of contributing to faster genetic progress for resilience and efficiency traits in sheep and goats through improved international cooperation.

Four tasks are being undertaken, related to:

- The harmonisation of phenotypes, genotypes and pedigree.
- Across country evaluations.
- The practicalities of international evaluations.
- The modelling of the benefits of harmonisation and international cooperation on long-term genetic gain.

This paper aims to describe the work carried out in the work package with a particular focus on the topics of harmonisations and international cooperation. Both of these are part of ICAR's core activities, namely guidelines, evaluation and certification services. In this respect, the outputs from SMARTER should be useful for ICAR community.

Harmonisation of phenotypes, genotypes and pedigree

The first batch of actions, related to harmonisation, has the triple objective of

1. providing the prerequisite for international evaluations;
2. conceiving an optimized and affordable genomic tool and
3. proposing recommendations for recording resilience and efficiency traits.

The following advancements are described in this section: description of breeding programs and evaluation systems in the partners' countries; production of sharing agreements for pooling data; proposition of file formats for exchanging phenotypes, genotypes, pedigree; research on allele frequency across country x breeds; listing of novel traits and their definition; codification of breeds.

Description of breeding programs and evaluation systems in the partners' countries

Genetic evaluation systems and breeding programs have been described and data collated from 45 sheep and goat populations across 12 countries. This was done through surveys distributed to all partners. This work was presented at the EAAP 2020 (Brito *et al.*, 2020). The main conclusions was that there are numerous challenges to be addressed for pooling data from different countries (for example: high heterogeneity of trait recording, SNP panels and statistical models used, average of ~30% of animals with unknown sires). However, there are also many opportunities to use the current resources to optimize selection for resilience and efficiency in small ruminants across countries.

Proposition of file formats for exchanging phenotypes, genotypes, pedigree

A coherent set of formats have been proposed to pool data from different countries, built on principles close to those used in Interbull and Interbeef. An appraisal will be undertaken at the end of the project to possibly update these formats, based on the issues encountered while using them.

Production of sharing agreements for pooling data

A template of a sharing agreement was produced for pooling data. Ten bilateral agreements were signed (between the organisation producing the data and the organisation in charge of the evaluation) covering 3 case-studies (meat and dairy sheep, dairy goats). The agreements detail the data and the purpose of aggregating the data and performing statistical analysis, and give the rights and duty of the providers and the researcher on the use of the data. This template, conceived for the needs of the projects, could serve beyond the project for the routine exchange of data.

Research on allele frequency across country x breeds

The conception of a genomic tool was carried out by pooling allele frequency information acquired from 18 sheep breeds (including 10 meat sheep and 8 dairy sheep populations from 5 countries – the UK, Ireland, Uruguay, Spain and France; some populations were represented in several countries, such as Charollais, Texel and Vendéens). Comparison of genotype metrics across populations enables the detection of the most informative SNPs across populations and breeds. This work could be deepened by adding other breeds and will result in an optimal panel of SNP for the breeds involved that could be exploited in a tool widely used and therefore more affordable.

The main results were presented at the EAAP in 2020 (O'Brien *et al*, 2020). Several metrics were produced from informative SNP, identified where the frequency of the "A" allele was between 0.2 and $\leq$ 0.8 in each of two pair-wise populations compared. In particular, the correlation between minor allele frequencies of the SNPs presents in two populations allows to assess the distance between them.

Listing of novel traits and their definition

An important practical result of this action is to produce ICAR guidelines on phenotyping resilience and efficiency traits. This work is based on the results that will be produced by the work packages dedicated to the novel traits, with a two-step approach: determination and genetic analysis of the more relevant traits in experimental farms, and the proposition of proxies usable on private farms for larger scale for selection. These tasks are on-going. However, a first milestone was produced that described

the traits for assessing resilience and efficiency in sheep and goats. The guidelines will be due by the end of the project when all the results are available.

Coding breeds

A first coding of the breeds involved in the work package was proposed. This code is based on 3 letters and could be extended beyond SMARTER. The interest of such a code relies on the existence of data exchanges across country. The extension of the code will be proposed to ICAR. Crossbreed livestock should also be addressed.

Across country evaluation

Once the prerequisites are set, the second general objective of the work package is to assess the interest of an across-country evaluation. This is done through 3 tasks: the implementation of 3 pilot studies on multi country evaluation in meat sheep, dairy sheep and dairy goats; the writing of the organisational and business model of a routine international evaluation; the assessment of the cost-benefit of international sharing of germplasm.

Implementation of across country evaluation in three case-studies

The case-studies concern:

- Ireland, the UK and France in meat sheep (Fitzmaurice *et al.*, 2021);
- France and Spain in dairy sheep;
- France, Canada, Switzerland and Italy in goats

The common purpose is to document the practical issues (ID, phenotypes), to assess the connectedness across country, to estimate the genetic correlations across country, and to run a BLUP / SSGBLUP animal model based on raw phenotypes through multi-trait analysis

The work is underway and practical results will be available in late 2021.

Creating an international initiative for across country evaluation in small ruminants

The operation and business model for a possible initiative on across-country evaluation in small ruminants is based on 3 axes:

- The willingness of countries to participate;
- The technical lessons derived from the case-studies, basically the strategy for pooling data (typically, raw phenotypes versus EBVs, with or without genotypes), the way to address the technical issues on the data, the connectedness between population;
- The opportunities and risks of international evaluation. This point was addressed through a survey within SMARTER that will be extended outside SMARTER. An interesting range of opinions and comments were already gathered, that can be summarised as follows.

The main opportunities mentioned in the survey are:

- Faster genetic gain obtainable from a larger reference population, a higher selection intensity and a higher accuracy.
- A way to select for difficult-to-measure traits (i.e. health, welfare, environmental challenges).
- The interest of having EBVs from abroad on the domestic scale.
- The insurance to have fair exchanges across countries.
- As an externality, the benefit from international collaboration and sharing of knowledge, especially through networking amongst stakeholders.
- An incentive to deliver on the harmonisation of phenotype recording.

The main risks mentioned in the survey are:

- The lack of genetic links between countries and the risk of having genotype by environment interactions.
- The promotion a few breeds of wide commercial applicability that might endanger further, some local breeds. This is because it is likely that very few breeds will benefit from the exploitation of genetic improvement to accelerate genetic gain, thereby diverging further away from the performance levels of the marginal breeds.
- The unbalanced benefits among countries, with the risk that the sale of genetics would only be one way.
- The risk that the initiative should be too expensive and too time consuming for the small ruminant sector. The question of cost-benefit balance is clearly raised.
- The loss of independence of genetic evaluations. This risk was highlighted by many respondents, suggesting a preference / need to maintain national research groups and genetics capability in this area.

The survey will be extended to different stakeholders in order to get a greater variety of respondents, and to propose a business plan taking into account the opportunities and risks, and how manage and mitigate them.

Estimating the cost-benefit of international genetic/ genomic evaluations and cooperation

Gene flow models were developed to quantify the impact a specific subpopulation can have over time on the genetic gain or economic benefit of an industry (Fetherstone *et al*, 2020). Importation of foreign germplasm is a widely adopted strategy in some populations. An Ireland-New Zealand case study was simulated in order to quantify the potential gain that could be achieved through the importation of foreign sire contributions (New Zealand) into a domestic sheep industry (Ireland). Within the study, multiple market scenarios were assessed. Results reveal that the maximum genetic (measured as average genetic gain) and economic (measured as an annualised cumulative value) benefit could be achieved by implementing a market scenario which involved shifting market share away from conservative domestic breeders and increasing the selection intensity of rams retained for breeding without the use of foreign genetics.

This developed framework could be used in other case-studies within the project.

Conclusion: practical outputs for ICAR community

Harmonisation and international cooperation are the major objectives of ICAR. The SMARTER project, by balancing academic and non-academic partners, as well as including various stakeholders in its network and by achieving both scientific and practical results, will be useful for the ICAR community involved in sheep and goat production. The findings and achievements of the work package described in this paper should contribute to a framework of future services towards small ruminants breeding organisations.

The guidelines for efficiency and resilience traits in small ruminants will complete the set of recommendations already existing for dairy traits recording in sheep and goats (ICAR, 2020) or on the verge of being published on meat and reproduction traits on small ruminants.

The creation of an international initiative and the preparation of necessary procedures to facilitate, encourage and motivate cooperation in international evaluations in small ruminants, might result in a routine international evaluation.

Finally, in order to coordinate the previous points and provide a support to the breeding organisations on performance recording and genetic evaluation in sheep and goats, the definition of a zootechnical Reference Centre for Small Ruminants will be proposed within SMARTER.

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List of references

Brito L.F., Berry D., Larroque H., Schenkel F., Ciappesoni G., O’Brien A., Tortereau F., Ugarte E., Palhière I., Bapst B., Jakobsen J., Antonakos G., Kominakis A., Clement V., Bruni G., Loywyck V., Massender E., Oliveira H.R., Posta J., and Astruc J.M. Genetic evaluation systems and breeding programs in sheep and goats: an international perspective. In EAAP, Virtual Meeting, Portugal, Book of Abstracts, December 2020.

Fetherstone, N., Hely, F.S., McHugh, N., McGovern F.M., Amer P.R. Genetic and economic benefits of foreign sire contributions to a domestic sheep industry; including an Ireland-New Zealand case study. Genet Sel Evol 53, 5 (2021). *https://doi.org/10.1186/s12711-020-00594-y*

Fitzmaurice, S, Conington, J, McHugh, N, Banos G. Towards future genetic evaluations for live weight and carcass composition traits in UK sheep. Small Ruminant Research 196: 106327 March 2021. *https://doi.org/10.1016/j.smallrumres. 2021.106327*

ICAR, 2020. ICAR guidelines. Section 16 on Dairy Sheep and Goats. https://www.icar.org/index.php/icar-recording-guidelines/

O’Brien A.C., Astruc J.M., Tolkamp A., Berry D.P. Comparison of sheep genotypes metrics across breeds and countries. In EAAP, Virtual Meeting, Portugal, Book of Abstracts, December 2020

SMARTER Project, 2019. Website *www.smarterproject.eu.* Selection tools to benefit from international cooperation in small ruminants: a comprehensive work package of the SMARTER project