28. Genetic parameters for feed efficiency, gas emissions, oxygen consumption and wool traits in Australian Merino

C.B. Marques[*], I. De Barbieri, J. Velazco, E.A. Navajas and G. Ciappesoni[*]

Instituto Nacional de Investigación Agropecuaria, INIA Las Brujas, 90100, Rincón del Colorado, Ruta 48 km 10, Canelones, Uruguay; cbalconi@inia.org.uy; gciappesoni@inia.org.uy

Abstract

The purpose of the present study was to estimate genetic parameters of growing globally important traits such as feed intake, residual feed intake, methane, carbon dioxide, oxygen consumption and greasy fleece weight in Uruguay. Data of three Australian Merino generations which integrate the Uruguayan National Genetic Evaluation for sheep were recorded (from 2019 to 2021). Heritabilities and genetic and phenotypic correlations were estimated for 930 animals sired by 19 rams. Results presented suggest that relevant genetic progress can be achieved in all traits (heritabilities between 0.23 and 0.41). Methane emission present moderate to high genetic correlations with the other traits (0.57-0.88). The most efficient animals will tend to consume less feed and emit less methane, without affecting wool production. The genetic correlation between wool production and the other traits were not significantly different from zero. The developing of this work will be the basis for the construction of agroecological breeding objectives.

Introduction

Ruminants emit methane (CH_4) through enteric fermentation in their digestive tract, which represents a loss of 6 to 10% of gross energy intake and is a significant source of anthropogenic CH_4 emissions globally (Schaefer *et al.*, 2016). Sheep emissions and their associations with feed intake and production traits are currently investigated as part of the implementation of greenhouse gas (GHG) mitigation strategies. Genetic selection of efficient and low-emitting animals is promising, as long as these traits are heritable. If a favourable correlation exists between traits such as feed efficiency and CH_4 emissions, a mitigation of CH_4 production could be obtained as a response of selecting for more efficient animals. The purpose of the present study was to estimate genetic parameters for feed efficiency, GHG emissions, oxygen consumption and wool production traits in Australian Merino lambs in Uruguay.

Materials & methods

Data and traits. Data of three Australian Merino generations which integrate the Uruguayan National Genetic Evaluation for sheep were recorded from 2019 to 2021. Information from 930 animals sired by 19 rams was available on the following traits: feed intake (FI), residual reed intake (RFI), CH_4, carbon dioxide (CO_2), oxygen consumption (O_2) and greasy fleece weight (GFW). The 2020 progeny was the first in which several of their dams (27%) or sires (15%) or both parents (4%) had also been recorded for feed intake and gas emissions as lambs in 2019. Descriptive statistics and data structure for ages (at trial and at shearing) and all the traits investigated are presented in Table 1.

Feed efficiency measurements. Three RFI tests were carried out per year (9 in total) where animals were allotted based on sex, birth type and age. After 14 days of acclimatization, each test period had a duration of 42 days, in which animals were allocated to one of five outdoor pens, with five automated feeding systems in each pen, according to body weight, sex and sire. Lambs were fed *ad libitum* with Lucerne haylage. Each pen had two automatic weighing platforms that allowed individual weight control.

Table 1. Descriptive statistics and data structure for ages, residual feed intake (RFI), feed intake (FI), oxygen consumption (O_2), methane (CH_4), carbon dioxide (CO_2) and greasy fleece weight (GFW) traits.

Trait	n	Mean	Standard deviation	Min	Max
Age at trial (days)	930	295.33	45.79	204	378
Age at shearing (days)	930	413.03	8.97	387	432
RFI (kg/dry matter/day)	930	-0.001	0.15	-0.43	1.58
FI (kg/dry matter/day)	930	1.33	0.27	0.67	3.16
CH_4 (g/day)	930	22.43	5.61	8.91	44.66
O_2 (g/day)	930	981.37	191.96	427.33	2,114.66
CO_2 (g/day)	930	1,067.45	234.71	478.18	2,269.63
GFW (kg)	918	4.13	0.73	2.10	6.53

Portable accumulation chamber measurements. Sheep emissions were measured in portable accumulation chambers (PACs) made of polycarbonate sheet with an internal volume of 861.8 l (118.8-cm length × 120.7-cm height × 60.1-cm width), similar to those described by Goopy *et al.* (2011). The CH_4, O_2 and CO_2 concentration measurements were taken after confining the sheep in the PACs for a minimum time of 40 min. Total gas space inside the portable static chamber was estimated by assuming that the volume occupied by the sheep was equal to 1.01 L/kg liveweight (Jonker *et al.*, 2018) and subtracting the liveweight of the sheep from the internal volume of the chamber. Data analysed was the mean value of two measurements collected around day 30 and day 37 in trial. Using an analogous methodology as the described by Goopy *et al.* (2011), a calculation was performed to convert the CH_4, O_2 and CO_2 concentration from PACs to daily measurements.

Statistical analyses. A Bayesian analysis and an assessment of variance and covariance components using GIBBSF90 computer package (Misztal *et al.,* 2002) was performed. The number of iterations after burn-in used for posterior inferences was 300,000 with the model:

$y_{ijklm} = CG_i + BT_j + DA_k + age_l + a_m + e_{ijklm}$ where: y_{ijklm}: m^{th} performance record of animal l, CG_i: fixed effect of the contemporary group i (year-management group-sex-pen-trial, 134 levels), BT_j: fixed effect of birth type j (2 levels), DA_k: fixed effect of dam age k (3 levels), age: age at m measurement of animal l as a co-variable, a_l:random additive genetic effect of animal l (1,962 animals), and e_{ijklm}: random residual.

Results

Heritabilities, genetic and phenotypic correlations estimated are shown in Table 2. Moderate magnitude heritabilities between 0.23 and 0.41 were found for all traits. The three gases presented the lowest values. High genetic correlations were observed between RFI with FI and CH_4, FI with the three gases, and CO_2 with O_2 and CH_4 (range 0.64-0.97). The genetic relationship of RFI with CO_2 and O_2 with CH_4 were moderate (0.50-0.57). In this work, genetic correlations estimated between GFW and feed efficiency and greenhouse traits, as well as between RFI and O_2, were not significantly different from zero.

When analysing the phenotypic results, high correlation values were found between RFI and FI, and between CO_2 and other two gases (0.64-0.93). Phenotypic relationship was moderate between FI and the three gases, and also between O_2 and CH_4 (0.28-0.57). The phenotypic correlations of RFI with CH_4, CO_2 and GFW were not significantly different from zero.

Table 2. Genetic and phenotypic parameters for residual feed intake (RFI), feed intake (FI), oxygen consumption (O_2), methane (CH_4), carbon dioxide (CO_2) and greasy fleece weight (GFW) traits in Australian Merino breed[1].

	RFI	FI	O_2	CH_4	CO_2	GFW
RFI	**0.27 (0.09)**	0.79 (0.10)	0.37 (0.22)	0.64 (0.22)	0.50 (0.20)	0.05 (0.18)
FI	0.75 (0.05)	**0.38 (0.12)**	0.68 (0.14)	0.88 (0.10)	0.77 (0.11)	0.13 (0.18)
O_2	0.15 (0.08)	0.45 (0.08)	**0.26 (0.09)**	0.57 (0.20)	0.97 (0.02)	-0.13 (0.18)
CH_4	-0.02 (0.10)	0.28 (0.13)	0.57 (0.06)	**0.23 (0.12)**	0.66 (0.18)	0.06 (0.20)
CO_2	0.11 (0.08)	0.44 (0.09)	0.93 (0.01)	0.64 (0.05)	**0.27 (0.09)**	-0.15 (0.18)
GFW	0.01 (0.07)	0.24 (0.07)	0.26 (0.07)	0.18 (0.07)	0.27 (0.07)	**0.41 (0.03)**

[1] Heritabilities (in bold) on the diagonal, phenotypic and genetic correlations below and above the diagonal, respectively, posterior standard deviation in parenthesis.

In general, genetic correlations were of higher magnitude than phenotypic, except for GFW that also had genetic correlations close to zero with all other traits.

Discussion

To the authors' knowledge, this is the first study that reports genetic parameters for feed efficiency related traits together with gas emissions, oxygen consumption and wool production. The current study presents phenotypic values very similar and at least comparable to several others in literature, such as for FI (François *et al.*, 2002), O_2 (Jonker *et al.*, 2018), CH_4 (Jonker *et al.*, 2018; Pinares-Patiño *et al.*, 2013), CO_2, and GFW (Huisman *et al.*, 2008). In the case of GFW phenotypic parameters, Ciappesoni *et al.* (2010) reported a lower mean for the same breed and country which can be explained by the population structure. The current study used data from recent years of an animal selection nucleus, where a favourable genetic trend for heavier GFW is observed (www.geneticaovina.com.uy).

As genetic improvement by animal selection is possible as long as the selected traits are heritable, the moderate heritabilities presented in this work indicate that promising and faster genetic gains can be achieved in all traits. The heritability values presented for RFI and FI are very similar to those described by François *et al.* (2002), but higher than the heritability values reported by Cammack *et al.* (2005) of 0.11 and 0.25 for RFI and FI, respectively. The limited published literature for heritability of O_2 consumption in sheep is reported as 0.21 (Jonker *et al.,* 2018). In the same study, heritability estimates for CH_4 production and CO_2 were 0.19 and 0.16 for lambs, and 0.20 and 0.27 ewes, respectively. Similar CH_4 heritability estimates were also reported by Pinares-Patiño *et al.* (2013) and Robinson *et al.* (2010). Regarding GFW heritability, our estimate is in agreement with those found by Huisman *et al.* (2008) (0.46), and Ciappesoni *et al.* (2010) (0.45).

A slightly higher value for the genetic correlation between CH_4 and CO_2 of (0.84) and (0.86) was reported by Jonker *et al.* (2018) and Paganoni *et. al*, (2017), respectively. Thus, still in accordance with our high genetic correlation between CH_4 and CO_2.

When evaluating greenhouse gas mitigation strategies, the favourable genetic correlation between RFI efficiency and greenhouse gas emissions is promising in the search for more efficient animals. However, these preliminary data must be taken with caution until more information continues to record, and more precise estimates can be achieved.

Furthermore, GFW correlations were not significantly different from zero, showing that animal selection with emissions mitigation purpose should not impact wool production, which is one of the most important selection objectives in Merino breed. Therefore, the current selection for GFW does not seem to affect the efficiency of the animals or increase emissions. These favourable to zero genetic correlations would make possible to find more animals that face several objectives at the same time: productive, economic, and environmental.

The development of intensive phenotyping systems for traits related to feed intake, efficiency, and greenhouse gas mitigation in association with the estimation of genetic parameters gets on greater significance when is linked to stud-flocks and commercial populations. This will allow the identification of potential trade-off between traits and the implementation of genetic improvement programs for individual traits, or within a more holistic vision such as the agroecological breeding objectives.

Acknowledgements

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