Ciência Rural, Santa Maria, v.53:10, e20220497, 2023

http://doi.org/10.1590/0103-8478cr20220497

ISSNe 1678-4596

ANIMAL PRODUCTION

Production and economic evaluation of the Corriedale, Highlander and Milchschaf sheep breeds in Southern Uruguay

Washington Bell[1*] **Ana Laura Sánchez**[1] **Raúl Ponzoni**[2]

[1]Departamento de Producción Animal y Pasturas, Facultad de Agronomía, Universidad de la República, Garzón 780, Montevideo, Uruguay. E-mail: wbell@fagro.edu.uy. *Corresponding author.

[2]Colegio de Posgrados, Facultad de Agronomía, Universidad de la República, Montevideo, Uruguay.

ABSTRACT: Sheep production is expanding among small farmers in Southern Uruguay. Currently, Corriedale and Milchschaf are being used, but not Highlander. However, there is lack of experimental information regarding the relative performance of these breeds. We conducted an experiment where these three sheep breeds were run together at the Southern Regional Centre, located in the region in question. Wool, body, reproductive and lamb growth traits were recorded from 2015 to 2019. Results were used as a basis for the calculation of gross margins for each breed, which we calculated for a range of production and economic scenarios. For scenarios based on the results of the present study Highlander was the best performing breed. If it was assumed to be wool-less, it performed even better. In some scenarios Corriedale performed best, especially when the higher wool price it used to enjoy was assumed. However, fetching such a price in the foreseeable future is unlikely. We concluded that in the absence of wool-less sheep that perform in a manner similar to Highlander or Milchschaf in terms of reproduction and lamb growth, Highlander is currently the best option for small farmers in Southern Uruguay. Until now, Milchschaf has been the recommended breed for the region and production system in question. The recommendation should be reviewed, Highlander should be recommended instead, and the performance of wool-less breeds should be investigated.Results could be applicable to other temperate regions in Latin America where similar production systems exist or may be developed.

Key words: reproductive performance, lamb meat production, small scale farmers, gross margin.

Produção e avaliação econômica das raças ovinas Corriedale, Highlander e Milchschaf no Sul do Uruguai

RESUMO: A produção de ovinos está se expandindo entre os pequenos produtores do Sul do Uruguai. Corriedale e Milchschaf estão sendo utilizados atualmente, mas não Highlander. Não obstante, há uma falta de informações experimentais sobre o desempenho relativo destas raças. Realizamos um experimento no qual estas três raças ovinas foram manejadas juntas no Centro Regional Sul, localizado na região em questão. As características de lã, corpo, reprodução e crescimento do cordeiro foram registradas de 2015 a 2019. Os resultados foram usados como base para calcular as margens brutas para cada raça, o que fizemos para uma série de cenários de produção e econômicos. Nos cenários baseados nos resultados deste estudo, a raça Highlander foi a que teve melhor desempenho. Se, se supunha que não tinha lã, seu desempenho era ainda maior. Em alguns cenários, Corriedale foi a raça com melhor desempenho, particularmente quando se supôs preços mais altos da lã, como os que se obtinham anos atrás. No entanto, é improvável que estes preços sejam atingidos novamente num futuro próximo. Concluímos que, na ausência de ovelhas sem lã, que tenham um desempenho semelhante ao Highlander ou Milchschaf em termos de reprodução e crescimento do cordeiro, Highlander é atualmente a melhor opção para os pequenos produtores do sul do Uruguai. Até agora, Milchschaf tem sido a raça recomendada para a região e para o sistema de produção em questão. Esta recomendação deve ser revista, o Highlander deve ser a raça recomendada, e o desempenho das raças sem lã deve ser investigado. Os resultados poderiam ser aplicáveis a outras regiões temperadas da América Latina onde sistemas de produção similares existem ou podem ser desenvolvidos.

Palavras-chave: desempenho reprodutivo, produção de carne de cordeiro, pequenos produtores, margem bruta.

INTRODUCTION

The number of sheep in Uruguay has been steadily decreasing, from 25 million in 1990, to 6.34 million in 2020 (MGAP, 2021; MONTOSSI et al., 2013). Factors such as increased areas occupied by agriculture, forestry, and dairy and beef cattle production, have contributed to the decline. In addition to the reduction in numbers there have been changes in the distribution and nature of production systems in the country (GANZÁBAL, 2014). In broad terms, there is now a concentration of relatively large flocks of fine wool sheep (mainly Merinos) in the Northwest region, in extensive production systems with little or no pasture improvement. By contrast, during the past decade small scale sheep meat production systems have proliferated in the South in family run farms (MGAP, 2021). The favourable prices for sheep meat

Received 09.06.22 Approved 11.10.22 Returned by the author xx.xx.xx
CR-2022-0497.R1
Editors: Rudi Weiblen Magda Vieira Benavides

and the suitability of sheep production in small family farms have resulted in an increase in both number of sheep and number of farms with sheep in the South of the country. In such meat oriented production systems reproduction and growth traits are of paramount importance. Due to the relatively recent expansion of sheep production in this area there is a paucity of information regarding breed comparisons and best choice for these production systems.

Introduced in 1912, Corriedale is the numerically most important breed in Uruguay (42 %, MGAP, 2018). Ewes of this dual purpose breed are readily available to producers willing to establish a small flock. Highlander and Milchschaf were introduced much more recently (2005 and 1990, respectively) and their number is small (~ 1 %) compared with Corriedale. However, these two breeds are more 'meat oriented' and could also be suitable for small scale producers. To date, there have been no evaluations of Corriedale, Highlander and Milchschaf sheep grazing together in an environment akin to that prevailing in many small farms in Southern Uruguay.

In this paper we present results of an evaluation of wool production, reproduction and lamb growth in Corriedale, Highlander and Milchschaf, managed together in a research centre in Southern Uruguay. We also conduct an economic evaluation of the three breeds, the results of which could be applicable not only to Uruguay, but also to other temperate regions of Latin America.

MATERIALS AND METHODS

The environment and production system

The experimental work was carried out in the Southern Regional Centre (acronym in Spanish: CRS), Department of Canelones (34°36'47"S 56°13'04"W). The average maximum and minimum temperatures are 23 °C in January and 12 °C in June, respectively. Average annual rainfall from 1980 to 2009 was 1101 mm, evenly distributed during the year (CASTAÑO et al., 2011; INUMET, 2019).

The sheep unit in the CRS consists of 11 ha divided into 6 paddocks and 5 holding pens representing about 25 per cent of the total area. The unit is sown with permanent pasture species (*Medicago sativa*, *Bromus sp*., *Trifolium repens* and *Cichorium intybus*), in a four year rotation with annual species (*Lolium multiflorum* and *Glicine max*). Holding pens are not included in the pasture rotation. The flock grazed the paddocks in 8 hour daily shifts, remaining the rest of the time in holding pens with access to water and hay. Grain (maize at a rate of 0.5 % of live weight) supplementation was provided to breeding ewes 3 weeks before lambing and to young sheep after weaning if pasture availability was limiting. Note that this reflects the relatively intensive production systems prevailing in the South of the country. Stocking rate and productivity could differ in more extensive ones based on natural pastures.

Flock management

Mating took place in Autumn from the 20th of March to the 10th of May, whereas lambing was from late August to October. Rubber rings were applied to lambs at birth to cut the tail, and to the scrotum, pushing testicles into the abdomen to induce cryptorchidism. Lambs were marked in November and weaned in the second half of December. Breeding ewes were shorn 4 to 6 weeks before the beginning of lambing (July or August), depending on weather conditions and shearers' availability. Young sheep were shorn at the same time (and for the first time) when they were 10 to 11 months old.

Gastrointestinal parasites are prevalent in the CRS. Breeding ewes were strategically drenched a week before mating, a week before the beginning of lambing, at lamb marking and at weaning. Ewe lambs were monitored for worm egg count (WEC) every three weeks during summer or as deemed necessary according to prevailing weather, pasture and sheep condition. Ewe lambs were tactically drenched if WEC exceeded 500. Health management practices included biannual vaccinations against clostridial diseases, preventive pour-on against lice and sheep scab at shearing, preventive foot-rot baths, and control of flystrike.

Brief background of breeds involved and experimental animals

The Corriedale breed was developed in New Zealand by crossing Merino with Lincoln sheep. The objective was to create a dual (wool and meat) purpose breed. It was introduced to Uruguay over a century ago. A recent survey estimated that it still represents almost half of the national flock (MGAP, 2018). Also originating in New Zealand, the Highlander breed was developed in 2001 as a synthetic combining Finish Landrace, Romney Marsh and Texel (FOCUS GENETICS, 2021). The objective was to instil early sexual maturity, high reproductive rate and rapid lamb growth in a maternal breed. It was introduced to Uruguay in 2005. Milchschaf is a dairy breed from the region of Frisia (Germany). It is known as Ostfriesisches Milchschaff in its country of origin, as East Friesian in English speaking countries, and as Frisona in Argentina and Spain. It was introduced to Uruguay in 1990. At the time, the intention was to develop a dairy sheep sector but the initiative did not prosper. Because Milchschaf has other virtues in addition to high milk production, promoted by the National Institute of Agricultural Research (INIA), it emerged as an option in small scale sheep farming in Southern Uruguay. Note; however, that to date there have been no earlier sheep breed evaluations for Southern Uruguay's sheep production systems. Numerically, both Highlander and Milchschaf are small compared to Corriedale (MGAP, 2018).

The research began with 40 Corriedale, 20 Highlander and 20 Milchschaf mixed age ewes. Thereafter the flock increased in size by the incorporation of the female progeny generated in the experiment. Corriedale ewes were surplus from a research station belonging to Agricultural School (acronym in Spanish: Fagro), in the Department of Cerro Largo, Northeast region. Rams used in this flock were either purchased or donated by the Corriedale Breed Society, and were considered of high standard by breed officials. Highlander ewes were donated by the firm Frileck S.A., sole source responsible for marketing the breed in Uruguay. Milchschaf ewes were donated by the National Institute of Agricultural Research (acronym in Spanish: INIA) in Las Brujas, Department of Canelones. Highlander and Milchschaf ewes were mated with rams of their own breed, supplied by Frileck S.A and INIA, respectively, and considered of high standard. Half of the Corriedale ewes were mated with Highlander rams and the other half with Milchschaf rams, initiating a process of upgrading (currently in progress) of Corriedale that will be reported elsewhere. Rams were replaced each year, provided by Frileck S.A. and INIA for Highlander and Milchschaf, respectively. Up to and including the 2019 mating, seven and eight rams were used of the former and latter breed, respectively. Highlander and Milchschaf ewes were mated to rams of their same breed, whereas half of the Corriedale ewes were mated to Highlander rams, and the other half to Milchschaf rams.

Ewes assigned to each ram were chosen avoiding the mating of close relatives. Whereas we acknowledge the limited number of sheep sampled from each breed, those chosen were considered representative of what was available at the time to producers in the region. A 'founder effect' cannot be ruled out, but it is likely to be small relative to the between breed differences, and further reduced by the incorporation of progeny generated in the course of the experiment.

Data recording

Wool production and reproduction records were taken from 2015 to 2019. During shearing greasy fleece weight (GFW) was recorded and a mid side wool sample was taken and sent to the Uruguayan Wool Secretariat (acronym in Spanish: SUL) wool laboratory for analysis and estimation of scouring yield (Yld) and average fibre diameter (FD). Ewes were weighed before mating (eLW1), post shearing (eLW2) and at weaning (eLW3).

After giving birth, ewes were individually identified and lambs were tagged. Date of lambing, sex and birth weight (BW) of each lamb were recorded daily. Assistance to ewes and lambs was minimal, essentially relying on the ewe's maternal instinct and the lambs' drive to suckle. Reproductive variables analysed were: number of ewes lambing per ewe mated (fertility, F), number of lambs born per ewe lambing (litter size, LS), number of lambs born per ewe mated (NLB) and number of lambs weaned per ewe mated (NLW). Dead lambs were recorded at birth and thereafter until weaning to calculate survival during lactation (Surv). Lambs were weighed at weaning (WW).

Statistical analyses

The following general model was fitted to ewe wool and body traits:

$$Y_{ijklm} = \mu + B_i + E_{j(i)} + Yr_k + A_l + RS_m + e_{ijklm}$$

where Y is the observed value, μ is the overall mean, B is the breed effect, E is the ewe effect nested within B, Yr is the year effect, A is the ewe age effect, RS is the effect of ewe reproductive status in the season before the wool or body trait was recorded and e is the experimental error. All effects were treated as fixed except E and e that were treated as random. The same model, but without *RS*, was fitted to reproductive traits.

The following general model was fitted to progeny records:

$$Y_{ijklm} = \mu + B_i + S_i + Yr_k + TB_l + AoD_m + Sx_n + \beta(DateBth_{ijklmno} - \overline{DateBth}) + e_{ijklmno}$$

where Y is the observed value, μ is the overall mean, B is the breed effect, S is the sire effect, Yr is the year effect, TB is the type of birth effect, AoD is the effect of age of the dam, Sx is the sex effect, $DateBth$ is the date of birth of the lamb, β is the regression coefficient of the trait in question on date of birth, and e is the experimental error. All effects were treated as fixed except S and e that were treated as random, and *DateBth* that was fitted as a linear covariate in the case of weaning weight but not for lamb survival.

In preliminary runs two way interactions among the fixed effects were fitted but almost without exception they were deleted from the model because they were non-significant or because they could not be fitted due to missing observations in some sub classes.

SAS 9.4 (SAS Institute Inc., 2013) was used to perform the analyses. PROC MIXED was used in the analysis of continuous data, whereas both PROC MIXED and PROC GLIMMIX were used to analyse discrete data (such as reproductive records). There were instances in which the analyses with PROC GLIMMIX did not converge or failed to produce sensible results due to non-positive definite matrices. When PROC GLIMMIX worked well it produced results that were almost identical to those produced by PROC MIXED. For this reason, and consistent with findings and the approach adopted by other researchers (EVERETT-HINCKS et al., 2014; NEL et al., 2021; VANDERICK et al., 2015) we present the results for discrete traits from fitting a linear model with PROC MIXED for consistency and ease of interpretation.

Calculation of gross margins

Gross margins for each breed were calculated following the methodology described in PIRSA (2021). Production (clean fleece weight, fibre diameter, live weights) and reproduction (number of lambs weaned) values were based on the least squares means estimated in this study for each breed. In the case of ewe live weight the average of eLW1 and eLW2 was used. Initially gross margins were calculated for a flock of 100 breeding ewes for each breed. Because of the significant between breed difference in ewe live weight (H and M heavier than C) we 'adjusted' the number of H and M ewes to a stocking pressure equivalent to that of 100 Corriedale ewes. We did this in two ways: (i) assuming that ewe feed intake was proportional to $eLW^{0.75}$ (KLEIBER, 1975), and (ii) by calculating ewe intake throughout the production cycle for each breed using the information in Nutrient Requirements of Sheep (NRC, 1985). The results from these two approaches were almost identical, hence, we only present the results from (i). In the case of M, a dairy breed, we investigated a further option assuming feed requirements at the same live weight would be 20 per cent greater than for a non-dairy breed of the same live weight (NRC, 2007, 2001, 2000).

Table 1 shows the assumed product prices and variable production costs. Variable costs are those that vary with the level of production and reproduction of the flock. Other costs (e.g. taxes, levies, electricity, labour) were assumed to be independent of the level of production and reproduction of the flock (i.e. fixed). When more than one value was tried for a price, the alternative appears in bold. When different values were used for each breed they are specified, otherwise the single value applied to all breeds is presented.

A SAS script (available from the senior author) was developed to perform the calculations. It can be used to explore scenarios other than those dealt with here.

RESULTS

Production and reproductive performance

Table 2 shows descriptive statistics for the traits recorded. In the presentation of results, and their later discussion, we mainly focus on among breed differences. Other effects may on occasions be commented upon, especially if they are of relevance to the breed evaluation.

Table 1 - Product prices and variable production costs.

Item	Value (US\$)[A]		
Product Price	Corriedale	Highlander	Milchschaf
Clean wool (US\$/kg)	1.80, 3.50	0.80	0.80
Lambs (US\$/kg of carcase)	2.00, 4.00	2.00, 4.00	2.00, 4.00
Cull for age ewes (US\$/kg of carcase)	4.00	4.00	4.00
Variable cost			
Shearing (US\$/animal)	0.70	0.70	0.70
Wool packing and transport (US\$/kg)	0.03	0.03	0.03
Vaccines (US\$/animal)	0.33	0.33	0.33
Anti helmintics (US\$/animal)	0.60	0.60	0.60
Dipping, lice, fly strike treatments (US\$/animal)	1.44	1.44	1.44
Finishing lambs (~24 to 32-34 kg) (US\$/lamb)	9.33	9.33	9.33

[A]In bold, alternative values tried for the calculation of gross margin in some of the scenarios investigated.

Table 2 - Descriptive statistics: number of observations (N), simple mean, minimum and maximum, standard deviation (σ) and coefficient variation (CV, %).

	N	Mean	Min	Max	σ	CV
-----Wool traits-----						
GFW (kg)	234	3.87	1.60	7.95	1.03	26.6
Yld (%)	235	78.4	54.1	89.5	5.69	7.26
CFW (kg)	234	3.02	1.23	5.87	0.77	25.6
FD (μm)	235	31.6	21.3	38.1	3.39	10.8
-----Reproductive traits-----						
F	239	0.84	0.00	1.00	0.37	43.6
LS	201	1.67	1.00	6.00	0.73	43.6
NLB	239	1.41	0.00	6.00	0.91	64.5
NLW	233	1.11	0.00	3.00	0.83	75.1
-----Body traits-----						
eLW1 (kg)	159	64.2	45.0	94.0	9.93	15.5
eLW2 (kg)	88	68.5	39.0	99.0	13.3	19.3
eLW3 (kg)	118	59.3	42.0	77.0	8.92	15.0
-----Progeny traits-----						
BW (kg)	287	4.63	2.00	8.20	1.02	21.9
WW (kg)	258	27.0	12.0	44.0	6.13	22.7
Surv	292	0.88	0.00	1.00	0.32	36.4

GFW: greasy fleece weight; Yld: scouring yield; CFW: clean fleece weight; FD: fibre diameter; F: fertility; LS: litter size; NLB: number of lambs born; NLW: number of lambs weaned; eLW1: pre mating liveweight; eLW2: post shearing liveweight; eLW3: post weaning liveweight; BW: lamb birth weight; WW: lamb weaning weight; Surv: survival to weaning.

Tables 3 and 4 show the analysis of variance and the least squares means for wool traits, respectively. There were significant between breed differences for all traits. For GFW, Yld and CFW, H and M differed from C but not from each other, whereas for FD all breeds differed from each other. The breed by reproductive status interaction was statistically significant (P < 0.01) for GFW and CFW, the values for C were always greater than those of H and M. However, within breeds the values for different levels of reproductive status varied without a consistent pattern. This gave rise to the significant interaction, which is most likely of spurious origin.

There were significant between breed differences for all ewe live weights (P < 0.01). For eLW1 (60.2 kg, 74.4 kg and 71.8 kg for C, H and M, respectively) and eLW2 (61.1 kg, 81.2 kg and 78.7 kg for C, H and M, respectively), C differed from H and M, whereas H and M did not differ from each other. In the case of eLW3 all breeds differed from each other (49.6 kg, 65.0 kg and 60.4 kg for C, H and M, respectively).

Table 3 - Analysis of variance greasy fleece weight (GFW), scouring yield (Yld), clean fleece weight (CFW) and fibre diameter (FD).

Effect	Ndf	-----GFW-----			-----Yld-----			-----CFW-----			-----FD-----		
		Ddf	F-val.	P>F	Ddf	F-val.	P>F	Ddf	F-val.	P>F	Ddf	F-val.	P>F
Breed	2	76	37.9	<0.01	76	8.88	<0.01	76	22.6	<0.01	76	50.4	<0.01
Age	2	143	0.13	0.88	148	1.43	0.24	143	0.03	0.97	148	0.29	0.75
RS	2	143	2.80	0.06	148	0.86	0.43	143	3.37	0.04	148	5.18	<0.01
Year	4	143	31.1	<0.01	148	10.5	<0.01	143	25.0	<0.01	148	8.55	<0.01
Breed*RS	4	143	9.16	<0.01				143	5.28	<0.01			
Residual		-----0.18-----			-----14.6-----			-----0.13-----			-----2.76-----		

RS: previous season reproductive status; Ndf: numerator degrees of freedom, Ddf: denominator degrees of freedom.

Table 4 - Least squares means (standard errors) for greasy fleece weight (GFW), yield (Yld), clean fleece weight (CFW) and fibre diameter (FD).

Effect - Level	GFW	Yld	CFW	FD
---Breed---				
Corriedale	4.62 (0.17)	77.1 (1.23)	3.55 (0.14)	30.2^{a} (0.56)
Highlander	3.32^{a} (0.18)	81.2^{a} (1.22)	2.70^{a} (0.15)	33.8^{b} (0.56)
Milchschaf	3.17^{a} (0.28)	81.0^{a} (1.38)	2.55^{a} (0.24)	35.4^{c} (0.63)
---Age^{A}---				
~ 2 years	3.64 (0.26)	81.4 (1.75)	2.91 (0.22)	33.5 (0.78)
~ 4 years	3.72 (0.17)	79.3 (1.07)	2.93 (0.14)	33.0 (0.48)
> 4 years	3.75 (0.17)	78.8 (1.01)	2.96 (0.14)	33.0 (0.46)
---RS---				
FRC	3.89^{ab} (0.61)	82.9 (3.99)	3.18^{ab} (0.51)	35.5^{a} (1.78)
NL	3.83^{a} (0.17)	78.8 (1.31)	3.01^{a} (0.14)	32.7^{a} (0.59)
L	3.40^{b} (0.17)	77.7 (1.12)	2.61^{b} (0.15)	31.3 (0.51)
---Year---				
2015	3.32^{abcd} (0.46)	77.0^{abc} (3.12)	2.55^{abc} (0.39)	29.2^{b} (1.39)
2016	3.88^{a} (0.31)	81.7^{a} (1.86)	3.13^{a} (0.26)	34.7^{a} (0.83)
2017	4.10^{b} (0.32)	83.4^{b} (2.02)	3.39^{b} (0.27)	34.7^{a} (0.90)
2018	4.40^{c} (0.33)	77.2^{c} (2.10)	3.32^{b} (0.28)	34.9^{a} (0.94)
2019	2.82^{d} (0.34)	79.8^{c} (2.30)	2.28^{c} (0.29)	32.2^{b} (1.02)

^{A}Age at lambing; RS: previous season reproductive status (FRC: first reproductive cycle in the experiment; NL: second or greater reproductive cycle, not lambed; L: second or greater reproductive cycle, lambed). Between levels for each source of variation, least squares means without a common superscript differ.

Tables 5 and 6 show the analysis of variance and least squares means for reproductive traits. There were significant between breed differences for all traits. For F, C differed from M but not from H, whereas H and M did not differ. All breeds differed from each other in LS. In the case of NLB and NLW, C differed from H and M, but the latter two did not differ from each other (P = 0.34 and P = 0.30 for NLB and NLW, respectively).

Tables 7 and 8 show the analysis of variance and least squares means for lamb traits. There were significant between breed differences in BW and WW but not for Surv. For BW, H differed from MxC but not from the other breeds, whereas M differed from both HxC and MxC, and the latter two breeds differed from each other. In the case of WW, there were no significant differences between H and M, or between HxC and MxC, whereas the former two breeds differed from the latter two.

Gross margins

Table 9 shows the gross margins for C, H and M for a range of scenarios. Base production and reproduction values correspond to the least squares means estimated in the present study. In addition to calculating gross margins with those values, we allowed for the fact that heavier H and M ewes would

Table 5 - Analysis of variance of reproductive traits: fertility (F), litter size (LS), number of lambs born (NLB) and weaned (NLW).

Effect	Ndf	---F---			---LS---			---NLB---			---NLW---		
		Ddf	F-val.	P>F	Ddf	F-val.	P>F	Ddf	F-val.	P>F	Ddf	F-val.	P>F
Breed	2	75	3.94	0.02	72	22.2	<0.01	75	20.9	<0.01	75	9.20	<0.01
Age	3	154	0.37	0.78	119	3.00	0.03	154	2.23	0.09	148	0.63	0.59
Year	4	154	2.44	0.05	119	1.29	0.28	154	2.87	0.02	148	1.52	0.20
Residual		---0.12---			---0.30---			---0.55---			---0.64---		

Ndf: numerator degrees of freedom; Ddf: denominator degrees of freedom.

Table 6 - Least squares means (standard errors) for reproductive traits: fertility (F), litter size (LS), number of lambs born (NLB) and weaned (NLW).

Effect - Level	F	LS	NLB	NLW
---Breed---				
Corriedale	0.78^{a} (0.07)	1.08^{a} (0.14)	0.81 (0.15)	0.73 (0.14)
Highlander	0.87^{ab} (0.06)	2.06^{b} (0.12)	1.79^{a} (0.13)	1.31^{a} (0.11)
Milchschaf	0.98^{b} (0.06)	1.67^{c} (0.13)	1.62^{a} (0.15)	1.15^{a} (0.14)
---Age^{A}---				
~ 2 years	0.92 (0.12)	1.44^{ab} (0.22)	1.29 (0.26)	0.88 (0.25)
~ 3 years	0.83 (0.07)	1.42^{a} (0.14)	1.10 (0.17)	1.01 (0.16)
~ 4 years	0.86 (0.06)	1.62^{a} (0.11)	1.40 (0.13)	1.10 (0.13)
> 4 years	0.89 (0.05)	1.94^{b} (0.09)	1.72 (0.11)	1.26 (0.10)
---Year---				
2015	0.80^{a} (0.05)	1.74 (0.09)	1.44^{ab} (0.10)	1.10 (0.10)
2016	0.96^{b} (0.05)	1.79 (0.10)	1.72^{a} (0.11)	1.29 (0.11)
2017	0.86^{ab} (0.07)	1.60 (0.14)	1.35^{b} (0.16)	1.09 (0.16)
2018	0.79^{ab} (0.09)	1.52 (0.18)	1.18^{b} (0.20)	0.84 (0.20)
2019	0.96^{ab} (0.11)	1.38 (0.20)	1.33^{ab} (0.25)	0.99 (0.26)

^{A}Age at lambing. Between levels for each source of variation, least squares means without a common superscript differ.

have greater feed requirements than C ewes, and also for the fact that M is a dairy breed. NLW in C was lower than in other studies (GANZÁBAL et al., 2001; RAMOS et al., 2021), so we also conducted calculations assuming a greater, achievable, value. At weaning lamb weights were below those that fetch the highest prices. We estimated the cost of finishing lambs to those greater weights and calculated the corresponding gross margins.

DISCUSSION

Production and reproductive performance

The results for wool production are consistent with the background of the three breeds involved in this study. C has been a traditional dual purpose breed, H was developed emphasizing meat production, whereas M is a recognized meat and dairy breed. Wool production was superior in C than in H and M, both in quantity and quality (Table 4). Our results for wool production in C and M were in remarkable agreement with those of GANZÁBAL et al. (2012).

Before mating and after shearing H and M ewes did not differ in live weight (P = 0.22 and 0.4, respectively) and were heavier than C ewes (P < 0.01). One may anticipate greater feed requirements among the heavier breeds, which in turn would result in the need to run fewer ewes per unit area in grazing conditions (SPEDDING, 1965). After weaning, H and M were heavier than C (P < 0.01), but H ewes were heavier than their M counterparts (P < 0.05).

Table 7 - Analysis of variance of lamb traits: birth weight (BW), weaning weight (WW) and survival to weaning survival (S).

Effect	Ndf	---BW---			---WW---			---Surv---		
		Ddf	F-val.	P>F	Ddf	F-val.	P>F	Ddf	F-val.	P>F
Breed	3	269	6.57	<0.01	237	4.62	<0.01	279	1.44	0.23
Year	4	269	3.21	0.01	237	1.27	0.28	279	2.88	0.02
Birth type	2	269	84.5	<0.01				279	0.37	0.69
Birth-rearing type	5				237	28.13	<0.01			
Dam age	3	269	4.09	0.01	237	1.43	0.23	279	0.26	0.85
Birth date	5	269	7.80	<0.01						
Weaning age	5				237	18.52	<0.01			
Residual		---0.51---			---16.6---			---0.10---		

Ndf: numerator degrees of freedom; Ddf: denominator degrees of freedom.

Table 8 - Least squares means (standard errors) for lamb traits: birth weight (BW), weaning weight (WW) and survival (Surv).

Effect - Level	BW	WW	Surv
--------Breed--------			
Highlander	4.83^{ab} (0.12)	25.7^{a} (0.91)	0.87 (0.05)
Milchschaf	4.55^{a} (0.14)	26.4^{a} (1.05)	0.80 (0.06)
Highlander x Corriedale	4.18^{b} (0.17)	23.6^{b} (1.20)	0.91 (0.07)
Milchschaf x Corriedale	3.90 (0.17)	23.6^{b} (1.24)	0.89 (0.07)
--------Year--------			
2015	4.29^{a} (0.11)	29.7 (0.91)	0.99^{a} (0.05)
2016	4.27^{a} (0.13)	25.4 (0.94)	0.88^{bc} (0.06)
2017	4.43^{a} (0.16)	23.7 (1.55)	0.94^{ab} (0.07)
2018	4.46^{a} (0.18)	21.3 (1.25)	0.78^{c} (0.08)
2019	3.80 (0.22)	24.0 (1.99)	0.76^{c} (0.10)
--------Birth type--------			
1	5.32^{a} (0.13)		0.86 (0.06)
2	4.05^{b} (0.12)		0.85 (0.05)
3	3.38^{c} (0.18)		0.90 (0.08)
--------Birth-rearing type--------			
1-1		31.0^{a} (0.86)	
2-1		26.3^{b} (1.23)	
2-2		24.0^{c} (0.84)	
3-1		25.4^{abcd} (3.12)	
3-2		22.0^{cd} (1.58)	
3-3		20.3^{d} (1.32)	
--------Age[A]--------			
~ 2 years	3.72^{a} (0.29)	23.2 (1.77)	0.84 (0.11)
~ 3 years	4.22^{abc} (0.30)	25.0 (1.81)	0.90 (0.12)
~ 4 years	4.38^{b} (0.11)	26.0 (0.94)	0.88 (0.04)
> 4 years	4.68^{c} (0.07)	25.2 (0.77)	0.85 (0.03)

[A]Age at lambing. Between levels for each source of variation, least squares means without a common superscript differ.

This could be due to greater milk production among M ewes, causing them to draw more intensely upon their body reserves.

H and M exhibited better performance than C in all components of reproductive rate, except for F, in which case the latter breed did not differ from H (Table 6). Results for C were similar to those reported by GANZÁBAL et al. (2012) and by PAPALEO & HOZBOR (2021), but below those obtained by some producers (SUL, 2009) and also than what has been reported in other researches (CARDELLINO et al., 1992; CARDELLINO, 1981; CARDELLINO et al., 1978; GANZÁBAL, 2014; GANZÁBAL et al., 2001; RAMOS et al., 2021). The results for NLB in M are above those of GANZÁBAL et al. (2012). KREMER et al. (2015) reviewed the work carried out with M in Uruguay and concluded that the animals of this breed introduced to Uruguay could not be considered prolific, or at least not as prolific as breeds such as Finnish Landrace. In the case of H the only other experimental report in Uruguay is that of RAMOS et al. (2021) whose results are in good agreement with ours. In Argentina, PAPALEO & HOZBOR (2021) report a LS value similar to ours, but much lower NLW due to high lamb mortality. In Chile, COX et al. (2015) report a mean NLB remarkably similar to ours. Note that in the comparison of our results with other reports, the breed effect is confounded with environmental effects specific to the location and circumstances in which the sheep are kept. Nevertheless, the comparison allows some insight regarding whether our results conform with published evidence.

H and M lambs were heavier than those born to C ewes. Note that in the latter case lambs were either HxC or MxC crosses that were generated in the context of the upgrading program of C by H and M.

Results for wool production, ewe live weights, ewe reproduction and lamb growth and survival, indicate that there would be trade offs in making a choice among the C, H and M breeds for a production system such as the one in question. Consideration of wool production and ewe live weight would result in a preference for C, whereas H and M would be favoured if the focus were on reproduction and lamb growth. An individual producer may find the physical performance of the three breeds insufficient to make a decision. In such cases the calculation of gross margins may be useful because it integrates the physical performance with product values and production costs, thus enabling a breed comparison in monetary units (CEBALLOS et al., 2021; PIRSA, 2021; ROA, 2012).

Gross margins

Table 9 summarizes the gross margins for each of the scenarios investigated. Scenario 1

Table 9 - Gross margin (GM, US$) for Corriedale (C), Highlander (H), Milchschaf (M) and Milchschaf accounting for the fact that its feed requirements would be greater because it is a dairy breed (Mdairy).

	Scenarios investigated (GM for best performing breed in ‘bold’ type)	C	H	M	Mdairy
1	Base production values and prices, per animal comparison, no allowance made for greater feed requirements in heavier ewes	3476	4800	4400	-
2	As 1, but allowing for greater feed requirements in H and M[A]	3476	3936	3740	3124
3	As 2, but NLW equal to 1.0 in C	3971	3936	3740	3124
4	As 2, but wool price for C equal to that in 2015	4027	3936	3740	3124
5	As 2, but for C, NLW equal to 1.0 and wool price equal to that in 2015	4522	3936	3740	3124
6	As 2, but finishing all lambs to 32-34 kg	4872	6135	5652	4721
7	As 3, but finishing all lambs to 32-34 kg	6083	6135	5652	4721
8	As 4, but finishing all lambs to 32-34 kg	5422	6135	5652	4721
9	As 5, but finishing all lambs to 32-34 kg	6633	6135	5652	4721
10	As 6, but no wool in H and M	4872	6274	5788	4835
11	As 7, but no wool in H and M	6083	6274	5788	4835
12	As 8, but no wool in H and M	5422	6274	5788	4835
13	As 9, but no wool in H and M	6633	6274	5788	4835

[A]Greater feed requirements due to heavier ewes assuming needs are proportional to ewe liveweight$^{0.75}$. A further increase in feed requirements of 20 % was assumed for Mdairy.

assumes production values from the present study, and current market prices and production costs (Table 1). It is a ‘per animal’ comparison, it does not take into consideration the fact that feed requirements among the breeds involved may differ depending on ewe size and productivity, as noted by COOP (1964), SPEDDING (1988, 1965) and more recently by LEWIS & EMMANS (2020, 2010). Under the assumptions made in this scenario the gross margin was greatest for H, followed closely by M, and it was lowest for C. The between breed differences were smaller when allowance was made for greater feed requirements in H and M in Scenario 2. Scenario 2 provides a more realistic basis for the breed comparison than Scenario 1. Furthermore, when the fact that M is a dairy breed was taken into account (Mdairy in table 9), the gross margin was smaller than for any other breed, including C, for all the scenarios examined.

We earlier commented that NLW for C in the present study was lower than that reported by other authors. We; therefore, investigated the impact of a greater value, namely 1.0, for NLW, as is reported in other, earlier mentioned, studies. When NLW was equal to 1.0, C outperformed the other breeds (Scenario 3). Note that in table 6 the difference in NLW between H and M was not statistically significant at the conventional 5 % level (P = 0.3) but the least squares means for both breeds conformed with other estimates in the literature, generally suggesting that H is more prolific than M. For that reason we used the least squares means for both breeds, H and M, assuming that they reflect their capability in terms of reproductive performance.

During recent years the price of wool produced by C has been considerably lower than in the past, say, in 2015. Scenario 4 reflects the higher price that such wool used to enjoy, and in it, the gross margin for C was higher than for the other breeds, and also higher than in Scenario 3. Not surprisingly, when it was assumed that for C, NLW was equal to 1.0 and wool price was as in 2015, the gross margin for C was even higher (Scenario 5).

In Scenarios 1 to 5 it was assumed that lambs were sold at weaning, weighing 24 to 26 kg. Lamb price at these weights is about half the value of finished lambs at 32 to 34 kg. In Scenarios 6 to 9 we made the same assumptions as in Scenarios 2 to 5, respectively, but we also assumed that all lambs were finished to 32 to 34 kg to fetch the better price. As expected gross margins for all breeds increased, H was best in these scenarios, except in one instance (Scenario 9), where C performed best.

Wool value for H and M is normally low due to its high fibre diameter. Coupled with the light fleece weight, the result is that normally, the margin it leaves after shearing costs are deducted is small or nonexistent. In Scenarios 10 to 13 we made the same assumptions as in Scenarios 6 to 9, respectively, except that in addition we assumed that H and M were wool-less, thus eliminating shearing and treatment costs specific to wool sheep, as well as income from wool sale. Gross margins increased for H and

M when it was assumed that they were wool-less for the simple fact that the cost of wool harvesting is greater than the value of the wool harvested. In these circumstances H outperformed the other breeds except in Scenario 13, where C was ahead. Note that with one exception (Scenario 3), C outperformed the other breeds when the price for its wool was assumed to be higher, namely, as in 2015 (Scenarios 4, 5, 9 and 13). In Scenario 3 a higher, but achievable, value was assumed for NLW, and lambs were sold at weaning. Under the same assumptions but finishing the lambs to 32 to 34 kg, C was outperformed by H. Whereas the better reproductive performance in C is achievable (note earlier mentioned studies), wool price is beyond the producer's control, and in the case of C wool, the drop in price in recent years has deep rooted justifications (CARDELLINO & RICHERO, 2020; CARDELLINO et al., 2018; MCKINSEY & COMPANY, 2000). For that reason, a price rise of its wool to a value equal or close to that in 2015 is something unlikely to materialize in the foreseeable future. The decline in the price of coarse wool, coupled with the increase in labor costs, justifies the consideration of wool-less sheep as an option for production systems such as that one in Southern Uruguay.

The rate of attrition among the ewes of each was not presented here, it is currently the subject of another paper. It is important because it influences flock structure and replacement needs, thus having an impact on production costs. Furthermore, if culled animals are affected by disease or malformations they may have to be killed on farm or may be penalised and fetch a lower price when sold. Note; however, that there were among breed differences in this respect. In particular, M suffered from a significantly greater need for culling due to udder problems (not surprising given that it is dairy breed that produces milk in excess of what the lambs can suckle) and to skin tumors caused by sun damage. Those issues are consistent with reports by COSTA et al. (2019), GARCÍA et al. (2018) and KREMER et al. (2015).

CONCLUSION

Based on the range of scenarios investigated, one could envisage that the breed of choice could be like H but without wool. There are wool-less breeds, also called hair sheep, such as Australian Whites in Australia, and Katahdin in the USA, that could serve this purpose. A rigorous evaluation of these and other wool-less breeds of sheep could yield valuable results for small sheep farmers in Southern Uruguay, but at the present moment, H appears as the best option among the breeds evaluated, situated well ahead of C and M, the current predominant breeds in that region. These conclusions could be applicable to other temperate regions of Latin America where similar production systems exist or could be developed.

ACKNOWLEDGEMENTS

This research was supported by the National Agency for Research and Innovation (acronym in Spanish: ANII) [grant numbers POS_NAC_2016_1_130961, POS_NAC_2016_1_130155] and University of the Republic's Postgraduate Academic Committee (acronym in Spanish: Udelar, CAP) [grant numbers BFPD_2020_1#40502771, BFPD_2019_1#38513029] through the doctoral fellowships awarded to Washington Bell and Ana Laura Sánchez.

We would like to thank: Santiago Cayota, Gabriel Ciappesoni, Andrés Ganzábal and Wilfredo Zamit from INIA; Daniel Castells, Ignacio Abella, Lucía Goldaraz and Sofía Salada from SUL; Martin Garicoïts from Frileck S.A.; Álvaro López, Carlos López Mazz, Carlos Batista and Mariel Regueiro from Fagro; CRS field staff Dana Montedónico and Pablo Suna were responsible for day to day flock management and support during data recording.

DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

BIOETHICS AND BIOSSECURITY COMMITTEE APPROVAL

We declare that all aspects of this manuscript referring to animal management were carried out following the Guide for the ethical production of sheep in Uruguay and with the ethical approval of all relevant agencies.

REFERENCES

CARDELLINO, R. et al. Efecto de la época de encarnerada y de la edad sobre la tasa reproductiva de ovejas Corriedale, Ideal y Merino en el Uruguay. In: **Conferencia Mundial de Producción Animal**, 4, 1978. Buenos Aires, p.566-574.

CARDELLINO, R. **Genetic differences between sheep breeds in Uruguay**. 1981. Thesis (Master of Science), University of New South Wales, Sydney. Avaliable from: <https://unsworks.unsw.edu.au/bitstreams/c99039d6-9d2b-4d3d-8780-60d25f23f955/download>. Accessed: Jun. 6, 2021. doi: 10.26190/unsworks/11666.

CARDELLINO, R. et al. **Desempeño reproductivo, producción de lana y peso vivo en hembras Corriedale, Ideal y Merino del Uruguay**. Montevideo: Secretariado Uruguayo de la Lana, 1992. 10p. Producción Ovina, 3.

CARDELLINO, R. et al. **El mercado de la lana y su efecto en la producción ovina uruguaya**. Montevideo: El País, 2018. 3p. El País Agropecuario.

CARDELLINO, R.; RICHERO, R. **La producción mundial y los usos finales de lanas con diferentes diámetros**. Buenos Aires: Asociación Argentina de Criadores de Merino, 2020, 10p. Anuario Merino, 2020. Available from: <https://www.merino.org.ar/ice/wp-content/uploads/anuario_merino_2020_web.pdf>. Accessed: Mar. 18, 2022.

CASTAÑO, J. P. et al. **Caracterización agroclimática del Uruguay 1980-2009**. Montevideo: Instituto Nacional de Investigación Agropecuaria, 2011. 40p. Serie Técnia, 193. Available from: <https://www.researchgate.net/publication/257023619_Caracterizacion_Agroclimatica_del_Uruguay_1980-2009>. Accessed: Apr. 5, 2020.

CEBALLOS, D. et al. Análisis productivo y económico de un engorde de ovejas de refugo en noroeste de la provincia de Chubut. **Revista Argentina de Producción Animal**, v.41, n.1, p.249-289, 2021. Available from: <https://www.aapa.org.ar/rapa/40/1Supl2021.pdf>. Accessed: May, 18, 2021.

COOP, I. E. Sheep nutrition and management. In: **Proceedings of the New Zealand Society of Animal Production Conference**, v.24, 1964, New Zealand. p.129-148. Available from: <https://www.nzsap.org/system/files/proceedings/1964/ab64011.pdf>. Accessed: Jun. 5, 2020.

COSTA, R. A. et al. High frequency of cutaneous squamous cell carcinoma in Friesian Milchschaf sheep in Uruguay. **Pesquisa Veterinaria Brasileira**, v.39, p.251-254, 2019. Avaliable from: <https://www.scielo.br/j/pvb/a/bxVcwHVZxnKL9mqKV8Psr6B/?lang=en>. Accessed: Jul. 8, 2021. doi: 10.1590/1678-5150-PVB-6170.

COX, J. F. et al. Characterization of the productive performance of Highlander sheep in Southern Chile. I. Female reproductive traits. **Small Ruminant Research**, v.130, p.183-188, 2015. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S0921448815002631?via%3Dihub>. Accessed Aug. 10, 2018. doi: 10.1016/j.smallrumres.2015.06.010.

EVERETT-HINCKS, J. M. et al. Genetic parameters for lamb birth weight, survival and death risk traits. **Journal of Animal Science**, v.92, p.2885-2895, 2014. Available from: <https://academic.oup.com/jas/article/92/7/2885/4702158>. Accessed: Sep. 15, 2018. doi: 10.2527/jas.2013-7176.

FOCUS GENETICS. **Highlander Maternal Sheep Breed**, 2021. Available from: <https://www.focusgenetics.com/>. Accessed: May, 20, 2021.

GANZÁBAL, A. et al. **Producción ovina intensiva**: La experiencia del INIA. Montevideo: Instituto Nacional de Investigación Agropecuaria, 2001, p.49-79. Boletín de Divulgación, 78. Available from: <http://www.ainfo.inia.uy/digital/bitstream/item/2777/1/15630031107111643.pdf>. Accessed: Oct. 9, 2019.

GANZÁBAL, A. et al. **Biotipos maternales y terminales para enfrentar los nuevos desafíos de la producción ovina moderna**. Montevideo: Instituto Nacional de Investigación Agropecuaria, 2012, p.14-18. Revista INIA, 29. Available from: <http://www.ainfo.inia.uy/digital/bitstream/item/2082/1/18429300612184836.pdf>. Accessed: Nov. 2, 2020.

GANZÁBAL, A. **Impacto productivo y económico del uso de biotipos maternales en la producción de corderos**. Montevideo: Instituto Nacional de Investigación Agropecuaria, 2014, p.152-160. Serie Técnica, 221. Available from: <http://www.inia.uy/Publicaciones/Paginas/st-221_2014.aspx>. Accessed: Dec. 19, 2019.

GARCÍA, J. A. et al. Occurrence of squamous cell carcinoma in Milchschaf sheep in Uruguay. **Ciência Rural**, v.48, n.01, p.1-7, 2018. Available from: <https://www.scielo.br/j/cr/a/RqHB6fBQ664J5qCVyM4ftLQ/?format=pdf&lang=en>. Accessed: Jun. 6, 2022. doi: 10.1590/0103-8478cr20170406.

INSTITUTO NACIONAL DE METEOROLOGÍA. **(INUMET)**, 2019. Available from: <https://www.inumet.gub.uy/clima/estadisticas-climatologicas/>. Accessed: Jul. 5, 2019.

KLEIBER, M. Metabolic turnover rate: A physiological meaning of the metabolic rate per unit body weight. **Journal of Theoretical Biology**, v.53, n.1, p.199-204, 1975. Available from: <https://www.sciencedirect.com/science/article/abs/pii/0022519375901101>. Accessed: Jul. 23, 2020. doi: 10.1016/0022-5193(75)90110-1.

KREMER, R. et al. Producción de ovejas Milchschaf en un sistema lechero en pastoreo. **Veterinaria**, v.51, n.199, p.12-23, 2015. Available from: <http://www.scielo.edu.uy/pdf/vet/v51n199/v51n199a02.pdf>. Accessed: Aug. 1, 2022.

LEWIS, R. M.; EMMANS, G. C. Feed intake of sheep as affected by body weight, breed, sex, and feed composition. **Journal of Animal Science**, v.88, n.2, 467-480, 2010. Available from: <https://academic.oup.com/jas/article-abstract/88/2/467/4740532?redirectedFrom=fulltext>. Accessed: Sep. 4, 2021. doi: 10.2527/jas.2008-1735.

LEWIS, R. M.; EMMANS, G .C. The relationship between feed intake and liveweight in domestic animals. **Journal of Animal Science**, v.98, n.4, skaa087, 2020. Available from: <https://academic.oup.com/jas/article-abstract/98/4/skaa087/5810285?redirectedFrom=fulltext>. Accessed: Sep. 4, 2021. doi: 10.1093/jas/skaa087.

MCKINSEY & COMPANY. **Report to New Zealand woolgrowers on improving profitability**. Auckland : McKinsey & Company, 2000. 168p.

MINISTERIO DE GANADERÍA, AGRICULTURA Y PESCA (MGAP). **Resultados de la encuesta ganadera nacional 2016**. Montevideo: Ministerio de Ganadería, Agricultura y Pesca, 2018. 62p.

MINISTERIO DE GANADERÍA, AGRICULTURA Y PESCA (MGAP). **Anuario estadístico agropecuario 2020**. Montevideo: Ministerio de Ganadería, Agricultura y Pesca, 2021. 668p.

MONTOSSI, F. et al. Intensification, diversification, and specialization to improve the competitiveness of sheep production systems under pastoral conditions: Uruguay's case. **Animal Frontiers**, v.3, n.3, 28-35, 2013. Available from: <https://academic.oup.com/af/article/3/3/28/4638630>. Accessed: Feb. 20, 2020. doi: 10.2527/af.2013-0021.

NEL, C. L. et al. Genetic parameters and trends for lamb survival following long-term divergent selection for number of lambs weaned in the Elsenburg Merino flock. **Animal Production**

Science, v.61, n.18, 1965-1981, 2021. Available from: <https://www.publish.csiro.au/an/AN21198>. Accessed Mar. 5, 2022. doi: 10.1071/AN21198.

NRC. **Nutrient requirements of sheep, sixth revised ed, National Research Council**. Washington DC: The National Academies Press, 1985. 109p.

NRC. **Nutrient requirements of beef cattle, seventh revised ed, National Research Council**. Washington DC: The National Academies Press, 2000. 249p. doi: 10.17226/9791.

NRC. **Nutrient requirements of dairy cattle, National Research Council**. Washington, DC: The National Academies Press, 2001. 401p. doi: 10.17226/9825.

NRC. **Nutrient requirements of small ruminants**: Sheep, Goats, Cervids, and New World Camelids, National Research Council, Washington DC: The National Academies Press, 2007. 385p. doi: 10.17226/11654.

PAPALEO, J.; HOZBOR, F. Datos reproductivos y productivos de cuatro razas ovinas bajo condiciones de pastoreo en la Reserva 8. **Visión Rural**, v.137, p.36-38, 2021. Available from: <https://repositorio.inta.gob.ar/handle/20.500.12123/9707>. Accessed: Apr. 10. 2022.

PIRSA. Farm gross margin and enterprise planning guide. **A gross margin template for crop and livestock enterprises**. Adelaide: Primary Industries and Regions SA, 2021. 102p.

RAMOS, J. F. et al. Desempeño reproductivo de Corriedale, Merino Dohne, Romney Marsh, Highlander y Corriedale Pro en el litoral oeste de Uruguay. **Archivos Latinoamericanos de Producción Animal**, v.29, 178-179p, 2021. Available from: <https://ojs.alpa.uy/index.php/ojs_files/article/view/2952/1543>. Accessed: Jan. 10, 2022.

ROA, A. A. **Invernada corta de corderos**: una alternativa para la integración productiva entre el área de secano y los valles irrigados. 2012. Tesis (Licenciatura), Universidad Nacional del Comahue, Neuquén.

SAS INSTITUTE INC. **SAS® 9.4 Statements: Reference**. Cary NC : SAS Inst. Inc., 2013. 460p.

SPEDDING, C. R. W. **Sheep production and grazing management**. London: Bailliere, Tindall & Cox, 1965. 380p.

SPEDDING, C. R. W. **An introduction to agricultural systems**, second ed. London: Elsevier Applied Science, 1988. 189p.

SUL. **El negocio ovino en el Uruguay, experiencias comerciales exitosas**. Montevideo: Secretariado Uruguayo de la Lana, 2009. 68p.

VANDERICK, S. et al. Derivation of a new lamb survival trait for the New Zealand sheep industry. **Journal of Animal Science**, v.93, n.8, p.3765-3772, 2015. Available from: <https://academic.oup.com/jas/article-abstract/93/8/3765/4701619?redirectedFrom=fulltext>. Accessed: Jun. 18, 2021. doi: 10.2527/jas.2015-9058.