Chilean J. Agric. Anim. Sci., ex Agro-Ciencia (2025) 41(2): 209-216.
https://doi.org/10.29393/CHJAAS41-19DEFE20019

ISSN 0719-3890 online

DEVELOPING A BREEDING OBJECTIVE FOR DUAL-PURPOSE MERINO PRECOZ BREED IN CENTRAL CHILE: DERIVATION OF ECONOMIC WEIGHTS

Felipe Lembeye [1]*, and Giorgio Castellaro[2]

[1] Departamento de Ciencias Animales, Facultad de Agronomía y Sistemas Naturales, Pontificia Universidad Católica de Chile, Santiago, Chile
https://orcid.org/0000-0001-5912-4524
[2] Departamento de Producción Animal, Facultad de Ciencias Agronómicas, Universidad de Chile, Santiago, Chile
https://orcid.org/0000-0003-0106-560X
* Corresponding author: flembeye@uc.cl

ABSTRACT

Defining economically important traits is crucial in the design of a genetic program. These are referred to as the breeding objective, and determining their economic values (v_i) is essential. Currently, no breeding objective has been established for Merino Precoz sheep in central Chile. This study proposes a breeding objective and calculates v_i for five traits: greasy fleece weight (GFW), fiber diameter (FD) with three pricing scenarios: 3.5%, 7% and 14% of GFW price, number of lambs weaned (NLW), weaning weight (WW), and adult weight (AW). Economic values were: USD5.42 for GFW; USD-0.59, USD-1.18, USD-2.35 for FD scenarios (3.5, 7, 14%, respectively); USD151.1 for NLW; USD4.93 for WW, and USD-0.09 for AW. The greatest emphasis was placed on NLW and WW, which collectively represent over 80% of the breeding emphasis. A negative value for AW indicates that smaller ewes are preferable in production systems operating in drylands like central Chile. Furthermore, the inclusion of NLW in the breeding objective must be supported by reliable data-recording protocols and effective management practices to ensure accurate selection.

Keywords: breeding objective, Chilean Mediterranean grassland, economic values, Merino Precoz, sheep.

INTRODUCTION

The first step in developing a comprehensive genetic program is defining the breeding goal and identifying the economically important traits that influence it. These traits are also expressed as the breeding objective. A well-defined breeding objective is crucial for creating opportunities for genetic improvement (Slavova, 2022). Hazel (1943) indicated that the breeding objective is calculated by weighting the true breeding values of each economic trait with their respective economic values (v_i), obtaining the aggregate breeding value.

The v_i of a trait specifies the change in economic outcomes in a defined production system caused by a change in the genetic value of the trait (Hazel, 1943). The estimation of each v_i is a critical step in developing any selection program and must reflect the specific production and economic conditions. Values should be breed-specific, takin into account environmental, management, and marketing factors (Conington et al., 2004; Wolfová et al., 2009). For comprehensive discussions on breeding objectives and v_i studies in sheep, readers are referred to Kuprová et al. (2008), Slavova (2022) and Oberpenning et al. (2025).

In Chile, one of the predominant breeds found in the central regions (Valparaíso, Metropolitana and O'Higgins) is the Merino Precoz sheep, which is a dual-purpose breed (Farias et al., 2010). Ewes weigh 55–65 kg and exhibit early maturity under favorable pasture conditions (García et al., 2006). Rams and ewes produce 3.5–4.3 kg and 2.8–3.3 kg of fleece, respectively, and exhibit reproductive indicators of 93% fertility, 113% lamb birth rate, and 98% lamb weaning rate (Avendaño et al., 2005). The relevance of this breed in central Chile lies in its adaptation to the Chilean Mediterranean

Received: April 29, 2025 Accepted: August 18, 2025

grasslands, where nutritional conditions are often limiting. The Merino Precoz's ability to thrive under such constraints makes it a key contributor to the sustainability of sheep farming in regions where feed resources are scarce or of low nutritional value. Given its dual-purpose nature, the Merino Precoz shares economically important traits with other breeds evaluated under similar conditions. Traits such as fleece quality, reproductive efficiency, and live weight have been highlighted in Corriedale (Köbrich et al., 1992; Mueller, 1995; Jara et al., 1997); in Targhee (Borg et al., 2007); and in Polwarth (Mueller and Aranguren, 2022). Nevertheless, Chile still lacks a formal definition of breeding objectives for purebred Merino Precoz sheep, which limits the potential for structured genetic improvement and long-term productivity gains.

Therefore, the objectives of this study were to: (i) propose a breeding objective and (ii) calculate the respective v_i for Merino Precoz sheep breed. The research was conducted with data from the Rinconada de Maipú Experimental Station of the Faculty of Agricultural Sciences of the University of Chile.

MATERIALS AND METHODS

This study was based on data from the Merino Precoz flock at the Rinconada de Maipú Experimental Station, University of Chile (33°31′ S, 70°50′ W; 470 m elevation). The site has a semi-arid Mediterranean climate, with temperatures ranging from 28.2 °C in January to 4.4 °C in July. The frost-free period lasts 231 days, with an average of 11 frosts annually (Santibáñez and Uribe, 1993). Annual rainfall averages 285.4 mm (1958–2024), with 93.4% occurring between April and September. The flock is managed extensively on natural pasture, with one lambing season per year. Natural mating occurs during February-March, lambing from late-June to late-August, and lambs are sold at weaning between September and early October.

Derivation of economic weights

The methodology used in this study for estimating involves calculating the ewe's cumulative production for each trait, as indicated by Köbrich et al. (1992), Mueller (1995) and Mueller and Aranguren (2022). The principle is to assess the production of an ewe throughout its lifespan. The result corresponds to the accumulated value during its lifetime, adjusted by discounting all production-related costs. The productive and economic assumptions to estimate each v_i of the propose breeding objective are as follows:

Greasy Fleece Weight (GFW; v_1). For this trait, fleece production was calculated by accumulating all the fleeces during the sheep's lifespan, accounting for the probability that a ewe survives to the next shearing. This probability was assumed to remain constant across all age groups at 95%, reflecting the actual survival rate for ewes at Rinconada over the last 10 years, and with no differences across ages. Ewes were presumed to be shorn six times throughout their lifetime. These parameters are outlined in Table 1.

At the Rinconada de Maipú Experimental Station, the average GFW is 3.1 kg per ewe (3.47 kg at 1st shearing and 3.0 kg in older ewes). First shearing occurs when females are in average 14 months old. For older ewes, shearing occurs at 12 month-intervals after first shearing. Consequently, according to Köbrich et al. (1992); Mueller (1995) and Mueller and Aranguren (2022) v_1 is calculated as $v_1 = (S - 1) \times \$\ GFW$, where S is the accumulated fleece production. One unit is subtracted from to account for the first shearing, reflecting the dam's genetic merit. The average selling price of GFW at the Rinconada Experimental Station has been US$1.26 in recent seasons (2014 to present).

Fiber Diameter (FD; v_2). Currently, there is no available information on penalties or bonuses associated with FD. Nevertheless, since Merino Precoz is a dual-purpose sheep breed, this trait is considered significant in all reviewed literature

Table 1. Survival Rate, shearing number, breeding number, weaned lamb and total accumulated weaned lambs.

Shearaing N°	Survival (%)	Accumulated fleece	Breeding N°	Weaned lambs	Accumulated weaned lambs
1	100	1	1	1.11	1.11
2	95	1.95	2	1.05	2.16
3	90	2.85	3	1.00	3.15
4	86	3.71	4	0.95	4.10
5	81	4.52	5	0.90	5-00
6	77	5.30			

and has therefore been included as a breeding objective. In Australia, evaluations conducted through Sheep Genetics and MERINOSELECT™ (Mortimer et al., 2010) consider FD as representing 3.5, 7, and 14% of the GFW price, depending on the improvement goals: increasing GFW while maintaining FD, increasing GFW while simultaneously decreasing FD, or decreasing FD while maintaining GFW, respectively. For dual-purpose breeds such as Merino Precoz, Mortimer et al. (2010) propose only two levels of micron premium (%): 7 and 3.5% values. In the present study, the same methodology was applied. Although Mortimer et al. (2010) do not describe the 14% figure for dual-purpose breeds, this study considered 14% micron premium as an alternative for a finer-wool breed better suited to restricted environments, such as central Chile. In that hypothetical case, other wool traits should also be considered (Guo et al., 2025).

Fleece production was assumed to incur no significant energetic cost, as its requirements are minimal (55 MJ per year; Nicol and Brookes, 2007). This assumption is supported by Connington et al. (2004), who reported no direct costs associated with increasing fleece weight, as evidence does not suggest a significant increase in feed requirements when ewe body weight remains constant.

Number of Lambs Weaned (NLW; v_3). This trait was defined as the number of lambs an ewe rears to weaning. A similar procedure was applied to estimate lamb production. Each ewe was mated five times (Table 1). Reproductive and production parameters, representing the performance of the Merino Precoz flock during the study period 2008-2024, are detailed in the Appendix 1. A 5% annual loss due to death and culling in females was assumed according with data recorded at the Rinconada Experimental Station. For traits related to increasing live weight, additional forage intake costs need to be considered (Connington et al., 2004).

In the present study, each kilogram of dry matter (DM) had an associated monetary cost, determined using the following equation (Daza, 1997):

$$C_g = \frac{E + M \cdot (n - 1)}{n \cdot P}$$

C_g = dry matter cost per kg
E = cost of establishing the pasture. No associated cost was considered because sheep are managed on Mediterranean annual rangeland
M = maintenance cost
n = number of years of the pasture (20 years)
P = average kg of DM of the pasture

The estimated annual maintenance cost of annual rangeland was determined based on the expense of maintaining 15% of the fences each year and trimming thorn bushes on the property during the same period. For this calculation, the linear perimeter of the field requiring annual trimming was estimated. The field area was assumed to be square-shaped with two internal subdivisions, representing an average sheep field in the central and south-central regions of the country (Lembeye, 2012). The result of the economic value of kg of DM is detailed in the Appendix 2 section. Furthermore, 250 g of oat grains is supplemented at the Riconada Experimental Station during the last third of the pregnancy period, with a cost of USD31.4 per breeding season.

Consequently, the $v_3 = B \times W_{120} \times \$kg_L - (\$DMI_E + \$S)$, where B is the cumulative number of lambs produced by an ewe over its lifespan, W_{120} is weight at 120 days, the average weaning age is 29.7 kg; Castellaro et al., 2016), "Price per kg" refers to the selling price of each kilogram of lamb, DMI_E is the dry matter intake (DMI) consumed by ewes from the last third of the gestation period until lambs are weaned, and $\$S$ is the cumulative cost of oat grain as supplement during the fives mating periods.

For the kilogram of live lamb, an average price expressed in US dollars was calculated using data from records published by ODEPA (2025) (Oficina de Estudios y Políticas Agrarias) spanning 1975–2024. The October data were used since lamb sales are concentrated during this month in central Chile, resulting in an average value of USD1.25.

DMI was calculated using the daily nutrient requirement tables for sheep published by Greiner et al. (2008). A total of 282 kg of DMI was estimated for the period from the last third of gestation until weaning at 120 days. This calculation assumes that lambs begin consuming forage at 10 weeks of age, with their intake increasing by 0.1 kg per week as they gain weight.

Appendix 1. Reproductive and survival parameters of the Experimental Station of Rinconada.

Trait	%
Fertility (%)	91
Prolificity (%)	135
Birth rate (%)	123
Survival (%)	90
Mortality (%)	10
Reproductive rate (%)	111

Appendix 2. Estimation of the economic cost of each kg of dry matter

Experimental station surface (ha)	878.0
Experimental station surface (m^2)	8,780,000.0
Linear perimeter (m)	17,778.6
Yearly surface (m) 15%	2,666.8
Cost to fix linear meter	6.6
Yearly maintenance cost (USD)	17654.8
E (establishment cost, USD)	0.0
M (maintenance cost per ha., USD)	20.1
n (N° of years of the pasture)	20
Production of dry matter/ha)	1,835
P (Production of dry matter of the farm kg)	1,611,130
Cost of each kg of dry matter (USD)	0.010

Weaning Weight (WW; v_4). Considering the cumulative number of lambs weaned and the value per kg of lamb sold, the expression $v_4 = (B - 1) \times \$kg_L - \$DMI_{E\text{-}L}$ represents the economic increase per additional kilogram that an ewe can contribute through its offspring. One of the accumulated lambs (B) is subtracted to account for a female lamb replacing its dam. $\$DMI_{E\text{-}L}$ refers to the additional DMI that the ewe-lamb pair must consume for that extra kilogram increase at weaning. According to Nicol and Brookes (2007), a one-kilogram increase in live weight at weaning requires an additional metabolizable energy intake of 58 MJ for the ewe-lamb pair within the weaning range. Given that Mediterranean rangeland has an energy concentration of approximately 9.5 MJ/kg during the typical lactation period (Ovalle and Squella, 1996), this corresponds to an additional DM intake of 6.1 kg.

Adult Weight (AW; v_5). The final source of income from an ewe comes from its sale at culling. By the end of the productive cycle, only 77% of the females are expected to survive (Table 1). The expression $v_5 = 0.77 \times \$kg_E - \$DMI_E$ represents the economic increase (decrease) per additional kilogram of weight for an ewe at culling, where DMI_E is the required DMI by an ewe that is one kilogram heavier.

Lastly, since each trait is measured differently, instead of the marginal values indicated by v_i a better comparison is standardized v_i by its genetic standard deviations (σ_g) such as $v_{si} = v_i \times \sigma_{gi}$, where v_{si} is the standardized value of a i-trait. These absolute values were expressed as percentage according to the following expression (adapted from Zhang and Amer, 2021):

$$v_{r_i} = \frac{|v_{s_i}|}{\sum_{i=1}^{t} |v_{s_i}|} \times 100$$

Where v_{ri} is the relative economic weight for the i-trait and $|v_{si}|$ is the absolute values of v_{si} and t is the total number of traits. Values of σ_{gi} are unavailable for the population; therefore, each σ_{gi} was obtained using phenotipic parameters of the population and literature values for heritabilities published by Safari et al. (2005) (Appendix 3).

RESULTS AND DISCUSSION

The v_i for the breeding objective proposed in this manuscript are presented in Table 2. Each ewe produces 4.30 fleeces, and with a selling price of USD1.26, v_1 is USD5.42. Given an average fleece weight of 3.1 kg (3.47 kg at 1st shearing and 3.0 kg for older ewes), this corresponds to 13.3 kg of greasy wool per ewe. Reducing the diameter by one micron represents a reward of USD0.04 (3.5%); USD0.09 (7%) and USD0.18 (14%). Consequently, the v_2 is USD-0.59; USD-1.18 and USD-2.35 for a 3.5, 7 and 14%, respectively. The v_i for live weight traits were: USD151.1 (NLW); USD4.93 (WW) and USD-0.09 (AW).

Comparing the results in the present study

Appendix 3. Derivation of genetic standard deviation, phenotypic variances of the population and heritability values form the literature (Safari et al., 2005).

	σ_g	σ^2_P	h^2
GFW	0.34	0.296	0.38
FD	1.37	3.306	0.57
NLW	0.08	0.142	0.05
WW	1.52	12.770	0.18
AW	3.84	47.472	0.31

σ_g: genetic standard deviation; σ^2_P : phenotypic variance; h^2: heritability; GFW: greasy fleece weight; FD: fiber diameter; NLW: number of lambs weaned, WW: weaning weight and AW: adult weight.

Table 2. Economic values for greasy fleece weight (GFW), fiber diameter (FD), number of lambs weaned (NLW), weaning weight at 120 d (WW) and adult weight (AW) expressed as function of FD for Merino Precoz sheep under three breeding purposes of the wool (%).

Breeding purposes of the wool (FD/GFW)	GFW	FD	NLW	WW	AW
3.5%	9.22	-1.0	257.04	8.39	-0.16
7%	4.61	-1.0	128.52	4.20	-0.08
14%	2.30	-1.0	64.26	2.10	-0.04

with those reported in previous publications is challenging due to differences in trait definitions, models, systems, breeds performance, and economic and marketing conditions. However, some similarities were found for clean fleece weight and FD, with ranges between 3.12 and 4.45 for GFW relative to FD (Köbrich et al., 1992; Mueller and Aranguren, 2022). However, Mueller (1995) and Jara et al. (1997) reported greater importance for fleece expressed as a function of FD, ranging from 4.1 to 20 in Corriedale breed. When comparisons were made between WW and FD, the approaches of Köbrich et al. (1992), Mueller (1995), Jara et al. (1997), and Mueller and Aranguren (2022) indicated that WW was of lesser importance compared with the findings of the present study.

This study reports a negative value for AW, indicating that the costs of increasing mature size outweigh the benefits (Table 2). Similar findings were reported by Conington et al. (2004); Morais and Madalena (2006); Wolfová et al. (2011) and Bohan et al. (2019), who also observed negative values for this trait. In contrast, Köbrich et al. (1992), Muller and Aranguren (2022) and Guo et al. (2025) reported positive values. A negative suggests a sustainable system for sheep reared in drylands of central Chile, as heavier ewes increase costs, reduced forage availability, and lower stocking rate, thereby affecting farm structure and management (Connington et al., 2004). Given the declining rainfall in the region over recent decades, reducing sheep size appears to be a reasonable adaptation strategy.

These v_r provide breeders a clearer approximation of the economic importance of each trait in the breeding objective, indicating the potential value of genetic improvements for a given trait (Byrne et al., 2010). Table 3 presents the standardized and relative weight of each trait. Notably, NLW represents >50% of the emphasis of the breeding objective. When WW is included, this proportion rises to nearly 80%, highlighting the relatively low importance of wool traits -even though Merino Precoz is a dual-purpose breed. This finding aligns with previous studies, emphasizing NLW as a critical factor for productivity across systems and consistently prioritized in breeding objectives (Connington et al. 2004; Borg et al., 2007; Kuprová et al., 2009; Byrne et al., 2010; McManus et al., 2011). Therefore, selection efforts should focus on traits closely linked to NLW and WW, as wool traits decline in economic importance (Slavova, 2022; Oberpenning et al., 2025). For Merino Precoz sheep farming, should be set when FD represents only 3% of GFW value (Table 2).

NLW is directly influenced by factors such as ewe fertility, prolificacy and lamb survival. Given the low heritability of these traits (Safari et al., 2005) and the challenges in inaccurately evaluating young candidates (Zhang and Amer, 2021), genetic progress is limited, and selection pressure on lamb survival remains weak.

Although NLW holds significant economic importance in sheep production, its relevance can decline under certain conditions. For example, in extensive farming systems with limited resources, increasing lamb production may not always be beneficial and could even have negative financial impacts (Connington et al., 2004). This may be particularly relevant in the semiarid Mediterranean grasslands of central Chile. Furthermore, NLW is highly dependent on environmental conditions, and extensive farming practices face challenges such as predation and cattle rustling, which limit accurate record-keeping (Mueller and Aranguren, 2022). Consistent with this, Moloney et al. (2023) report that enhancing pre-weaning traits is more profitable than increasing lambing percentage. For instance, increasing WW by 10, 20 and 30% farms may increase cash operating surplus by 29-76 $/ha, compared with equivalent increases in lambing percentage. For these reasons, a simulation was conducted excluding NLW from the breeding objective. In this new scenario, the relative economic emphasis for GFW, FD, WW and AW is shown in Fig. 1.

In this new analysis, WW accounts for 58.0-

Table 3. Relative economic emphasis for greasy fleece weight (GFW), fiber diameter (FD), number of lambs weaned (NLW), weaning weight at 120 d (WW) and adult weight (AW) for Merino Precoz sheep under three breeding purposes of the wool (%).

Breeding purposes of the wool DF/PVS	GFW	FD	NLW	WW	AW
3.5%	7.8	3.5	54.8	32.3	1.6
7%	7.6	6.7	53.0	31.2	1.5
14%	7.1	12.6	49.7	29.2	1.4

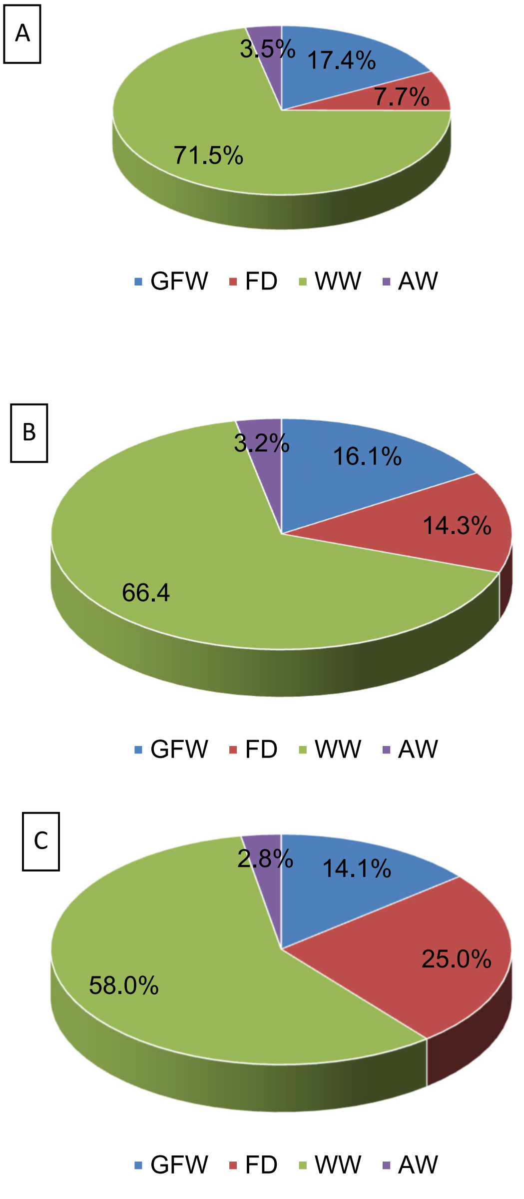

Fig. 1. Relative economic emphasis (%) for greasy fleece weight (GFW), fiber diameter (FD), weaning weight at 120 d (WW) and adult weight (AW) for Merino Precoz sheep when FD represents 3.5% (A), 7% (B) and 14% (C) of GFW value.

71.5% of the breeding objective, followed by GFW (14.1-17.4%), FD (7.7-25%), and AW (2.8-3.5%) (Fig. 1). It may be argued that AW should also be excluded from the breeding objective, since traits representing less than the 10% of profit may be of limited value for selection (McManus et al., 2011). However, as noted previously, reducing sheep size appears advisable in dryland environments. A major challenge is ensuring reliable data collection and controlling environmental factors to make NLW a viable breeding trait. This is particularly difficult under extensive farming practices in central Chile, where record-keeping is limited by factors such as predator activity and cattle rustling. Additionally, the limited use of artificial insemination restricts reproductive control, further complicating efforts to improve NLW selection.

CONCLUSIONS

This research identifies the keys traits of importance for increasing overall farm profitability in Merino Precoz sheep in central Chile and proposes a breeding objective that include five traits: greasy fleece weight (GFW), fiber diameter (FD), number of lambs weaned (NLW), weaning weight (WW), and adult weight (AW). The greatest emphasis was placed on NLW and weigh of those lambs at selling. However, the inclusion of NLW should be accompanied by a robust data-recording protocol and effective management practices to ensure accurate selection. The economic values developed in this study may be valuable for designing a selection scheme for Merino Precoz breed and for estimating potential genetic gains in the traits included in the proposed breeding objective.

Author contributions

The authors declare active participation in conceptualization: Felipe Lembeye; in the methodological design: Felipe Lembeye and Giorgio Castellaro; in writing revision and discussion: Felipe Lembeye and Giorgio Castellaro; in the bibliographical review: Felipe Lembeye; in the approval of the final version of the article: Felipe Lembeye and Giorgio Castellaro.

LITERATURE CITED

Avendaño, J., C. Muñoz and H. Vilchez. 2005. Razas ovinas. p. 17-38. In Mujica. F. (ed.) Razas ovinas y caprinas en el Instituto de Investigaciones Agropecuaria (INIA). Boletin INIA N° 127, INIA, Osorno, Chile.

Bohan, A., L. Shalloo, P. Creighton, D. Berry, T. Boland, A.C. O' Brien, T. Pabiou, E. Wall, K. McDermott and N. McHugh. 2019. Deriving economic values for national sheep breeding objectives using a bio-economic model. Livestock Science 227: 44-54. https://doi.org/10.1016/j.livsci.2019.05.018

Borg, R.C., D.R. Notter, L.A. Kuehn and R.W. Kott. 2007. Breeding objectives for Targhee sheep. Journal of Animal Science 85(11): 2815-2829. doi: 10.2527/jas.2006-064

Byrne, T.J., P.R. Amer, P.F. Fennessy, A.R. Cromie, T.W.J. Keady, J.P. Hanrahan, M.P. McHugh, and B.W. Wickham. 2010. Breeding objectives for sheep in Ireland: A bio-economic approach. Livestock Science 132: 135-144.

Castellaro, G., X. García, J.C. Magofke and G. Marín. 2016. Liveweight and growth of Merino Precoz, Suffolk and crossbred lambs in a semiarid Mediterranean grassland of Chile. Chilean Journal of Agriculture & Animal Science 32(1): 60-69.

Conington, J., S.C. Bishop, A. Waterhouse and G. Simm G. 2004. A bioeconomic approach to derive economic values for pasture-based sheep in genetic improvement programs. Journal of Animal Science 82:1290-1304. https://doi.org/10.2527/2004.8251290x

Daza, A. 1997. Reproducción y Sistemas de Explotación del ganado ovino. Ediciones Mundi Prensa, España-Barcelona-México.

Farías, E., F. Mujica y M. Hervé. 2010. Diagnóstico de la distribución del recurso genético ovino desde las regiones de Coquimbo a Magallanes y Antártica chilena. Agro Sur 38(2): 97-108.

García, X., J.C. Magofke, and C. Aubert. 2006. Performance of Merino Precoz and Suffolk in the range area of the Metropolitan Region, Chile. Avances en Producción Animal 32:35-56.

Greiner, S.P., M.L. Wahlberg, B.R. McKinnon. 2008. Sheep Nutrition and Management. p 115-152. In: E.B. Rayburn (ed.) Animal Production Systems for Pasture-Based Livestock Production RAES-171. Published by Natural Resource, Agriculture and Engineering Service, Cooperative Extension, Ithaca, New York, USA

Guo, T., W. Li, C. Yuan, X. Wang, J. Liu and B. Liang. 2025. Defining multi-trait breeding objectives and selection indexes to develop more efficient breeding programs for superfine wool sheep. Animals 15 (13):1873. https://doi.org/10.3390/ani15131873

Hazel, L.N. 1943. The genetic basis for constructing selection indexes. Genetics 28: 476-490.

Jara, A., V. Martínez, P. Sapunar and N. Barria. 1997. Estimaciones de ponderadores económicos para la raza Corriedale en Magallanes. p. 78-79. In: Strauch O., N. Covacevich and A. Cárdenas (ed.). Sochipa en Magallanes 30 años. Serie actas INIA N°35. 2006. Instituto de Investigaciones Agropecuarias, Punta Arenas, Chile.

Köbrich, C., N. Barría and P. Sapunar P. 1992. Estimación de ponderadores económicos para un índice de selección de la raza Corriedale en Magallanes. Avances en Producción Animal 17(1-2): 123-126.

Kuprová, Z., M. Oravcová, E. Keupa and D. Peskovicová. 2008. Methods for calculating economic weights of important traits in sheep. Slovack Journal of Animal Science 41(1): 24-29.

Lembeye, F. 2012. Comparación de diferentes índices de selección masal en ovinos doble propósito y carne de la zona central de Chile. Tesis de Magíster. Facultad de Ciencias Agronómicas, Universidad de Chile. Chile, Santiago, Chile. Available on: https://repositorio.uchile.cl/bitstream/handle/2250/116089/Felipe%20Lembeye.pdf?sequence=1

McManus, C., B. F. Pinto, R.F.S. Martins, H. Louvandini, S.R. Paiva, J.B. Neto and T.D.P. Paim. 2011. Selection objectives and criteria for sheep in Central Brazil. Revista Brasileira de Zootecnia 40(12): 2713-2720. https://doi.org/10.1590/s1516-35982011001200014

Moloney, A.J., P.R. Tozer, T. S.T. Morris and P.R. Kenyon. 2023. Bigger lambs or more lambs: The conundrum for New Zealand lamb producers. Livestock Science 270:105204. https://doi.org/10.1016/j.livsci.2023.105204.

Morais, O.R. and F.E. Madalena. 2006. Economic values for production traits in Santa Inés Sheep. CD-ROM, Paper 04-32 In: 8th World Congress on Genetics Applied to Livestock Production, August 13-18, Belo Horizonte, MG, Brasil. Available on: https://www.cabidigitallibrary.org/doi/pdf/10.5555/20063169428

Mortimer, S.I., K.D. Atkins, S.J. Semple and N.M. Fogarty. 2010. Predicted responses in Merino sheep from selection combining visually assessed and measured traits Animal Production Science 50: 976–982.

Mueller, J.P. 1995. Procedimientos PROVINO para la raza Merino y para razas doble propósito - Zafra 1995/6. Comunicación Técnica INTA Bariloche, Nro 293, 12 pp.

Mueller, J.P. and E. Aranguren. 2022. Implementación y resultados de un programa de mejora genética en ovinos. Revista de Investigaciones Agropecuarias 48(1):16-23.

Nicol, A.M. and I.M. Brookes. 2007. The metabolizable energy requirements of grazing livestock. pp 151-172. In: Rattray, P.V., I.M. Brookes and A.M. Nicol (ed). Pasture and supplements for grazing animals. Hamilton, New Zealand.

Oberpenning, J., K. Brügemann and S. König. 2025. Characterization of German sheep production systems and derivation of respective economic values for breeding traits. Veterinary and Animal Science 27: 100432. doi: 10.1016/j.vas.2025.100432

ODEPA, 2025.Series de precios, Santiago, Chile. https://aplicativos.odepa.gob.cl/series-precios/series-tiempo (Accessed 24 April 2025).

Ovalle, C. y F. Squella F. 1996. Terrenos de pastoreo con pastizales anuales en el área de influencia climática mediterránea. En I. Ruiz (ed) Praderas para Chile, 2a. edición. Instituto de Investigaciones Agropecuarias, Santiago, Chile.

Safari E., N.M. Fogarty and A.R. Gilmour. 2005. A review of genetic parameter estimates for wool, growth, meat and reproduction traits in sheep. Livestock Production Science 92: 271-289.

Slovova, S. 2022. Bio-economic models for deriving economic values for sheep: a review. Agricultural Science & Technology 14(3): 3-9.

Santibanez, Q., M. Uribe. 1993. Atlas Agroclimático de Chile. Regiones sexta, séptima, octava y novena. Laboratorio de Agroclimatología. Departamento de Ingeniería y Suelos. Universidad de Chile, Facultad de Ciencias Agrarias y Forestales, Santiago.

Wolfová, M., J. Wolf, and M. Milerski M 2011. Calculating economic weights for sheep sire breeds used in different breeding systems. Journal of Animal Science 89(6): 1698-1711 https://doi.org/10.2527/jas.2010-3237

Wolfová M, J. Wolf, Z. Krupová and J. Kica. 2009. Estimation of economic values for traits of dairy sheep: I. Model development. Journal of Dairy Science 92: 2183-2194.

Zhang, X., and P. Amer. 2021. A New selection index percent emphasis method using subindex weights and genetic evaluation accuracy. Journal of Dairy Science 104: 5827-5842. https://doi.org/10.3168/jds.2020-19547