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Phenotypic characteristics of male lambs of woolen sheep breeds and their relationship with liquidity and price offered at auctions in Uruguaiana - Rio Grande do Sul

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ABSTRACT - This study aimed at analyzing and comparing the phenotypic characteristics of height, body length, and fleece wool fineness with the liquidity and final price sold in auctions in the city of Uruguaiana, RS, Brazil, for three consecutive years (2015 to 2017). A total of 412 one-year-old (two teeth) male sheep, of the Australian Merino (n = 50), Polwarth (n = 130), and Corriedale (n = 232) breeds were evaluated. Height and length of the animals were measured on the day of the auction with a measuring tape, and animals were grouped into small or tall and short or long categories, as defined in this study. Wool fineness was measured using an Optical-based Fibre Diameter Analyser (FDA 2000) device and classified according to official wool classification standards (the Bradford System). There was no statistical difference in the average selling price of different breeds. There was a correlation between the breed and liquidity, in which Corriedale lambs were sold more than the Polwarth lambs, as expected; however, there was no such correlation for Merino lambs. The tall Merino lambs were sold at a higher selling price (R\$ 2,449.11) than the small ones (R\$ 1,826.59). Polwarth lambs exhibited positive correlations among height, length, and liquidity. Long and tall Corriedale lambs had a higher selling price (R\$ 1,963.40 and R\$ 1,915.02) than the short (R\$ 1,656.38) and small (R\$ 1,698.20) ones, respectively. In the case of Corriedale lambs, there was a positive correlation between length and liquidity. Wool fineness did not influence the selling price and liquidity in the three studied breeds. Conclusively, buyers of the Polwarth and Corriedale lambs prefer tall and long animals, regardless of the fleece wool fineness; only the height (taller lambs) seems to be a relevant factor for choosing the Merino breeders.

Keywords: commercialization, fleece wool, price, sheep

1. Introduction

Sheep farming, especially for wool production, is a traditional economic activity on farms in Uruguaiana, Rio Grande do Sul (RS), Brazil. Since the beginning of the 20th century, sheep farming has been considered the greatest wealth producer in this area, as the livelihood of farmers depended almost entirely on the commercialization of wool, often called the "white gold" (Viana and Souza, 2007).

A change in the wool market was observed after the First World War, resulting from a crisis in Russia (a large wool importer) and other factors such as high Australian wool stock and Brazilian government

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fluctuations. Competition within the industry with synthetic fibers (a fabric of lower quality) and quick acceptance of this by the international market had a specific negative influence on the value of wool (Viana and Silveira, 2009). The fall in the price of wool led to a significant and progressive reduction in the size of flock of sheep in RS after the 1980s (Malheiros et al., 2017). From 2000 onwards, the sheep herd in RS became smaller than those in northeast region of Brazil (Raineri et al., 2014), and RS currently supports 2,950,926 million head of sheep (Magalhães et al., 2021) on 47,063 farms (IBGE, 2017), where most of the production is for subsistence.

As a result of the decline in the value of sheep for wool, and further influenced by an increase in the population's purchasing power, sheep meat was no longer considered a byproduct and became more valued by the national and international consumer market, developing into a new commercial alternative for wool production.

The Corriedale breed is the most prevalent in RS (490 herds in RS), as it is considered for dual purposes, both for meat and wool production. The Polwarth (345 herds in RS) and Australian Merino (137 herds in RS) breeds are primarily raised for the production of fine-quality wool. Australian Merinos, specifically, are known to produce fine wool, enhancing their value (McManus et al., 2014).

There is a scarcity of studies on sheep farming in RS that assess trends and commercial value of male lambs according to its phenotypic characteristics, particularly with regard to the market value of the breeders and criteria used by sheep farmers to choose such animals. Conversely, bovine species have been well studied in terms of animal characteristics and related market value (Gonçalves et al., 2018).

This study aims to evaluate and correlate the phenotypic characteristics of lambs from the three main breeds raised in RS with the liquidity and final price in official auctions, and determine the preferences of sheep farmers when choosing breeders for their commercial herds.

2. Material and Methods

Traditionally, three sheep auctions are held annually in the city of Uruguaiana, located on the western border of the State of RS (Latitude: 29°44'58" South and Longitude: 57°5'18" West). The records of auctions from 2015 to 2017 were examined. A total of 412 one-year-old male lambs (two teeth) of the Australian Merino (n = 50), Polwarth (n = 130), and Corriedale (n = 232) breeds were evaluated phenotypically to determine height and length of the body and fleece wool fineness.

The height and length of the animals were measured on the day of the auction, using a measuring tape. The height was considered the distance between the withers and the ground, with the animals being grouped into small (Australian Merino between 67.0 and 76.9 cm; Polwarth between 62.0 and 76.9 cm, and Corriedale between 63.0 and 76.9 cm, respectively) and tall (Australian Merino between 77.0 and 89.0 cm, Polwarth between 77.0 and 92.0 cm, and Corriedale between 77.0 and 87.0 cm, respectively). A default threshold for height classes (76.9 cm) was defined, based on the data collected, as the best measure to balance the two groups (small and tall).

The length was measured from the cranial edge of the scapula to the tip of the musculature of the femur, with the animals being grouped into short (Australian Merino between 73.0 and 90.0 cm, Polwarth between 71.0 and 90.0 cm, and Corriedale between 63.0 and 90.0 cm, respectively) and long (Australian Merino between 91.0 and 111.0 cm, Polwarth between 91.0 and 106.0 cm, and Corriedale between 91.0 and 123.0 cm, respectively). A default threshold for length classes (90.0 cm) was defined, based on the data collected, as the best measure to balance the two groups (short and long).

Fleece wool fineness was evaluated in terms of the auction catalog, using an Optical-based Fibre Diameter Analyser (OFDA 2000, BSC Electronics, Australia). A sample of wool fleece, with a diameter of 1×1 cm^2, was collected, on average 30 days prior to the auction, from the left side of the last rib of each animal by a technician accredited by the Associação Brasileira de Criadores de Ovinos (ARCO; Brazilian Association of Sheep Breeders). The sample was processed using the OFDA, as described by the manufacturer, to obtain the average diameter of the wool fiber for each fleece sample, which was

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then classified according to the official wool classification standards (the Bradford System) (Merino: between 19.0 and 22.0 microns; Amerinada: between 22.1 and 23.2 microns; Prima A: between 23.5 and 24.9 microns; Prima B: between 25.0 and 26.4 microns; Cross 1: between 26.5 and 27.8 microns; Cross 2: between 27.9 and 30.9 microns; Cross 3: between 31.0 and 32.6 microns; and Cross 4: between 32.7 and 34.3 microns). The fleece of the animals where the wool fineness of the sample was greater than 22.0, 26.4, and 31.0 microns for the Australian Merino, Polwarth, and Corriedale breeds, respectively, was considered not compliant with the breed standard.

The number of bids offered and the final price of each animal as recorded during the auction were collected. Subsequently, the data were tabulated in a Microsoft Excel® spreadsheet, and a statistical analysis of the data was performed, with the absolute and relative frequencies determined for each characteristic evaluated.

Selling prices of male lambs were evaluated using a generalized linear model for breed following the model below:

$$y_{ij} = \mu + B_i + \varepsilon_{ij},$$

in which y_{ij} = animal selling price; μ = overall average of all observations; B_i = breed effect, with i = 3; and ε_{ij} = random effect.

Also, models were performed for selling prices to each breed considering the measures of height, length, and wool fineness. In that case, all the first-order interactions were evaluated as a fixed effect; however, they resulted in non-significant effects and were excluded from the final model. No random effects were considered in those generalized linear models because we did not have repeated measures for animals or farms. The final model for each breed was the following:

$$y_{ijkl} = \mu + HEI_i + LE_j + WF_k + \varepsilon_{ijkl},$$

in which y_{ijkl} = animal selling price; μ = overall average of all observations; HEI_i = height effect, with i = 2; LE_j = length effect, with j = 2; WF_k = wool fineness effect, with k = 9; and ε_{ijkl} = random effect.

The assumptions of homoscedasticity and normality of the models were evaluated by a graphical analysis of the standardized residues against the adjusted predicted values and the quantile-quantile plots of the standardized residues (normal probability plot) plus histograms, respectively. No normality of residuals was found, so a lognormal distribution was tested on the model fit. Lognormal distribution resulted in residuals normality, and it was maintained for the final modelling. Finally, when an effect was significant, the means differences were compared using the Tukey-Kramer test.

In addition, a chi-square test was performed to verify associations between commercialized and non-commercialized groups with breed, and for each breed considering length, height, and wool fineness. When chi-square test was significant, *post hoc* tests were performed using the adjusted standardized residuals (z-scores) to verify whether the observed cell frequency was above or below the expected cell frequency. An adjusted standardized residue greater than 1.96 indicates that observed frequency is greater than the expected for that cell, whereas an adjusted standardized residue lesser than −1.96 indicates that observed frequency is less than the expected for that cell (Meyers et al., 2013; Sharpe, 2015).

All analyses were performed on SAS (Statistical Analysis System, University Edition). The generalized linear model was performed using SAS PROC GLIMMIX, whereas normality assumption was performed using SAS PROC UNIVARIATE, and chi-square tests were performed using SAS PROC FREQ. Statistical significance was considered at level of 5% of probability.

3. Results

There was no significant effect (P = 0.1785) of breed on the average selling price of lambs (Tables 1 and 2). However, there was a correlation between breed and liquidity (P<0.0001), indicating that a greater proportion of Corriedale lambs and a lower proportion of Polwarth lambs were sold than expected (Table 3). For the Merino breed, no difference was observed between the sold and unsold

lambs in terms of the expected frequency (Table 3). Accordingly, the parameters including body length and height, as well as wool fineness, were evaluated exclusively for each of the three studied breeds.

For the Merino breed, there was no selling price difference in relation to wool length (P = 0.1609) and fineness (P = 0.9303). However, tall lambs were sold at a higher (R$ 2,449.11; P = 0.0023) price than the small ones (R$ 1,826.59) (Table 4). The Merino breed also exhibited no correlation between liquidity and length (P = 0.9390), height (P = 0.6997), and wool fineness (P = 0.4099) (Table 5).

The selling price of Polwarth lambs exhibited no difference in terms of height (P = 0.8107) and length (P = 0.4296) of the animals. However, Polwarth lambs with non-standard wool classification (R$ 2,019.94) and Amerinada (R$ 2,008.42) had a higher (P = 0.0327) selling price than those with the Prima B wool (R$ 1,497.30), with no difference between the other wool fineness classes (Table 6).

Considering liquidity, long Polwarth lambs were sold more than the short ones (P<0.0001); similarly, tall lambs were significantly (P = 0.0246) sold more than the small ones (Table 7). Conversely, Polwarth lambs classified with non-standard wool were significantly (P = 0.0002) sold more than those with the Prima B wool, which contradicted the expectation (Table 7).

For the Corriedale breed, the average selling price was higher (P<0.0001) for the long lambs (R$ 1,963.40) than the short ones (R$ 1,656.38). The price was also higher (P = 0.0021) for tall lambs (R$ 1,915.02) than for the small ones (R$ 1,698.20). However, there was no difference (P = 0.3714) in the selling price with regard to wool fineness (Table 8). For liquidity, there was a correlation (P = 0.0478) between length and sale, indicating that the long Corriedale lambs are sold more than the short ones, but there was no correlation (P = 0.2733) among liquidity, height, and wool fineness (Table 9).

Table 1 - Liquidity and average selling price of male lambs of the Merino, Polwarth, and Corriedale breeds

Breed	N	Sold (N)	Liquidity (%)	Average price (R$)
Merino	50	36	72.0	2183.61
Polwarth	130	75	57.7	1942.13
Corriedale	232	208	89.7	2079.09
Total	412	319	77.4	2068.28

Table 2 - Modelling results for selling price per breed of commercialized male lambs

Breed	Adjusted mean	Standard error of the mean	P-value
Merino	2086.33	99.253	
Polwarth	1877.59	61.866	0.1785
Corriedale	1969.70	38.965	

Table 3 - Chi-square test and absolute and relative frequencies (in parentheses) for not sold and sold lambs according to breed

Breed	Sale		P-value
	Not sold	Sold	
Merino	14 (3.4)	36 (8.7)	
Polwarth	55 (13.4)*	75 (18.2)#	<0.0001
Corriedale	24 (5.8)#	208 (50.5)*	

* Significant association resulting in a cell frequency above the expected based on the z-score *post hoc* test for chi-square.
# Significant association resulting in a cell frequency bellow the expected based on the z-score *post hoc* test for chi-square.

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Table 4 - Modelling results for selling price of commercialized male Merino lambs regarding length, height, and wool fineness

Variable	Adjusted mean	Standard error of the mean	P-value*
Length			0.1609
Short	1981.56	143.021	
Long	2257.87	156.663	
Height			0.0023
Short	1826.59b	120.699	
Tall	2449.11a	179.887	
Wool fineness			0.9309
Merina 1	2099.05	117.851	
Merina 2	2175.26	182.915	
Amerinada	2085.30	272.880	

* Statistical significance based on Tukey-Kramer's test in which different letters indicate means differences.

Table 5 - Chi-square test and absolute and relative frequencies (in parentheses) for selling with length, height, and wool fineness of sold Merino lambs

Variable	Sale		P-value
	Not sold	Sold	
Length			
Short	6 (12.00)	15 (30.00)	0.9390
Long	16 (27.59)	42 (72.41)	
Height			
Short	9 (18.00)	21 (42.00)	0.6997
Tall	5 (10.00)	15 (30.00)	
Wool fineness			
Merina 1	9 (18.00)	22 (44.00)	0.4099
Merina 2	5 (10.00)	10 (20.00)	
Amerinada	0 (0.00)	4 (8.00)	

Table 6 - Modelling results for selling price of commercialized male Polwarth lambs regarding length, height, and wool fineness

Variable	Adjusted mean	Standard error of the mean	P-value*
Length			0.4296
Short	1785.26	105.541	
Long	1881.55	68.303	
Height			0.8107
Short	1846.95	66.399	
Tall	1818.78	109.231	
Wool fineness			0.0327
Merina	1837.40ab	133.688	
Amerinada	2008.42a	150.694	
Prima A	1864.55ab	99.224	
Prima B	1497.30b	120.754	
Do not comply with the breed standard	2019.94a	134.394	

* Statistical significance based on Tukey-Kramer's test in which different letters indicate means differences.

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Table 7 - Chi-square test, absolute, and relative frequencies (in parentheses) for selling with length, height, and wool fineness of the sold Polwarth lambs

Variable	Selling		P-value
	Not sold	Sold	
Length			
Short	38 (29.23)*	25 (19.23)#	
Long	17 (13.08)#	50 (38.46)*	<0.0001
Height			
Short	48 (36.92)*	53 (40.77)#	
Tall	7 (5.38)#	22 (16.92)*	0.0246
Wool fineness			
Merina	9 (6.92)	12 (9.23)	
Amerinada	9 (6.92)	12 (9.23)	0.0002
Prima A	14 (10.77)	26 (20.00)	
Prima B	23 (17.69)*	10 (7.69)#	
Do not comply with the breed standard	0 (0.00)#	15 (11.54)*	

* Significant association resulting in a cell frequency above the expected based on the z-score *post hoc* test for chi-square.
# Significant association resulting in a cell frequency bellow the expected based on the z-score *post hoc* test for chi-square.

Table 8 - Modelling results for selling price of commercialized male Corriedale lambs regarding length, height, and wool fineness

Variable	Adjusted mean	Standard error of the mean	P-value*
Length			<0.0001
Short	1656.38b	78.627	
Long	1963.40a	98.743	
Height			0.0021
Short	1698.20b	83.953	
Tall	1915.02a	91.862	
Wool fineness			0.3714
Prima B	1504.97	242.096	
Cross 1	1887.82	134.108	
Cross 2	1919.77	60.232	
Do not comply with the breed standard	1961.25	51.82	

* Statistical significance based on Tukey-Kramer's test in which different letters indicate means differences.

Table 9 - Chi-square test, absolute, and relative frequencies (in parentheses) for selling with length, height, and wool fineness of the sold Corriedale lambs

Variable	Sale		P-value
	Not sold	Sold	
Length			
Short	15 (6.47)*	86 (37.07)#	0.0478
Long	9 (3.88)#	122 (52.59)*	
Height			
Short	15 (6.47)	96 (41.38)	0.1290
Tall	9 (3.88)	112 (48.28)	
Wool fineness			
Prima B	1 (0.43)	3 (1.29)	
Cross 1	15 (6.47)	15 (6.47)	0.2733
Cross 2	12 (5.17)	77 (33.19)	
Do not comply with the breed standard	11 (4.74)	113 (48.71)	

* Significant association resulting in a cell frequency above the expected based on the z-score *post hoc* test for chi-square.
# Significant association resulting in a cell frequency bellow the expected based on the z-score *post hoc* test for chi-square.

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4. Discussion

The data from the present study revealed no significant difference in terms of the average selling price between lambs of the three evaluated breeds (Table 2). These data suggest that the individual price offered for the lambs is not influenced by breed. Moreover, there does not seem to be a "fashionable breed" or overvaluation of one breed at the expense of another.

Conversely, the liquidity data showed that Corriedale lambs were sold more than expected, the Polwarth lambs were sold less than expected, and Merino exhibited no difference between the expected frequencies of sold and unsold lambs (Table 3). A potential factor is that Corriedale is a dual-purpose breed, for which characteristics related to wool and meat are both considered as breeding criteria, generally resulting in earlier and heavier lambs compared with lambs of the Australian and Polwarth Merino breeds (Souza, 2018). Currently, these characteristics of the Corriedale breed seem to be highly desirable by sheep farmers.

Silva et al. (2013) analyzed the representativity of sheep breeds in a random sample from 705 farms in RS and found that 20.0% were Corriedale, 18.5% were Polwarth, 17.0% were of mixed breed, 15.0% were Texel, 11 were Australian Merino, and the other breeds accounted for 5%. These data demonstrate the importance of the three breeds evaluated in the present study, which, if considered together, represent almost half of the sheep herds of RS.

Also, many sheep farmers decided to keep producing fine wool, and thus, they bred the Australian Merino breed, which historically had the highest price for fleece wool. This also resulted in a reduced demand for Polwarth lambs. Additionally, empirically, there does not seem to be a significant difference in size, weight, and meat production between lambs of the Merino and Polwarth breeds.

For the Australian Merino breed, whose greatest aptitude includes the production of fine wool, the results revealed that wool fineness and body length did not influence the average selling price; however, tall lambs were sold at a higher (P = 0.0023) average selling price (R$ 2,449.11) than the small ones (R$ 1,826.59) (Table 4). Liquidity was not influenced by height, length, or wool fineness of the Merino lambs (Table 5). These results suggest that wool fineness is no longer a relevant criterion when choosing Merino lambs as sires but that increased body height seems to be valued by breeders, perhaps for those who are in search of sires that could raise the average height of the herd.

The Polwarth breed, which has always been considered to exhibit 70% wool and 30% meat aptitude, and more recently has been considered a fine wool and dual-purpose breed, exhibited no difference in terms of the average selling price of lambs in correlation with neither body length nor height. The higher (P = 0.0327) average selling price for Polwarth lambs with Amerinada wool (R$ 2,008.42) than for those with the Prima B wool (R$ 1,497.30) is fully justifiable, because the former exhibits greater wool aptitude; however, lambs with non-standard wool (R$ 2,019.94) also had a higher average selling price than those with the Prima B wool, which was in contrast to the expectations.

Considering the wool aptitude of Polwarth and Merino breeds, it was expected that lambs with thinner fleece wool would have a high selling price. However, the results revealed that wool fineness is no longer a relevant criterion when selling the breeding lambs, even for these two breeds. Furthermore, height and body length did not exhibit a correlation with the average selling price of the Polwarth lambs.

Conversely, liquidity was favored in longer and taller Polwarth lambs, as well as those with non-standard wool, which were sold more than expected. However, lambs with thinner wool (Prima B) were sold less than expected (Table 8), suggesting that, similar to the observation for the Merino breed, the wool fineness of Polwarth lambs is no longer a relevant factor influencing the selection of breeders. However, producing long and tall Polwarth lambs seems to meet the preference of buyers in terms of liquidity, although these phenotypic characteristics are not accompanied by high prices at the time of sale.

In the Corriedale breed, as expected, long lambs were sold at a higher (R$ 1,963.40; P<0.0001) average selling price than the short ones (R$ 1,656.38); similarly, tall lambs were sold at a higher (R$ 1,915.02; P = 0.0021) average selling price than the small ones (R$ 1,698.20). These results suggest that Corriedale

lamb buyers prefer the longer and taller animals over the shorter and smaller ones. Conversely, the average selling price did not differ in correlation with wool fineness, which can perhaps be explained by the greater focus on meat production than on wool production; this lack of correlation seems to be a current trend for the Corriedale breed. The liquidity of Corriedale lambs was also greater (P = 0.0478) for the long animals than for the short ones (Table 9), which corroborates the idea that a long-lined sire is more desirable and valued in the Corriedale breed. However, the data did not show any correlation between liquidity and height or wool fineness of lambs (Table 9).

It seems that fineness of fleece wool has become less important in the phenotypic evaluation of breeders when compared with other characteristics, such as height and body length, at least for Corriedale breed. This is possibly because greater size and final live weight of the lambs produced is valued primarily, and the annual squirrel of the flock's wool is not as profitable. When the focus of production is lamb meat, they are marketed between four and eight months old and their wool has no significant commercial value (at this age). Even in the breeds investigated in the present paper, wool only has significant commercial value from 12 months old, and traditionally 1 kg of wool is paid to the squirrel.

In the last few years, the wool market has shown great variability in the price raised by the sheep farmer. This lack of consistency affects the profitability of the activity negatively and limits investment planning, for example, in improvements in nutrition and the use of technologies. Herds of the breeds evaluated in the present study produced, on average, three kilograms of fleece wool/sheep/year (Amarilho-Silveira et al., 2015). The amount paid annually for the lamb carcass produced was thus significantly higher compared with the profitability from wool production, even in the Merino breed. This results in the sheep farmer attributing less relevance to the fineness of the fleece wool when selecting breeders, and rather prioritizing larger size and body volume, projecting value from the progeny of precocious and heavy lambs. The results of the present study corroborate this common understanding. There were breeding lambs with fleece wool fineness non-compliant with the breed standard in the three breeds analyzed; despite this, the liquidity and average selling price did not suffer in comparison with those with finer wool fleece, within the breed standards.

The state of RS produced 94.2% of total wool produced in Brazil in 2020. Wool production in Brazil has been decreasing in recent years, from 9.7 million kilograms in 2016 to 7.9 million kilograms in 2020 (Magalhães et al., 2021). These data demonstrate that there has been a gradual change in the nature of sheep farming in RS, which is trending strongly towards meat production. There is added value for specific market niches and, in many cases, for the subsistence of small-scale farmers and their families.

While wool is a product increasingly aimed at specific niche markets, sheep meat feeds a variety of markets and is more accepted by the most demanding consumers in a range of markets (EMBRAPA, 2018).

In addition to the phenotypic criteria, as investigated in the present study, genotypic traits have great relevance in animal selection. Molecular markers, for example, have been adopted as "another tool" for the selection of bovine breeders, whose frozen semen is commercialized on a large scale (Ferreira et al., 2021). However, genotypic selection in sheep species is not yet a reality in Brazil and presents a promising avenue for research. Farmers will become more successful acquiring breeding stock for their herds when information based on both phenotype and genotype is evaluated and made readily available.

Further studies are needed to identify which criteria are relevant for farmers selecting breeders for their herds. In this way, breed associations and sheep farmers will be able to establish a new standard based on the characteristics most desired by the breeder of each breed, with a view to efficient and profitable animal production. More studies are also necessary to explore genotypic and phenotypic characteristics related to price of commercialization of male lambs to direct selection criteria and, thus, increase liquidity and profitability by sheep farmers. Finally, updated studies seem to be important to characterize sheep farming and its related industry in Brazil.

5. Conclusions

The average selling price of the Merino, Polwarth, and Corriedale lamb sires in Uruguaiana, RS, is not influenced by the breed. Most Corriedale lambs offered are sold, indicating a good preference by sheep farmers, especially for the taller and longer ones. Polwarth lambs have low liquidity. Wool fineness is no longer a relevant criterion for sheep farmers from Uruguaiana in terms of the choice, liquidity, and selling price of sire lambs of the three evaluated breeds.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

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