Performance of Hair Breeds and Prolific Wool Breeds of Sheep in Southern Illinois: Wool Production and Fleece Quality[1,2,3,4]

R. Bunge[5], D. L. Thomas[6], T. G. Nash, and C. J. Lupton[7]

Department of Animal Sciences, University of Illinois, Urbana 61801

ABSTRACT: The objective of this study was to compare weight and quality of fleeces of different F_1 ewe types produced from breeds with a broad range of fleece types. Weights of 629 fleeces produced during 1988 through 1991 from F_1 ewes that were daughters of Suffolk and Targhee dams and Finnsheep, Combo-6, Booroola Merino, St. Croix, and Barbados sires were recorded. Staple length was measured on the mid-side of each ewe present in 1991. Fleeces shorn in 1991 were sent to a wool marketing organization, and staple length, wool grade, and clean fleece yield were subjectively estimated (n = 220). Mid-side fleece samples were collected from no more than two randomly selected ewes from each subclass (breed of dam-breed of sire-age of ewe) in 1991 (n = 78) and sent to a wool laboratory where fiber diameter, yield, and percentage of colored, med, and kemp fibers were objectively determined. Ewes from Targhee dams produced fleeces with greater weight, greater fiber length, smaller fiber diameter, lower yield, and fewer colored fibers than ewes from Suffolk dams (all differences significant, $P < .01$). Booroola Merino-sired ewes produced heavier ($P < .01$) fleeces than did Finnsheep- and Combo-6-sired ewes (4.13 and 3.09 kg, respectively), and in turn, Finnsheep- and Combo-6-sired ewes produced heavier ($P < .01$) fleeces than did ewes sired by hair breed rams (3.09 and 1.70 kg, respectively). Among hair breed-sired ewes, St. Croix-sired ewes produced heavier ($P < .01$) fleeces than did Barbados-sired ewes (1.88 and 1.52 kg, respectively). Fleeces produced by Booroola Merino-sired ewes had smaller ($P < .01$) fiber diameter than all sire breed groups except Combo-6-sired ewes, and fleeces produced by St. Croix-sired ewes had greater ($P < .01$) fiber diameter than all other sire breed groups. Lab scoured yield was greater ($P < .01$) for fleeces from ewes from hair breed than for fleeces from ewes from wool breed sires (74.2 vs 66.1%). Proportions of undesirable fibers (med, kemp, and colored) were 20 to 600 times greater ($P < .01$) in fleeces of ewes from hair breed sires than in fleeces of ewes from wool breed sires. In general, F_1 ewes from Booroola Merino sires produced the heaviest, highest quality fleeces, and ewes from the hair breed sires of St. Croix and Barbados produced the lightest, lowest quality fleeces. Ewes from Finnsheep and Combo-6 sires produced fleeces that were more similar to the fleeces of ewes from Booroola Merino sires than to the fleeces of ewes from the hair breed sires.

Key Words: Sheep, Wool, Barbados, St. Croix, Finnsheep, Booroola Merino

J. Anim. Sci. 1996. 74:25–30

Introduction

Previous papers in this series have described lamb production of Suffolk and Targhee ewes when mated to Finnsheep, Combo-6, Booroola Merino, St. Croix, and Barbados rams (Bunge et al., 1993b) and lamb

[1]Project 340 of the Illinois Agric. Exp. Sta. and contribution to regional project NC-111 “Increased Prolificacy in Sheep and Its Impact on Nutritional Needs.” This study contributed to NC-111’s comparison of the Finnsheep and Booroola Merino breeds. Larry Young, U.S. Meat Animal Research Center, Clay Center, NE, is thanked for use of Finnsheep and Booroola Merino rams.

[2]This research was partially supported by grant no. US-1153-86 from BARD, The United States—Israel Binational Agricultural Research and Development Fund.

[3]Staff at the Dixon Springs Agricultural Center are thanked for data collection and animal management.

[4]The authors acknowledge and thank the collaboration of Dick Boniface, former Director of Field Services, North Central Wool Marketing Corp., Minneapolis, MN, for collection of commercial fleece data, and Claudino and Maria Matos for collection of fleece samples and measurement of staple length.

[5]Present address: Belgrano 271 5°, 1092 Capital Federal, Argentina.

[6]To whom correspondence should be addressed. Present address: Dept. of Meat and Anim. Sci., University of Wisconsin, 1675 Observatory Dr., Madison 53706.

[7]Texas A&M University Wool and Mohair Research Laboratory, San Angelo 76901.

Received December 29, 1994.

Accepted September 26, 1995.

production of the resulting F_1 ewes when mated to Dorset rams (Bunge et al., 1993a, 1995). These sire breeds represented the full range of fleece quantity and quality, from the fine-wooled Booroola Merino to the coarse, medullated hair sheep of the St. Croix and Barbados breeds. Wool is an additional source of income in most sheep operations and can represent 15 to 25% of gross income (Hohenboken 1976; Cedillo et al., 1977). Therefore, breed effects for traits that influence fleece value should be a consideration when selecting breeds for a crossbreeding system. The objective of this study was to compare weight and quality of fleeces of different F_1 ewe types produced from breeds with a broad range of fleece types.

Materials and Methods

The sheep were produced and maintained at the University of Illinois Dixon Springs Agricultural Center (DSAC) located in southern Illinois (37° 26′ N latitude and 88° 40′ W longitude). The area has hot, humid summers with high rainfall and cool winters with moderate amounts of snow. Temperatures vary from a high of 35.6°C in the summer to a low of –21.7°C in the winter. In the autumns of the 4 yr of 1985 through 1988, flocks of Suffolk and Targhee ewes were exposed to rams of the following five breeds: Finnsheep, Combo-6 (synthetic composed of Suffolk, Finnsheep, Dorset, Rambouillet, Targhee and Border Leicester breeding), Booroola Merino, St. Croix, and Barbados. Three different rams of each breed were used each year (12 total rams per breed). Origins of the rams and ewes were reported by Bunge et al. (1993b). The F_1 ewe lambs from these matings were retained and lambed annually in the late winter-early spring through 1991. Ewes were shorn annually in the winter before lambing. A total of 629 fleece weight observations were available from 2-, 3-, 4-, and 5-yr-old F_1 ewes (Table 1). Fleece weights were corrected to a 365-d growth period using the current and previous shearing dates and actual fleece weight. Daily fleece growth was calculated and multiplied by 365.

The day before shearing in 1991, mid-side staple length of the fleece was measured on all ewes by gently parting the fleece on the side of the ewe, placing a ruler on the skin surface, and recording the length of fleece. Immediately after recording staple length, mid-side fleece samples weighing approximately .5 kg were sheared from not more than two randomly selected ewes from each of the 40 subclasses (breed of sire-breed of dam-age of ewe). These 78 samples (two of the 5-yr-old subclasses were represented by only one ewe) were sent to the Texas A&M University Wool and Mohair Research Laboratory, San Angelo, where objective measures of average fiber diameter (microns (μm), Lynch and Michie, 1976), lab scoured yield (percentage, ASTM, 1990a), and colored, med, and kemp fibers (percentage, ASTM, 1990b) were determined for each sample. Subsequent fleece weights of ewes that contributed mid-side fleece samples were not adjusted for weight of the sample.

Fleeces (n = 235) from the 1991 shearing were sent to the North Central Wool Marketing Corp. (Minneapolis, MN) where subjective wool grades, staple lengths, and clean fleece yields were estimated (n = 220). No subjective evaluations were available for 15 fleeces that lost their identification at the wool warehouse. The subjective wool grades were spinning counts, which can range from 80 to 36 with larger values assigned to fleeces with smaller estimated fiber diameter (ASTM, 1990c). Commercial, subjective estimates of fleece characteristics are important because, in the absence of objective measurements, they determine the market value of fleeces. For fleeces that contained a substantial amount of hair, commercial grade was based only on wool fibers present and not on the hair. Actual and estimated mid-side staple

Table 1. Number of F_1 ewes shorn by year of birth, year of shearing, age, and breed of sire

Year of birth	Year of shearing	Age, yr	Breed of sire					Total
			Finnsheep	Combo-6	B. Merino	St. Croix	Barbados	
1986	1988	2	5	11	12	17	7	52
	1989	3	5	9	11	15	7	47
	1990	4	4	8	8	11	7	38
	1991	5	3	6	8	9	6	32
1987	1989	2	13	18	14	24	23	92
	1990	3	11	17	14	23	21	86
	1991	4	11	15	11	18	16	71
1988	1990	2	13	21	13	18	14	79
	1991	3	12	18	12	15	12	69
1989	1991	2	18	7	10	12	16	63
Total			95	130	113	162	129	629

lengths were corrected to a 365-d growth period.

The animal model used to analyze fleece weight was as follows:

Y = age of ewe-year of shearing + breed of dam (**BOD**) + breed of sire (**BOS**) + BOD × BOS + important (P < .10) two-way interactions with age of ewe-year of shearing + ewe_a + ewe_p + error.

Main fixed factors in the model were age of ewe-year of shearing (2-1988, 2-1989, 3-1989, 2-1990, 3-1990, 4-1990, 2-1991, 3-1991, 4-1991, and 5-1991), BOD (Suffolk and Targhee), and BOS (Finnsheep, Combo-6, Booroola Merino, St. Croix, and Barbados). Because 71% of ewes had repeated fleece weight records, the random factor of ewe was separated into ewe_a (ewe's additive genetic effect distributed $N(0,\mathbf{A}\sigma_a^2)$, where **A** = numerator relationship matrix and σ_a^2 = variance of additive genetic effects) and ewe_p (ewe's permanent environmental effect). In the analyses of the other wool traits, data were available only for fleeces sheared in 1991, so the factors of year of shearing and ewe_p were dropped from the model.

Best linear unbiased estimates (**BLUE**) of the means of levels of each fixed factor, averaged over levels of other fixed factors, for each trait were obtained using the PEST software program (Groeneveld and Kovac, 1990a,b). Differences of interest were those among years of production, among 2-, 3-, 4-, and 5-yr-old ewes, between ewes with Suffolk or Targhee dams, among ewes sired by the five breeds of sire, between ewes sired by hair breed vs wool breed sires, and among breed of sire-breed of dam combinations. The null hypotheses that the differences were equal to zero were tested by the general linear hypothesis procedures in PEST. Single-trait estimates of variance components were estimated using the DFREML program (Meyer, 1989) for use in PEST. Because the variances were not known but estimated, the estimates of the various fixed effects were not strictly BLUE. However, throughout this paper the term BLUE is used for these estimates instead of the more correct but more cumbersome term of "approximate BLUE."

Partial correlation coefficients between measured and estimated staple length, measured fiber diameter and estimated wool grade, and measured and estimated yield were determined using the MANOVA option of the GLM procedure (SAS, 1985), fitting age of ewe, BOS, BOD, and the BOS × BOD interaction.

Results and Discussion

Correlations Between Measured and Estimated Values. Partial correlation coefficients were estimated between staple length measured at the mid-side on the sheep before shearing at DSAC and visually estimated from the whole fleece at North Central Wool Marketing Corp., between fiber diameter measured from mid-side samples at the Texas A&M University Wool and Mohair Research Laboratory and wool grades visually estimated from the whole fleece at the North Central Wool Marketing Corp., and between lab scoured yields from mid-side samples at the Texas A&M University Wool and Mohair Research Laboratory and yields visually estimated from the whole fleece at the North Central Wool Marketing Corp. Correlations were based on data from fleeces of the 78 ewes randomly selected for mid-side sampling. These correlations were of interest because they provide information on how laboratory values for fleece samples compare with commercial visual estimates on the whole fleece. Fleece value for many U.S. producers is determined by a visual evaluation of the fleece.

The partial correlation coefficients were very low to moderate in size. Correlations between measured and estimated staple length (.42) and between measured fiber diameter and fleece grade (−.29) were different from zero (P < .01 and P < .05, respectively); however, the correlation between calculated and estimated yield was very low (.01) and not different from zero. Because differences between fibers in length and diameter can be visually discerned to a certain extent, but fleece yield cannot be directly visualized, the relative size of the absolute values of these partial correlation coefficients is not too surprising. Lack of large correlations between any of the measured and estimated values suggests that visual assessment of fleeces for length, grade, and yield is not accurate and that objective measures of these traits should be used. Throughout the remainder of this paper, only the measured values will be reported.

Age of Ewe-Year of Shearing. For the trait of fleece weight, age of ewe and year of shearing are partially confounded, and age of ewe-year of shearing subclass was fit to the model used to analyze fleece weight to account for the joint effects of these two factors. However, the main effect of age of ewe on fleece weight is of more interest than the joint effect of age of ewe and year of shearing, so the BLUE for age of ewe (averaged over year of shearing) was calculated (Table 2). Age of ewe had a significant effect on fleece weight (P < .05). Fleece weights increased with age, peaked at 3 yr of age (3.02 kg), and then decreased. Fahmy (1987) working with purebred and crossbred Finnsheep ewes and Atkins (1990) working with Australian Merino ewes also found that fleece weight peaked at 3 yr of age. Actual staple length decreased as age increased to 4 yr of age and then increased in 5-yr-old ewes. Vesely et al. (1965) also observed that younger ewes produced longer stapled fleeces than older ewes.

Two-year-old ewes produced fleeces with a smaller (P < .05) fiber diameter than ewes of the other ages.

Table 2. Best linear unbiased estimates ± SE of age of ewe for wool traits of F_1 ewes

	Age, yr			
Trait	2	3	4	5
Fleece weight, kg	2.58 ± .05^{f}	3.02 ± .06^{d}	2.70 ± .07^{e}	2.59 ± .12^{ef}
Actual staple length, cm	12.78 ± .34^{a}	10.81 ± .32^{b}	8.35 ± .30^{c}	10.88 ± .47^{b}
Fiber diameter, μm	26.14 ± .49^{f}	28.23 ± .49de	27.12 ± .49^{e}	28.79 ± .56^{d}
Lab scoured yield, %	67.63 ± 1.5^{ef}	70.57 ± 1.5^{de}	66.15 ± 1.5^{f}	72.92 ± 1.6^{d}
Colored fibers, %	.16 ± .16	.25 ± .16	.18 ± .16	.42 ± .18
Med fibers, %	1.37 ± 1.2^{e}	.94 ± 1.2^{e}	1.02 ± 1.2^{e}	5.8 ± 1.4^{d}
Kemp fibers, %	.51 ± .24	.20 ± .24	.34 ± .24	.67 ± .25

[a,b,c]Within a row, values lacking a common superscript letter differ ($P < .01$).
[d,e,f]Within a row, values lacking a common superscript letter differ ($P < .05$).

Atkins (1990) also found that 2-yr-old ewes had a smaller fiber diameter than older ewes, but Vesely et al. (1965) reported that age of ewe had no significant effect on fiber diameter or wool grade. Age of ewe had a significant ($P < .05$) effect on lab scoured yield, but no particular pattern was evident as ewe age increased. Though Fahmy (1987) found no significant effect of age of ewe on clean fleece yield, Vesely et al. (1965) reported a significant decrease in yield as age of ewe increased.

Age of ewe had no significant effect on proportion of colored or kemp fibers. However, fleeces of 5-yr-old ewes had approximately four to six times ($P < .05$) as many med fibers as fleeces of 2-, 3-, or 4-yr-old ewes. It is difficult to believe that such a large change in med fibers in one year is a true age effect. Because each age group was produced by a different group of sires, it is possible that the sires used to produce the 5-yr-old ewes had high breeding values for proportion of med fibers.

Breed of Dam. The BLUE of breed of dam for wool traits of F_1 ewes are presented in Table 3. Fleeces of F_1 ewes from Targhee dams were .84 kg heavier ($P < .01$) than fleeces from ewes having Suffolk dams. In studies with purebred ewes, Sidwell et al. (1971) found that Targhee yearling ewes produced fleeces that were 2 kg heavier than those from Suffolk yearlings, and Dickerson (1977) reported .8 kg heavier clean fleece weights from Targhee ewes than from Suffolk ewes. Ewes from Targhee dams produced fleeces of greater ($P < .01$) actual staple length. In the study by Sidwell et al. (1971), Targhee ewes had fleece staple length of 12.4 cm, whereas Suffolk ewes had fleece staple length of 9.8 cm. Fleeces of ewes from Targhee dams had a smaller ($P < .01$) fiber diameter than fleeces of ewes from Suffolk dams. These results agree with those of Sidwell et al. (1971), who reported a 7-μm difference in fiber diameter between purebred Targhee and Suffolk ewes.

Table 3. Best linear unbiased estimates ± SE of breed of dam for wool traits of F_1 ewes

	Breed of dam	
Trait	Suffolk	Targhee
Fleece weight, kg	2.32 ± .06^{b}	3.16 ± .06^{a}
Actual staple length, cm	10.24 ± .27^{b}	11.17 ± .22^{a}
Fiber diameter, μm	29.54 ± .36^{a}	25.60 ± .36^{b}
Lab scoured yield, %	72.42 ± 1.1^{a}	66.21 ± 1.1^{b}
Colored fibers, %	.49 ± .12^{a}	.02 ± .11^{b}
Med fibers, %	2.49 ± .86	2.07 ± .86
Kemp fibers, %	.57 ± .16	.28 ± .16

[a,b]Within a row, values lacking a common superscript letter differ ($P < .01$).

Ewes from Targhee dams produced fleeces with approximately 6 percentage units lower ($P < .01$) actual yield of clean fleece than ewes from Suffolk dams. Fleeces of ewes from Suffolk dams had a higher ($P < .01$) percentage of colored fibers than did fleeces of ewes from Targhee dams, which is a result of the Suffolk being a “black-faced” breed, whereas the Targhee is an unpigmented “white-faced” breed. Breed of ewe had no significant effect on the percentage of med or kemp fibers.

Breed of Sire. The BLUE of breed of sire for wool traits are presented in Table 4. The effect of breed of sire was significant ($P < .01$) for all traits analyzed. The F_1 ewes from Booroola Merino sires produced fleeces weighing 4.13 kg, which was approximately 1 kg heavier ($P < .01$) than fleeces produced by F_1 ewes from Finnsheep and Combo-6 sires and more than 2 kg heavier ($P < .01$) than fleeces produced by F_1 ewes from St. Croix and Barbados sires. The hair vs wool breed contrast indicated that fleeces from hair breed-sired ewes were 1.73 kg lighter than fleeces from wool breed sired-ewes. Young and Dickerson (1987) also reported heavier fleece weights for Booroola Merino-cross ewes compared with Finnsheep-cross ewes (3.9 and 3.2 kg, respectively). In a study involving crosses between DLS (a Dorset, Leicester, Suffolk synthetic) ewes and Finnsheep and Booroola Merino rams, Fahmy (1990) reported heavier grease fleece weights for Booroola Merino than for Finnsheep crossbred ewes (3.7 and 3.2 kg, respectively).

With a measured staple length of nearly 11 cm, fleeces from F_1 ewes sired by Finnsheep rams had a

Table 4. Best linear unbiased estimates ± SE of breed of sire for wool traits of F_1 ewes

	Breed of sire					
Trait	Finnsheep	Combo-6	Booroola Merino	St. Croix	Barbados	Contrast of: Hair − Wool
Fleece weight, kg	3.07 ± .12[b]	3.11 ± .10[b]	4.13 ± .10[a]	1.88 ± .09[c]	1.52 ± .11[d]	−1.73 ± .11[e]
Actual staple length, cm	10.96 ± .33[a]	9.18 ± .30[b]	9.05 ± .27[b]	9.64 ± .25[b]	8.94 ± .27[b]	−.58 ± .36[e]
Fiber diameter, μm	27.57 ± .60[b]	27.04 ± .57[bc]	24.94 ± .55[c]	30.45 ± .57[a]	27.86 ± .55[b]	2.64 ± .11[e]
Lab scoured yield, %	72.32 ± 1.8[a]	64.39 ± 1.7[b]	61.50 ± 1.6[b]	73.68 ± 1.7[a]	74.69 ± 1.6[a]	8.12 ± 1.5[e]
Colored fibers, %	.02 ± .19[b]	.02 ± .18[b]	.00 ± .18[b]	.44 ± .18[ab]	.79 ± .18[a]	.60 ± .17[e]
Med fibers, %	.07 ± 1.5[b]	.02 ± 1.4[b]	.01 ± 1.3[b]	5.97 ± 1.4[a]	5.36 ± 1.3[a]	5.06 ± 1.3[e]
Kemp fibers, %	.04 ± .29[b]	.05 ± .27[b]	.03 ± .27[b]	.88 ± .27[ab]	1.16 ± .27[a]	.98 ± .25[e]

[a,b,c,d]Within a row, values lacking a common superscript letter differ ($P < .01$).
[e]($P < .01$).

longer ($P < .01$) staple length than fleeces from F_1 ewes sired by the other breeds of sire. Cedillo et al. (1977) reported that 1/2 Finnsheep (and 1/2 Columbia or 1/2 Suffolk) ewes produced fleeces with longer staple length than other crossbred types in the study (1/2 Romney, 1/2 North Country Cheviot, or 1/2 Dorset and 1/2 Columbia or 1/2 Suffolk). Fahmy (1987) reported that fleeces from Finnsheep-sired ewes had a staple length of 13.7 cm, which was longer than that of purebred DLS ewes. The hair vs wool breed contrast is of little meaning because the longer ($P < .01$) staple length of the fleeces from wool breed-sired ewes is a result of the longer staple length of fleeces from Finnsheep-sired ewes alone. The other two wool breed-sired groups actually had fleeces with shorter average staple length than the average of the two hair breed-sired groups.

Fleeces of F_1 ewes with St. Croix sires had greater ($P < .01$) fiber diameter than fleeces from ewes from the other sire breeds. Booroola Merino crossbred ewes produced fleeces with the smallest fiber diameter, but they were not significantly different for this trait from Combo-6-sired ewes. Mason (1980) reported 32.4 μm as the mean fiber diameter for fleeces from Barbados Blackbelly ewes, which is slightly more than the value determined in this study for Barbados-sired ewes. This seems reasonable, because the Barbados-sired ewes in this study were of 50% wool breeding. On average, fleeces of ewes with hair breed sires had 2.6 μm greater ($P < .01$) fiber diameter than fleeces of ewes with wool breed sires.

Fleeces produced by F_1 ewes sired by hair breed rams had 8.1 percentage units greater ($P < .01$) actual yield than fleeces of ewes sired by wool breed rams. Among the ewes with wool breed sires, Finnsheep-sired ewes had the greatest ($P < .01$) yielding fleeces. This result is somewhat supported by the results of Cedillo et al. (1977), who reported a 71% yield for fleeces of Finnsheep crossbred ewes, which was greater than for any other crossbred group in their study.

On the average, fleeces of ewes with hair breed sires had a greater ($P < .01$) percentage of colored, med, and kemp fibers than fleeces of ewes with wool breed sires. Because white wool is normally discounted for the presence of colored and medullated fibers, it is obvious that hair sheep crossbreeding will produce wool that is less valuable than that produced by Finnsheep, Combo-6, or Booroola Merino crosses.

Breed of Sire × Breed of Dam Interactions. A significant breed of sire × breed of dam interaction was found for the percentage of colored fibers. The BLUE for breed of sire-breed of dam combinations for this trait are presented in Table 5. Ewes with Targhee dams produced fleeces with few colored fibers, even when they had hair breed sires. Ewes with Suffolk dams and wool breed sires had fleeces with small amounts of colored fibers, similar to fleeces from ewes with Targhee dams. However, 1/2 Suffolk ewes with hair breed sires produced fleeces with a large amount of colored fibers. It seems that in order to reduce the incidence of colored fibers in the fleeces of hair breed-wool breed crosses, white-faced instead of black-faced wool breeds should be used.

Table 5. Best linear unbiased estimates ± SE of breed of sire and breed of dam combination for percentage of colored fibers in fleeces of F_1 ewes

Breed of sire-breed of dam	Colored fibers, %
Finnsheep-Suffolk	.02 ± .27[b]
Combo-6-Suffolk	.05 ± .27[b]
Booroola Merino-Suffolk	.01 ± .25[b]
St. Croix-Suffolk	.88 ± .25[ab]
Barbados-Suffolk	1.53 ± .25[a]
Finnsheep-Targhee	.02 ± .26[b]
Combo-6-Targhee	.00 ± .25[b]
Booroola Merino-Targhee	.00 ± .25[b]
St. Croix-Targhee	.01 ± .26[b]
Barbados-Targhee	.06 ± .25[b]

[a,b]Values lacking a common superscript letter differ ($P < .01$).

Implications

Fleeces from F_1 ewes from the three wool breeds of Finnsheep, Combo-6, and Booroola Merino and the two hair breeds of St. Croix and Barbados were evaluated. Among the wool breeds, Booroola Merino-sired ewes would be expected to have greater wool production of superior value than either Combo-6- or Finnsheep-sired ewes. The use of hair breed-wool breed crossbred ewes will result in a significant decrease in wool production and commercial value. There is currently little or no demand for fleeces produced by hair breed-cross sheep. For hair breed-cross ewes to be used effectively in commercial production systems, they must produce more weight of lamb than wool breed ewes in order to compensate for the lower value of their fleece.

Literature Cited

ASTM. 1990a. Standard test method for wool content of raw wool-laboratory scale. American Society for Testing and Materials, Desig. D 584-90. Sec. 7. Vol. 07.01:193. ASTM, Philadelphia, PA.

ASTM. 1990b. Standard test method for med and kemp fibers in wool and other animal fibers by microprojection. American Society for Testing and Materials, Desig. D 2968-89. Sec. 7. Vol. 07.07:812. ASTM, Philadelphia, PA.

ASTM. 1990c. Standard specifications for fineness of wool or mohair and assignment of grade. American Society for Testing and Materials, Desig. D 3991-85. Sec. 7. Vol. 07.02:226. ASTM, Philadelphia, PA.

Atkins, K. D. 1990. Incorporating parameters for lifetime productivity into breeding objectives for sheep. Proc. 4th. World Congr. on Genet. Appl. to Livest. Prod. Edinburgh, U.K. XV:17.

Bunge, R., D. L. Thomas, and T. G. Nash. 1993a. Performance of hair breeds and prolific wool breeds of sheep in southern Illinois: Lamb production of F_1 ewe lambs. J. Anim. Sci. 71:2012.

Bunge, R., D. L. Thomas, and T. G. Nash. 1995. Performance of hair breeds and prolific wool breeds of sheep in southern Illinois: Lamb production of F_1 adult lambs. J. Anim. Sci. 73:1602.

Bunge, R., D. L. Thomas, T. G. Nash, and R. L. Fernando. 1993b. Performance of hair breeds and prolific wool breeds of sheep in southern Illinois: Effect of breed of service sire on lamb production of Suffolk and Targhee ewes. J. Anim. Sci. 71:321.

Cedillo, R. M., W. Hohenboken, and J. Drummond. 1977. Genetic and environmental effects on age at first estrus and on wool and lamb production of crossbred ewe lambs. J. Anim. Sci. 44: 948.

Dickerson, G. E. 1977. Crossbreeding evaluation of Finnsheep and some U.S. breeds for market lamb production. North Central Reg. Publ. No. 246.

Fahmy, M. H. 1987. The accumulative effect of Finnsheep breeding in crossbreeding schemes: Wool production and fleece characteristics. Can. J. Anim. Sci. 67:1.

Fahmy, M. H. 1990. Growth, fertility, prolificacy and fleece weight of Booroola, Romanov and Finnsheep first cross and backcross with the DLS breed. Proc. 4th. World Congr. on Genet. Appl. to Livest. Prod. Edinburgh, U.K. XV:369.

Groeneveld, E., and M. Kovac. 1990a. A generalized computing procedure for setting up and solving mixed linear models. J. Dairy Sci. 73:513.

Groeneveld, E., and M. Kovac. 1990b. PEST, a general purpose BLUP package for multivariate prediction and estimation. 4th World Congr. on Genet. Appl. to Livest. Prod. Edinburgh, U.K. XIII:488.

Hohenboken, W. D. 1976. Genetic, environmental and interaction effects in sheep. III. Wool production and gross income per ewe. J. Anim. Sci. 42:317.

Lynch, L. J., and N. A. Michie. 1976. An instrument for the rapid measurement of fiber fineness distribution. Text. Res. J. 46: 653.

Mason, I. L. 1980. Prolific Tropical Sheep. FAO Animal Production and Health Paper 17. United Nations, Rome, Italy.

Meyer, K. 1989. Restricted maximum likelihood to estimate variance components for animal models with several random effects using a derivative-free algorithm. Genet. Sel. Evol. 21:317.

SAS. 1985. SAS User's Guide: Statistics (Version 5 Ed.). SAS Inst. Inc., Cary, NC.

Sidwell, G. M., R. L. Wilson, and M. E. Hourihan. 1971. Production in some pure breeds of sheep and their crosses. IV. Effect of crossbreeding on wool production. J. Anim. Sci. 32:1099.

Vesely, J. A., H. F. Peters, and S. B. Slen. 1965. The effects of breed and certain environmental factors on wool traits of range sheep. Can. J. Anim. Sci. 45:91.

Young, L. D., and G. E. Dickerson. 1987. History and current status of Booroola Merino flock at MARC. USDA ARS-68:3.