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# Hair Sheep Genetic Resources and Their Contribution to Diversified Small Ruminant Production in the United States<sup>1,2</sup>

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**ABSTRACT:** Two Caribbean hair sheep breeds, the St. Croix (SC) and Barbados Blackbelly (BB), are found in the United States, and the SC has led to the development of the Katahdin (K), a synthetic breed of hair sheep. These breeds have mature ewe BW ranging from 32 to 54 kg (for BB and SC) and from 55 to 73 kg (K). Hair sheep and hair sheep crosses have lower rectal temperatures and respiration rates than wool breeds and a lower DMI and water intake. There are indications of increased resistance to internal parasites in hair sheep. Although hair sheep are seasonal breeders under U.S. photoperiodic conditions, they tend to perform better under accelerated lambing systems than traditional wool breeds. Fertility, prolificacy, and lamb survival is high in BB and SC, but hair × wool crossbred ewes tend to have a higher

level of fertility than hair and wool parent breeds. Ewe productivity is also higher in hair × wool crosses than in wool crosses, particularly when adjusted for ewe BW or under accelerated lambing systems. Hair sheep have a lower ADG and intake of high-energy diets, as well as a lower gain/feed ratio, than wool breeds. Growth rates tend to be higher in SC than in BB. Differences in carcass characteristics are inconsistent between hair and wool breeds. Production characteristics of hair sheep, particularly hair × wool crosses, make them suitable for low-input, sustainable production systems that do not require high growth rates and large carcasses. There is a need to preserve the existing U.S. hair sheep germplasm base in support of such systems.

Key Words: Sheep, Adaptation, Reproductive Performance, Growth Rate, Carcass Quality

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## Introduction

Hair sheep comprise approximately 10% of the world sheep population (Bradford and Fitzhugh, 1983) and originate and are located predominantly in the tropical regions of Africa, South America, and the Caribbean. Their hair coat and other adaptive characteristics make them uniquely qualified to be productive under hot and humid environmental conditions. Hair sheep in the Caribbean are prolific and breed throughout the year (Fitzhugh and Bradford, 1983a) and as such are of interest to the U.S. sheep industry, particularly in the southeast.

This review seeks to summarize research characterizing the performance of hair sheep breeds and their crosses under varying production environments

in the United States. Based on these findings, an attempt is made to define a role that hair sheep may play for lamb production in the United States.

## Hair Sheep Breeds

An overview and brief description of different hair sheep breeds has been provided in books by Mason (1980) and Fitzhugh and Bradford (1983a). Additional descriptions of hair sheep breeds, focusing on breed resources of South and Central America and the Caribbean, are found in reviews by Figueiredo et al. (1990) and Thomas (1991). The following is a brief description of hair sheep breeds with immediate relevance for U.S. sheep production.

**Barbados Blackbelly.** The Barbados Blackbelly (**BB**) found in the United States are considered to be the result of an importation from the Caribbean by the USDA in 1904. Although initially brought to Maryland, they established themselves predominantly on the Edwards Plateau in Texas, where numbers as high as 300,000 may have been present in the 1970s (Shelton, 1983b). Today their numbers are drastically reduced and no official census figures are available for

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the breed (Bixby et al., 1994). Research flocks of this breed have been or are present at North Carolina State University, Texas A&M University, Mississippi State University, Ohio State University, and in California. The U.S. BB population differs from its Caribbean ancestors due to the crossbreeding, primarily with Moulton and Rambouillet, that followed importation. As a result, U.S. BB males carry horns and ewes are considered less prolific than those found in Barbados. Barbados Blackbelly sheep have a light to dark-reddish brown color with conspicuous black markings and underbelly (badger face). Mature ewe BW of Caribbean Blackbelly range from 32 to 44 kg, and ewe lambs reach puberty around 215 d of age at a BW of 25 kg (Wildevs et al., 1995). Mature BB ewes have a prolificacy of 184% with 78.5% lamb survival to weaning (Fitzhugh and Bradford, 1983b). On the U.S. mainland ewe BW of 30 to 43 kg have been reported (Boyd, 1983; Shelton, 1983b) with prolificacy ranging from 147 (Shelton, 1983b) to 181% (Levine and Spurlock, 1983).

**St. Croix.** The St. Croix sheep (SC) population on the U.S. mainland is a result of a 1975 importation of 22 Virgin Islands White ewes and three rams, selected from three flocks based on white coat color, lack of wool, and above-average size and conformation (Foote, 1983). Following some initial multiplication in Utah, ewes were dispersed to research flocks in Ohio and Florida as part of a performance evaluation program. Sire lines were established to prevent inbreeding. After the initial dispersal more animals were made available to other research flocks and the breed was eventually made commercially available. In 1990, 300 animals were registered in the United States (Bixby et al., 1994).

Virgin Islands White populations from which SC were selected are found on the British and U.S. Virgin Islands, where they were developed from West African stock with a possible influence of the Wiltshire Horn (Faulkner, 1962; Devendra, 1977). Hupp and Deller (1983) reported ewe BW of 35 to 45 kg with a prolificacy of 144 to 189% in commercial flocks on St. Croix, displaying a wide range in phenotypes and color patterns between flocks. Subsequent data collected on St. Croix over 5 yr in a research setting indicated an average ewe BW of 37 kg with a prolificacy of 166% and 85% lamb survival to weaning at 9 wk (Wildevs et al., 1991c). Ewe lambs reached puberty between 6 and 9 mo of age depending on plane of nutrition (Evans et al., 1991) and season of birth (Wildevs et al., 1995). Under temperate climatic conditions of the U.S. mainland ewes achieved higher BW, ranging from 36 kg in Florida to 54 kg in Utah (Foote, 1983), with a prolificacy of 150 to 212%, dependent on location and management system (Foote, 1983; Parker et al., 1991; Wildevs et al., 1991c). Under temperate conditions, SC ewe lambs reached puberty earlier ( $P < .05$ ; 150 to 175 d) and at a lighter BW (30

to 36 kg) than Rambouillet and Suffolk ewes (Evans et al., 1991).

**Katahdin.** The Katahdin breed (K) was developed in Maine in the 1950s from crosses of Virgin Islands White with various British breeds, particularly the Wiltshire Horn and Suffolk. Selection has been for growth rate, mutton conformation, prolificacy, and against horns and wool. Animals are mostly white but can be tan or multicolored. The number of registered animals in the United States was 825 in 1990 (Bixby et al., 1994). Their mature BW ranges from 55 to 73 kg in ewes and 68 to 90 kg in rams. Mason (1980) reported a prolificacy of 168%, with a 55% frequency of multiple birth and litter weaning weight of 19.5 kg at 90 d. In North Carolina and Kansas, K ewes had a prolificacy and lamb survival of 167% and 80% (Pond et al., 1991) and 159% and 85% (Schwulst, 1994), respectively.

**Dorper.** Efforts are under way to import the South African Dorper sheep to the United States. The Dorper is a synthetic breed developed from crosses of Dorset Horn and Blackhead Persian in the 1940s for slaughter lamb production. It is reputed for its adaptation to harsh production conditions, however, an objective evaluation of this breed will be required before recommendations can be made to U.S. producers. Under South African conditions mature Dorper ewes weigh approximately 60 kg. In an accelerated mating system with 1.05 lambings per year ewes have fertility rates of 85%, with a litter size of 1.41, and litter weaning weight of 18.7 kg at 94% lamb survival to weaning (Schoeman and Burger, 1992). Comparative data indicate that Dorper ewes are heavier ( $P < .05$ ) at puberty and have lower ovulation rates than Romanov and Romanov crosses (Greeff et al., 1993) and Finnsheep composites (Schoeman et al., 1993), which would point to the Dorper as a late-maturing breed.

## Environmental Adaptation

Having evolved in a tropical environment, hair sheep are considered to be better adapted to more stressful production conditions than temperate wool breeds. In their native environmental settings hair sheep have to cope with hot ambient temperatures associated with a high relative humidity, diets consisting of low-quality tropical forages, and severe exposure to internal parasitism.

In North Carolina under summer pasture conditions (30.9°C maximum mean ambient temperatures), cyclic BB and BB × Dorset ewes had lower ( $P < .05$ ) rectal temperatures (38.7 vs 39.1°C) and respiration rates (54 vs 82 breaths/min) than Dorset ewes (Ross et al., 1985). Late-pregnant Dorset ewes (125 to 140 d of gestation) maintained in environmental chambers (33.8°C hot room temperature), had higher ( $P < .05$ ) rectal temperatures and respiration rates

(39.3°C and 134 breaths/min) than BB (38.7°C and 97 breaths/min) and BB × Dorset ewes (39.1°C and 107 breaths/min) (Ross et al., 1985). These authors also observed that thyroxine concentrations were similar under both cool and hot room conditions in BB and BB × Dorset crosses but decreased ( $P < .05$ ) in Dorset ewes at elevated ambient temperatures. However, the elevated ambient temperatures did not affect birth weights and dimensions or uterine structures in any of the breed types, compared to non-stressed controls.

In a further study, Goode et al. (1983) showed lower ( $P < .05$ ) rectal temperatures in BB (38.4 and 39.0°C) than in Dorset (39.2 and 40.4°C) and Suffolk (39.1 and 40.0°C) ewes under cool (15.6°C) and hot (35.0°C) ambient temperatures, respectively, whereas hair × wool crossbred ewes had rectal temperatures intermediate to those of the pure breeds. Similar differences in rectal temperature (39.6 vs 40.1°C;  $P < .05$ ) and respiration rate (63 vs 80 breaths/min;  $P < .05$ ) at elevated environmental chamber temperatures (30°C) between hair (SC) and wool (Targhee) sheep were reported by Horton et al. (1991). Their study also indicated that SC wethers were able to maintain higher ( $P < .05$ ) levels of feed intake than the Targhee wethers at increased ambient temperatures.

Differences in feed and water intake between hair and wool sheep have been described in several studies. On range in Texas, BB sheep consumed significantly more browse in their diet than Rambouillet and Karakul sheep and seemed to select a diet intermediate in composition of browse and grass compared with traditional sheep breeds and goats in this region (Warren et al., 1984). Quick and Dehority (1986) found lower ( $P < .05$ ) forage DMI and water intake in SC (2.66% of BW and 2.59 L/d) than in Targhee × Dorset crosses (3.17% of BW and 4.66 L/d) but no differences in digestive function (DM digestibility and turnover). In contrast, Mann et al. (1987) found higher ( $P < .05$ ) DMI/kg BW<sup>.75</sup> in BB than in Dorset rams when fed chopped orchard grass-alfalfa hay and a decreased mean retention time and increased CP digestibility in BB × Dorset crosses compared with pure hair and wool breed types. In a study by Horton and Burgher (1992), DMI of a commercial pelleted diet was lower ( $P < .05$ ) in BB than in Dorset wethers. Water intake in this study tended to be lower in BB and SC than in Dorset wethers and thus confirmed similar earlier findings (Quick and Dehority, 1986; Horton et al., 1991). In this study K, as a temperate hair sheep type, had a DMI and water intake similar to that of the Dorset.

Hair sheep seem to have an increased resistance to internal parasitism compared with most wool breeds. Data collected in North Carolina under a natural mixed parasite challenge showed consistently lower ( $P < .05$ ) fecal egg counts for BB and BB × Dorset ewes than for wool breed types during the reinfection period following anthelmintic treatment (Yazwinski

et al., 1979). However, no difference between hair and wool breeds were observed under an artificial challenge with *Haemonchus contortus* larvae only.

In Ohio, Courtney et al. (1985b) found no differences in *H. contortus* worm burdens in BB and SC compared to Rambouillet and Finnsheep-Dorset × Rambouillet crosses. However, the same workers observed no periparturient rise in fecal egg counts in hair breed and Florida Native ewes, evident in wool breed ewes at 6 to 7 wk after lambing (Courtney et al., 1984). This breed effect in the periparturient ewes was attributed to differences in the relaxation of the immune response. Young SC lambs showed greater ( $P < .05$ ) resistance to reinfection following artificial challenge with *H. contortus* larvae than wool breed lambs, whereas BB and Florida Native lambs were intermediate (Courtney et al., 1985a). Though these findings have not been entirely consistent, they do point to an improved parasite resistance in the hair breed types compared to the traditional wool breeds, with the exception of the Florida Native.

### Reproductive Performance

Tropical hair sheep are often prolific year-round breeders in their native environment. Several studies have evaluated their seasonal breeding capabilities under the temperate environmental conditions of the U.S. mainland and results have varied dependent on the breed and location (Table 1). In an accelerated lambing study in North Carolina using 16 ewes/breed (Goode et al., 1983), 63% of Dorset × BB ewes conceived to a May mating, whereas wool-cross ewes (Finn × Dorset, Finn × Rambouillet) and wool ewes (Suffolk) failed to conceive during this period. In Ohio hair (SC and BB) and wool (Targhee, Dorset, Polypay, and Rambouillet) breeds showed similar fall (September/October) breeding activity, whereas March/April conception rates of SC (55%) were comparable to those of Polypay (50%) and Dorset (68%) but higher ( $P < .05$ ) than those of Targhee (20%) ewes (Pope et al., 1989). January/February exposure of SC and BB ewes in Ohio resulted in conception rates ≤25% (Parker et al., 1991). In contrast, in single-breed studies in Utah (Foote, 1983) and Arkansas (Brown and Jackson, 1995) with flock sizes of 21 and 51, SC ewes achieved conception rates of 62 and 84%, respectively, in February/March matings.

Environmental effects on seasonal breeding activity of SC ewes were compared using genetically similar SC ewes under a standardized nutritional and managerial regimen in tropical (St. Croix) and temperate (Utah) environments (Wildeus et al., 1991a). On St. Croix, SC ewes (n = 15) displayed estrus and ovulation throughout the year, whereas ewes in Utah (n = 15) had a transitional period in May and August and showed no estrus in June and

Table 1. Seasonal breeding activity<sup>a</sup> in hair and wool ewes and their crosses in the United States

Location and management	Breed or cross <sup>b</sup>	Jan/Feb	Mar/Apr	May/June	Jul/Aug	Sep/Oct	Nov/Dec	Reference
North Carolina <sup>cd</sup> Pasture, semicontinuous mating	D × BB		94 (16)	63 (16)	100 (16)	94 (16)		Goode et al., 1983
	F × D		88 (16)	0 (16)	100 (16)	94 (16)		
	F × R		63 (16)	0 (16)	100 (16)	75 (16)		
	S		60 (16)	0 (16)	100 (16)	60 (16)		
Ohio Confinement feeding, spring/fall mating	SC		55 <sup>e</sup>			74		Pope et al., 1989
	T		20 <sup>f</sup>			86		
	P		50 <sup>ef</sup>			95		
	D		68 <sup>e</sup>			88		
Ohio <sup>c</sup> Confinement feeding, spring/fall mating	SC	25 (24)			95 (40)			Parker et al., 1991
	BB	19 (26)			78 (40)			
Ohio <sup>c</sup> Confinement feeding, spring/fall mating	SCX			90 (51)			97 (37)	McClure and Parker, 1991
	RX			92 (51)			92 (39)	

<sup>a</sup>Percentage of ewes lambing in response to mating during these different time periods.

<sup>b</sup>Breed designations: BB, Barbados Blackbelly; D, Dorset; F, Finnsheep; P, Polypay; R, Rambouillet; RX, Rambouillet cross; SC, St. Croix; SCX, St. Croix cross; S, Suffolk; T, Targhee.

<sup>c</sup>Number of observations are indicated in parentheses.

<sup>d</sup>Values calculated by author from data presented in reference.

<sup>e</sup>Values in same column within study with unlike superscripts differ ( $P < .05$ ).

July. Ovarian activity was reduced in May, June, and July, but ovulation rates were not affected by the two environments (1.93 to 1.97). The interval to first postpartum ovulation, but not estrus, was shorter ( $P < .05$ ) in the temperate (27 d) than in the tropical (36 d) location (Wildeus et al., 1991b). A similar interval to first postpartum ovulation (33.9 d) was reported in SC ewes in Ohio, with no significant effect of lambing season (spring vs fall) and no difference from contemporary wool breeds (Pope et al., 1989).

Table 2 summarizes the comparative reproductive performance of hair, wool, and hair  $\times$  wool crossbred ewes at various locations in the United States. Fertility (ewes lambing/ewes exposed) in contemporary, spring-mated purebred hair sheep in North Carolina was 79, 91, and 27% for BB ( $n = 72$ ), SC ( $n = 11$ ), and K ( $n = 11$ ), respectively (Pond et al., 1991). Fall-mated K ewes in Kansas ( $n = 42$ ) achieved fertility levels of 88% (Schwulst, 1994). Hair  $\times$  wool crossbred ewes generally had similar or higher levels of fertility compared to pure hair and wool contemporaries in fall, accelerated, and summer mating systems, ranging from 84 to 100% (Boyd, 1983; Foote, 1983; Goode et al., 1983; McClure and Parker, 1991; Bunge et al., 1995). However, under spring mating conditions, Pond et al. (1991) reported low fertility in Dorset  $\times$  SC (20%,  $n = 11$ ) and Suffolk  $\times$  SC (50%,  $n = 8$ ), which was similar to fertility of pure wool breeds (Dorset, 36%,  $n = 73$ ; Suffolk, 14%,  $n = 108$ ). Fertility of all these breeds was numerically lower than that of pure SC (91%,  $n = 11$ ). Differences have to be interpreted with caution due to the limited animal numbers per breed.

Prolificacy (number of lambs born/ewe lambing) of purebred hair sheep breeds in the United States ranged from 1.40 to 2.25, varying widely with location and management (Table 2). Although BB are considered a more prolific hair sheep breed than the Virgin Islands White in the Caribbean, no such distinction can be made for SC and BB populations based on data from the U.S. mainland. In North Carolina SC and BB had comparative prolificacies of 2.10 and 1.83, respectively (Pond et al., 1991). Prolificacy in SC  $\times$  wool breed crosses ranged from a low of 1.13, 1.44, and 1.50 in SC  $\times$  Florida Native, Rambouillet  $\times$  SC, and Dorset  $\times$  SC, respectively, to 1.78 and 2.00 in SC  $\times$  Suffolk/Targhee and Suffolk  $\times$  SC, respectively (Foote, 1983; Pond et al., 1991; Bunge et al., 1995). In BB  $\times$  wool breed crosses, a similar range of 1.45, 1.48, and 1.54 in Dorset  $\times$  BB to 1.71 and 1.73 in BB  $\times$  Suffolk/Targhee and BB  $\times$  Rambouillet, respectively, has been reported (Boyd, 1983; Goode et al., 1983; Shelton, 1983a, Pond et al., 1991; Bunge et al., 1995). Direct comparisons of Finnsheep and hair breeds for the production of prolific crossbreds indicate a higher prolificacy in the Finnsheep crosses by .1 to .2 lambs/ewe lambing (Goode et al., 1983; Shelton, 1983a; Bunge et al., 1995).

No pronounced environmental effects on fertility and prolificacy have been demonstrated. Genetically similar, fall-mated SC ewes in St. Croix and Utah had similar values at tropical and temperate locations (94.7% and 1.94, and 93.8% and 2.03, respectively), despite differences in ewe BW (Wildeus et al., 1991a).

Lamb survival to weaning in hair sheep in the United States also varied with location, breed type, and management system (Table 2). High lamb survival was reported for BB under pasture conditions in North Carolina (Goode et al., 1983; Pond et al., 1991) and Mississippi (Boyd, 1983), ranging from 94 to 97%. Values for SC on the U.S. mainland ranged from 66 to 79% (Pond et al., 1991; Wildeus et al., 1991c; Brown and Jackson, 1995). In general, hair and hair  $\times$  wool crossbreds achieved 4 to 15% higher lamb survival rates in comparative studies with wool and wool-cross ewes (Boyd, 1983; Foote, 1983; Goode et al., 1983; Pond et al., 1991; Bunge et al., 1995). Noteworthy is the improved ( $P < .05$ ) lamb survival observed by Bunge et al. (1995) in SC- and BB-sired  $F_1$  ewes (92 and 89%, respectively), compared with  $F_1$  ewes sired by prolific Finnsheep and Booroola Merino wool crossbreds (76.6 and 74.2%, respectively) under the environmental conditions of Southern Illinois.

## Ewe Productivity

Limited comparative offtake data are available for purebred hair sheep in the United States. In early-weaning systems (weaning at 60 to 63 d postpartum), confinement-housed SC ewes produced 25.9 and 21.4 kg of lamb/ewe lambing in Utah and St. Croix, respectively (Wildeus et al., 1991c). This value decreased by 5 to 6% at both locations when offtake was expressed on the basis of ewe exposed. Under a late weaning (90 d), semicontinuous mating system on pasture in Arkansas (Brown and Jackson, 1995), offtake from SC ewes was 22.4 kg; however, this decreased by 41% when expressed on the basis of ewe exposed.

Offtake data have been presented for hair  $\times$  wool-cross ewes in Illinois and Ohio (Table 3). In Illinois, SC and BB-sired  $F_1$  ewes had a higher ( $P < .05$ ) offtake (24.8 and 22.1 kg of lamb/ewe exposed, respectively) than prolific wool breed-sired  $F_1$  ewes (15.7 to 20.5 kg of lamb/ewe exposed) managed under a pasture-based, 56-d weaning system (Bunge et al., 1995). In this study the improved offtake of the hair crosses was largely a function of the higher lamb survival in these breed types. Data from Ohio suggest that SC  $\times$  wool- and wool  $\times$  Rambouillet-cross ewes performed similarly under a confinement system (50 d weaning), producing 18.0 to 18.8 kg of lamb/ewe lambing (McClure and Parker, 1991). Offtake from either breed type was not affected by season of mating (spring vs fall).

Table 2. Reproductive performance of hair and wool ewes and their crosses in the United States

Location and management	Breed or cross <sup>a</sup>	n	Fertility (ewes lambing/ewes exposed), %	Prolificacy (no. of lambs/ewe lambing)	Lamb survival to weaning, %	Reference
Florida <sup>b</sup>						
Pasture, summer mating	SC	13	77	1.40	71	Foote, 1983
	SC × FN	49	94	1.13	96	
	FN	55	90	1.20	96	
Illinois						
Pasture, concentrate at lambing, confinement lambing, fall mating	SC × S/T	123	92 <sup>d</sup>	1.78 <sup>de</sup>	92 <sup>d</sup>	Bunge et al., 1995
	BB × S/T	102	94 <sup>d</sup>	1.73 <sup>de</sup>	89 <sup>de</sup>	
	F × S/T	77	88 <sup>de</sup>	1.93 <sup>d</sup>	77 <sup>ef</sup>	
	C6 × S/T	102	78 <sup>e</sup>	1.55 <sup>e</sup>	93 <sup>d</sup>	
	BM × S/T	87	77 <sup>e</sup>	1.93 <sup>d</sup>	74 <sup>f</sup>	
Mississippi <sup>b</sup>						
Pasture, supplement during lactation, accelerated mating	BB	15	94	1.70	97	Boyd, 1983
	BB × D	14	88	1.48	95	
	D	15	66	1.28	87	
North Carolina						
Pasture and hay, concentrate during lambing and lactation, semicontinuous mating	D × BB	10	100	1.45		Goode et al., 1983
	F × D	9	85	1.64		
	F × R	10	100	1.90		
	D	9	70	1.63		
North Carolina						
Pasture and hay, concentrate during lambing and lactation, fall mating	BB	48	92 <sup>d</sup>	1.65	94	Goode et al., 1983
	D	74	83 <sup>e</sup>	1.58	80	
North Carolina <sup>c</sup>						
Pasture, accelerated mating within 30 d of lambing	D × B	16	87 <sup>d</sup>	1.86	88	Goode et al., 1983
	F × D	16	70 <sup>de</sup>	2.14	79	
	F × R	16	60 <sup>e</sup>	2.21	85	
	S	16	61 <sup>e</sup>	1.81	86	
North Carolina <sup>c</sup>						
Pasture, spring mating	BB	72	79	1.83	95	Pond et al., 1991
	SC	11	91	2.10	76	
	D × BB	75	73	1.54	97	
	D × SC	11	20	1.50	100	
	S × SC	8	50	2.00	88	
	K	11	27	1.67	80	
	D	73	36	1.58	50	
	S	108	14	1.78	71	
Ohio						
Confinement feeding, spring mating	SCX	51	90	1.72		McClure and Parker, 1991
	RX	52	92	1.71		
Texas						
Range with supplement, accelerated mating	BB × R	24		1.71		Shelton, 1983a
	F × R	38		1.80		
	R	25		1.41		
Utah						
Confinement feeding, summer mating of 6-mo accelerated mating	SC	18	44	2.25	75	Foote, 1983
	R × SC	20	84	1.44	95	
	R	19	70	1.36	79	

<sup>a</sup>Breed designations: BB, Barbados Blackbelly; BM, Booroola Merino; C6, Combo 6; D, Dorset; F, Finnsheep; FN, Florida Native; K, Katahdin; R, Rambouillet; RX, Rambouillet cross; SC, St. Croix; SCX, St. Croix cross; S, Suffolk; T, Targhee.

<sup>b</sup>Values for lamb survival calculated by author from data presented in reference.

<sup>c</sup>Values calculated by author from data presented in reference.

<sup>d,e</sup>Values in same column within study with unlike superscripts differ ( $P < .05$ ).

Table 3. Estimates of ewe productivity (offtake) in hair and wool sheep and their crosses in the United States

Location and management	Breed or cross <sup>a</sup>	n	Wt lamb weaned/ewe exposed, kg	Wt lamb weaned/ewe lambing, kg	Reference
<b>Illinois</b>					
Pasture, concentrate at lambing, confinement lambing, fall mating, 56 d weaning	SC × S/T	123	24.8 <sup>b</sup>		Bunge et al., 1995
	BB × S/T	102	22.1 <sup>bc</sup>		
	F × S/T	77	20.5 <sup>bc</sup>		
	C6 × S/T	102	19.7 <sup>cd</sup>		
	B × S/T	87	15.7 <sup>d</sup>		
<b>Ohio</b>					
Confinement feeding, spring mating, 50 d weaning	SCX	37		18.8	McClure and Parker, 1991
	RX	39		18.0	
<b>Ohio</b>					
Confinement feeding, fall mating, 50 d weaning	SCX	51		18.3	McClure and Parker, 1991
	RX	52		18.5	

<sup>a</sup>Breed designations: B, Barbados Blackbelly; BM, Booroola Merino; C6, Combo 6; F, Finnsheep; RX, Rambouillet cross; SC, St. Croix; SCX, St. Croix cross; S, Suffolk; T, Targhee.

<sup>b,c,d</sup>Values in same column within study with unlike superscripts differ ( $P < .05$ ).

Estimates of relative ewe efficiency can be refined when offtake is related to BW as a measure of maintenance requirements for an animal. In this context comparisons of wool and hair breeds favor the latter due to their smaller mature size. Wildeus et al. (1991c) estimated that ewe productivity of SC ewes on St. Croix tended to be higher ( $P < .05$ ) than in Utah when weight of lamb weaned was expressed as a function of BW of ewe lambing (.64 vs .58 kg/kg ewe BW). Calculations presented by Bunge et al. (1995) suggest that productivity estimates of hair sheep-sired F<sub>1</sub> ewes improved further compared to those of prolific wool breed-sired F<sub>1</sub> ewes when weight of lamb weaned/ewe exposed was adjusted for ewe BW. Values for SC and BB-sired ewes were .475 and .488 kg/kg ewe BW, respectively, compared with .329 to .383 kg/kg ewe BW for the wool breed-sired ewes.

Additional improvements in ewe productivity can be achieved when lambing interval is reduced to less than 12 mo. Hair sheep offer an advantage over traditional wool sheep due to their extended seasonal breeding capabilities. Under continuous mating in Texas, Shelton (1983a) observed a higher number of lambs weaned/ewe<sup>-1</sup>·yr<sup>-1</sup> in BB × Rambouillet crosses (n = 24) compared with Finnsheep × Rambouillet crosses (n = 24; 1.64 vs 1.27) despite a similar number of lambs being born/ewe lambing as the result of the increased number of lambings/year in the BB cross (1.24) compared with the Finnsheep cross (.98); however, these numerical differences were not subjected to statistical analysis. In St. Croix, SC ewes weaning 18.2 kg of lamb/ewe lambing under a semicontinuous 8-mo lambing cycle on pasture (Wildeus et al., 1991c) produced an annual offtake of 27.1 kg, which is comparable to the annual production of 22.3 to 27.9 kg in Finn and Finn-cross ewes in annual lambing systems (Fahmy and Dufour, 1988; Nugent and Jenkins, 1991).

The additive advantage of lower ewe BW and accelerated lambing of hair sheep on ewe productivity was demonstrated by Goode et al. (1983) when Dorset × BB crosses produced 41% more ( $P < .05$ ) weight of lamb marketed per unit weight of ewe than Finnsheep × Dorset, Finnsheep × Rambouillet, and Suffolk breed types. This difference was as much a function of ewe BW, which was lower ( $P < .05$ ) in the Dorset × BB ewes (56.7 kg) than in the Suffolk (85.3 kg) and Finnsheep × wool breed crosses (67.1 and 72.1 kg), as it was a function of the increased ( $P < .05$ ) number of ewes lambing in the hair × wool cross than in the other breed types under this system.

### Growth Rates and Carcass Characteristics

Growth rates of hair sheep are generally lower than those of traditional wool breeds in the United States. This difference can be partially attributed to the low input management systems and stressful tropical environmental conditions under which these breeds were developed. In feeding trials with SC lambs on St. Croix, ADG was 0 to 65 g/d on native grass pasture and improved to 140 g/d when supplement was provided (Wildeus and Fugle, 1991; Hammond and Wildeus, 1993). In North Carolina an ADG of 48 g/d was reported for BB and BB × Dorset rams fed diets of pelleted bermuda grass (Mann et al., 1987).

When hair sheep lambs were fed high-concentrate diets, growth rates were always lower than those of hair × wool crosses and wool breeds (Table 4). Purebred SC lambs achieved an ADG of > 200 g/d and purebred BB lambs of < 175 g/d in trials in New Jersey (Horton and Burgher, 1992) and Ohio (Ockerman et al., 1982). Katahdin wethers had an ADG of 267 g/d and were comparable to Dorset (246 g/d) (Horton and Burgher, 1992). Wool breed × SC

wethers had the same ADG as wool breed  $\times$  Polypay wethers (Phillips et al., 1995), whereas BB  $\times$  Rambouillet rams had a numerically lower ADG than blackfaced  $\times$  Rambouillet rams (Shelton, 1983a), but differences were not validated statistically in the latter trial.

Differences in ADG between SC and BB were also reflected in the gain/feed ratio, with SC and SC crossbreds having ratios similar to those of wool breeds (McClure et al., 1991; Horton and Burgher, 1992; Phillips et al., 1995), whereas the ratios of BB and BB crossbreds were lower (Shelton, 1983a; Horton and Burgher, 1992). The DMI of high-energy diets was lower ( $P < .05$ ) in SC and BB lambs than in Dorset and K (Horton and Burgher, 1992). Shelton

(1983a) also reported a numerically lower DMI in BB  $\times$  Rambouillet (1,125 g/d) than in Rambouillet lambs (1,474 g/d) that was, however, not statistically evaluated. When lower-quality diets were supplied, no differences in dry matter intake were observed between hair and wool sheep (Mann et al., 1987).

In line with the lower growth rates are the smaller carcasses of hair breeds compared to wool breeds of similar age (Table 5). No consistent differences in dressing percentage between hair and wool breeds have been reported. Longissimus muscle area (**LMA**) of hair sheep carcasses tended to be smaller than that of wool breeds in a number of studies (Ockerman et al., 1982; Foote, 1983; McClure et al., 1991; Solomon et al., 1991; Horton and Burgher, 1992), but this

Table 4. Growth and feed efficiency in hair and wool sheep and their crosses in the United States

Location and diet	Sex and breed or cross <sup>a</sup>	n	ADG, g/d	Intake, g/d	Gain/feed	Reference
New Jersey <sup>b</sup> Pen trial; pelleted concentrate diet	Wether					
	SC	4	203 <sup>ef</sup>	117 <sup>f</sup>	.152	Horton and Burgher, 1992
	BB	4	138 <sup>f</sup>	129 <sup>f</sup>	.115	
	K	4	267 <sup>e</sup>	150 <sup>e</sup>	.151	
D	4	246 <sup>e</sup>	143 <sup>e</sup>	.149		
North Carolina <sup>bc</sup> Pen trial; pelleted bermuda grass	Ram					
	BB	6	48	95		Mann et al., 1987
	BB $\times$ D	7	48	100		
D	7	37	101			
Ohio Pen trial; high-concentrate diet	Ram					
	SC	12	222			Ockerman et al., 1982
	BB	12	172			
	FN	10	259			
SX	12	349				
Ohio Pen trial; high-energy diet	Mixed					
	SCX	57	270		.196	McClure and Parker, 1991
	SCX $\times$ RX	50	310		.213	
SCX $\times$ H	49	370		.227		
Ohio Pen trial; high-energy diet	Mixed					
	SC	12	200		.200	McClure et al., 1991
T	12	330		.204		
Oklahoma <sup>d</sup> Feedlot; high-energy diet	Wether					
	SC		187 <sup>f</sup>	1,360	.137	Phillips et al., 1995
	RV $\times$ SC		227 <sup>e</sup>	1,350	.167	
	TX $\times$ SC		238 <sup>e</sup>	1,450	.164	
	RV $\times$ P		239 <sup>e</sup>	1,420	.167	
	TX $\times$ P		232 <sup>e</sup>	1,430	.161	
Texas Feedlot	Wether					
	BB $\times$ R	20	176	1,125	.156	Shelton, 1983a
	BF $\times$ R	20	254	1,397	.181	
R	14	251	1,474	.175		
Utah Pen trial; alfalfa pellets and rolled barley	Ram					
	SC	13	259			Foote, 1983
	SC $\times$ R	12	292			
R	7	355				

<sup>a</sup>Breed designations: BB, Barbados Blackbelly; BF, Blackfaced; D, Dorset; FN, Florida Native; H, Hampshire; K, Katahdin; P, Polypay; R, Rambouillet; RX, Rambouillet cross; RV, Romanov; SC, St. Croix; SCX, St. Croix cross; SX, Suffolk cross; T, Targhee; TX, Texel.

<sup>b</sup>Intake expressed on the basis of kg wt<sup>75</sup>.

<sup>c</sup>ADG calculated by author from data presented in reference.

<sup>d</sup>Gain/feed calculated by author from data presented in reference.

<sup>e,f</sup>Values in same column within study with unlike superscripts differ ( $P < .05$ ).

Table 5. Carcass characteristics of hair and wool sheep and their crosses in the United States

Location and breed or cross <sup>a</sup>	Sex and n	Age, d	Slaughter wt, kg	Dressing %	Quality grade	Yield grade	LMA, cm <sup>2</sup>	Backfat, mm	KPH, %	Reference
Florida	Ram									
SC	5		37.2	53.6		2.0	10.7			Foote, 1983
SC × FN	7		37.4	48.5		2.1	12.6			
FN	6		37.9	52.2		2.3	12.3			
Maryland	Ram									
SC	4	214	40.0 <sup>e</sup>				10.1 <sup>e</sup>	2.8 <sup>e</sup>	2.1	Solomon et al., 1991
T	4	214	60.0 <sup>d</sup>				15.5 <sup>d</sup>	5.1 <sup>d</sup>	2.1	
Mississippi	Mixed									
BB	18	220	42.3 <sup>e</sup>	53.1	12.9	3.9 <sup>d</sup>	13.5	6.1	5.5 <sup>d</sup>	Boyd, 1983
BB × D	16	226	46.3 <sup>d</sup>	51.7	13.8	3.6 <sup>d</sup>	13.7	5.6	4.1 <sup>d</sup>	
D	10	200	42.3 <sup>e</sup>	50.9	13.4	3.0 <sup>e</sup>	13.8	4.8	2.9 <sup>e</sup>	
New Jersey <sup>b</sup>	Wether									
SC	4		39.0 <sup>e</sup>	60.6 <sup>e</sup>			10.1 <sup>e</sup>		4.2 <sup>d</sup>	Horton and Burgher, 1992
BB	4		31.1 <sup>f</sup>	64.5 <sup>d</sup>			12.1 <sup>e</sup>		4.8 <sup>d</sup>	
K	4		46.2 <sup>d</sup>	65.1 <sup>d</sup>			14.1 <sup>e</sup>		5.2 <sup>d</sup>	
D	4		44.6 <sup>f</sup>	60.6 <sup>e</sup>			17.2 <sup>d</sup>		1.5 <sup>e</sup>	
Ohio <sup>c</sup>	Ram									
SC	12	173	37.1	49.6	13.7		9.7	2.5	4.3	Ockerman et al., 1982
BB	12	158	35.2	48.8	9.5		7.8	1.0	2.8	
FN	10	158	38.8	52.8	14.2		10.9	3.0	6.0	
SX	12	139	46.8	48.9	14.2		11.5	2.8	3.8	
Ohio <sup>c</sup>	Mixed									
SC	12	166	41.5	49.2			10.8	1.5	2.4	McClure et al., 1991
T	12	130	50.6	47.6			13.7	4.3	2.8	
Oklahoma <sup>c</sup>	Wether									
SC			42.2 <sup>e</sup>	49.5						Phillips et al., 1995
RV × SC			50.3 <sup>d</sup>	47.5						
TX × SC			50.9 <sup>d</sup>	48.5						
RV × P			50.9 <sup>d</sup>	46.8						
TX × P			50.9 <sup>d</sup>	46.8						
Texas	Wether									
BB × R	20			55.7			11.9		6.2	Shelton, 1983a
BF × R	20			56.8			12.6		3.6	
R	14			54.7			12.8		4.4	

<sup>a</sup>Breed designations: BB, Barbados Blackbelly; BF, Blackfaced; D, Dorset; FN, Florida Native; K, Katahdin; P, Polypay; R, Rambouillet; RV, Romanov; SC, St. Croix; SX, Suffolk cross; T, Targhee; TX, Texel.

<sup>b</sup>Dressing percentage includes head remaining on carcass.

<sup>c</sup>Values for dressing percentage calculated by author from data presented in reference.

<sup>d,e</sup>Values in same column within study with unlike superscripts differ (P < .05).

difference was likely to be an effect of the smaller carcass size of the hair lambs rather than a true breed effect. However, K wethers had smaller ( $P < .05$ ) LMA ( $14.1 \text{ cm}^2$ ) than Dorset wethers ( $17.2 \text{ cm}^2$ ), despite similar slaughter weights (Horton and Burgher, 1992), and in a Florida study SC rams had a smaller LMA ( $10.7 \text{ cm}^2$ ) than SC  $\times$  Florida Native and Florida Native rams ( $12.6$  and  $12.3 \text{ cm}^2$ ) at the same slaughter weight (Foote, 1983), but differences were not statistically validated.

Data on differences in backfat thickness in hair and wool breeds are also not consistent. McClure et al. (1991) and Solomon et al. (1991) found increased backfat thickness ( $P < .01$ ) in Targhee ( $4.3$  and  $5.1$  mm, respectively) compared to SC ( $1.5$  and  $2.8$  mm, respectively) lambs, which had 20 to 30% lower slaughter weights. It is not clear to what extent these differences are influenced by age, slaughter weight, and breed type. Data on the percentage of kidney, pelvic, and heart fat (**KPH**) are similarly inconclusive in regard to differences between hair and wool breeds. No differences were observed in two studies between SC and Targhee lambs (McClure et al., 1991; Solomon et al., 1991), but a greater ( $P < .05$ ) KPH was reported for hair breeds (SC, BB, and K) than for Dorset lambs in two other studies (Boyd, 1983; Horton and Burgher, 1992). Ockerman et al. (1982) found a lower ( $P < .05$ ) KPH in BB than in SC, Florida Native, and Suffolk-cross lambs, whereas Shelton (1983a) found a numerically greater KPH in BB  $\times$  Rambouillet than in Rambouillet and Rambouillet wool-cross wethers; however, the difference was not statistically validated.

These inconsistencies in carcass traits were also reflected in quality grades, which were lower ( $P < .05$ ) in BB than in SC and wool breeds in an Ohio study (Ockerman et al., 1982). These lower grades may be the result of a lower slaughter weight; Boyd (1983) failed to show differences between BB, BB  $\times$  Dorset cross, and Dorset lambs that were slaughtered at similar weights. No differences between breed types were reported for yield grades (Boyd, 1983; Foote, 1983).

### Implications

The limited data available on hair sheep in the United States point to advantages in environmental adaptation to hot and humid conditions and seasonal breeding and ewe productivity, but they have lower growth rates than traditional wool breeds. Hair sheep and strategic hair  $\times$  wool crosses have the potential to produce lamb efficiently under marginal conditions and are suited for lower input, more sustainable production systems, but they should not be expected to perform well in a traditional feedlot production system.

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