

Potential for Hair Sheep in the United States

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Abstract

Development of “easy-care” sheep germplasm would aid in improving the competitiveness of the U.S. sheep industry. Various hair sheep breeds could contribute to this development by increasing resistance to internal parasites; providing high levels of reproductive efficiency, lamb vigor, and environmental adaptation; and reducing costs for production and harvesting of wool. However, purebred hair sheep are generally small, slow-growing, and poorly muscled, so their use in traditional production systems and markets will likely be in crossbreeding or through use of composite breeds. Existing hair sheep composites such as Katahdins and Dorpers contain approximately 50% hair sheep breeding. Their maternal characteristics, environmental adaptations, and acceptable growth rates and mature size would permit them to contribute as dam lines in traditional production systems. However, parasite resistance in these composite breeds has been shown to be less than that expressed by purebred hair sheep such as the St. Croix and Barbados Blackbelly, and development of additional genetic types may be indicated. Composite lines or crossbreeding systems that use up to 75% hair sheep genetics would likely provide higher levels of parasite resistance and more desirable coat characteristics but would require intense selection of foundation animals to achieve acceptable growth rates and carcass characteristics.

Key Words: Sheep, Breeds, Hair, Pest Resistance, Wool Fibers, Growth

Introduction

The U.S. sheep industry needs to improve its competitiveness relative to other meat-producing species in the United States and relative to other lamb- and wool-producing nations. Rapid increases in U.S. demand for sheep meat are not likely to occur. Likewise, global demand for wool, and particularly for medium wools, is unlikely to increase in the near future to a level that will restore profitability to this segment of the industry. Thus, the industry has few short-term alternatives except to attempt to further reduce costs of production while maintaining emphasis on gradual improvement of product quality and consumer demand. For meat production, maintenance of high-quality product (lean and flavorful) will be necessary to maintain existing consumer demand, whereas meaningful expansion of demand for sheep meat will require a combination of new product development to attract affluent, but time-conscious, consumers and control of product costs to capture cost-conscious consumers and compete with imported product.

Restoration of a competitive advantage for sheep production under U.S. conditions would be aided by 1) reductions in labor costs for sheep production; 2) more efficient control of internal parasites; 3) consistent achievement of high rates of reproduction through a combination of multiple-season lambing, prolificacy levels of 2.0 to 2.5 lambs born per ewe lambing, and high lamb survivability; and 4) opportunity to avoid costs of wool production and harvesting in systems that emphasize meat production.

The identification and further development of “easy-care” sheep germplasm would assist in achieving these objectives. This review will assess the potential contributions of various

types of hair sheep to such an effort and outline utilization and improvement strategies that might be implemented.

Discussion

Hair sheep genetic resources that are currently available to U.S. producers include pure and composite breeds of Caribbean hair sheep and the South African Dorper. Wildeus (1997) summarized the performance of two Caribbean breeds, the St. Croix (**SC**) and Barbados Blackbelly (**BB**), in the United States. He also included brief descriptions of the Katahdin, a composite breed developed in the United States from crosses among St. Croix, Suffolk, Wiltshire Horn, and other breeds, and the South African Dorper. More recently, a special issue of *Small Ruminant Research* reviewed performance of Dorpers in South Africa (Brand, 2000; Cloete et al., 2000; de Waal and Combrinck, 2000; Schoeman, 2000).

More extensive reviews of hair sheep genetic resources around the world were provided by Fitzhugh and Bradford (1983) and Wildeus (1991). Hair sheep in the United States are all of African origin. African hair sheep breeds include the small, thin-tailed West African breeds, the long-legged, thin-tailed Sahelian breeds, and the East and South African fat-rumped and fat-tailed breeds (Bradford and Fitzhugh, 1983; Campbell, 1995). Caribbean hair sheep are descended from thin-tailed West African breeds (Bradford and Fitzhugh, 1983). The Dorper was developed in South Africa from crosses between Dorset and Blackhead Persian around 1940; subsequent selection within the breed emphasized conformation, size, fat distribution, color pattern, and reduced wool cover (de Waal and Combrinck, 2000).

Caribbean Hair Sheep

Reproduction. Studies in the United States reviewed by Wildeus (1997) and experimental results from the Caribbean and Latin America (Wildeus, 1991) indicate that both SC and BB have relatively high twinning rates. Prolificacy levels reported by Wildeus (1997) for purebred BB and SC in the United States ranged from 1.40 to 2.25 and were consistently higher than those achieved by contemporary ewes of traditional U.S. wool breeds. In comparisons with Dorset ewes (Boyd, 1983; Goode et al., 1983; Pond et al., 1991), BB and SC ewes produced an average of .26 more lambs/ewe lambing.

Prolificacy of F_1 ewes produced by crossing BB and SC to U.S. wool breeds ranged from 1.44 to 2.0 (Wildeus, 1997). Boyd (1983) reported that BB \times Dorset ewes in Mississippi produced .20 more lambs/ewe lambing than Dorset ewes. Clarke (1985) reported that adult BB \times Dorset ewes lambing in various seasons in Virginia produced 1.59 to 2.01 lambs/ewe lambing, which averaged .29 more, .12 more, .44 fewer, and .10 fewer lambs/ewe lambing than contemporary Dorset, Rambouillet, Finnsheep, and Finnsheep \times Dorset reciprocal-cross ewes, respectively. Bunge et al. (1995) reported that SC- and BB-sired crossbred ewes out of Suffolk and Targhee dams in Illinois averaged 1.75 lambs/ewe lambing, compared with 1.93 lambs/ewe lambing for Finnsheep- and Booroola Merino-sired ewes.

In studies reviewed by Wildeus (1997), fertility of Caribbean hair sheep and their crosses was generally equal or superior to that of U.S. wool breeds. However, Foote (1983) reported that fertility of SC ewes in Utah was lower than that of contemporary Rambouillet ewes and fertility of SC ewes in Florida was lower than that of contemporary Florida Native ewes. Clarke (1985) reported that fertility of adult BB \times Dorset ewes mated in August 1981, May 1982, and April 1983 was 100%, which was equal or superior to that of contemporary Dorset, Finnsheep, Rambouillet, and Finnsheep \times Dorset reciprocal cross ewes. Fertility of these BB \times Dorset ewes in May and April supported the conclusion of Wildeus (1997) that hair sheep tend to perform better under accelerated lambing systems than traditional wool breeds.

Few estimates of age at puberty were found for Caribbean hair sheep or their crosses. Bunge et al. (1993b) reported that age at puberty was similar for F_1 ewe lambs by BB (211 d), SC (208 d), Booroola Merino (209 d), and Combo-6 (a composite of six breeds including the Finnsheep; 205 d) rams but earlier (194 d) for F_1 ewe lambs by Finnsheep rams. Evans et al. (1991) reported that SC ewe lambs in Utah were younger at first estrus (169 d) than Suffolk (226 d) or Rambouillet (242 d) ewe lambs.

In mainland U.S. studies summarized by Wildeus (1997), lambs produced by SC or BB F_1 crossbred ewes were equal or superior in lamb survival to lambs produced by ewes of wool breeds. Lamb survival for purebred BB and SC ewes was generally, but not always, equal or higher than that of contemporary lambs of wool breeds. Clarke (1985) reported that lamb death losses within the first 3 d after lambing in both spring and fall lambing in Virginia were lower for lambs

out of BB \times Dorset ewes (2.3%) than for lambs out of Dorset (11.5%), Finnsheep (11.1%), or Dorset \times Finnsheep reciprocal cross ewes (8.3%). Clarke (1985), in a somewhat different sample of lambing years and seasons, also found that death losses were essentially the same for lambs out of BB \times Dorset ewes (.9%) and Rambouillet ewes (1.7%). Because of their high fertility, prolificacy, and lamb survival, the BB \times Dorset ewes studied by Clarke (1985) had more lambs reared to 2 wk of age per ewe exposed (1.51) than Dorset (.98), Finnsheep (1.32), Rambouillet (1.06), or Finnsheep \times Dorset reciprocal-cross (1.06) ewes. Similarly, Bunge et al. (1995) reported that weight of lamb weaned per ewe exposed in fall matings in Illinois was higher for SC- and BB-sired ewes (24.8 and 22.1 kg, respectively) than for ewes sired by Finnsheep (20.5 kg), Combo-6 (19.7 kg), or Booroola Merino (15.7 kg) rams.

Growth Rates and Carcass Characteristics. The SC and BB have smaller mature body sizes than U.S. wool breeds and correspondingly slower growth rates. Wildeus (1997) reported mean mature ewe body weights on the U.S. mainland of 30 to 43 kg for BB and 36 to 54 kg for SC. In the studies reviewed by Wildeus (1997), postweaning average daily gains of SC lambs ranged from 187 to 259 g/d, and those of BB lambs ranged from 138 to 176 g/d. In studies that directly compared SC and BB, BB lambs gained 27% less rapidly than SC lambs. Purebred SC and BB lambs always grew more slowly postweaning than lambs of traditional U.S. wool breeds, usually by 17 to 39% for SC and by 44 to 51% for BB.

Postweaning growth rates of hair sheep crosses were invariably superior to those of purebred hair sheep but generally remained below those of wool breeds and crosses (Wildeus, 1997). Clarke (1985) reported that adult BB \times Dorset ewes had an average body weight of 63 kg, compared to 72 kg for Dorset, 58 kg for Finnsheep, 71 kg for Rambouillet, and 69 kg for Finnsheep \times Dorset reciprocal crosses. Bunge et al. (1995) reported that 2- and 3-yr-old F_1 BB and SC ewes weighed 45 and 52 kg, respectively, whereas contemporary F_1 Finnsheep, Booroola Merino, and Combo-6 ewes weighed 54, 48, and 55 kg, respectively. However, Phillips et al. (1995) reported that lambs out of St. Croix ewes had similar ADG (233 g/d) to lambs out of Polypay ewes (236 g/d). Bunge et al. (1993b) reported that lambs sired by BB and SC rams had lower weaning weights (17.1 and 15.9 kg, respectively) than lambs sired by Finnsheep (18.9 kg) or Combo-6 (18.3 kg) rams but similar weaning weights to lambs sired by Booroola Merino rams (16.7 kg).

Performance of lambs out of F_1 hair sheep crossbred ewes often approached that of traditional maternal types. Bunge et al. (1993a, 1995) reported that lambs produced by F_1 BB or SC ewes did not differ in weaning weight from lambs produced by F_1 Finnsheep or Booroola Merino ewes but were lighter at weaning than lambs out of Combo-6 F_1 ewes. Clarke (1985) reported that lambs out of BB \times Dorset ewes had similar preweaning ADG (275 g/d) to lambs out of Rambouillet (280 g/d), Dorset (275 g/d), Finnsheep (255 g/d), and Finnsheep \times Dorset reciprocal-cross (270 g/d) ewes. These BB \times Dorset ewes produced more milk than

Rambouillet, Finnsheep, or Finnsheep × Dorset ewes (by 21, 38, and 12%, respectively) but 16% less milk than Dorset ewes (McCarthy et al., 1988).

Carcass characteristics of hair sheep and hair sheep crosses reported by Wildeus (1997) were inconsistent and difficult to interpret, mainly because of variation within and among studies in degree of maturity at slaughter. The optimal slaughter weight of market lambs comes at approximately 66% of the mature weight of ewes of the same breeding. Thus, purebred hair sheep would be predicted to reach optimal composition at about 24 kg for BB and 30 kg for SC. Based on ewe weights reported by Clarke (1985), F₁ BB × Dorset lambs would reach this degree of maturity at about 42 kg and purebred Dorset lambs would reach this degree of maturity at about 48 kg. Market lambs produced by crossing BB × Dorset ewes to Suffolk rams (with a corresponding Suffolk adult ewe weight of perhaps 100 kg) would reach 66% of mature ewe weight at 54 kg, which is within the current range of acceptable slaughter weights.

Health and Fitness. Studies reviewed by Wildeus (1997) confirm that SC, BB, and their crosses have lower rectal temperatures and respiration rates under heat stress than wool breeds. These breeds should thus cope relatively well with the hot, humid summer conditions often experienced in the eastern United States. Grazing behavior in BB sheep also seems to differ somewhat from that of wool breeds. Warren et al. (1984) reported that BB consumed more browse and less grass than Rambouillet and Karakul sheep.

Higher levels of parasite resistance in BB, SC, and their crosses compared with U.S. wool breeds were documented by Zajac (1995) and Wildeus (1997). Within hair sheep breeds, SC tend to be superior to BB in parasite resistance (Zajac, 1995), perhaps because of a greater incidence of crossing with less resistant breeds. In a recent study (Notter et al., 1999), BB × SC lambs were much more resistant to internal parasites than a composite line containing Dorset, Finnsheep, and Rambouillet breeding. Fecal egg counts in BB × SC lambs were 40% lower at 3 to 5 and 86% lower at 6 and 7 wk after infection. Mean packed cell volume averaged 11% higher for BB × SC lambs. Crosses between BB and Suffolk or Hampshire were intermediate in fecal egg counts but equal to BB × SC in packed cell volume.

Katahdin

Comparative evaluations of the Katahdin with other breeds have not been published in refereed journals (ABA, 1980 to 1997), yet the breed has become relatively popular in the southeastern United States and for export to tropical areas. Based on various research reports, Wildeus (1997) characterized the Katahdin as having a mature ewe weight of 55 to 73 kg and a mean ewe prolificacy of 1.63.

Dorper

Information on performance of Dorper sheep and their crosses in North America has not yet appeared in the scientific literature. Thus, results presented in this review were

obtained under South African (SA) conditions unless specifically noted otherwise.

Reproduction. Dorpers are adapted to arid conditions, and levels of reproduction are consistent with that adaptation. In studies summarized by Schoeman (2000), Dorper ewes generally were equal or superior to other South African breeds in fertility but were less fertile than Dorper × Merino ewes in the study of Olivier et al. (1984) and less fertile in accelerated lambing than Finnsheep composite breeds (Schoeman and van der Merwe, 1994).

Reported levels of prolificacy (lambs born per ewe lambing) for Dorper ewes varied widely, from 1.08 to 1.52 in studies reviewed by Schoeman (2000). Cloete and de Villiers (1987) reported one of the highest mean prolificacies for adult Dorper ewes: 1.62 for 4- to 6-yr-old ewes from a single flock monitored across 11 yr. de Waal and Combrinck (2000) reported considerable variation among years in prolificacy of Dorper ewes. In an experimental flock in the Free State, prolificacy of adult ewes varied from 1.12 to 1.45 over 16 yr and seemed to be rather strongly associated with pasture conditions and ewe body weights. In this flock, postpartum body weight of adult (2 yr old and older) ewes varied among years from 42 to 61 kg. Cloete and de Villiers (1987) reported a significant relationship between ewe weight at mating and prolificacy. The mean regression coefficient (averaged across ewe age groups) was $.0087 \pm .0029$ lamb/kg. The very high Dorper prolificacy values reported by Cloete and de Villiers (1987) corresponded to one of the highest reported mean Dorper adult ewe weights (73 kg for 4- to 6-yr-old ewes). If this reported prolificacy is adjusted to the mean ewe body weight of 54 kg reported by de Waal and Combrinck (2000) using the above regression coefficient, the predicted prolificacy is reduced from 1.62 to 1.45.

In comparative studies reviewed by Schoeman (2000), Dorper ewes were less prolific (1.50 vs 1.70) than the Afrino (a composite breed composed of ¼ Merino, ¼ fat-tailed Ronderib Afrikaner, and ½ Mutton Merino; Olivier et al., 1984) but had higher prolificacy than Merino (+.18), Dorper × Merino (+.15), Mutton Merino (+.07), and Dohne Merino (+.07) ewes. These results suggest that mean prolificacy of adult Dorper ewes in average condition is generally around 1.5 lambs/ewe lambing and may be relatively responsive to changes in body weight and condition.

Schoeman (2000) also reviewed survival rates of Dorper lambs in South Africa for the period from birth through 90 to 120 d. Mean survival rates in the studies that were reviewed ranged from 83 to 86%. Survival rates for Dorper lambs were equal to or higher than those of Merino, Dohne Merino, Mutton Merino, and Afrino lambs.

Several studies have evaluated age at puberty in Dorper ewe lambs. Schoeman et al. (1993) reported that Dorper ewe lambs reached puberty at $8.14 \pm .29$ mo of age, which was similar to a ½-Finnsheep, ½-Blackhead Persian composite (Composite 1; $8.03 \pm .36$ mo) and slightly later than a 3/8-Finnsheep, ¼-Blackhead Persian, ¼-Van Rooy, and 1/8-Afrikaner composite (Composite 2; $7.64 \pm .26$ mo). Greeff et al. (1993) compared the reproductive performance of Dorper,

Romanov, and various Dorper-Romanov crosses. The proportions of ewe lambs that had exhibited three estrus cycles by 7 to 8 mo of age were 0% for Dorper; 50% for $\frac{3}{4}$ Dorper, $\frac{1}{4}$ Romanov; 66% for Dorper \times Romanov, 74% for $\frac{1}{4}$ Dorper, $\frac{3}{4}$ Romanov, and 71% for Romanov ewes. Fifty percent of Dorper ewe lambs had one or two estrous cycles by this age, but 50% had not yet cycled.

There is limited information on seasonal breeding patterns in Dorper ewes. Joubert (1972; cited by Cloete et al., 2000) reported that postpartum anestrus in Dorper ewes was influenced by season of lambing, ranging from 62 d for fall lambing to 89 d for summer lambing and 123 d for spring and winter lambing. Schoeman et al. (1993) compared Dorper ewes to Composite 1 and 2 ewes (defined above) over three matings: late April and May, late December and January, and late August and September. Fertility in these matings tended to be higher for composite breeds than for Dorpers (.905 vs .750; $P = .10$), but fertility of Dorper ewes was acceptable in these mating seasons.

These results suggest that fertility in autumn and lamb survival in Dorper ewes should at least equal those of traditional U.S. breeds. Dorpers may be inferior to Finnsheep and Romanov ewes and crosses in age at puberty and fertility in multiple lambing seasons but should be competitive with other U.S. breeds for these traits. Dorper ewes are adapted to arid environments and may adjust ovulation rates in response to changes in feed conditions. Still, even under good conditions, Dorpers seem less prolific than Caribbean hair sheep; prolificacy of adult ewes is not expected to exceed 1.60.

Growth Rates and Carcass Characteristics. Mature body weights of Dorper ewes ranged from 61 to 74 kg (Schoeman, 2000). Within the flock monitored by de Waal and Combrinck (2000), postpartum ewe weight varied among years from 42 to 62 kg. Cloete and de Villiers (1987) reported adult ewe weights of 73 kg. If 60 to 70 kg is a typical adult Dorper ewe weight, projected optimum lamb slaughter weights at 66% of adult ewe weight would be 40 to 47 kg. These projected weights are somewhat higher than the slaughter weights of 25 to 45 kg summarized by Cloete et al. (2000).

Schoeman (2000) reported mean weaning weights for Dorper lambs of 16 to 17 kg at 50 d and 26 to 32 kg at 100 d. Dorper lambs were usually equal or superior in weaning weight to lambs of contemporary breeds including the Merino, Dohne Merino, Mutton Merino, and Afrino. However, in a summary of body weights of animals in the South African National Sheep Performance Testing Scheme (Schoeman, 2000), Dorper lambs were lighter than Dormer (a Dorset-Merino composite), Hampshire, Ile de France, Merino Landsheep, Mutton Merino, and Suffolk lambs at both 42 and 100 d. Dorpers were similar in body weight to Corriedale lambs at 42 d but were lighter at 100 d. In studies reviewed by Cloete et al. (2000), preweaning ADG by Dorper lambs averaged 246 g/d and ranged from 210 to 330 g/d. Estimates of ADG from birth to slaughter of 215 and 297 g/d were reported by Schoeman (2000). de Waal and Combrinck (2000) reported that 100-d weights of single Dorper ram lambs varied among years from 22 to 34 kg.

Information on fatness of Dorper sheep carcasses is limited, especially under U.S. conditions. In South Africa, lambs slaughtered at 45 kg and 150 d of age had 3.3 to 5.6 mm of backfat, lambs slaughtered at 42 kg and 294 d of age had 5.6 mm of backfat, and lambs slaughtered at 40 kg and 245 d of age or at 41 kg and 169 d of age had 5.9 and 4.2 mm of backfat, respectively (Cloete et al., 2000). All backfat measures were taken between the 9th and 10th rib, 25 mm from the midline.

Cloete et al. (2000) characterized the Dorper as early-maturing and capable of depositing excess fat at an early age. Optimal carcass weights in South Africa are 18 to 22 kg, and Cloete et al. (2000) indicated that under intensive feeding or favorable environmental conditions, Dorper lambs are slaughtered at 32 to 35 kg live weights. Thus under U.S. conditions, Dorpers seem best suited to production of lightweight lambs or to crossbreeding systems that will increase leanness and delay maturity.

Health and Fitness. The Dorper breed was developed for use under harsh, arid conditions (de Waal and Combrinck, 2000). Several studies have reported behavioral or physiological adaptations that would support performance in such environments. Schoeman and Visser (1995) compared water intake patterns of Mutton Merino, Dorper, and Blackhead Persian (a parent breed of the Dorper) ewe lambs. Blackhead Persian ewe lambs consumed less water than Dorper or Mutton Merino ewe lambs, in absolute amount or in relation to body weight, cumulative feed intake, or cumulative gain. Dorper ewe lambs were intermediate to Blackhead Persian and Mutton Merino ewe lambs. They did not always differ significantly from Mutton Merino ewe lambs but consumed 15% less water ($P < .05$), despite being 10% heavier, and 16% less water/kg feed intake ($P < .10$). By comparison, Blackhead Persian ewe lambs weighed 31% less and consumed 59% less water, 46% less/unit metabolic body size, 43% less/kg weight gain, and 41% less/kg feed intake than Mutton Merino ewe lambs.

Brand (2000) reviewed grazing preferences of Dorper sheep. Dorper ewes selected less grass (14.8 vs 22.9% of the diet) and correspondingly more shrubs and summer annuals than Merino sheep on mixed Karoo grazing in the Eastern Cape. Dorpers also consumed less grass than Merinos under arid Karoo conditions in the Eastern Cape (63.7 vs 86.1% of the diet). Dorpers are often described as relatively nonselective grazers, and results reviewed by Brand (2000) suggest that there is some truth in that assessment.

Performance of Dorper, Red Masai (a fat-tailed, indigenously East African breed), and their crosses under hot, sub-humid conditions in coastal Kenya was reviewed by Schoeman (2000). Performance of Dorper ewes and lambs under these conditions was poor. Prolificacy averaged only 1.02 lambs/ewe lambing, lamb survival was much lower than that of the Red Masai (51 vs 90% between 3 and 9 mo of age), and mature ewe weight averaged only 30.1 kg (vs 26.2 kg for Red Masai). The poor performance of the Dorper relative to the Red Masai in this environment was primarily attributable to lower resistance to gastrointestinal nematode parasites (mainly *Haemonchus contortus*). In both growing lambs

(Baker et al., 1994) and adult lactating ewes (Baker et al., 1999), Dorpers had higher fecal egg counts and lower packed cell volume than Red Masai. Thus, Schoeman (2000) concluded that Dorpers were well-adapted to the harsh semidesert regions of southern Africa but were not suitable for commercial use in the African tropics.

Performance of Hair vs wool Types. Animals within the Dorper breed may be categorized according to fleece cover and characteristics into hair, wool, and intermediate types. Cloete et al. (2000) reviewed the comparative performance of hair- and wool-type Dorpers. No differences were observed in reproductive performance, growth rate to 100 d, or carcass fatness. Based on a sample of 262 lambs, wool lambs had higher dressing percentages, longer hind legs, and longer carcass in one of the two studies reviewed but did not differ from hair lambs in the second (and much smaller) study. These results suggest that wool-type Dorpers in the larger study may have been slightly larger-framed but did not differ from hair-type Dorpers in any productive trait.

Utilization Strategies and Breeding Programs

Hair sheep have the potential to contribute to development of easy-care sheep germplasm. Positive contributions include freedom from wool, resistance to internal parasites, and excellent lamb and ewe vigor, especially in crossbreds. Most breeds, because of their tropical origins, also are capable of reasonable levels of out-of-season breeding. Hair sheep are generally early maturing and, if properly managed, should be capable of lambing for the first time at 12 mo of age.

The thin-tailed breeds of West African origin are relatively prolific, sometimes exceeding an average of 2.0 lambs born/ewe lambing. These breeds are also adapted to hot, humid production environments. Dorpers, which were derived from a fat-rumped African breed, seem less prolific but provide compensatory adaptation to harsh, arid conditions.

Because of their small mature size, purebred hair sheep cannot produce the properly finished 25- to 30-kg carcasses that are currently desired in high-volume U.S. lamb markets (Field and Whipple, 1998). However, hair sheep carcasses may be desirable in some ethnic or other niche markets, and these markets are becoming more important, especially in the eastern United States (Kazmierczak, 1998). Optimum slaughter weights of purebred hair sheep are unlikely to exceed 30 to 35 kg. The relatively light muscling of most hair sheep breeds and the fat distribution patterns of the fat-tailed and fat-rumped breeds are additional problems.

Effective use of hair sheep genetics in high-volume U.S. markets will require crossbreeding and/or use of composite breeds to combine the fitness and freedom from wool of the hair breeds with the growth and muscling of existing U.S. breeds. Katahdins and Dorpers are composite hair-wool breeds that are currently available to U.S. producers. Both are anticipated to be acceptable as dam breeds in existing U.S. markets when mated to terminal sire breeds to produce market lambs, but experimental validation of this expectation is required. The acceptability of purebred Katahdin and Dor-

per lambs is less clear, because little comparative research data are yet available. Katahdins seem to be slightly smaller at maturity than Polypays, and less prolific (Wildeus, 1997). Purebred Katahdin lambs would thus likely go to market near the bottom of the currently acceptable weight range. Purebred Dorper lambs in South Africa are generally slaughtered at 40 kg or less; heavier slaughter weights were associated with greater fatness, and achievement of slaughter weights of more than 50 kg with existing genetics seems unlikely. However, research in South Africa suggests that the carcass conformation of Dorpers may allow them to contribute to markets that desire lightweight, high-quality carcasses.

Use of Katahdins and Dorpers in crossbreeding would likely be as dam lines in two-breed terminal crossbreeding systems. Use of Katahdins or Dorpers as a component of a crossbred ewe may be of limited value because the resulting crossbred female would carry only ¼ hair sheep genetics. Such a crossbred ewe would almost certainly have to be shorn and would likely express little parasite resistance. However, Katahdin × Dorper crossbred ewes would merit evaluation in matings with terminal sires.

Use of Dorpers as a terminal sire breed has also been discussed but seems less promising than use as a maternal breed. Use of Dorper sires on Dorset, Polypay, other Finnsheep crosses or Romanov crosses to produce lightweight carcasses of acceptable quality may be feasible, but it seems unlikely that Dorpers would be superior to other breeds. However, Duckett et al. (1999) reported that meat from Dorper crossbred lambs in the United States was more tender than that of Suffolk crosses, which would be an asset in systems focusing on high-quality product.

Use of Caribbean hair sheep breeds would require additional development efforts to improve growth and carcass merit. The F₁ crosses between Caribbean hair breeds and existing terminal sire breeds would likely produce acceptable carcasses, but further study of lambing difficulty and milk production relative to lamb nutrient requirements would be required before recommending use of purebred BB or SC ewes in terminal crossbreeding programs. Effective use of Caribbean hair breeds may involve development of composite breeds. Katahdins are the only such breed that is currently available. One must consider, then, whether the goal of development of a wool-free, easy-care, parasite resistant commercial ewe can be best achieved by continued selection within the Katahdins or by development of new hair sheep composites. Issues that must be addressed in that consideration include how best to achieve 1) adequate growth rates, muscling, and slaughter weights; 2) high levels of parasite resistance; and 3) freedom from shearing.

Resistance to internal parasites decreased as the proportion of Red Masai (Baker et al., 1994, 1999) or Caribbean hair sheep (Notter et al., 1999) breeding declined. The optimal contribution of parasite-resistant hair sheep breeds to the crossbred ewe will thus vary with the level of parasite challenge and mating system. If the crossbred ewe is to be mated to a nonresistant terminal sire breed, a larger contribution from parasite-resistant breeds may be required to provide adequate protection for both ewe and lamb. However, studies

involving selection for resistance to internal parasites in wool breeds (Bishop and Stear, 1997) have pointed out that the presence of resistant animals on pastures can also reduce worm burdens for susceptible animals by removing infective larvae from the environment. Thus, ewes with high levels of parasite resistance may provide a protective environment for their lambs, even if the lambs are of a more susceptible genotype.

Shearing is not generally required for Dorpers as a result of many generations of selection since formation of the breed or for Katahdins as a result of both selection and their propensity to shed their fleece. The latter characteristic is often attributed to the use of the Wiltshire Horn in development of the breed, but essentially no information on shedding of fleeces in advanced crosses between hair and wool breeds is available to confirm that this is a unique contribution of the Wiltshire Horn. The F_1 BB \times Dorset ewes studied by Clarke (1985) and the F_1 hair \times wool crosses produced by Notter et al. (1999) required shearing (D. R. Notter, unpublished data) but the fleece was of no value. Growth of some wool in winter followed by shedding in summer is also a common characteristic of some SC and BB sheep in the United States. Wool growth and shedding behavior may differ among breeds and with variation in climate and ewe age. In Sumatra, Gatenby et al. (1997) reported that crosses of native Sumatran ewes, which generally have a coarse, kempy fleece, with BB rams had lower wool scores than crosses with SC rams at 9, but not 3 or 6, mo of age. The F_1 lambs were clearly not wool-free at 3 or 6 mo of age, but by 9 mo BB-sired lambs had much less wool than lambs of the other groups.

Minimization of wool cover and achievement of relatively high levels of parasite resistance in newly constructed hair \times wool composite breeds would be more easily achieved in populations containing 75% hair sheep genetics. However, such crosses would require stringent selection for growth rate and mature size, both among foundation animals and within the newly constituted composite line.

Using selected ewes of a terminal sire breed with mature body weights of 100 kg in crosses with selected SC and BB rams (with corresponding mature ewe weights of 45 kg) and with retained hybrid vigor for adult ewe weight of 3% could yield $\frac{3}{4}$ -hair, $\frac{1}{4}$ -terminal ewes weighing 60.5 kg. If slaughtered at 66% of adult ewe weight, market lambs of this breeding could be slaughtered at 40 kg, and crossbred lambs by terminal sires and out of this crossbred ewe could be slaughtered at 53.5 kg. Resulting lambs by terminal sires are thus anticipated to achieve acceptable market weights for current markets but surplus male lambs from the $\frac{3}{4}$ -hair, $\frac{1}{4}$ -terminal composite would be too light for traditional high-volume markets and likely too poorly muscled for seasonal markets involving lighterweight, high-quality carcasses. Use of elite hair sheep rams (with corresponding mature ewe weights of 50 kg) to form the composite would increase adult ewe weight in the composite to 64 kg and slaughter weights of surplus male composite lambs and lambs by terminal sires to 43 and 55 kg, respectively. If a minimum acceptable lamb weight is 45 kg, attainment of this market weight by composite lambs would require a mature ewe weight of 67.5 kg. Fat

distribution patterns in hair sheep and their crosses will likely also influence carcass acceptability but have not been adequately studied.

A propensity to deposit fat internally would allow carcasses of hair sheep breeds to remain relatively lean, but total fat deposition at heavier weights is likely to remain high, thereby affecting total lean yield and feed efficiency.

These results suggest that continuing selection on lamb growth and leanness would be required during formation of a $\frac{3}{4}$ -hair, $\frac{1}{4}$ -wool composite breed to permit all lambs (composite and terminal sire) to be acceptable in high-volume U.S. markets. With use of elite hair sheep rams and with a selection response for optimal lamb slaughter weight of 1.5% (.65 kg)/yr, a target mean slaughter weight of 45 kg could be attained within 3 to 4 yr of formation of the composite line. However, the correlated responses in health and fitness traits that would accompany intense selection for growth and muscling in such lines are not known. Estimates of the pertinent genetic correlations are not available for such populations.

In summary, important steps in evaluation and use of hair sheep genetics in the United States would include the following:

1. comparative evaluation of the Katahdin and Dorper breeds for lamb growth and carcass characteristics, maternal performance, parasite resistance and fleece characteristics as purebreds and in crossing. These evaluations will provide baseline evaluations against which other hair sheep breeds and crosses should be judged.
2. development and comparative evaluation of composite lines containing 50% and 75% Caribbean hair sheep breeding. Emphasis should be placed on use of the relatively high prolificacy of these breeds, attainment of high levels of parasite resistance, minimization of wool cover, and evaluation of growth characteristics in relation to Katahdin, Dorper, and U.S. wool breeds. Evaluations should continue through two to three generations of *inter se* mating to allow segregation of genes affecting fleece type.

Implications

Hair sheep can contribute to development of "easy-care" sheep germplasm. Resistance to internal parasites, high levels of lamb and ewe vigor, and freedom from wool can reduce costs of production and facilitate entry of new producers into the sheep industry. Existing composite breeds such as the Katahdin and Dorper are currently available to the industry and seem to display adequate growth rates. Further characterization of carcass merit is needed, however, for these breeds. The use of higher proportions of hair sheep breeding will require associated selection to improve growth rates and carcass muscling to meet current standards of high-volume U.S. markets.

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Notes

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