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Relationships Among Traits: Growth Rate, Mature Size, Carcass Composition and Reproduction

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Genetic variation in any one trait is often associated with variation in other traits. Thus successful selection for one performance trait may impact other traits affecting efficiency of production. The correlated changes may be favorable or unfavorable, depending on the nature of the genetic relationships among the traits and the contribution of each to production efficiency.

Size and carcass composition.
Average carcass weight of federally inspected lambs slaughtered in the US has increased from 50 lb. in 1968 to 66 lb. in 1998. The principal reason for this trend is apparently packer demand. It costs little more to slaughter and process a lamb producing a 65 lb. carcass than one producing a 50 lb. carcass, and thus the cost/lb. is less for the heavier lamb. Heavier lambs are on average fatter, and fatter lambs in general have a higher dressing percent. The latter is an additional factor in packer preference for heavier lambs.

This shift in carcass weight has important ramifications for the sheep industry, because of basic relationships among growth rate, mature size, carcass composition and adaptability to production environments.

Heavier carcasses can be obtained from lambs of larger breeds, or by feeding animals of smaller breeds for a longer period before slaughter. These two approaches will lead to quite different carcass composition and thus consumer acceptance of the product.

The most important variable in carcass composition is fat content, a trait with an intermediate optimum. Some fat is necessary, for eating quality and for carcass firmness and keeping/shipping quality, while excessive fat reduces consumer acceptance and is usually more expensive to produce.

The proportion of fat in carcasses of continuously grown animals differs to some extent between breeds and sexes, but is most influenced by degree of maturity, i. e. percent of mature weight at slaughter. On average, it is estimated that wether and ewe lambs will have optimum finish (fatness) if slaughtered at 70% to a maximum of 75% of the mature weight of dry ewes (in good condition, condition score 3.0 to 3.5 on a 1 to 5 scale) of their breed or cross. Sakul et al. (1993) calculated equations for predicting carcass fat depth and fat % from slaughter weight, using wether lamb data from crosses of performance-selected Rambouillet and Targhee sheep. Assuming a mature ewe weight of 150 lbs. for such sheep, the recommended lamb slaughter weight would be 105 to 112 lbs., yielding carcasses with about 0.2 in. of backfat and 24-25% fat in the carcass, i. e. yield grade 2. If ewes of a 150 lb. breed are bred to rams of a breed with mature ewe weight of 200 lbs., average parental breed weight will be 175 lbs., and estimated optimum slaughter weight would be 122 to 131 lbs. If slaughtered at heavier weights, they are likely, on average, to be overfat. Since the mature weights used in these examples represent breeds towards the upper end of the size of currently available breeds, it is suggested that lambs slaughtered at weights much above 130 lbs., currently a common practice, are likely to be fatter than desired for optimum consumer acceptance.

Lambs fed to higher degrees of maturity will also, on average, require more feed per pound of gain. However, current low grain prices minimize the economic impact of this effect. Cheap corn has undoubtedly contributed to the observed increase in lamb slaughter weights.

It should also be noted that variation in the growth pattern of animals due to variation in level of nutrition during the growing period can affect carcass composition. Lambs grown out relatively slowly for an extended period will tend to be leaner at a given weight than lambs which continuously grow rapidly, and thus some of the heavier weight lambs currently being marketed may have desired degree of leanness at weights above the guidelines indicated above. The choice of such a system of production is usually determined by seasonal variation in cost or availability of feed. A disadvantage of this means of producing animals that are lean at heavy weights is that periods of slow growth increase the total feed required for a given amount of meat produced, because of the longer maintenance period.

The relationship of degree of maturity to carcass fatness of continuously grown animals indicates that producing heavier carcasses by feeding lambs of small or intermediate sized breeds to heavier weights is not a good option. In the experiment reported by Sakul et al. (1993), carcasses from lambs sired by the smallest sire breed had the highest fat content when all lambs were slaughtered at the same range of weights. Using breeds of larger mature size, if available, is a better approach, and one that should be a long-term goal if the demand for heavy carcasses persists. However, it is the opinion of this author that current slaughter weights preferred by US packers are too high for the genetic potential of most currently available breeds, and that a reduction in average slaughter weight would result in a product more appealing to consumers. Also, there are other factors related to effects of size on production efficiency that need to be taken into account.

There is a strong genetic relationship between growth rate and mature size. Animals from larger mature size breeds grow more rapidly than those from smaller breeds, or, stated alternatively, a genetic increase in growth rate is almost invariably accompanied by an increase in mature size and therefore maintenance feed cost of the breeding flock. For example, in a long term selection experiment for increased 120-day weight (Sakul et al. 1999; Bradford et al., 1999), mature ewe weight increased more (15lb.) than 120-day weight (11lb.). It was estimated in this case that the increased feed cost of the larger ewes would be more than paid for by the increased lamb weight. However, ewe maintenance cost does need to be taken into account in assessing the net benefits of an increase in genetic potential for growth rate and the accompanying increase in slaughter weight.

Size and reproductive efficiency.
An assumption often made in comparing breeds or individuals of different growth potentials is that reproductive rates are the same for animals of different sizes. This may not be true. Numerous observations on natural populations, and long term selection for measures of growth rate or size in laboratory animals, document that animals farther from the average for the species are less "fit", i. e. they have lower fertility or viability and lower net production per breeding animal. This applies to animals at both the upper and lower end of size ranges.

In sheep, estimates of genetic correlations between measures of growth rate or size and traits such as fertility, prolificacy and lamb livability are highly variable, and include both positive and negative estimates with an average not far from zero (Baker et al., 1982; Fogarty, 1995; Al Shorepy and Notter, 1996; Bromley et al. 2000, 2001). Rao and Notter (2000) analysed NSIP data on three breeds and concluded that there were no major antagonisms between litter size and weaning weight or post weaning gain. Michels et al. (2000) concluded from their review that "a clearcut relationship between litter weight components and ewe weight cannot be generalized but may vary among differentially selected breeds and lines within them".

Although the information on genetic correlations from the scientific literature does not provide conclusive evidence one way or the other, the belief that there is a negative relationship between size and reproduction persists (Shelton, this issue). Closer examination of the correlations reported suggests that the relationship between size and prolificacy (ovulation rate and litter size) may be slightly positive (e. g. Rao and Notter, 2000), while those for weight with fertility and viability are slightly negative. However, the variability and low mean values of these estimates preclude firm conclusions. Evidence supporting the postulated relationships comes from results of selection. Lasslo et al. (1985) and Bradford et al. (1999) reported that two lines selected for weaning weight were consistently lower in fertility and lamb livability than an unselected control line or a line selected for multiple births, while litter size increased slightly in one of the weight lines and substantially in the other.

Additional evidence comes from analysis of lifetime production of ewes of different body weights. Shelton (1959) reported a negative relationship between yearling ewe weight and number of years in the breeding flock. Not only did below average weight ewes leave the flock earlier than average ewes, but the heaviest group left the flock almost a year earlier than average weight ewes. A similar pattern held for the relationship between ewe size and lifetime production of pounds of lamb per ewe bred. Some of these differences were probably due to environmental effects on size, but there is evidence, from a wide range of species, of lower fitness of animals farther from the mean in genetic potential for traits such as size.

Differences in fitness tend to be accentuated in stressful environments, for example in situations where feed is scarce or of poor quality part of the year, or the animals are subjected to temperature extremes or serious disease or parasite challenges. Sheep in many production environments unavoidably experience one or more of such stresses. Lower reproductive efficiency of breeds or strains with genetic potential for large mature size are likely to be greatest in stressful environments, and may be of much less concern in favorable production situations. This may contribute to the observed variability among estimates of genetic correlations between size and reproduction.

While increased growth potential and its accompanying increased mature size may be advantageous from the perspective of desired carcass weight, it may result in increased costs of production. For example, lambs from one of two lines selected for increased 120-day weight were significantly leaner than those from an unselected control line when slaughtered at the same weight (Brown et. al., 1987). However, as noted earlier, both weight-selected lines were lower in fertility and lamb viability than either the unselected control or a line selected for multiple births (Bradford et al., 1999).

Because of the indications of a negative relationship between size and reproduction, Shelton (this issue) has proposed that producers use caution in selecting for increased size in dam breeds and general purpose breeds, in which reproductive fitness is critical, and emphasize selection for growth rate only in terminal sire breeds. This will certainly reduce the total impact of a negative association between fitness and reproduction, but the reproductive rate and general fitness of terminal sire breeds also affects overall costs of production, through three pathways.

First, net reproductive rate of the terminal sire pure breeds affects cost of production of the rams used for crossing. This cost is spread over a potentially large number of crossbred lambs for each ram, but is nevertheless an appreciable part of the cost of each lamb. Secondly, the mating capacity, fertility and longevity of the terminal sire breed rams have an important impact on sire cost per lamb. For example, rams from one breed may settle only 25 ewes on average per breeding season, and may average only 2.5 years of productive life in the flock. Rams of another breed that is more active, perhaps less seasonal in breeding capacity, or inherently more fertile may settle 50 or more ewes per year, and breed satisfactorily for an average of 4 years. Differences will be greatest under extensive range conditions, where the largest flocks are found. Thirdly, viability of crossbred lambs may differ between sire breeds. These factors combined can result in a 3- to 4-fold difference in sire cost per crossbred lamb.

Currently in the US, the most commonly used sire breed is the Suffolk, with the closely related Hampshire second, and crosses between the two also used as terminal sires. This is because Suffolks have the highest growth potential and largest mature size of any sheep available; analysis of US NSIP data document their superior growth potential compared to the two other most widely recorded breeds. From this perspective, they provide the best breed for producing heavy, lean carcasses. However, this breed is below average in viability of both purebred (Cundiff et al., 1982; Leymaster, 1991) and crossbred (Bradford et al., 1960; Leymaster and Jenkins, 1993) lambs. The lower prenatal survival of crossbred lambs sired by this breed (Meyer, this issue) also affects relative sire cost of each lamb marketed. While it does not appear to be documented in the scientific literature, producer reports indicate that rams of the breed have a relatively short productive lifespan. The lack of adaptation of ewes of the breed to stressful conditions is widely recognized, and they are generally not used as purebreds for commercial lamb production under range conditions.

The shorter lifespan typically observed for terminal sire breed rams compared to those of other breeds is probably due in part to the fact that the former are usually raised on a very high plane of nutrition, a practice known to shorten lifespan.

Whether the lower lamb and adult viability of the Suffolk breed is associated with their exceptional genetic potential for growth, or simply represents a breed difference independent of growth and size, cannot be stated with certainty.

Producing leaner lambs with desired eating qualities should improve consumer acceptance of US lambs. In the short term, achieving this goal will require either slaughter of lambs at lower average weights than at present, or increasing the genetic potential growth rate/mature size of the breeds used. The latter will not only require time to accomplish, but may increase costs of production as a result of reduced net reproductive rate. It therefore appears that some reduction in slaughter weights would benefit the US sheep industry. If the demand for heavy, lean carcasses from efficiently produced animals is to be met, an important need of the sheep industry is terminal sire breed(s) that combine rapid growth/large mature size with good ram and lamb livability.

Meeting this need could be accomplished by improving the fitness of existing sire breeds, improving the growth potential of higher fitness breeds, or developing new breeds by crossing and subsequent selection. Given enough time, any of these approaches should permit reaching the desired goal, but the time required may be one or more decades. Since growth rate has a higher heritability than fertility and viability, the second and third approaches might take less time than the first. However, attention would need to be paid continuously to fitness, because of the suggested relationship between growth rate and fitness.

An approach that could produce useful results in a much shorter time is comparison of additional existing breeds (including possibly new importations), composites or crosses, as terminal sires. The evaluations should take into account cost of raising the rams, length of service life and numbers of ewes settled per ram, and numbers of lambs marketed per ewe, i. e. sire cost per lamb marketed, as well as growth rate and price received for the lambs.

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