Strategies for Genetic Improvement of Carcass Value in Lambs

D.F. Waldron

Texas Agricultural Experiment Station, Texas A&M University System, San Angelo, 76901

Introduction

Improving carcass composition is one factor that can have an impact on lamb consumption and demand (Ward, 1995; Purcell, 1998). Increased size of cuts and decreased fatness are two factors that affect consumer acceptability of lamb (Jeremiah et al., 1993). The lamb producer that markets superior carcasses, with greater consumer appeal, expects to realize financial rewards from doing so. The expectation of greater income received from marketing superior lambs is motivation for producers to develop a strategy to improve carcass value through selection of genetically superior breeding stock. Using genetic selection to change traits measured on carcasses is different from many traits that can be measured on live animals because direct measurements are not available on the animals to be used for breeding stock. However, progress from selection on correlated traits can yield substantial changes over time.

The importance of increasing our knowledge of lamb carcass composition has been recognized for years. There were several publications from US scientists in the 1960's that addressed prediction of lamb carcass composition, (Field et al., 1963; Judge et al., 1966; Spurlock & Bradford, 1965) lamb carcass value, (Carpenter et al., 1964; Carpenter et al., 1969; Cunningham et al., 1967) and genetic selection for improvements in carcass traits (Botkin, et al., 1969; Bradford, 1967). These US publications were preceded by earlier work of scientists in New Zealand (Barton and Kirton, 1958; Kirton and Barton, 1962; Kirton et al., 1962) and the UK (Bichard and Yalcin, 1964; Bowman et al., 1968).

The 57th Annual Meeting of the American Society of Animal Science, held in 1965, included an invited presentation by Dr. G. E. Bradford (1967) tided: "Genetic and economic aspects of selecting for lamb carcass quality". The working definition of quality in this paper was "percent of lean meat, especially in the preferred cuts, and having desirable eating quality." One of Dr. Bradford's conclusions was "... significant genetic improvement in lamb carcass quality will depend upon the development of reasonably accurate live animal measures of carcass quality."

Considerable developments have occurred in the technology available to measure body composition in live animals. However, the change in carcass composition of US lambs has been limited. Although the technology to measure body composition is available, the financial incentive to make genetic improvement in body composition has not been large enough to encourage breeders to place much emphasis on carcass traits. Therefore, the issue of genetic improvement of carcass composition involves not only genetics and measurement of body composition, but also economics. Nsoso et al. (1999) reviewed several aspects of selection for growth and carcass composition. The purpose of this paper is to review issues relevant to developing a strategy for US lamb producers to select for improved carcass value in lambs.

Determinants of Carcass Value

There are several factors that determine carcass value: carcass weight, composition of carcass (% lean, fat, and bone), pelt condition, animal health, etc. Carcass weight and composition are influenced, in the short term, by choice of feeding regimen, and, in the long term, by choice of breeds and animals within breeds. In general, as weight increases, animals get fatter. However, selection for animals that will produce a heavier carcass while maintaining desirable composition can be accomplished with the use of multiple-trait selection. The response to selection for any one trait depends on the extent to which the trait is under genetic control, the amount of variation, and the accuracy of predicting genetic merit for the trait from the available phenotypic measurements. Response to selection for multiple traits is also a function of the quantitative relationship between the traits. Selection for carcass traits is hindered by the fact that carcass measurements are not available from animals that are candidates for selection. Therefore, genetic merit of the candidates for selection must be predicted from carcass measurements of related animals, or from correlated traits that can be measured on live animals.

Because of the differences in value of the different cuts from a lamb carcass, increases in proportion of lean in the higher value cuts would lead to greater carcass value. Breed differences, and within-breed genetic variation, for distribution of lean tissue within a carcass have been studied by Wolf (1982). He reported heritability estimates ranging from .15 to .46 for proportion of total carcass lean in specific cuts. However, the coefficients of variation were generally low when heritability estimates were high. The difficulty in measuring lean tissue distribution in live animals and the cost of measuring it on carcasses indicate that lean tissue distribution is not likely to be changed by traditional quantitative genetic

methods. The Callipyge gene reported in US sheep in the 1990's (Freking et al., 1998) does result in a desirable change in tissue distribution. However, undesirable effects on meat quality/tenderness (Duckett et al., 2000) have prevented widespread industry acceptance and use of the Callipyge gene. The substantial change in the size of some muscles due to the Callipyge gene has the potential to impact the lamb industry. The effects of this single gene, which can be realized in one generation, are greater than what could be produced by several generations of selection in the absence of a major gene. While work is being conducted to address the meat quality issue, the lamb industry should also pursue other genetic means of improving carcass value.

The selection objectives of increasing carcass weight and improving carcass composition should be considered together because an increase in carcass weight coupled with a decline in composition, or improved carcass composition (greater % lean and lower % fat) coupled with a lower carcass weight may not result in a net gain in carcass value.

Bradford & Spurlock (1972) concluded that weight per day of age is the single best selection criterion for increased lean meat production per animal. This conclusion is supported by high genetic correlation estimates among live weight, carcass weight, and lean or fat-free weight (Bennett et al., 1991; Waldron et al., 1992) from New Zealand studies. However, other selection criteria can be used to alter body composition while selecting for improved growth rate. The correct balance between selecting for more lean tissue and greater growth rate versus less fat tissue and improved carcass composition should be determined as a function of the relative economic value of changes in these traits. The value-based New Zealand lamb market has been shown to financially reward heavier carcasses and penalize fat carcasses (Waldron et al., 1991). It is anticipated that the US lamb market will become more value-based in the future as advances in information technology allow for more carcass data being used to assess value and communicate that value to the producer through financial incentives. Consumer's preference for cuts of lamb is affected by fatness (Jeremiah et al., 1993) and even though the prices paid to US producers do not indicate a strong financial disincentive for overfat lambs, continued production of overfat lambs may lead to a further decrease in consumption of lamb. Therefore, lamb producers and sheep breeders who are making genetic improvement in lamb growth and carcass composition will be positioned to realize the rewards available in a value-based market and they may help the sheep industry to produce a superior product that will build demand.

How then should we select toward the goal of increased growth rate and improved composition?

Measurement of Composition on Live Animals

Substantial resources have gone into research and development of methods of prediction of lamb carcass composition from live animal measurements over the last 35 yr. A goal of live animal measurement is to predict carcass traits that are determinants of carcass value.

Which method(s) of prediction will have an impact depends on accuracy, cost, and availability. The live-animal measurements that have the greatest potential are: realtime ultrasound (RTUS), bioelectrical impedance analysis (BIA), magnetic resonance imaging (MRI), and x-ray computed tomography (CT). A review by Stanford et al. (1998) of published research on these methods concluded that the relatively higher costs of MRI and CT will prohibit their use on large numbers of animals. Because genetic merit is evaluated from a combination of the animal's own record and the records of related animals, not having large numbers of records on related animals is a disadvantage for these two methods, even though CT and MRI have advantages in accuracy. Unless there are substantial changes in the cost of CT and MRI, they are unlikely to have an impact on the US sheep industry. However, in countries where genetic gain in carcass traits can be spread to a larger population of lambs to be slaughtered, CT has been used for evaluating body composition in elite rams (Simm, 1992; Jopson et al., 1995). Jopson et al. (1997) estimated a positive return on investment for using CT scanning on a 1400-ewe nucleus flock and rapidly disseminating the improved genetics to a large (100,000 ewes) commercial flock. Young et al. (1999) have identified scanning positions that provide for accurate prediction of carcass components using multiple scans.

Both, BIA and RTUS are less expensive and more portable than CT and MRI and therefore obtaining measurements on a large number of animals is more feasible. Bioelectrical impedance analysis uses the difference in electrical properties of the different tissues in the body. Berg et al. (1998) reviewed several studies where BIA measurements were used along with carcass weight to predict carcass composition. Generally, the BIA information reduced residual variation after carcass weight was taken into account, but Slanger et al. (1994) reported that using carcass weight and 12th rib fat was as useful as carcass weight and BIA information for predicting total weight of retail-ready cuts. Jenkins et al. (1988) reported similar results, where the predictive value of BIA information was similar to that of a carcass fat depth measurement. The use of BIA in live animals has been evaluated by Slanger et al. (1994) who reported lower precision when using BIA in live lambs relative to carcasses, while the results of Berg and Marchello (1994) showed live animal prediction equations to have R2 values similar to the carcass equations. However, BIA does not provide information about the distribution of lean or fat within a carcass.

The cost of CT scanning in the analysis of Jopson et al. (1997) was 90 times the cost of RTUS scanning. Because of the lower cost of RTUS scanning, and the availability of portable RTUS machines, RTUS has the greatest potential to impact selection practices for improved carcass value. The lower cost of RTUS, compared to CT, must be weighed against the lower accuracy. The lower cost makes it feasible to measure more animals and collect repeated measures on the same animal. The accuracy of measurements obtained from RTUS images has been reviewed by Houghton & Turlington (1992) and was reported to be influenced by the ultrasound equipment used and the skill of the operator. The technology of the equipment and quality of images available has increased since the 1950s and therefore not all research results are directly comparable. In a summary of reports from 1977 to 1989, Wilson et al. (1992) found that ultrasound fat measurements were more often reported to be useful in predicting carcass composition than ultrasound muscle measurements. Genetic evaluations in beef cattle have used measurements from carcasses and ultrasound measurements. The trend seems to be toward making more use of ultrasound measurements because of the ability to get measurements on more animals and a broader range of animals (Wilson et al., 2000). Therefore, the use of RTUS of live lambs appears to have more potential to impact selection practices for improving carcass value than other methods.

Selection Objective

To increase carcass value at a given age of lamb, the weight of lean tissue (muscle) should be increased and the weight of fat tissue decreased. The relative emphasis of these two components should be a function of the relative economic values. Historically, the US lamb market has not paid financial incentives for differences in carcass composition. It is anticipated that as the technology becomes more affordable to record measurements on individual carcasses and use that information to calculate returns to the producer, a value-based marketing system for lamb will become a reality in the US. Therefore, breeders interested in improving carcass value should consider the relative economic values of the future when choosing a selection objective. Because the future is uncertain, consequences to different selection strategies should be evaluated.

Responses to Selection

Clarke et al. (1991) illustrated how the responses to selection for improved carcass value are influenced by the choice of relative economic values for increasing lean and decreasing fat. They reported that selection on live weight at a given age would result in a greater increase in lean compared to fat. Therefore, because lean would increase more than fat, the result is an improvement in percent lean. However, increasing emphasis on selection against fatness, by including additional selection criteria, will lead to greater improvements in carcass composition, but will also result in smaller gains in weight of lean tissue. The goals of decreasing fat and increasing lean must therefore be balanced. The balance can be achieved by using other selection criteria along with live weight. Live weight at a given age is an indicator of growth rate in all three of the primary components of a carcass: lean, fat and bone. Additional selection criteria should be chosen such that they add predictive value for composition. Traits that are positively correlated with one component but independent of, or negatively correlated with, the other components can more effectively discriminate between heavy lambs and heavy, lean lambs.

The high correlation between live weight and weight of lean is due to the part-whole relationship between the traits. Live weight is the single most important trait in selecting for improved carcass value. Live weight is also easy and inexpensive to measure. In order to be effective in increasing carcass value, additional selection criteria must improve the accuracy of prediction of carcass components above that which can be predicted by live weight alone. To be used on a significant portion of the population, the additional trait must be able to be measured inexpensively on a large number of animals. The American Angus Association has calculated genetic evaluations for carcass traits from carcass records of steers. A second genetic evaluation for carcass traits is calculated from RTUS measurements primarily from heifers and bulls (Wilson et al., 2000). It appears that the evaluations calculated from the RTUS are becoming increasingly more valuable than the evaluations calculated from the carcass data because the benefit of using a much larger number of records is greater than the loss due to the lower accuracy of RTUS measurements relative to physical carcass measurements. A single carcass measurement is more valuable than a single RTUS measurement. But, the most significant limitation of carcass data is that it is only available on a subset of the non-breeding animals. Therefore, for genetic evaluation of carcass traits for a breed, RTUS appears to have more potential than carcass measurements.

Which Traits to Use in Selection?

Partial genetic correlations with lean and fat were calculated for combinations of selection criteria (Waldron et al., 1992). The results indicated that among the carcass measurements evaluated, longissumus muscle width was the most useful measure to use along with carcass weight to select for increased carcass value. However, measuring longissumus muscle width accurately by RTUS is difficult because the boundaries between muscle and fat are parallel to the sound waves and RTUS is more suited for showing boundaries that are perpendicular to the sound waves. Several external carcass fat measurements showed to be useful selection criteria in selecting for increased carcass value. Fat depth over the longissumus muscle was the best external carcass fat measurement in terms of selecting for increased carcass lean and decreased carcass fat. Because the boundary between fat and muscle for the measurement of fat depth is perpendicular to the sound waves, fat depth can be measured more accurately than muscle width. Therefore, RTUS measurement of fat depth appears to hold the most promise in improving carcass value. Because RTUS-measured fat depth has strong positive genetic correlations with total carcass fat content (Waldron et al., 1992), leaner carcasses are expected from selection on live weight and RTUS fat depth. Selecting for lower fat depth along with greater live weight is expected to result in more lean tissue and less fat tissue and thus, improved composition (Waldron et al. 1992).

The study reported by Waldron et al. (1992) did not evaluate RTUS muscle measurements. The benefit of including carcass muscle measurements after carcass weight and fat depth are taken into account is small (Bennett, 1991). But, because the marginal cost of obtaining an additional muscle measurement from a RTUS image is small, it is sensible to use the information in calculating genetic evaluations for carcass value. Muscle depth is the muscle measurement that is best suited to RTUS because the boundaries of interest are perpendicular to the sound waves. However, longissumus muscle area and the product of muscle depth and width measured on carcasses are predicted to result in a greater response in carcass value (Waldron et al., 1992). More work is required with modern RTUS equipment to determine the best RTUS muscle measurement to use.

The relative emphasis to place on each of the selection criteria, live weight, fat depth, and longissumus muscle area or depth, should be chosen so that the expected response in carcass value is maximized. New Zealand lamb price schedules indicated that the greatest economic response to the producer called for a relative economic value of 1.25 for increased weight of lean when the value of fat was set at -1 (Waldron et al., 1992). Greater emphasis on increasing the weight of lean will lead to heavier lambs, but not as much improvement in composition. The survey reported by Ward et al. (1995) indicated that improving composition by decreasing fat content is an important factor in efforts to increase lamb consumption. This indicates that more emphasis should be placed on improving composition. The proper balance of selection pressure between increased growth and improved composition depends on customer preferences (consumer or packer) and characteristics of the production and marketing systems (Bennett, 1990). A complete discussion of relative economic values is beyond the scope of this paper.

Application to US Seedstock Industry

Although it is expected that financial incentives for improved carcass value will be seen in the US in the near future, selection on carcass value only is not recommended for all breeds. Greater carcass value may be the primary selection objective for breeds used as terminal sires in crossbreeding programs. However, reproductive rate and adaptability to environmental conditions are important traits for the ewe flock that produces slaughter lambs. Dual-purpose breeds will also need to consider the selection emphasis placed on wool traits.

One factor that limits progress toward selecting sheep for improved carcass value is the low level of performance recording. Performance recording in other countries and other species has been adopted when an economic benefit was perceived. The US lamb market has not provided enough economic incentive to entice lamb producers to invest more in genetic improvement for carcass traits (Purcell, 1998). If the US lamb industry is to grow in the future it must deliver a product to the consumer that is more desirable. Unfortunately, the present marketing system does not efficiently communicate consumer preferences (Williams & Davis, 1998) to those that are generating breeding stock. Therefore, lamb producers may need to make the first move toward producing and marketing lambs that meet consumer preferences, even if they are not financially rewarded in the short term. Improved communication from the retail consumer through the processor to the producers and breeders would help facilitate change toward larger, leaner carcasses.

Dr Dan Waldron
Texas Agricultural Experiment Station
Texas A & M University
7887 U.S. Highway 87 North
San Angelo, TX 76901-9714
Telephone: 915-653-4576

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