The Genetic Improvement of Carcass Composition in Beef Cattle

Reynold Bergen, University of Guelph

Introduction

Although carcass trait selection programs have primarily focused on carcass marbling (quality grade), recent changes in the North American beef industry will very likely increase the economic importance of carcass composition (yield grade). Ultrasound technology is a valuable tool in these efforts. This review summarizes recent research pertaining to the role of ultrasound in improving carcass lean percentage in beef cattle. Incorporating commercial carcass data generated by new grading technologies to improve ultrasound-based genetic evaluations for carcass composition is discussed. The potential value of including genotype data from quantitative trait loci is addressed, as well as negative genetic correlations between carcass composition and other economically relevant traits in commercial beef production.

Literature Review

1. Echoes from the Past

Although carcass traits have received a great deal of attention in North America in recent years, the first well-documented selection for beef carcass value occurred in Britain in 1750 (Towne and Wentworth, 1955). Robert Bakewell's objective was to breed British Longhorn cattle with a high proportion of carcass weight in cuts with the greatest commercial value, and "particularly aimed at early maturity and readiness to put on fat" (Towne and Wentworth, 1955). Bakewell's methods were studied by Charles and Robert Colling and applied to Shorthorn cattle. Whether by accident or design, the efforts of Bakewell and the Colling brothers to improve carcass composition resulted in a dramatic increase in fatness rather than leanness. This fact is amply illustrated in the portraits of cattle bred and exhibited by the Colling brothers early in the 19th century (Figure 1).

In the days of Bakewell and the Collings, increased beef carcass fatness was not entirely negative since there was a genuine need for tallow in candle making during the industrial revolution (Epstein and Mason, 1984; Porter, 1991). The more vigorous lifestyle of that time also meant that people required greater levels of dietary energy (Towne and Wentworth, 1955). However, intensive selection for increased fatness reduced the milk production of the British Longhorn so drastically that it was no longer valued as a triple-purpose breed, and nearly became extinct in the 1800's (Porter, 1991). As we shall see, concerns regarding unfavorable genetic correlations among carcass composition and other production traits still apply today.

Then, as now, "a superior carcass is characterized by a high proportion of muscle, a low proportion of bone, and an optimal level of fatness" (Berg and Butterfield, 1976). However, the "optimal level of fatness" has changed over the years. Since the days of Bakewell and the Colling brothers, the development of petroleum products has greatly reduced the value of tallow. Increased mechanization and a more sedentary lifestyle have also reduced the need for fat in consumer diets. For many years, researchers have recognized that "consumers generally do not wish to eat fat because they believe this may well result in a plumper figure and a shorter life, both of which are undesirable to them" (Brady, 1957). The relatively recent rise and continued popularity and expansion of the fast food industry notwithstanding, the observations of Brady (1957) still apply today.

Voluntary federal beef carcass quality grading started in the U.S. in 1926 (Taylor and Field, 1999) and in Canada in 1928 (Nielson and Prociuk, 1998). However, many packers maintained their own "house grades" until mandatory federal grading was instituted during World War II to ensure product quality standards during wartime price controls (Ewing, 1995). Yield grades estimating the percentage of saleable lean beef in the carcass were introduced in the U.S. in 1965 (Taylor and Field, 1999) and in Canada in 1972 (Nielson and Prociuk, 1998).

Price signals to discourage the production of over-fat beef are communicated to feedlot operators through discounts for fatter (high yield grade) carcasses. These price discounts are relatively small until carcasses reach yield grade 4 (U.S.) or Canada 3 since packers prefer high levels of marbling due to it's association with beef eating quality and tenderness (Barkhouse et al., 1996; Reverter et al., 2003). High quality and yield grades come at a high cost. Fat deposition increases feedlot production costs. Carcass fabrication costs also rise since excess external and seam fat must be trimmed from retail beef cuts to improve consumer appeal. Identifying cattle with the genetic potential to attain high quality grades while maintaining high carcass lean percentage (low yield grades) would benefit the feedlot and packing industries.

Carcass lean percentage has also been largely neglected due to the complex structure of the beef industry. The beef production traits that are important to one level of the industry may be of less (or negative) value to other industry segments. For example, cow-calf producers may prefer moderate birth weights in order to minimize calving difficulty and to maintain a 365 day calving interval. However, calves with low birth weights often tend to have somewhat lower post-weaning feedlot growth performance (Koots et al., 1994). Similarly, although lean carcasses might be preferred by packers and feedlot operators provided that quality grade is not compromised, cow-calf operators often prefer cows with natural fleshing ability in order to reduce winter feed costs and optimize reproductive performance (Broring et al., 2002). Consequently, beef sire purchasing decisions made by cow-calf producers seeking to maximize their own profit may not result in commercial cattle with ideal carcass lean percentage.

Convincing cow-calf producers of the need to improve carcass composition is therefore problematic. Very few cow calf producers retain ownership of their calves through to slaughter; most weaned calves are sold at auction marts to order buyers acting on behalf of backgrounding or finishing feedlots (Small and McCaughey, 1999). These calves are commonly re-tagged upon arrival at the feedlot and co-mingled with calves from numerous other sources. Consequently, the herd of origin and identity of these calves is lost, along with the ability to communicate feedlot performance or carcass data to the primary producer. Efforts to communicate carcass information among the various sectors of the industry is further complicated by the practice of selling finished cattle to the packer on a live basis, in which case the packer is not obligated to provide any carcass data to the previous owner. Even when cattle are sold rail-grade, individual carcass weight and grade data may be returned to the feedlot, but individual animal identification numbers may not since brands and ear tags are removed with the hide. These factors make it extremely difficult for seedstock breeders to obtain information regarding the carcass merit of the commercial cattle generated by their selection programs.

Although yield grades have been in place for nearly 40 years, genetic selection for carcass traits was also largely ignored until recently for another important reason. When beef carcass grading was introduced in the mid 1960's, the simplest way to increase carcass value was by crossbreeding. This requires explanation, since heterosis generally benefits low-heritability traits such as fertility to a greater extent than moderate heritability traits such as carcass composition (Gregory et al., 1994). The importation of "exotic" beef breeds such as Charolais, Limousin and Simmental in the late 1960's to early 1970's meant that drastic improvements in yield grade could be achieved by selecting an appropriate sire breed without investing a great deal of effort in within breed selection. However, since there are few "new" breeds left to import, future genetic improvements will rely on the identification and selection of desirable alleles by within-breed selection rather than the introgression of new alleles from "exotic" breeds.

The intrepid seedstock breeders who did choose to include carcass traits in their breeding programs faced another serious challenge. Since actual carcass data cannot be measured without slaughtering the animal, the genetic improvement of carcass traits required extensive progeny testing. The rate of genetic improvement from progeny testing is relatively slow since progeny of a yearling bull would not produce carcass data until the sire was over three years of age. Structured progeny tests are also extremely expensive and carry a high risk of losing the offspring's unique identification or the carcass data itself. These challenge limited selection for carcass traits in seedstock selection programs (Wilson, 1992).

This was the industry and economic environment to which ultrasound technology specifically designed for collection of live animal carcass data in beef cattle was introduced in the early 1990's. Since then, two major upheavals in the North American beef industry have drastically changed the importance of carcass traits in beef cattle breeding programs.

The first major change was the reappearance of "house grades" in North American packing plants. These branded beef programs offer premiums for individual carcasses meeting specifications for weight, yield and quality grade. It is estimated that over fifty percent of Canadian beef is sold under a branded beef program (Beef Information Center, 2004). This growth in value-based marketing has led to an increase in vertical coordination among the different sectors of the beef industry. Consequently, carcass traits are becoming more important.

Secondly, the recent discovery of Bovine Spongiform Encephalopathy (BSE) in Canada and the U.S. are also altering the cost structure of the beef packing industry. Although beef consumption by domestic consumers has not decreased in response to BSE (Canadian Cattlemen's Association, 2003), the value of ruminant meat and bone meal certainly has (Cochrane, 2003). If market forces, or regulatory intervention or irrational fears cause other livestock industries to also stop using tallow as an energy supplement, a source of packer revenue would be eliminated while simultaneously increasing waste fat disposal costs. In this case, discounts or premiums based on carcass composition would become steeper.

2. Use of Ultrasound to Select for Beef Carcass Composition in North America

Ultrasound technology has become a valuable tool to evaluate carcass traits in seedstock selection programs. Since ultrasound allows 'carcass' measurements to be collected on live animals, this technology may allow breeders to reduce their reliance on actual carcass data (Wilson, 1992). Ultrasound therefore presents the potential to lower the cost and increase the rate of genetic improvement, with a higher confidence of maintaining correct animal identification. The last fifteen years have witnessed a great deal of research regarding the value of ultrasound measurements as predictors of carcass merit in beef cattle. This research is summarized below.

2.1. Repeatability and Accuracy of Ultrasound Measurements

The relationship between ultrasound measurements collected on the same animal on the same day (repeatability), and the relationship between ultrasound measurements collected on the live animal with carcass measurements collected after slaughter (accuracy) have been studied extensively. These studies concluded that trained and experienced ultrasound technicians are capable of obtaining highly repeatable ultrasound fat depth and l. dorsi area measurements (Bergen et al., 1996; Hassen et al., 1998; Herring et al., 1994b; Perkins et al., 1992b; Robinson et al., 1992). Accuracy statistics indicate that ultrasound measurements also compare reasonably well with the corresponding carcass measurements (Bergen et al. 1996; Charagu et al., 2000; Greiner et al., 2003b; Hassen et al., 1998; Herring et al., 1994b; Perkins et al., 1992b; Robinson et al., 1992). Although overall ultrasound accuracy statistics are acceptable, many of these studies have shown that ultrasound fat measurements under- and overestimated carcass fat depth on lean- and over-fat carcasses, respectively (Charagu et al., 2000; Hassen et al., 1998; Greiner et al., 2003b; Herring et al., 1994b; Robinson et al., 1992). Similarly, ultrasound measurements tended to overestimate muscle size on carcasses with small l. dorsi area, and underestimate muscle size on carcasses with large l. dorsi area (Charagu et al., 2000; Hassen et al., 1998; Herring et al., 1994b). Although ultrasound technician error plays some role in these discrepancies, factors such as hide removal, carcass hanging, shrouding, rigor mortis, and quartering also influence the relationship between live and carcass measurements (Perkins et al., 1992a; Robinson et al., 1992).

Regardless of the cause of live ultrasound vs. carcass discrepancies, these findings may impact genetic evaluations based primarily on ultrasound data from yearling bulls. Since young bulls tend to be leaner and more heavily muscled than typical commercial carcasses, they represent the very cases that are most likely to be in error. If ultrasound measurements do not detect the true degree of variation in fat depth and l. dorsi area in seedstock cattle, estimates of additive genetic (co)variance, heritabilities, genetic correlations, accuracy and the rate of genetic improvement may be adversely affected.

2.2. Using Ultrasound Measurements to Predict Carcass Composition

Although it is important that ultrasound measurements are repeatable and bear a reasonable relationship to subsequent post-slaughter carcass measurements, the real objective of measuring fat depth and l. dorsi area is to obtain an estimate of carcass lean percentage. Several studies have addressed this issue.

The majority of ultrasound measurements are collected at the 12/13th rib interface, since this is also the site of carcass grading. Most studies have found that ultrasound measurements collected at the 12/13th rib interface can predict carcass lean percentage nearly as precisely as the corresponding carcass measurements. Precision (R^2) of equations predicting carcass lean percentage based on 12/13th rib ultrasound (vs. carcass) measurements include 0.73 (vs. 0.69; Bergen et al. 1996), 0.64 (vs. 0.68; Greiner et al. 2003a), 0.49 (vs. 0.60; Herring et al. 1994a), 0.38 (vs. 0.40; Realini et al. 2001), and 0.18 (vs. 0.31; Williams et al. 1997). Furthermore, ultrasound fat depth is a much stronger predictor of beef carcass composition than ultrasound l. dorsi area. Partial r^2 values in the above studies indicate that fat measurements are three to eight times as important as l. dorsi area as predictors of carcass lean meat yield.

Since ultrasound measurements are not restricted to the 12/13th rib interface, efforts have been made to identify alternative scan sites that may improve predictions of carcass composition. These include depths of the body wall (Greiner et al., 2003a), rump fat (Greiner et al., 2003a; Realini et al., 2001), gluteus medius (Realini et al., 2001) and biceps femoris (Williams et al., 1997). The results of these papers indicate that the majority of variation in carcass composition is explained by 12/13th rib ultrasound fat and muscle measurements, and there is little benefit to adding additional ultrasound measurements. The possible exception to this is rump fat, which showed considerable benefit in the study of Williams et al. (1997), though not in the studies of Greiner et al. (2003a) or Realini et al. (2001).

2.3. Genetics of Carcass and Ultrasound Measurements

The effective use of ultrasound measurements in beef cattle breeding programs requires that ultrasound traits be heritable and genetically correlated to carcass traits measured in commercial offspring. Several recent reports have addressed this issue (Crews and Kemp, 2001 and 2002; Crews et al., 2003; Devitt and Wiltonk 2001; Moser et al., 1998; Reverter et. al., 2000). These papers generally agree that ultrasound traits are as heritable as the corresponding carcass traits, and that corresponding ultrasound and carcass traits are moderately correlated with each other (Figure 2). This suggests that selection based on live animal ultrasound indicator traits for carcass lean percentage should be reflected in the corresponding indicator traits of their commercial progeny.

These findings have led to the development of carcass trait EPDs based on ultrasound measurements collected from yearling seedstock bulls and heifers. Many seedstock producers are using these evaluations in their breeding programs, and a variety of private commercial interests have arisen to collect, interpret, and manage ultrasound data. The next section of this paper will address potential improvements that can be made to current ultrasound-based genetic evaluations for carcass composition.

3. Scanning the Horizon: Improving Genetic Evaluations for Beef Carcass Composition

Although several purebred beef breed associations have begun to include ultrasound carcass data in their genetic evaluations, more work is needed to take full advantage of the data. The main conundrum is that although carcass data collected from commercial cattle and ultrasound data collected from seedstock bulls and heifers are genetically correlated, they are not the same traits. Evidence that genetic correlations between seedstock ultrasound and commercial carcass measurements are less than 1.00 is illustrated in Figure 2. This is not surprising. Young bulls and heifers are frequently raised on diets designed to limit fat deposition and may not be able to fully express their genetic potential for fattening. In addition, unlike bulls and heifers, fat and muscle development in steers is unaffected by endogenous reproductive hormones. Finally, seedstock bulls and heifers evaluated at 365 days of age are likely at a different stage of physiological maturity than commercial cattle adjusted to a slaughter age of 440 days. Recent research has examined how to best deal with the separate but correlated carcass traits measured in live seedstock and commercial beef carcasses, and has provided preliminary answers to three important questions.

3.1. Should EPDs be reported as "seedstock ultrasound" or as a "commercial carcass" equivalent?

Although live ultrasound and carcass traits are not genetically identical, reporting separate evaluations for commercial carcass vs. seedstock ultrasound data risks information overload and confusion for the target audience of bull buyers. Consequently, combining commercial carcass data and live animal ultrasound measurements into a single evaluation for carcass merit will enhance the adoption of these genetic evaluations by the bull buying public.

The question then becomes whether genetic evaluations for carcass traits should be reported as a "live seedstock ultrasound" or as a "commercial carcass" EPD. Since the objective of the selection program is to improve commercial carcass value, EPDs should be reported as a "commercial carcass" EPD rather than as a "seedstock ultrasound" EPD. This distinction is important.

Since an EPD indicates the animal's expected average genetic contribution to it's progeny, a one-unit increase in sire EPD should result in a one-unit increase in progeny phenotype. Crews (2002) regressed progeny phenotype on sire EPD for progeny tested sires using carcass data from a structured Charolais progeny test. Regression coefficients for carcass weight, fat depth, l. dorsi area and marbling score did not differ from one, indicating that the carcass trait EPD functioned as expected. However, since ultrasound and abattoir carcass traits are not perfectly correlated, reporting carcass trait evaluations solely as live ultrasound data may give misleading results. Crews et al. (2004) showed that a sire fat depth EPD based solely on ultrasound data collected in Simmental seedstock tended to greatly underestimate the response seen in progeny carcass fat depth; a 1.00 mm increase in ultrasound fat depth EPD resulted in a 1.73 mm increase in carcass fat depth. This suggests that genetic evaluations for fat depth based exclusively on seedstock ultrasound data may underestimate the animal's genetic propensity for fat deposition. While this may not drastically affect sire rankings, it may undermine commercial producer confidence in the merit of an ultrasound-based genetic evaluation system. Crews et al. (2004) then scaled these ultrasound-based EPD to a carcass equivalent using genetic regression (Cameron, 1997):

$$EPD_{CFat} = \left[\frac{d_{gUSFat,CFat}}{d^2_{gUSFAT}} \right] \times EPD_{USFat}$$

where,

EPD_{CFat} = seedstock EPD for commercial carcass fat depth,

$d_{gUSFAT,CFAT}$ = genetic covariance between seedstock ultrasound and commercial carcass fat depth,

d^2_{gUSFAT} = genetic variance of seedstock ultrasound fat depth, and

EPD_{USFat} = seedstock EPD for ultrasound fat depth.

After applying this genetic regression to the ultrasound EPDs, the regression of progeny phenotype on sire EPD produced coefficients equal to 1.00 for all ultrasound traits (Crews et al., 2004).

3.2. How can commercial carcass data be incorporated into ultrasound-based evaluations?

Although ultrasound data can be collected more economically and rapidly than carcass data with a higher confidence of maintaining correct animal identification, recent developments in the beef industry may conspire to drastically increase the amount of reliable carcass data available for genetic evaluations. Firstly, several video-based automated grading systems have been developed in Canada (Cannell et al., 2002) and the U.S. (Shackelford et al., 2003). These systems can predict carcass lean percentage more accurately and precisely than graders working at line speeds (Cannell et al., 2002), and would augment the development of databases containing individual carcass weight, fat depth, l. dorsi area and marbling score data. A great deal of work has also been invested to develop birth-to-slaughter animal tracking systems in Canada (Canadian Cattle Identification Agency, 2004) and the United States (Antosh, 2004) in response to human health and animal disease concerns. These identification programs have enormous potential value in collecting carcass data from commercial cattle, provided animal identification is maintained to the point of carcass grading, data ownership and security issues can be resolved, and commercial carcass data collection can be linked to suitable genetic evaluation database.

Crews et al. (2003) combined live ultrasound data from Simmental bulls and replacement heifers and carcass data from commercial crossbred cattle as three separate but correlated traits in a multiple trait genetic evaluation. This approach makes the most efficient use of all available data, produces genetic evaluations for carcass traits much more quickly than progeny testing alone, and facilitates the evaluation of carcass traits at the level of the producing animal.

3.3. Should carcass trait EPD be reported for indicator traits or for the economically relevant trait?

As mentioned above, carcass traits should be evaluated at the level of the producing animal rather than seedstock. Similarly, it would be of value to evaluate the economically relevant trait (i.e. carcass lean percentage) rather than simply evaluating indicator traits (i.e. fat depth and l. dorsi area). Reporting separate evaluations for fat depth and l. dorsi area may imply that these traits are of equal value in predicting carcass composition, when results shown in section 2.2 indicates that this is clearly not the case.

To date, two studies have examined the relationship between live seedstock ultrasound measurements and commercial carcass lean percentage based on carcass dissection. Crews and Kemp (2001) examined these relationships in composite seedstock (404 bulls and 514 heifers) and partial carcass dissection data from 235 steers. Reverter et al. (2000) used ultrasound data from purebred Angus (4209 bulls and 3987 heifers) and Hereford (1793 bulls and 1612 heifers) and complete carcass dissection data from 604 Angus and 333 Hereford steers and heifers. Genetic correlations between live seedstock ultrasound and commercial carcass measurements with dissected lean percentage from Reverter et al. (2000) illustrated in Figure 2. These data indicate that seedstock ultrasound fat depth and l. dorsi area have a moderate genetic correlation with the dissected carcass lean percentage of commercial cattle.

We must then determine how to calculate a carcass lean percentage EPD in a genetic evaluation program. There are essentially two options.

3.3.1. Calculation of an ultrasound lean meat yield phenotype

Firstly, several equations predicting carcass lean percentage based on pre-slaughter ultrasound measurements are available in the literature (Bergen et al., 1996 and 2003; Greiner et al., 2003a; Herring et al., 1994a; Realini et al., 2001; Williams et al., 1997). Multiplying ultrasound fat depth and l. dorsi area measurements by their respective regression coefficients would generate a phenotype for carcass lean percentage. Genetic evaluations could then generate a single EPD for carcass lean percentage rather than separate evaluations for fat depth and l. dorsi area. If genetic (co)variances between seedstock ultrasonically predicted lean percentage and commercial carcass lean percentage were available, the genetic regression approach used by Crews et al. (2004) could be used to scale the seedstock ultrasound lean percentage EPD to a commercial carcass lean percentage EPD.

However, there is a potential weakness associated with using any regression equation to predict carcass lean percentage in the live animal. The regression coefficients for fat depth and l. dorsi area in any given equation each have their own standard errors. This suggests that although these are the "best" regression coefficients for the data set as a whole, many individuals might be better described by a slightly different set of regression coefficients. Consequently, applying a "one size fits all" equation to an entire breed may bias the genetic evaluations for animals that are not adequately described by the set of regression coefficients chosen.

3.3.2. Multiple trait evaluation of commercial carcass lean percentage

An alternative method to calculate EPD for commercial carcass lean percentage may be to use multiple trait evaluation. For example, a seven-trait evaluation would use seedstock ultrasound fat depth and l. dorsi area data (treating bull and heifer data as separate but correlated traits) and commercial carcass fat depth and l. dorsi area data as indicator traits to calculate an EPD for dissected lean meat percentage of the commercial carcass (which would not be routinely measured). Genetic (co)variances among bull and heifer ultrasound traits and commercial carcass lean percentage reported by Crews and Kemp (2001) and Reverter (2000) would be very valuable in these efforts.

This approach would efficiently use all available data and improve the accuracy of the genetic evaluation. However, a weakness analogous to that mentioned for the phenotypic pre-adjustment approach discussed in section 3.3.1 may also apply here, since "one size fits all" genetic (co)variances would be applied in all EPD calculations. Further investigation is needed to determine whether there are non-linear genetic correlations among the indicator traits with the economically relevant trait (i.e. dissected lean percentage of the commercial carcass). Additive genetic variances may also change across the range of the indicator traits, particularly at the extremes of the distribution. This would affect genetic parameters of the indicator traits and the accuracy of the genetic evaluation for carcass lean meat percentage. However, these issues are clearly beyond the scope of this review.

4. Additional Considerations Regarding the Evaluation of Beef Carcass Composition

Although this paper has concentrated on the use of ultrasound technology to identify animals with superior genetic potential for improved carcass lean percentage, several additional factors must be considered.

4.1. Unfavorable Genetic Correlations With Other Economically Relevant Traits

Given the near demise of the British Longhorn breed in the 19th century (Porter, 1991), It would be remiss not to briefly mention the potential costs associated with increasing leanness. Unintended and undesirable effects on reproductive traits (Bennett and Williams, 1994) as well as marbling and tenderness (Reverter et al., 2003) may result from selection for increased leanness. Fortunately, since these unfavorable genetic correlations are not -1.00, careful seedstock selection decisions and use of terminal crossbreeding systems should help to minimize the negative effects on other performance and quality traits.

4.2. Inclusion of Molecular Data in Genetic Evaluations for Beef Carcass Composition

Molecular genetics research has revealed several loci influencing carcass composition. Examples of these include leptin (Nkrumah et al., 2003) and myostatin (Wheeler et al., 2001). Since physiological roles of these loci have been determined, they can be considered "quantitative trait loci" (QTL) rather than simply linked markers. These QTL may allow valuable refinements to selection programs for carcass traits. Since traditional animal breeding is based on the infinitesimal model, it considers the average effect of all loci but ignores the specific effect of any given locus. In contrast, in the absence of pedigree information, QTL analyses examine the specific effect of a single locus, while ignoring the influence of all other loci in the genome. In order to take full advantage of all available genetic information, current animal models will need to be modified to report an EPD that accounts for the fixed effect of known QTL genotypes as well as the average effect of the remaining loci. Collection of QTL genotype data from seedstock and commercial livestock may be aided by the development of DNA-based animal tracing and parentage verification systems (Shaw, 2004).

5. Conclusions and Implications for the Genetic Improvement of Beef Cattle

Ongoing changes in the North American beef industry will likely cause carcass composition to become a more important trait in seedstock selection programs. Although ultrasound technology has made an important contribution to the genetic improvement of carcass composition, the manner in which genetic evaluations incorporate and report ultrasound data can be improved. In particular, EPD should be reported for the economically relevant trait (carcass lean percentage) rather than indicator traits (fat depth and l. dorsi area), and should be expressed as a commercial carcass equivalent EPD (rather than as a seedstock ultrasound EPD). Development of birth to slaughter animal identification programs and automated grading technologies present the opportunity to greatly increase the amount of commercial carcass data available for genetic evaluations. However, close attention needs to be paid to the impact of genetic selection for increased carcass leanness on other beef production and quality traits. Additional improvements in the genetic evaluation of carcass composition will likely be gained through the incorporation of QTL data as it becomes more widely available.

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Figure 1. "A White Short Horned Heifer, 7 Years Old" (left) painted by Thomas Weaver in 1811, and "The Durham Ox" (right) painted by John Boultbee in 1802. These cattle were bred and raised by Charles and Robert Colling. Images obtained from http://www.ruralhistory.org/online_exhibitions/livestok/cat_ls.html, with permission from the Museum of English Rural Life.

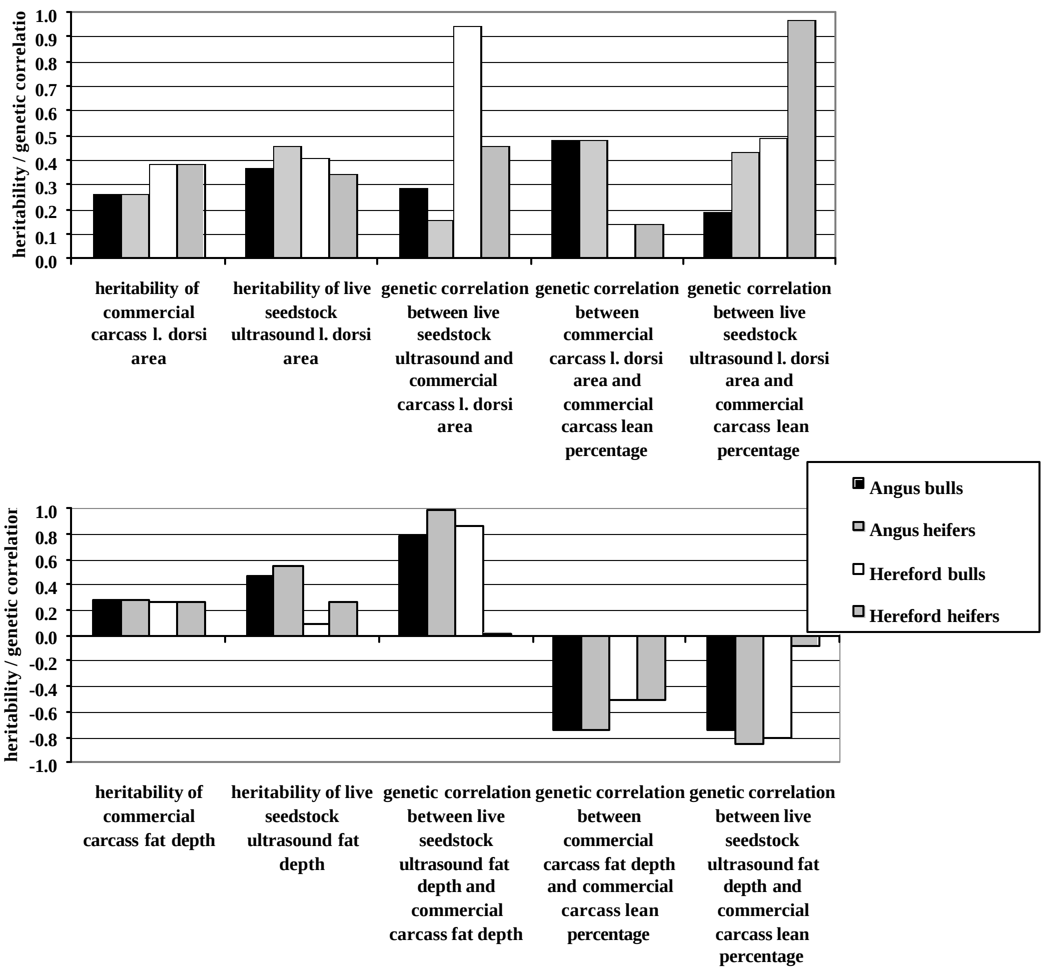

Figure 2. Heritabilities and genetic correlations among commercial carcass and live seedstock ultrasound indicator traits and dissected commercial carcass lean percentage in Angus and Hereford bulls, heifers and commercial cattle (data from Reverter et al., 2000).