Selecting Superior Meat Sheep in the 21st Century

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In the next few years, there will be increased availability of multiple DNA tests that identify specific genes, alleles or regions of chromosomes that enhance meat production, performance and disease resistance. Will this totally change how sheep producers select superior stock?

Last Three Decades of the 20th Century

Before thinking about the future, a look at the end of the 20th century is needed. By far the greatest advancement in selecting superior livestock genetics in the latter half of the 20th Century was the development of quantitative genetic procedure called Best Linear Unbiased Predictor (BLUP). These advanced statistical analyses provide EPDs (expected progeny differences). The theory behind BLUP originated in the 1950s, but its practical use by livestock breeders required more accessible and powerful computers. The use of BLUP and the resultant EPDs have dominated selection of superior stock in the US beef, dairy and pork industries since the 1970s and 80s.

Start of the 21st Century

At the start of the 21st century, EPDs produced by BLUP are still the best that producers have to identify genetics for superior performance. There is nothing better. Ten, fifteen or even one hundred DNA tests will not replace BLUP when it is used to identify balanced optimal performance. Growth and reproduction are controlled by hundreds of genes with complex interactions between them. So the livestock industry will still require the on the ground evaluation that BLUP provides to determine how new genetic combinations perform in a multitude of environments and production systems.

EPDs increase accuracy in predicting the performance of the progeny of breeding stock. In sheep, common traits include weaning weight, post-weaning gain, prolificacy, milk, loin/rib eye area, back fat and also fiber traits for wool sheep. Two difficulties in selecting superior breeding stock are: a) the observed phenotypes of all important performance traits are only partially heritable and b) how to create selection indices that balance performance for the economically important traits. Even when raised in the same flock under the same conditions, selecting the lambs with the fastest growth is not as accurate as using EPDs. Comparing lambs born in different seasons and different years or in different flocks is even more difficult. Basically, we use EPDs to increase the accuracy of selection. Each performance trait is composed of both genetic and environmental components ("nature and nurture").

We do need to step back from the use of EPDs and DNA tests and point out a couple of things. EPDs are not the only components used to identify superior animals. A teacher and mentor of mine, Dr. Charles Parker, likened the selection of superior genetics to a three-legged milking stool. The three legs of the stool are performance, conformation and pedigree. Animals that are structurally incorrect and have unacceptable conformation need to be culled.

Ignoring structural soundness and conformation will eventually result in animals that are unacceptable. Another issue is that many livestock producers have used EPDs to maximize performance and have not balanced selection. Just as with race cars that are designed for extreme performance, continually selecting for maximal post weaning growth and loin eye can result in extreme animals with significant production issues. Race cars are not balanced for comfort or efficiency. A protocol for selection of superior livestock for meat performance needs to balance economically important traits, including reproductive efficiency and maternal behavior as well as rate of growth and muscling. Too often, breeding animals are picked only for maximal performance for only one or two traits and are not balanced.

Superior performing stock needs optimal growth, reproductive efficiency and carcass yield. One approach is to use indices which weight each trait with its importance for the breed and production system. Indices are typically constructed for "maternal", "terminal-sire", wool or dual purpose breeds. A few indices also include costs of inputs (forage, purchased feeds) and market (selling price).

New Sheep Selection Indices

Many of the advances in selection of superior sheep genetics in the 21st century will be the result of developing improved selection indices that weight and balance the most important traits needed for increased profit and production. EPD selection indices are available in the major sheep producing countries but they can be improved. Two examples of indices created in the US for the National Sheep Improvement Program are highlighted in this section. Other countries have good indices as well. They can all be improved.

Lamb Survival to Market. Common sense indicates that we need to emphasize selection for lamb survival to market age. Too many sheep in the US and the world require

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significant assistance during lambing and the lamb's first few days. If they survive the first few days many die before market. Common sense is that no matter how superior the genetics are for growth or muscling, if the lamb isn't born or alive at market, there will be no income and no meat. In the past, lamb survival has been considered important only for maternal breeds.

Preliminary studies at research centers in the USA indicate that the sire breed selection may affect lamb survival to market by at least 15%. Breed sires were used on a common ewe breed so that prolificacy and maternal behavior had no effect and the differences in survival and production were due to the breed used as the sire. If the producer is selling lambs by the pound at weaning or slaughter weight, a 15% decrease in survival has a much greater effect on sale barn receipts than a 15-30% increase in weight gain. The producer in most marketing scenarios in the USA will be rewarded by using sires with moderate gain and high survival and not selecting sires only on maximal gain and muscling and ignoring lamb vigor. These producers will not be bragging about weight gains over coffee at the cafe on Saturday morning, but quietly smiling about their bank accounts being fatter.

Future sheep selection indices must include survival as a component trait, no matter whether the breed is used as a terminal, maternal or dual purpose breed in the production system. An example of the importance of survival for meat production is the Pounds Lamb Weaned/Ewe Lambing index developed for NSIP for the Katahdins and in the future for other breeds. This trait was developed by Vanimisetti, Notter and Kuehn from Virginia Tech (2004, 2007). Their evaluations indicate the relative importance of each component that contributes to total pounds weaned. Genetic correlations in this study emphasize the importance of number weaned. The genetics for ewes that reliably wean is much more important at predicting pounds weaned than other traits such as growth or number born (Table 1). A mature Katahdin ewe averages 2.1 lambs/litter and there are significant numbers of triplet litters (Table 2). This study once again emphasizes the importance of selecting for live weaned lambs rather than just for number born, growth and superior conformation. One of the key points from this study is that 94% of the "total pounds weaned" in Katahdins can be predicted by the number weaned. Other breeds or cross-breds are surely similar. Weaning percentage and total pounds weaned are heritable (0.10 to 0.14) in the Katahdin.

Table 1. Genetic correlations among ewe productivity[a] and component traits in the Katahdin

Trait 1	Trait 2	Genetic correlation
Number born	Number weaned	0.5
Number born	Average pounds weaned	0.16
Number born	Total pounds weaned	0.42
Number weaned	Average pounds weaned	0.52
Number weaned	Total pounds weaned	0.94
Average pounds weaned	Total pounds weaned	0.77

[a] Ewe productivity measured as total pounds weaned per ewe lambing

Table 2. Frequencies for number born and number weaned

Number born	Number weaned				
	0	1	2	3	All
1	62	1035	0	0	1097
2	46	238	1388	0	1672
3	26	56	171	168	421
4	2	3	11	8	24
All	136	1332	1570	176	3214

From Vanimisetti, Notter & Kuehn, 2004

Selection Indices Weighted for Financial Return. Seed stock producers in the major sheep producing countries of the world use indices to meet breeding objectives. All of these include financially important traits, but few weight the component traits for production costs and market returns. To optimize selection for financial return, seed stock producers need indices that weight the economic costs and market value. Recently, the National Sheep Improvement Program in conjunction with researchers at Virginia Polytechnic Institute and State University and Montana State University released a new breeding objective for Targhee sheep (Borg et al, In Press). Targhees are a medium/fine wool breed general purpose breed often used in extensive range conditions of the western USA.

Borg and coworkers produced an aggregate breeding value predicted directly from a published multi-trait EPD by weighting each EPD by its economic value. Weightings were determined by using a bio-economic model that predicted changes in animal performance, feed requirements, costs and returns associated with changes in each EPD. Feed costs for ewes and lambs were predicted to be greater with selection for increased weaning weight, maternal milk, fleece weight and percent lamb crop. The majority of these flocks sell lambs as feeders. Lambs with high weaning weights are discounted by the lamb buyers. Thus, the model had to include economic losses for lambs discounted for being too large.

Borg's results are summarized in Figure 1. It is a complex figure, but makes a few very important points.

The simple approach to understanding Figure 1 is that if a trait has a value of greater than 100, then selecting for that trait will increase economic return. If the height of the bar is less than 100 then selecting for that trait will decrease economic return.

Each bar in the graph indicates the change in economic value from

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one generation to the next by selecting for improvement in one trait while holding the genetics for all other EPD traits constant. The trait of interest is moved one standard deviation greater between the two generations. Values greater than 100% for a trait indicate an increased financial return by selecting for that trait. Values below 100% indicated decreased return for increased selection for that trait. The greatest economic return for both Targhee farm and range flocks is created by increasing the percent lamb crop. The amount of increased economic return varies based on cost of feed and the discount for selling heavy feeder lambs. Significant increase in value of marketed lambs is also realized by selecting on weaning weight. Note that increased ewe size (yearling weight) decrease economic returns.

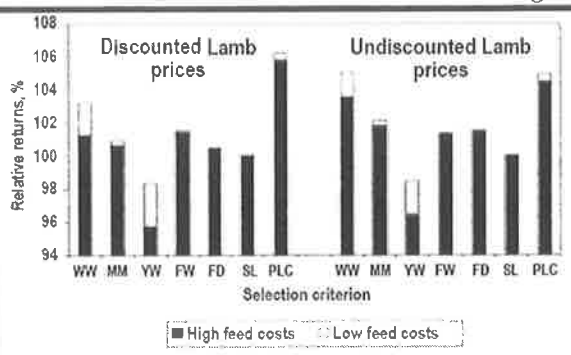

Figure 1. Returns over feed costs with different selection criteria with high and low feed costs and with and without discounting for heavy lambs.
EPDs: WW = weaning wt, MM = maternal milk, YW = yearling weight, FW = fleece weight, FD = fiber diameter, SL = staple length, PLC = percent lamb crop
From: Borg and coworkers, In Press.

Key points from Borg and coworkers' results include that no matter the cost of feed or the price received for lambs: a) the greatest financial return results from increasing the number of lambs born. While the selection index does not weight survival, increasing the number born is predicted to increase the number of live lambs marketed. b) Increasing rate of gain (weaning weight) is predicted to increase financial return but to a lesser extent than increasing number born, but the amount of return for increasing weaning weight is affected by cost of feed and price received for lambs. c) Increasing yearling weight (mature size) of the ewes decreases financial returns. The authors state that larger ewes eat more feed and have higher maintenance costs.

GENOMIC WORK

The genome of sheep has been sequenced. In the future, as genetic markers and specific genes are identified with important production traits, sheep breeders will be able to send in DNA (blood samples or hair) and receive results back indicating whether a sheep is carrying specific traits. The most common current use of this in the USA sheep industry is for scrapie resistance as many seedstock producers sell sheep that are RR at codon 171. Similarly, other genes available for selection include the myostatin gene in Texels and the Carwell gene in Dorsets which both improve muscling, carcass yield and decrease fat thickness. Selection for these genes increase loin eye area (longissiumus dorsi) and decrease fat thickness without any negative effects on tenderness. These genes can be added to many breeds with open flock books. In the future we can expect several more DNA tests to be available.

New DNA Technology To Be Released. In the next year, new DNA technology will be released. For $300 to $1000, a potential service sire can be tested at 64,000 different sites in the sheep genome. These are called 64K SNP chips (single nucleotide polymorphisms; acronym pronounced "snip chips"). This is an incredibly powerful tool. The power of this new DNA tool is way ahead of our knowledge of the sheep genome to know how to use it. Over the years it will become more useful, as the sheep scientists and genetic companies determine which of these 64,000 sites at which sheep can differ are functionally important. At this point, few are known.

Let's take an example. In the next year, we will be able to compare the differences at 64,000 different sites in the sheep genome for a Katahdin sire, Suffolk and a Texel sire. We find a few hundred to a thousand DNA sites where they differ, but which of these 64,000 sites are important? Which of the 64,000 make a Texel a Texel and make a Katahdin a Katahdin? Which of the several differences lead to shedding? It will take many years of research to determine which of the 64,000 SNP's (single nucleotide polymorphisms) are important and for what traits.

In a few years, the leading sheep breeds and leading breeders will be selecting and selling sires based on EPD indices that couple EPD traits and with specific DNA markers identified by the 64K SNP Chip. EPDs will remain important because a) EPDs integrate the activities of many genes and how they affect growth and milk and prolificacy and b) superior EPDs will be very helpful in the identification of DNA markers in the 64K SNP chip. Artificial insemination will be required for leading breeders to recover the costs of using the 64K SNP chips to genotype their rams. If ewes are genotyped with the new chips, then embryo transfer will help offset the costs of these tests.

Disease Resistance. Of particular interest is the identification of gene markers or genes associated with increased disease and parasite resistance. New Zealand researchers have patented tests for genetic resistance to foot rot and gastrointestinal parasites. It remains to be seen if these tests identify foot rot and parasite resistance in all breeds of sheep and for all nematodes throughout the world. Using a genetic lab test for disease resistance

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is particularly attractive, since very few producers wish to expose their whole flock to a disease or high levels of parasites to identify which of the animals are more resistant. The thought of exposing all animals in a flock to contagious foot rot to determine which are genetically resistant to foot rot is particularly unattractive and inhumane.

Selection for genetic resistance to gastrointestinal parasite using BLUP and fecal egg counts (FEC) has been successful in many countries. Australia, United Kingdom, New Zealand and the USA have all released FEC-EPDs that identify sires that have offspring with increased parasite resistance. With the development of gastrointestinal nematodes with resistance to multiple anthelmintics (dewormers) the need for genetic tests for parasite resistance is important. It will be a huge labor saving approach compared to collecting fecal samples and counting nematode eggs that the current technology involves. The question still remains whether resistance to gastrointestinal parasites can be identified with a single DNA test, but this is greatly needed.

NEEDED RESEARCH

The sheep seedstock industry needs research and more funds for research in the following areas. All selection indices need to include lamb survival to at least weaning age. The researchers can develop these indices but it will require a high level of commitment from those breeders submitting to NSIP and other genetic evaluation programs to track and accurately report birth and then losses. Genetics for survival is often complicated by predator losses which usually are random and not due to genetics. Selection indices need to be balanced for optimal performance and increased economic return. Research needs to be continued on specific DNA tests that identify traits and markers that improve growth, muscling and disease resistance. Finally, seedstock producers will need help from the sheep researchers to develop indices that incorporate DNA tests with EPD selection indices and produce balanced genetics.

SUMMARY

After 40 years of use in the livestock industry, the major technology for identifying superior performance in sheep breeding stock is still BLUP (Best Linear Unbiased Prediction) and its use to produce EPDs. Developments in the last 40 years have included the release of several new EPD selection indices that improve the seed stock industry's ability to identify superior genetics. In particular, it is suggested that breeding objectives for terminal sire as well as maternal breeds include trait selection for lamb survival. Recent evidence indicates that sire breed selection can have significant effects on lamb survival and thus financial return.

Sheep genetic researchers need more encouragement and especially more funds to develop indices that link genetic trait selection to economics of production and marketing. Using indices weighted by bio-economic factors will increase the financial return to sheep producers. As anthelmintic resistance continues to increase, the sheep industry needs to continue to prioritize selecting superior genetics for parasite resistance. In particular, the industry needs to investigate the potential of breeds from the tropics or with tropical breed ancestry to greatly improve the genetics for parasite resistance in commercial meat production.

Within five years, the leading sheep breeds and breeders will be using the new power of the 64K DNA SNP chip coupled with EPDs. They will improve sheep producers' ability to identify superior performance and disease resistance.

Breeds interested in staying commercially important in the future will need to keep up and use the new technology coupled with new EPD selection indices.

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