Recent Developments in Beef Cattle Improvement

Dorian Garrick
Lush Chair in Animal Breeding & Genetics
Iowa State University

Beef improvement - background and context

Profit from cattle enterprises is influenced by the value of sale animals, less the costs of their production. Ever-changing production and economic circumstances provide both threats and opportunities to cow-calf producers, bull breeders and feedlotters. Feeding strategies and other aspects of management typically require continuous between- and within-year modification in order to optimize margins. Responses to such management changes typically occur immediately. In contrast, genetic improvement is a long-term exercise with within-breed changes from selection seldom exceeding 1-2% per year. During favorable periods in the cow-calf economy, producers may feel that there is little need for genetic improvement. Then, during economic downturns, producers may feel they can't afford to invest in genetic improvement. Both these behaviors lead to suboptimal rates of genetic improvement.

Returns on investment in successful genetic improvement programs are much better than can be achieved in many other endeavors. Designing a cost-effective improvement program is not trivial but is relatively straight-forward. Genetic improvement is not inexpensive and the costs of measurement and selection can exceed the benefits from improvement in that herd. The key to cost-effective improvement occurs at industry level - improvement costs should be concentrated in a small percentage of herds (perhaps 1-2% cows), passed on to other herds through the sale of improved bulls and the benefits enjoyed by all the industry.

The major challenge in implementing such a program is market failure. The costs of measuring and ranking animals in order that improved animals can be produced each generation are incurred by the bull breeder. Improved bulls will be more profitable than alternative bulls when used in cow-calf herds. However, cow-calf producers are often reluctant to pay a premium for improved bulls. There are two reasons for this. First, cow-calf producers seldom get rewarded for selling weanlings that are capable of improved feedlot efficiency, carcass grading or eating quality. Second, cow-calf producers cannot easily quantify the likely differences in future profit from using alternative bulls. For these reasons, genetic improvement tends to have been more successful in other industries, such as those with greater levels of vertical integration (pigs, poultry) or those with clearer brand recognition and easily quantified benefit (eg annual crops of alternate varieties of soybeans or corn).

The economy is ultimately driven by the consumer. Effective improvement in alternate agricultural products leads to reduction in food costs and substitution by the consumer. Beef production must become more efficient in order to compete in the long term. In recent decades, efficiency has increased at feedlot and processor level through increasing the harvest weight of finished animals. This has provided some direction to the kinds of animals that are preferred and has resulted in the typical animal born since 2000 being quite different from the typical animal that was bred twenty-five years ago in the 1980's.

Research Challenges

A major challenge for researchers is to investigate issues today, to discover knowledge that will be required in the future. This is challenging because we don't know what the problems will be in the future, and by their very nature, they are novel endeavors. In the arena of beef cattle improvement, there are three such areas of research that are being investigated at Iowa State University, the U.S. Meat Animal Research Center (Clay Center) and by colleagues and collaborators at other Land Grant universities. These represent work on the genetics of cattle health, the genetics of beef healthfulness, and the use of genomic sequence to identify superior animals based on their DNA rather than the performance of their relatives. All three of these research areas will lead to new tools for genetic improvement. The extent to which these tools are adopted will depend upon economic circumstances along with the attitudes and vision of future bull breeders and bull buyers.

Goal vs data driven selection. It has long been recognized that phenotype or observed performance is determined by the collective actions of genotype and environment. Further, it was known that the genotype for a quantitative trait such as sale weight could be expressed numerically, in the units of usual measurement, to express the superiority or inferiority of an individual for use as a parent with respect to that particular trait. In the beef industry, an Iowa State University researcher, Dr Richard Willham, coined the term Expected Progeny Difference or EPD to describe this number. The first EPDs that were produced were generated for weaning weight, as this was clearly a determinant of cow-calf income, and was easily measured by producers. Along with pedigree information, it allowed sires to be accurately represented. Further, it allowed the genotypes that influence weaning weight to be partitioned into the effects of genes that drive growth (known as the direct effects) and the effects of genes that influence milk production (known as maternal effects). Differences in observed weaning weights between calves in the same contemporary group in any particular herd and year come about because of differences in direct effects between calves, and differences in maternal effects between their mothers.

The establishment of EPDs for weaning eight was a great step forward, but failed to properly account for the fact that a portfolio of traits needed to be simultaneously considered for selection. Overemphasizing weaning weight caused increases in birth weight, leading to increased calving difficulty and mature weight. Such unfavorable changes that were developing in these characteristics was motivation to research and implement additional EPD. Records were collected on these characteristics in bull breeding herds and the portfolio of EPD published in sire catalogues grew accordingly. However, these developments have largely been "data driven". That is, the new EPDs have been developed simply because the data was there, or easy to collect.

More recently, we have communicated an alternative approach to research, and to development and implementation of new EPDs. This is what we refer to as a "goal driven" approach. In the goal driven approach, we first ask livestock managers to consider the goal of their livestock operation. Second, we ask them to consider the list of traits that influence their goal. If their goal includes future profit, the list of traits will include characteristics that will influence future income, and future expenses. This approach led to recognition that beef cattle improvement programs and their associated EPDs were deficient in four different areas. These included reproductive merit, longevity, cow and calf health, healthfulness of beef (for humans). Accordingly, we have undertaken research to develop and implement EPDs for reproduction and longevity, based on calving success and the ability of a cow to stay in a herd for a long productive life. The EPDs for heifer pregnancy and stayability are increasingly being adopted by various breed associations.

Cow and calf health are two areas that have received little attention from a genetic viewpoint, at least in terms of research that could go all the way through to the development of an EPD used for selection in national programs. Two diseases that have been the subject of research at Iowa State University include pinkeye and respiratory disease. The pinkeye research has shown that scores reflecting the occurrence of pinkeye in individual calves will provide a useful measure to identify genetic differences among sires and dams for resistance or susceptibility to this disease. In common with many other diseases, one problem from an animal improvement perspective is that the incidence of the disease can vary widely between regions and from year to year within a region. The most effective data for discriminating animals arises when the incidence of the disease is close to 50%. It is more difficult to identify outstanding parents when most calves are unaffected. Calves with pinkeye tend to exhibit reduced performance, for example in weaning weight, so one might expect that selection for growth would have inadvertently selected for pinkeye resistance. Sadly, this is unlikely to be the case, because most breed associations collect performance information across the entire nation, and many regions do not suffer from pinkeye.

Respiratory disease is another characteristics that is a major cause of wastage in the beef industry. The problem is exacerbated by the industry practice of shipping young cattle long distances and then combining cattle from many sources onto the same feedlot. The travel causes stress to the animals, and stress tends to increase susceptibility to any disease. The contact of animals from different sources tends to expose animals to infectious organisms or strains of organisms to which they have not previously been exposed. Recent graduate research on this topic in Iowa has demonstrated promise for the development of an EPD. However, it is not yet clear as to the value of recording visual disease (eg pulls) as opposed to recording lung lesions during processing. A significant proportion of animals can be pulled, but not exhibit lung damage at slaughter. Other animals show lung damage, but were not detected and pulled while on feed. The value of live animal vs post-slaughter assessment of lungs for respiratory disease needs further research. A new project has just been initiated by the National Beef Cattle Evaluation Consortium (NBCEC) involving sire-identified weanling cattle from the Rex Ranch in Nebraska that are being fed in Colorado State University's research feedlot, without the usual prophylactic treatments on the arrival of the cattle in the feedlot. It is hoped that this large scale genetic study will identify appropriate indicators for use in EPDs. The U.S. Meat Animal Research Center is also studying this topic from historical records and planning further new studies.

Healthfulness. The profitability of beef production can be enhanced by improving production efficiency, and thereby reducing production costs or by increasing consumer demand, and increasing the price paid for beef. Genetic improvement of beef cattle has principally focussed on changing the animal to increase the efficiency of production. Changing beef attributes was problematic, because beef quality could only be directly assessed at slaughter, and typically in animals, such as steers, that were not used for breeding. This was revolutionized by the development of ultrasound techniques for live animal assessment. Iowa State University had a major role in the research and implementation of ultrasound scanning for the production of EPDs that reflect fat depth, ribeye area, carcass yield and marbling. Although these attributes might influence the visual attractiveness or perhaps even the tenderness of the beef, they do not bear any relation to the healthfulness of the beef.

The media frequently presents information arguing the relative benefits of red vs white meat, or meat vs fish. Close inspection of nutritional guidelines often shows the composition of alternative foods, for example the iron content of beef. These values are overly simplistic and do not reflect that fact that there can be wide variation in almost all nutritional characteristics, Such variation can reflect differences in animal management, such as feeding level and age. However, within a contemporary group there can be wide variation in nutritional composition. The FDA recently required publication of trans-fat content.

No longer is simply the amount of fat of primary interest, but the nature of the fat has become of interest. This is so because fat is not simply an indication of caloric value. The composition of the fat (and other nutrients) can influence cancer susceptibility, heart disease, and diabetes, among other diseases. Research in these areas are still in their infancy in terms of delivering EPDs for selection, but I have no doubt that such characteristics that describe the nature of mineral, fat or protein contents will become traits of interest in the future. This has already happened in milk, with HyVee in Ames marketing A2-milk that represents only one of two variants in beta-casein, a protein that occurs in cows milk. Like cow and calf health, one of a number of limitations to the adoption of these new traits in selection programs is the ability to cheaply and easily measure phenotypes. The third area of new research offers promise in solving that problem.

Genomic Selection. The media has been filled with articles over more than a decade that have claimed that new molecular techniques will revolutionize animal improvement. Inspection of the breed association graphs in sire catalogues that display the rates of genetic improvement over the last decade or two do not show much evidence of any revolution. This may soon change, with genomic selection being the first major technology that could completely change the structure and nature of genetic improvement since the advent of artificial insemination.

The problem with the conventional approach to animal selection is that our prediction of future offspring merit is limited to the average of our knowledge of the parents. Even when parents EPDs are known perfectly, we can only predict the average merit of offspring. If we generated a number of offspring, for example by multiple ovulation and embryo transfer, we would discover that half of them are better than we thought they would be, and half are worse. However, we cannot predict which ones will be better than parent average, and which ones will be worse than parent average, without measuring the phenotypes of interest on the offspring themselves, or better still on progeny tests using the offspring as the parents in the test. This need for individual information or progeny testing produces selection costs. These costs may be in the form of cash, for example to collect information such as ultrasound or carcass measures on offspring, but are also represented by time delays. Genes do not improve with age, so waiting until an animal can be measured or progeny tested delays the rate at which we can pass the superior genes onto the next generation, and slows our rate of annual improvement.

Many scientists believed that we could use molecular tests to identify a few big genes that would be easily characterized. Despite enormous intellectual and capital investments in gene discovery all around the world, relatively few such tests have ever shown sufficient promise to make it to market. Two tests for tenderness and a test for marbling are beef examples that have been validated, but such tests only account for a small proportion of variation in the traits of interest. 5

Genomic selection is a technique that is not based on finding a few tests for traits of interest. Genomic selection arises out of recent U.S. and international investment in the complete sequencing of the bovine genome, and uses new technologies to cheaply and simultaneously test for a hugh number of markers across all chromosomes. In cattle, a currently available test allows for 58,000 marker tests to be undertaken at one time, for around $2-300 per animal. These tests allow the transmission of all chromosome fragments to be simultaneously tracked across generations.

Tracking chromosome fragments allows something like an EPD to be computed for each chromosome fragment. This process of evaluating fragments we refer to as "training". These fragment values are of no interest to bull breeders in themselves, but the collective value of all the fragments one individual inherits is effectively its conventional EPD. Reconsider the earlier example of a family of sibs (with the same sire and dam) whose true EPD would all vary but whose conventional EPD can only be assessed as their parent average until we get any of their own records, or the records on offspring. Given access to the information from a prior training, and the dense marker genotypes on the calves themselves, it should be possible to identify above- and below-average individuals prior to puberty. Provided training has been done on novel traits, such as reproduction, longevity, health or healthfulness, all these characteristics can be evaluated from the same gene test. In the case of animal health, selection could occur without having to expose or challenge the animals with the disease.

Clearly $200 per animal is probably too much to spend on any animal to assess its merit. However, the identification of bull merit may justify this spend, especially for identifying candidate bull fathers. This may create new opportunities for identifying superior bulls without the need for any a pedigree or performance information. Accordingly, this technology represents both a threat and an opportunity to existing players in the seedstock industry, both bull breeders, breed associations and AI companies.

The Future

Many researchable issues remain to be investigated before genomic selection becomes mainstream. In cattle, the comprehensive marker tests are accessible for the first time for research and other use as of the beginning of 2008. However, the size and nature of training populations and the need for re-training has only been assessed by simulation, not from real field data. Iowa Sate University, the U.S. Meat Animal Research Center and other research and industry collaborators are actively pursuing research in this area. Evaluation and validation of this technology is required before it can be reliably promoted, and for structural reasons it may not suit all livestock industries. The collective findings of researchers, and actions of bull breeders and cow-calf producers will determine its eventual place in the Iowa and U.S. beef industries.