The potential value of DNA-based tests for host bovine respiratory disease resistance to the beef cattle industry

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Abstract

Recent developments in molecular genetics and genotyping platforms offer a unique opportunity to use modern genomic tools to manage the future health of beef cattle. Reducing the considerable animal morbidity, mortality, and economic losses associated with bovine respiratory disease (BRD) will require the simultaneous development of DNA tests to enable the selection of resistant animals, and the incorporation of this trait into breeding objectives of relevance to US beef production systems. This study focused on determining the relative weighting that should be given to selection for BRD resistance in a multi-trait selection index for Angus terminal sires. All herd-level economic statistics were modeled for a 1000 cow-calf enterprise, and retained ownership through the feedlot was assumed. All progeny of terminal sires were harvested, and so no economic value was associated with maternal traits. Reducing BRD incidence was the trait that was associated with the highest relative economic value. To maximize profitability for the operation, it was determined that reducing BRD incidence should be weighted approximately seven times more heavily in a terminal sire selection index than weaning weight, postweaning average daily gain and feed intake, and that these traits should receive two to three times more emphasis than marbling score and yield grade. To incentivize the inclusion of genomic BRD susceptibility criteria in breeding decisions, and to offset the concomitant decreased selection pressure on growth traits that return value directly to producers who do not retain ownership (i.e. sell on a weight basis prior to feeding), there would need to be some mechanism analogous to a backgrounding premium to transfer the savings from improved feedlot health back up the supply chain to producers and breeders.

Résumé

Les récents développements en génétique moléculaire et dans les plateformes de génotypage offrent une occasion unique d'utiliser les outils génomiques modernes pour gérer la santé des bovins dans l'avenir. Afin de réduire la morbidité, la mortalité et les pertes économiques considérables associées au syndrome respiratoire bovin il faudra mettre au point simultanément des tests d'ADN qui permettront la sélection d'animaux résistants et l'inclusion de ce trait dans les objectifs de reproduction pertinents pour les systèmes de production bovine aux États-Unis. Cette étude est axée sur la détermination de la pondération relative qu'il faut accorder à la sélection de la résistance au syndrome respiratoire bovin dans un indice de sélection à traits multiples pour les reproducteurs Angus. Toutes les statistiques économiques à l'échelle du troupeau ont été modélisées pour une exploitation de 1 000 vaches/veaux, et le maintien de la propriété était assuré dans le parc d'engraissement. Toute la progéniture des reproducteurs était récoltée, donc aucune valeur économique n'était associée aux traits maternels. La réduction de l'incidence du syndrome respiratoire bovin était le trait associé à la plus grande valeur économique relative. Afin de maximiser la rentabilité de l'opération, on a déterminé que la réduction de l'incidence du syndrome respiratoire bovin devait être pondérée environ sept fois plus dans un indice de sélection d'un reproducteur que le poids au sevrage, le gain moyen quotidien après le sevrage et la consommation , et qu'il faudrait accorder de deux à trois fois plus d'importance à ces traits qu'au persillage et à la catégorie de rendement. Afin d'encourager l'inclusion de critères génomiques de susceptibilité au syndrome respiratoire bovin dans les décisions en matière de reproduction, et pour compenser la diminution concomitante de la pression de sélection sur les traits de croissance qui procurent une valeur directe aux producteurs qui ne conservent pas la propriété (c.-à-d. qui vendent en fonction du poids avant l'engraissement), il devrait y avoir certains mécanismes analogues à une prime pour la semi-finition afin de transférer dans la chaîne d'approvisionnement des producteurs et des éleveurs les économies que constitue l'amélioration de la santé des animaux en parc d'engraissement.

Introduction

"We now stand at a defining moment in the history of agriculture wherein we can use modern genomic tools to subtly influence the future evolution of the animals we have farmed for thousands of years."[1]

There is growing interest in selective breeding of domestic livestock for enhanced disease resistance.

Disease resistant animals contribute to sustainability goals, in that they have improved health, welfare, and productivity.[16] In the dairy industry, selection programs have been developed to take advantage of genetic variability in mastitis resistance, despite the fact that the heritability of clinical mastitis is low and mastitis resistance has an adverse correlation with production traits.[14] Likewise, chicken breeders have long used breeding to improve resistance to avian lymphoid leucosis complex and Marek's disease.[16] Understanding the genetic basis for susceptibility has become an increasingly important target for research, especially with the availability of genome sequence.

In the United States, 1.4% of all feedlot cattle perish before reaching harvest weight and of those, the majority are due to bovine respiratory disease (BRD). Indeed, more feedlot cattle die from BRD than all other diseases combined, and this trend is increasing.[6] Bovine respiratory disease accounts for 28% of all US cattle industry deaths and causes annual losses of more than one million animals and $643,146,000.[11] In the beef industry, this loss is largely experienced by the feedlot sector, and may not directly impact the economics of commercial cow-calf producers.

Evidence that BRD susceptibility/resistance is under genetic control is demonstrated by breed differences in BRD morbidity and mortality, the fact that BRD prevalence in unweaned calves and feedlot cattle is heritable, and the finding of genomic regions that have been shown to be associated or "linked" with BRD incidence. Prior to entry into the feedlot, the incidence of BRD in weaned calves varied by breed from a low of 10% in Angus to a high of 35% in Pinzgauer.[15] Mortality also differs by breed, ranging from 0.1% in Braunvieh cattle to 8.9% in Red Poll cattle. Susceptibility differs among various breeds, ranging from 28% in Braunvieh to 73% in Hereford. Heritability estimates also suggest there is a genetic underpinning of the disease. The heritability estimate for feedlot animals was 0.18, when adjusted to an underlying continuous scale.[15]

BRD resistance represents an obvious target for selective breeding programs. However, as with any trait selection, emphasis needs to be weighted by its effect on profitability relative to other economically-important traits. Multiple-trait selection indexes offer an approach to appropriately weight all of the economically relevant traits that influence the profitability of beef cattle production. They provide an economic evaluation of the genetic differences among sires, and an objective way to determine likely differences in the profitability of progeny from different sires.

As DNA testing becomes more comprehensive and encompasses a larger number of traits, it will provide a selection tool for traits where no other information or selection criteria currently exist. There are many economically relevant traits in this category, including feed efficiency, and disease resistance.[12] This outcome will enable the development of more comprehensive selection indexes that include all of the economically relevant traits of importance to US beef production systems.

Over 90% (692,050) of US beef farms have fewer than 100 head, and these producers raise almost half (46%) of the US beef herd (Figure 1). The large number of small beef producers is in marked contrast to the concentration in the feedlot industry, where the 260 feedlots that have a one-time capacity of more than 16,000 head feed approximately 60% of the nation's cattle. At any one point in time there are around 13.6 million US cattle on feed, and 26 million head were fed in 2009. Although

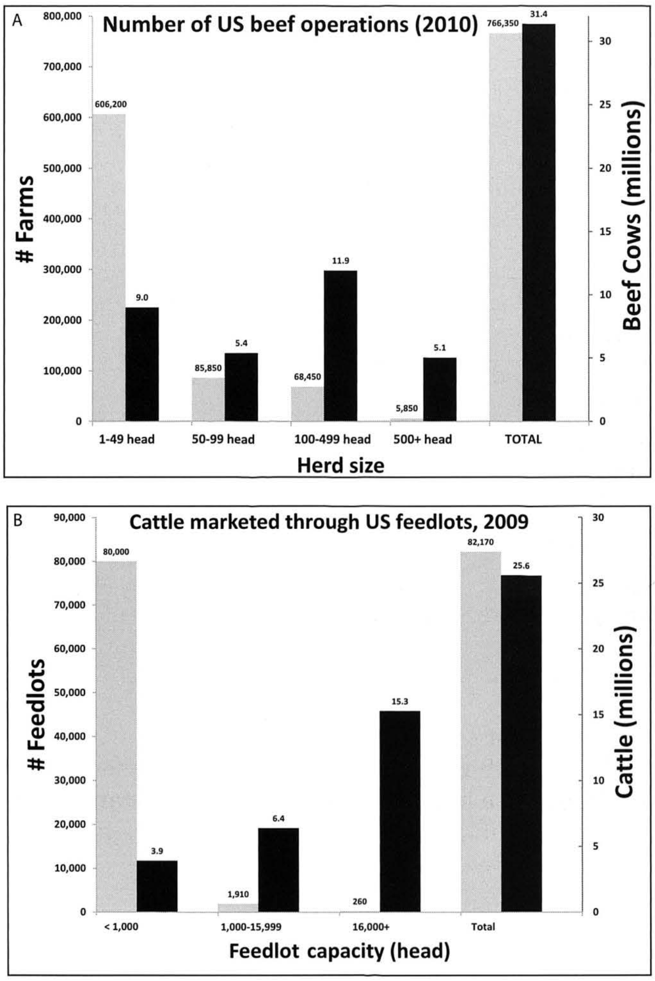

Figure 1. Number (gray) and size (black) of (**A**) beef operations in US, 2010; and (**B**) US feedlot operations. National Agricultural Statistics Service. Cattle (2011). Available at http://www.vdacs.virginia.gov/livestock/textfiles/Catt-01-28-2011.txt (Released 28 January 2011) ISSN: 1948-9099, Agricultural Statistics Board, United States Department of Agriculture (Washington DC).

many cattle ultimately go through the feedlot, little consideration is given to health traits of importance to the feedlot sector in selection decisions. The objective of this paper was to calculate the weighting that should be given to selection for BRD resistance in a multi-trait selection index for Angus terminal sires.

Materials and Methods

Methods were based on those outlined in MacNeil[7] for the development of breeding objectives for terminal sires in US beef production systems. All herd-level economic statistics were modeled for a 1000-cow-calf enterprise, and retained ownership was assumed. All progeny of terminal sires were harvested, and so no economic value was associated with maternal traits. Only phenotypes for weaning weight, feedlot average daily gain, feed intake, USDA yield grade, marbling score, and BRD incidence (%) contributed to the breeding objective. The feedlot phase was divided into three periods. The first period (backgrounding) was terminated at a weight-constant end point of 850 lb (386 kg). The second (growing) and third (finishing) periods were of 50 and 100 days duration, respectively. The genetic parameter estimates and phenotypic characterization used to develop the terminal sire index were those used to develop the Angus Sire Alliance Index detailed in MacNeil and Herring,[8] although the liveweight and carcass prices were updated in 2008, as detailed in Table 1.

To parameterize the model to include BRD, the following was assumed: 1) All BRD occurred when calves were moved to the feedlot phase at weaning; 2) the fixed cost of feedlot phase was unchanged; 3) a dead calf incurred no feed costs; 4) there was a 10% mortality from BRD;[3,5] 5) there was a 13% reduction in ADG for the first phase of feeding (weaning to 850 lb; 386 kg[5]); 6) final yield grade was reduced by 0.1;[13] and 7) the cost to diagnose and treat a BRD calf was $44 (Randall Raymond DVM, Simplot Land and Livestock, personal communication).

To obtain the genetic standard deviation for BRD incidence, the following calculations were made. The phenotypic variance of the binomial at a mean incidence of 10% was calculated to be p(1-p) = 0.09. A binomial scale heritability of 0.07[15] was applied to get a genetic variance of 0.0063, or a genetic standard deviation of 0.0794. Transforming from decimal to a percentage resulted in a genetic standard deviation of 7.94.

Economic values were calculated by performing bio-economic simulations using a modified version of the computer software described by MacNeil.[9] The main modification was that harvest phenotypes were generated stochastically, and steers were valued based on a multivariate normal distribution of marbling, yield grade, and carcass weight. In separate simulations, the phenotypes for each of the economically relevant terminal sire traits were changed by one unit. The difference between simulated profit with a phenotype perturbed by one unit and profit in the baseline simulation was taken to be the economic value for that trait (Table 2). The results are expressed on an enterprise basis, rather than per cow exposed or progeny produced. To provide some indicator of the relative magnitude of the economic values, each economic value was multiplied by the corresponding trait genetic standard deviation to give the relative economic value (REV). To simplify trait comparisons, each REV was divided by the REV for the trait with the smallest value (i.e. yield grade in this index), and the absolute value of that calculation is shown as "Relative Importance" in Table 2.

Results

Selection index methodology is designed to weight traits by their economic merit. Following Henderson,[4] the appropriate terminal sire selection index weight-

Table 1. Prices, premiums and discounts used in developing the multi-trait selection index for Angus terminal sires.

Weaned calf weight (lb)	**$/lb**	**Quality/Yield Grade**	**$/100 lb**
< 350	1.21	Prime	28.07
351-400	1.15	High Choice	5.53
401-450	1.09	Choice	0
451-500	1.04	Select	-10.20
501-550	1.01	Standard	-20.20
551-600	0.96		
>600	0.92	Yield Grade 1	3.00
Carcass weight (lb)	**$/100 lb**	Yield Grade 2	2.00
Base price	155.95	Yield Grade 3	0.00
<550	-15	Yield Grade 4	-10.20
>950	-15	Yield Grade 5	-20.20

ing for EPDs the economically-relevant traits listed in Table 2 would be the economic value for each trait. The REVs suggest that to maximize the profitability of the commercial production system modeled in this study, BRD incidence should be very heavily emphasized in terminal sire selection, followed by a relatively uniform emphasis on weaning weight, postweaning average daily gain and feed intake, and less emphasis should be placed on marbling score and yield grade.

This emphasizes the economic importance of BRD on feedlot profitability. It should be noted that other potential benefits were not considered in these calculations. These include reduced shedding and transmission of pathogens from resistant hosts, and externalities like improved animal welfare and public support for the decreased use of antibiotics in food animal production.

The values derived in this study were for terminal sire selection. There is a higher relative importance of maternal traits compared to feedlot and carcass traits when the goal is to also produce replacement females. Melton[10] suggested that US cow-calf producers keeping replacement heifers and selling calves at weaning should have a relative economic emphasis of 47% on reproduction, 24% on growth, and 30% on carcass traits, whereas producers in an integrated (retained ownership) system should have a relative economic emphasis of 31% on reproduction, 29% on production, and 40% on carcass traits. This relative emphasis that is ultimately applied to selection for BRD resistance will depend on how much the value derived from genetic gain in disease resistance is shared with the producer in the integrated system.

Discussion

Our preliminary data based on this terminal sire selection index suggest that there would be considerable value associated with the successful development of DNA tests to enable selection for BRD resistance. This index was developed to maximize the profitability of the entire industry as though it were one vertically integrated production system. In reality, even though nearly all US calves go through the feedlot and are sold on a carcass-quality basis, most commercial producers market their calves at weaning or shortly thereafter. Ninety percent of US cattle operations have fewer than 100 head (Figure 1A), and most sell their cattle at auction prior to feedlot entry. Consequently, producer financial returns are tied very closely to the number of calves, a function of reproduction, and less to feedlot performance and health, and even less to carcass traits. To incentivize the inclusion of BRD resistance in selection decisions, a mechanism analogous to a calf preconditioning bonus would be needed to equitably share some of the value derived from reduced feedlot disease incidence and to compensate breeders and producers for reduced selection emphasis on other economically relevant traits.

There are a number of issues that will need to be addressed in the development of DNA tests for BRD resistance. The first is that disease resistance heritabilities tend to be low, especially under field conditions. There are a number of reasons for this, including suboptimal diagnosis (e.g. not all sick animals are identified and healthy animals may be incorrectly diagnosed as ill), and some susceptible animals will appear resistant to a disease, when in fact they have not been exposed to the disease agent.[2] These factors add environmental noise to field data. Field studies therefore likely underestimate heritability, and thus also undervalue the potential gains that could be made by breeding for disease resistance.[1]

A five-year USDA grant entitled the "Integrated Program for Reducing Bovine Respiratory Disease Complex (BRDC) in Beef and Dairy Cattle" has the objective of capitalizing on recent advances in genomics to enable novel genetic approaches to select for cattle that are less susceptible to BRD. This effort, known as the BRD CAP (Coordinated Agricultural Project), involves a multi-institutional team led by Dr. James Womack at Texas A&M University, and involves research groups from Washington State University, University of Missouri, Colorado State University, New Mexico State University, and University of California, Davis. For more information on the BRD CAP see http://www.BRDComplex.org.

Table 2. Enterprise economic values, relative economic value, and relative importance of economic values for traits in the terminal sire breeding objective.

Trait (unit)	Economic value ($)	Genetic SD	Relative economic value (REV) $	Relative importance (relative to YG)
BRD incidence (%)	-8424.7	7.94	-66892	37.7
Weaning wt. (lb)	241.4	41.76	10081	5.7
Feed Intake (lb/d)	-5811.8	1.41	-8195	4.6
Feedlot ADG (lb/d)	27654.5	0.24	6637	3.7
Marbling score	8926.0	0.51	4552	2.6
Yield Grade	-5379.2	0.33	-1775	1

The USDA, through the Agricultural and Food Research Initiative (AFRI) competitive grants program, is investing in several other similar grants focused on using DNA-based technologies to make genetic progress in traits that have proven difficult to improve using traditional selection on expected progeny differences (EPDs). These include projects focused on the development of genomic approaches to improve feed efficiency and fertility of beef cattle. These traits are not the "low hanging fruit" of genetic improvement. They are typically traits that are measured late in life, are expensive to measure or are not routinely measured at all, and frequently have low heritability, making it difficult to differentiate the genetic component of phenotype from the environmental influences. However, they are the most valuable traits in terms of the beef cattle industry. A 1% improvement in feed efficiency, fertility, or reduced BRD disease incidence in the feedlot would generate tremendous value to the US beef cattle industry.

Conclusions

The development of high-accuracy DNA tests for the selective breeding of beef cattle for enhanced BRD resistance would be beneficial from an industry wide perspective, but the commercial viability will strongly depend upon whether breeders and producers are able to share in the value realized from improved feedlot health. The segmented nature of the beef cattle industry often hinders the efficient transfer of market signals between industry sectors. BRD resistance is a highly valuable trait and if DNA tests provide a selection criterion for this trait, that information should be included in economic selection indexes. Because the value of genetic improvement in this trait would be derived mostly by the feeding sector, feedlots may choose to incentivize selection for BRD resistance among their suppliers though partnerships with breeders/producers who incorporate this trait into their selection objective. Alternatively, they may use a payment mechanism analogous to a calf preconditioning bonus to encourage producers to place selection emphasis on BRD resistance.

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SALMONELLA IS RISKY BUSINESS

Reducing risk is key to managing *Salmonella*. Although a dairy might never have experienced a clinical outbreak, the risk of disease exposure can loom large. *Salmonella* is a tricky disease that can enter many ways, including via recently purchased cattle, the boots or clothes of visitors and workers, and even rodents and birds.

Salmonella prevention has two key components:

1. **Reducing exposure.** A strong disease-management program is essential. Work with your clients to evaluate on-farm protocols and develop an effective disease-management program.
2. **Building immunity.** Consistent, adequate nutrition is important for supporting overall herd health. Whole-herd vaccination together with the right nutrition can help create whole-herd immunity.

Remember, no herd can hide from *Salmonella*, but recognizing the risks and taking proactive control measures can help lessen the likelihood of a disastrous outbreak. Veterinarians can team up with producers to assess *Salmonella* risk by using a new online tool from Pfizer Animal Health to develop a *Salmonella* reduction plan.

To take the assessment, log on to www.SalmonellaRisk.com/Assessment. Visitors to the website also can find other materials and educational videos about *Salmonella* on dairy operations.

The assessment tool was created with contributions from industry experts, including John M. Gay, Washington State University; Ernest Hovingh, Penn State University; Larry Slinden, Epitopix, LLC; and Brett Hopkins, Pfizer Animal Health. It asks questions about on-farm hygiene and animal health practices. Once completed, the tool provides a personal *Salmonella* reduction plan, which can be used to help start a conversation about protocols and management practices to help reduce the risk of a *Salmonella* outbreak.