GENETIC PREDICTION OF EFFICIENCY IN THE FUTURE: *AN AUSTRALIAN PERSPECTIVE*

David Johnston
Animal Genetics and Breeding Unit[*]*, University of New England,*
Armidale, NSW 2351, AUSTRALIA

Introduction

The cost of feed is an important variable affecting the profitability of beef production. The cow herd has been estimated to consume 65-85 % of the energy required for beef production and slaughter stock often consume expensive feed, particularly those finished on high concentrate feedlot diets. Manipulation of the environment and cattle management (e.g. age of turn-off) can be used to reduce feed costs and it has also been known for several decades that feed intake and measures of feed efficiency are heritable in beef cattle. However to date, no direct selection based on feed intake data has occurred in the beef industry. Recently there has been a wave of new genetics research on feed intake with particular focus on implementation into industry breeding programs. Research in Australia has been lead by NSW Agriculture's team at Trangie NSW and continued by the Cooperative Research Centre for Cattle and Beef Quality (Beef CRC). Results to date show feed intake and various measures of efficiency are under genetic control and sufficient variation exists, along with the high economic importance of feed, to warrant inclusion of a suitable measure in a genetic evaluation scheme and in the formulation of breeding objectives. Outlined in this paper are results from Australian research and our recent development of an estimated breeding value (EBV) for net feed intake (NFI) for use in the Australian seedstock industry.

Research Projects

Measuring individual feed intake in beef cattle is expensive, requiring sophisticated equipment and considerable labour. Therefore generating sufficient data for genetic studies is difficult and costly. Two major studies in Australia over the past 10 years have measured individual feed intake on over 3000 straightbred cattle with known pedigree and management information. The first project was a comprehensive study on feed efficiency at the Agricultural Research Centre, Trangie, NSW, Australia. Angus bulls and heifers (N =1500) were tested for postweaning feed efficiency between 1993-1999 using an automated feeding system. Each animal was fitted with an electronic ear tag and every feeding event was recorded over a 120 or 70 day period. Animals had *ad lib* access to a pelleted alfalfa and wheat diet with an average energy density of 10.5 MJ ME/kg DM and 15 to 17 % crude protein. In 1994, NFI selection lines were established by dividing the heifers from each test into "Low" (high efficiency) and "High" (low efficiency) lines based on their NFI performance. Each year 3-6 bulls (selection based on their own NFI performance) were used in each line. Progeny were measured for feed intake and NFI using the postweaning test.

[*] AGBU is a joint venture of NSW Agriculture and The University of New England

The second large project that measured feed intake was conducted by the Beef CRC. It was a very large integrated research program that investigated production and processing factors affecting meat quality (Bindon 2001). The straightbreeding project provided almost 8000 pedigree recorded animals for both quantitative and molecular genetics work. Animals used in the study were from four temperate breeds (Angus, Hereford, Shorthorn and Murray Grey) and three tropically adapted breeds (Brahman, Santa Gertrudis and Belmont Red). A subset of the feedlot finished cattle (N =1590) had individual feed intake measured using computerised automatic feeders and data loggers developed as part of the Beef CRC, in conjunction with the Ruddweigh International Scale Company. A total of sixteen feeders were installed. Each pen was fitted with a single feeder and could hold up to 12 animals. Each animal was fitted with an electronic ear tag and every feeding event was recorded over the test period after an initial warm-up period. Animals had *ad lib* access to a typical feedlot finishing diet of 75% barley with a 12.1 MJ ME/kg DM energy density. Animals (predominantly steers) ranged in age and weight depending on their market weight treatment group (i.e. domestic or export). On average the domestic market group (target carcass weight of 220 kg) consumed 11.6 kg of feed per day and were 377 kg liveweight compared to the export market groups (target carcass weights of 280 or 320 kg) that consumed on average 12.3 kg/d and were 510 kg liveweight. Due to feedlot constraints, animals were only recorded for feed intake for an average of 50 and 65 days for domestic and export groups, respectively.

Defining efficiency traits

The collection of large numbers of individual feed intake records has enabled researchers to investigate the genetics of daily feed intake and also compute several measures of efficiency. Although initially it may seem logical, selection for reduced feed intake alone inevitably results in a correlated reduction in body weight. Therefore various functions of output of beef per unit of feed are used as measures of feed efficiency. The most common index of efficiency is gross efficiency defined as the ratio of output (e.g. gain) over feed inputs (e.g. kg feed eaten). Feed conversion ratio (FCR) is the inverse of gross efficiency. FCR has been used as a measure of efficiency for several decades, particularly in the chicken and swine industries. Many researchers have shown FCR to be strongly negatively correlated with growth rate. It is therefore argued that selection for faster growth rates will achieve improvements in feed efficiency mainly through a reduction in maintenance costs due to less days on feed to the same weight endpoint. Whilst selection for growth rate may negate the need to measure feed intake, it is likely to lead to higher mature weights, which may be undesirable in the cow herd. Conversely, the trait net feed intake (NFI), or residual feed intake (RFI) as is it sometimes called, is computed in such a way as to be phenotypically independent of weight and gain. NFI was first proposed by Bob Koch (Koch et al. 1963) and is the difference between actual feed intake and the expected feed intake requirements for maintenance of body weight and production (e.g. gain). Kennedy et al. (1993) showed that although NFI is phenotypically independent of production it is not necessarily genetically independent. Many other measures and definitions of efficiency exist (e.g. cow/calf efficiency, maintenance efficiency) and several are discussed in detail in the review of Archer et al. (1999).

Although clear definition of a trait is important in a genetic evaluation program, the key trait that must be measured is feed intake. Selection index methodology can be used to ensure the correct trait emphasis in a multi-trait selection framework. Barwick (2002) discusses the effect of trait definition and presence of other measures on the derivation of economic values and index weightings for costing feed. The choice of which trait to include in a genetic evaluation program will depend on the data being recorded, the model used to compute EBVs and the method used to construct indexes. However, for industry adoption, consideration is required on the definition of a trait such that breeders will be encouraged to take the new measurements. In Australia, researchers in consultation with industry, have decided to use NFI as the trait to be used in genetic evaluation to improve feed efficiency.

Key research Outcomes

Numerous publications exist from the Trangie work (e.g. Arthur et al. 2001a,b; Archer et al. 1998; Herd et al. 1997; Archer and Barwick 1999, 2001; Richardson et al. 2001). In brief, daily feed intake (FI) of young animals measured post-weaning over a 70 day test was heritable (h^2=0.39) as were the measures of efficiency; FCR (h^2 = 0.29) and NFI (h^2 = 0.39). The phenotypic correlation between FCR and ADG was -0.74 with a genetic correlation of -0.62. Whereas, NFI had phenotypic correlations of -0.06 and 0.02 with ADG and metabolic weight (MWT) (i.e. mid-test weight raised to the power 0.73), respectively. Although the computation of NFI has removed the phenotypic relationship with weight and gain, the genetic correlations between NFI and weight traits were not zero and tended to be negative (-0.02 ADG, -0.06 MWT, -0.45 weaning wt direct, -0.26 yearling wt direct). NFI was still positively correlated (0.69) genetically with FI. These results suggest that selection for reduced NFI would result in correlated increases in weight and reduction in FI. Hence the efficiency appears to be achieved by the animals being genetically able to eat less whilst not reducing growth. The genetic correlation between NFI and measures of fatness tended to be slightly positive.

Data from the Trangie divergent NFI selection lines, after 5 years of selection (1.73 and 1.96 generations, for the Low and High NFI lines, respectively) showed average selection differentials of -0.32 and 0.39 kg/d per year for the Low and High lines, respectively. An average annual divergence rate in NFI of 0.21 kg/d was achieved between the lines with a realised heritability of 0.33 (Arthur et al. 2001).

The final results from the Beef CRC are being prepared for publication and preliminary results have been presented by Robinson et al. (1999a,b; 2001). Feed intake measurements were taken on predominantly steers being finished under commercial feedlot conditions. As previously mentioned, the animals were finished to different market weights and the length of feeding was shorter than the Trangie tests. The major problem encountered with the analysis of the data was in computing an accurate measure of weight gain. This occurred due to the small numbers of weight records during the test and the relatively short test length. These problems highlighted the shortcomings of using ADG but did however allow us to make changes to all future protocols for testing feed intake and measuring ADG. The problem with the inaccurate

estimate of ADG was overcome in the analyses by using all weights of an animal whilst in feedlot and not just those measured during the feed test period. The resulting heritability estimates were 0.24, 0.20 and 0.18 for FI, finishing ADG and NFI. The phenotypic and genetic correlations between the three traits: FI, NFI and ADG were very similar to the Trangie results. However the genetic correlations between NFI and fatness were stronger (i.e. more positive) in magnitude, possibly the result of greater genetic expression of fatness in these cattle due to them being older and on a higher energy diet.

Overall the results from both experiments showed feed intake and measures of efficiency were heritable. The trait NFI has several properties that may be preferred over FCR. The genetic correlations suggest that animals with genetically lower NFI (at the same weight and gain) are eating less, are likely to be leaner, with larger eye muscle areas. Unfortunately the data structure was not sufficient to allow the estimation of the genetic correlation between the Trangie postweaning seedstock measure and the Beef CRC feedlot finishing measure. This will be addressed in a current research project (see below).

Note: A 17 paper special edition of the Australian Journal of Experimental Agriculture on Feed Intake and efficiency is expected by next year and will contain new results, some of which have been referred to in this paper.

Economic analyses and costing feed

The relative importance of a trait in a breeding program is dependent on the economic value (EV) of the trait and the amount of genetic variation that exists for the trait. However unlike many other traits, determining an economic value for feed costs is not a trivial task. Deriving an economic value for feed requires, for each market production system, consideration of the unit cost of additional feed (pasture and feedlot), the amount of time spent on pasture and feedlot for the young animal, and for cows and replacements the period of a year when feed has a cost. Commonly techniques are used to discount the EV of a trait to present day dollars. This is the general approach used by Barwick et al. (1999) to derive EVs for feed costs for different production systems and to quantify the increased profit of a breeding program resulting from measuring feed intake and including it in the selection index. The BreedObject system uses two main methods for costing feed: the cost of bought feed and secondly the cost equivalent to lost profit from the reduction in herd numbers.

Recent simulation research (Barwick et al. 1999) showed that recording NFI can increase the accuracy of selection by up to 40 % particularly for production systems that include a considerable period in a feedlot (+200 days at $210/tonne of feed). Archer and Barwick (1999) also investigated the impact of altering the number of animals in a breeding population tested and the effect of altering the cost of testing and the design of industry breeding programs (e.g. 2 stage selection strategies, individual versus progeny testing) on the gains.

Feed intake at pasture

Both Australian experiments reported measured individual feed intake in a feedlot (although with different diets) and not at pasture. The question that needs to be answered is how does this measure relate genetically to feed intake and efficiency at pasture? Follow-up work has occurred at Trangie where almost 1000 of the heifers tested at postweaning were returned to the testing unit as 4 year old cows. Although still not a pasture measure, the cow feed intake data is providing valuable information on feed intake and efficiency measures of the cow and its relationship to other cow traits (weight, fat and fertility) and importantly with the postweaning measures.

Some small studies have also occurred where steers at pasture have had their feed intake estimated using synthetic alkanes administered using intra-ruminal controlled-release devices (CRD). Results to date are encouraging, steers from the High and Low NFI divergence selection lines from Trangie were estimated to have consumed similar amounts of pasture but the Low NFI line (i.e. more efficient) were tending to gain more weight (R.M. Herd personal communication). Analysis of data from a second study is underway where 160 steers were measured post-weaning for feed intake using the CRD technique at pasture and again during feedlot finishing in the Beef CRC automatic feeders.

It is very unlikely that industry-wide measurements of feed intake will be possible given the current technology. Therefore research projects will be critical in generating data that can be used to determine the genetic relationships between the feedlot measure and pasture intake, and between the young animal and the cow. These estimates (including trait variances) along with correlations with other traits will be essential in developing the framework necessary to include genetic measures of feed intake in the formulation of breeding objectives.

Net Feed Intake EBV

The encouraging results from Trangie and the Beef CRC and the potential economic benefits to commercial producers prompted us at AGBU, through our MLA funded research project, to use the feed intake data to develop an EBV based on the postweaning test. Preceding this decision the group at Trangie developed a Standards Manual for the feed intake testing of cattle. The manual outlines the standards and procedures required to become an accredited testing facility and ensures the quality and consistency of data is suitable for genetic evaluation. Data from Trangie, Beef CRC and several accredited on farm and central testing facilities were pooled and used to develop a database that could be easily merged with the performance/pedigree BREEDPLAN databases of the various breeds. Data extracts, along with complete pedigrees was used to develop a Trial BREEDPLAN single trait NFI EBV. A heritability of 35% was used, and an adjustment was made for higher residual variances for NFI data from the Beef CRC.

The Angus NFI EBVs and accuracies were computed using 5093 animals with 2128 animals having individual feed intake records. The EBVs generated ranged from -1.32 to +1.23 kg/day, with BREEDPLAN accuracies up to 87%. A total of 37 Angus sires had an NFI EBV with a BREEDPLAN accuracy greater than 80%.

Fewer records existed for the Hereford/Poll Hereford breed, EBVs being computed for 2265 animals using 562 animals with individual feed intake records. EBVs generated ranged from -0.81 to +0.89 kg/day, with accuracies up to 77%. A total of 12 Hereford or Poll Hereford sires had an NFI EBV with an accuracy of 60% or greater. EBVs with a minimum accuracy of 50% were published on the BREEDPLAN web site (http://breedplan.une.edu.au) for each breed.

Where to now?

1) Further Research

Several projects are underway that will further our knowledge of feed intake and net feed intake. The research is very diverse but is primarily aimed at reducing the cost of obtaining genetic predictions in a beef breed and their implementation into selection programs.

i) Reducing the cost of testing

Work has been completed on determining the optimal length of test. Installation of weigh scales to the automatic feeder units allows an animal's weight to be measured several times a day. This data, accumulated over the whole test period, allows a more accurate calculation of weight gain. Therefore the length of test may be able to be shortened from 70 days to around 50-60 days. This will increase the potential number of animals tested in a year given the finite number of testing units and also reduce the cost of testing for an individual.

Another CRC project is generating additional progeny that will allow the estimation of the genetic correlation between the postweaning test and the feedlot finishing test. These results will be very important for the further development of the breeding objectives and the correlations will also help determine how to best use data in a genetic evaluation from the different sources. Feed intake data from steer progeny test programs may in the future be an important source of data for the genetic evaluation of NFI. This data will also be very useful for several researchers that are investigating the most effective design of breeding programs to optimise selection for feed efficiency in industry. A two stage selection strategy with recording of feed intake on elite young bulls is one option that looks promising.

ii) Indirect measures

Given the cost of recording feed intake and the limitations on the number of animals that can be tested, research is underway to determine if suitable correlated measures exist.

One promising measure being investigated is the circulating concentrations of the hormone insulin-like growth factor 1 (IGF-1). Johnston et al. (2001) showed IGF-1 was heritable (h^2 = 0.31) in young growing beef cattle, and more recently preliminary analyses obtained estimates of 0.39 and 0.56 between IGF-1 and NFI in Trangie and Beef CRC populations, respectively. Genetic correlations between NFI and measures of fatness and certain weights make these traits useful as indirect measures of NFI.

Gene markers for feed efficiency would also be extremely useful in increasing the accuracy of an NFI EBV. A South Australian gene mapping experiment for feed efficiency in Limousin x Jersey crosses was recently completed and results from their work will be released later this year. The Beef CRC is also using the DNA on all feed intake tested animals to do gene mapping and confirmation studies. This will include over the next 3 years approximately 2,000 feed intake tested progeny from the Beef CRC Northern breeding project, representing over 100 Brahman and Red Composite sires.

iii) Incorporating NFI into the breeding objective

To utilise the genetic information on feed efficiency it is important that the trait is included into a multiple selection index for profitability. In Australia, selection index software called BreedObject uses BREEDPLAN EBVs to compute index values ($EBVs) for different production systems. In the absence of genetic information on feed intake BreedObject has included the feed costs in the economic value assessments of traits affected in the breeding objective (both young animal and cow). In each case the cost of increased feed required associated with a unit increase in the trait is used. This method accounts for differences in gross feed efficiency but not for differences in feed use. The next version of BreedObject will include net feed intake in the breeding objective. However to include NFI EBV as selection criteria (and/or in the objective) will require genetic correlations with other traits be known. Some of this estimation work has been done but more will be required. The Beef CRC Northern Breeding project will provide important estimates of the correlation between NFI and female reproduction and adaptability traits for tropically adapted breeds.

2) Industry implementation

Science is rapidly advancing our understanding of the genetics of feed intake and efficiency but the challenge is to gain widespread adoption by industry such that selection decisions on young bulls in seedstock herds can use knowledge of genetic differences in NFI. To date, most of the testing of animals in Australia has been done through research experiments. However with the recent publication of the first Trial BREEDPLAN NFI EBVs for Angus and Hereford/Polled Herefords the incentive exists for innovative seedstock breeders to test their young bulls. Currently, two options exist for testing bulls (and steers). On-farm testing is possible with some breeders purchasing their own units or using mobile testing units that can be transported to a farm. Secondly, several commercial central test facilities exist to measure individual feed intake. It is hoped that in the next 12 months approximately 1000 animals will be measured as part

of research projects and an additional 650 individuals will be measured by industry. An important initiative of the Australian Shorthorn and Angus breed societies has been the development of progeny test herds for the testing of elite young sires. Both these programs will include individual feed intake testing of the steer progeny and the data used to compute NFI EBVs for the sires.

Conclusions

Although genetic differences in feed intake and efficiency were estimated over 30 years ago no known direct selection for improvement of these traits has occurred in the beef industry. This is primarily due to restrictions in the number of individuals that can be measured for feed intake and its cost. Recent research into reducing the cost of the test and increasing the accuracy by including indirect measures will hopefully ensure the adoption of this new trait into beef cattle breeding programs.

References

Archer, J.A., Arthur, P.F., Herd, R.A., Richardson, E.C (1998). Genetic variation in feed efficiency and its component traits. In: Proc. 6th World Cong. Genet. Appl. Livest. Prod. Armidale, NSW, Australia, 25:81-84.

Archer, J.A., Richardson, E.C., Herd, R.M. and Arthur, P.F. (1999). Potential for selection to improve efficiency of feed use in beef cattle: a review. *Australian Journal of Agricultural Research* 50, 147-161.

Archer J.A. and Barwick, S.A. (1999). Economic analysis of net feed intake in industry breeding schemes. *Proceedings Association Advancement Animal Breeding Genetics* 13, 337-340.

Archer J.A. and Barwick, S.A. (2001). An analysis of investment in advanced breeding program designs for beef cattle. *Proceedings Association Advancement Animal Breeding Genetics* 14, 465-468.

Arthur, P.F., Archer, J.A., Herd, R.A. and Melville, G.J. (2001). Response to selection for net feed intake in beef cattle. *Proceedings Association Advancement Animal Breeding Genetics* 14, 135-138.

Arthur, P.F., Archer, J.A., Johnston, D.J., Herd, R.A., Richardson, E.C. and Parnell, P.F. (2001). Genetic and phenotypic variances and covariance components for feed intake, feed efficiency, and other postweaning traits in Angus cattle. *Journal of Animal Science* 79:2805-2811.

Barwick S.A. (2002). Costing feed in selection: reconciling some differences in approach and revisiting issues for beef cattle selection. In: Proc. 7th World Cong. Genet. Appl. Livest. Prod. Montpellier, France.

Barwick, S.A., Graser, H.-U. and Archer, J.A. (1999). Recording new beef performance measures – effects on the accuracy of selection for profitability. *Proceedings Association Advancement Animal Breeding Genetics* 13, 203-206.

Bindon B.M. (2001) Genesis of the Cooperative Research Centre for the Cattle and Beef Industry: integration of resources for beef quality research (1993-2000) *Australian Journal of Experimental Agriculture* 41, 843-853.

Herd, R.M., Archer, J.A., Arthur, P.F., Richardson, E.C., Wright, J.H., Dibley, K.C.P. and Burton, D.A. (1997). Performance of progeny of High vs Low net feed conversion

efficiency cattle. *Proceedings Association Advancement Animal Breeding Genetics* 12, 742-745.

Johnston, D.J., Herd, R.M., Reverter, A. and Oddy, V.H. (2001). Heritability of IGF-1 in beef cattle and its association with growth and carcase traits. *Proceedings Association Advancement Animal Breeding Genetics* 14, 135-138.

Kennedy, B. W. van der Werf, J.H.J, and Meuwissen, T.H.E. (1993). Genetic and statistical properties of residual feed intake. *Journal of Animal Science* 71, 3239-3250.

Koch, R. M, Swiger, L.A., Chambers, D., and Gregory, K. E. (1963). Efficiency of feed use in beef cattle. *Journal of Animal Science* 22, 486-494.

Richardson, E. C., Herd, R.M., Oddy, V.H., Thompson. J.M., Archer, J.A. Arthur, P.F. (2001). Body composition and implications for heat production of Angus steer progeny of parents selected for and against residual feed intake. *Australian Journal of experimental Agriculture* 41, 1065-1072.

Robinson, D.L., Oddy, V.H., and Smith, C. (1999a). Preliminary genetic parameters for feed intake and efficiency in feedlot cattle. *Proceedings Association Advancement Animal Breeding Genetics* 13, 492-495.

Robinson, D.L. and Oddy, V.H. (1999b). Modelling feed intake and efficiency in feedlot cattle. *Proceedings Association Advancement Animal Breeding Genetics* 13, 496-499.

Robinson D.L. and Oddy, V.H. (2001). Improving estimates of weight gain and residual feed intake by adjusting for the amount of feed eaten before weighing. *Australian Journal of Experimental Agriculture* 41, 1057-1063.