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EXPERIENCE IN BREEDING OBJECTIVES FOR BEEF CATTLE, SHEEP AND PIGS, NEW DEVELOPMENTS AND FUTURE NEEDS

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SUMMARY

Breeding objectives and their derivation are considered in relation to numerous changes occurring in genetics, in societal attitudes, and in the environment. We outline the experience in Australia with breeding objectives for beef cattle, sheep and pigs and discuss ramifications of the new developments for future objectives. Areas are suggested where more attention will be needed, and where the framework for deriving objectives may need to be extended to encompass the new issues. It is important that all issues are able to continue to be considered within a consistent breeding objective framework and industries are able to maintain focus on selection for the whole breeding objective.

INTRODUCTION

The scientific origins of breeding objectives, including the indexes derived for them, can be traced at least as far as Hazel (1943). The concepts were expanded on and debated in some detail in the 1970s (Dickerson 1970; Harris 1970; James 1978), 1980s (Goddard 1983; Brascamp *et al.* 1985; Smith *et al.* 1986; Ponzoni and Newman 1989) and 1990s (Gibson and Kennedy 1990; Stewart *et al.* 1990; Amer and Fox 1992; Barwick 1992; Schneeberger *et al.* 1992; Weller 1994), and there have since been numerous developments (e.g. Barwick *et al.* 1992,1994; Atkins *et al.* 1994; Dekkers and Gibson 1998; Harris 1998; Amer *et al.* 2001; Barwick and Henzell 2003, 2005; van Raden 2004; Wolfova *et al.* 2005; Amer 2007). The focus of breeding objectives is usually economic merit in the commercial production system, with the breeding objective being the function describing aggregate breeding value for that net measure of merit. The most recent decade has seen marked change in understandings at the gene and genome level, and also in other areas such as societal attitudes to the management of animals and the environment (Kanis *et al.* 2005). Here we revisit breeding objectives and their derivation, how these relate to the new developments, and whether some extensions are needed to the breeding objective framework. We briefly describe the Australian experience in beef cattle, sheep and pigs, and suggest some areas that will need greater attention in the future.

BREEDING OBJECTIVES IN THE AUSTRALIAN BEEF CATTLE, SHEEP AND PIG INDUSTRIES

Beef Cattle. Research to assist derivation of breeding objectives began for beef cattle in Australia soon after the introduction of BREEDPLAN in the mid 1980s, and led to development of the BreedObject software system for developing customised objectives and $Indexes (Barwick *et al.* 1992; Schneeberger *et al.* 1992; Barwick and Henzell 2005). Industry adoption increased during the 1990s as recording expanded to encompass more traits (Graser *et al.* 2005). It increased substantially after web systems of delivery made EBVs and $Indexes more accessible (Barwick *et al.* 2001). Systematically derived breeding objectives and $Indexes, developed in close cooperation with industry, are now available in all major breeds and service production systems

* AGBU is a joint venture of Industry & Investment NSW and University of New England

that represent over 90% of the national cow herd (http://breedobject.com/). Many developments have also occurred for production systems of other countries that use BREEDPLAN EBVs.

The breeding objectives and $Indexes that are in widespread use are for the main production systems of the different breeds. The focus of these breeding objectives is net economic merit in the commercial production system. Economic merit is measured as returns net of feed costs and other costs over the period from birth in the commercial cow herd through to sale of the finished animal. When the system includes a change of ownership, such as for example between the cow-calf producer and finisher, trait improvements are valued as if the system were vertically integrated. The principle followed is to sum trait value over each of the sectors of the production chain.

The breeding objective specified includes traits of both the young animal and the cow. The young animal traits include calving ease (direct), sale liveweight (direct), dressing %, saleable meat %, carcase fat depth, and carcase marbling score. The cow traits include calving ease (maternal), sale liveweight (maternal), cow weaning rate, cow survival rate, and cow liveweight. Trait economic values include account of feed costs. They also include adjustment for the time delays that are expected before improvements are expressed (McArthur and del Bosque 1990). The trait economic value unit is $ per cow. Because feed is costed in the calculations, the relativities determined for traits are also those that are expected if the unit was $ per ha or $ per unit of feed.

Trends occurring in genetic gain in the major breeds were summarised by Barwick and Henzell (2005). Rates of gain in economic merit are increasing and favourable genetic change is occurring across multiple traits. Gains have increased as new BREEDPLAN EBVs have become available. Rates of gain are higher in Angus than in other breeds. Recent estimates suggest rates of gain in Angus, over all recorded herds, are at least 0.10 genetic standard deviations per year for all 4 objectives for which $Indexes are available. Much greater rates are occurring in individual herds. Rates of gain of over 0.20 genetic standard deviations occur in some high-performing herds.

In some breeds there are gains occurring in traits that have not yet been included in $Index values (e.g. temperament in Limousin). Despite these, rates of genetic gain over the whole industry (over all breeds and production systems) clearly could be higher. The main limitation to faster overall industry rates of gain occurring remains the low level of performance recording of some breeds. Gains in the main performance-recording breeds might be aided by more breeders going through the process of developing their own breeding objectives. There is a facility for this within the BreedObject website (http://breedobject.com/). This process increases ownership and commonly also confidence in the breed standard objectives and $Indexes that are available.

Sheep. Research on economic breeding objectives for Merino sheep gained momentum in Australia in the early 1980's with key papers from Ponzoni (1982, 1986), Jones (1982), and James (1987). The first selection indexes based on this work became available to breeders through the WOOLPLAN evaluation system (Ponzoni 1987). Unfortunately adoption of WOOLPLAN was poor, with one contributing factor being a lack of options for breeding objectives. This situation improved with the introduction of the OBJECT software package (Atkins *et al.* 1994) allowing the development of customised objectives. As more and more breeders went through the process of designing their own objectives, confidence grew in the concept of a small number of standard objectives.

As with BreedObject, Merino breeding objectives are based on analyses of net returns calculated as a function of income from wool and meat and costs including feed intake. The traits assumed to influence net returns include wool weight and quality, body weight in surplus young animals and mature ewes, and reproduction. Specialised objectives may also include indirect carcass measurements (scanned muscle and fat depth), and resistance to gastrointestinal parasites.

Objectives for the terminal and maternal sire sectors have been available through LAMBPLAN since the late 1990's, with high adoption levels despite the lack of customised options. In the early stages desired gains objectives were used but more recently economic objectives have been introduced, based on methodology similar to Merino objectives. The traits considered in terminal sires include body weight in sale animals and indirect carcass measurements. Maternal objectives also include reproduction, body weight, and wool traits, although there is little emphasis on wool quality. Both terminal and maternal objectives may also include parasite resistance.

All sectors of the industry have made significant genetic gain in their breeding objectives, with terminal and maternal sire breeds showing accelerated rates of gain since 2000 (Swan *et al.* 2009). Compared to relatively simple simulated breeding programs, terminal sire breeds have been exceeding their potential gain (111%), maternal sire breeds have been approaching potential gain (75 – 85%), while Merinos have been achieving 33% of their potential gain. Importantly, there has been widespread acceptance of indexes as a currency for genetic improvement, with elite sire lists comprised of the sires that rank highest on index.

A new customised breeding objectives software system, SheepObject, has been developed recently, adapted from BreedObject. The advances over previous systems are an improved definition of returns from meat considering direct carcass traits such as dressing percent and lean meat yield, the inclusion of fitness related traits such as lambing ease and ewe longevity, and the ability to model a wider variety of wool, meat and dual purpose enterprises, including situations where the benefits of improvement accrue in multiple enterprises. Further research on aspects of meat and wool quality, and on the concept of resilience, may see these also accommodated in breeding objectives.

Pigs. The first version of PIGBLUP, released to breeders in 1989, included a $Index module to define a breeding objective based on the profit function developed by Stewart et al. (1990). The profit function accounted for the main costs during the life cycle of a sow and her offspring and considered returns as a function of number and quality of offspring. The approach was based on two main equations quantifying a sow herd sub-objective (SHSO) and a growing-finishing sub-objective (GFSO). These two main equations were then weighted to derive the total herd objective. Information required in the PIGBLUP $Index module included economic inputs outlining payment details and cost structures relevant for Australian conditions, performance level in key characteristics of pig production, and a marketing weighting for the sub-objectives.

Over time the number of traits considered in genetic evaluations increased following research in sow stayability (Bunter 1997), carcase and meat quality traits (Hermesch 2008), piglet survival (Hermesch *et al.* 2001) and juvenile IGF-I (Bunter *et al.* 2005). Breeding companies required greater flexibility in the setup of company-specific breeding objectives and moved to utilising objectives developed in-house. Individual seedstock suppliers vary in the emphasis they place on individual traits and in their adoption of new traits developed in Australian research projects. Trait economic values calculated by Cameron and Crump (1999) for Australian conditions have been used as a guide and include economic values for lifetime average daily gain (g/d), backfat (mm), feed conversion ratio (kg feed/kg gain) and number born alive per farrowing sow.

Growth rate, backfat, feed conversion ratio and number born alive are considered by all breeding companies. Changes in feed costs and non-feed costs (e.g. housing, labour) affect the economic importance of feed conversion ratio and growth rate, and both cost components have increased over the last ten years in Australia. In addition, selection emphasis has been removed from backfat during the last decade since fat depth has decreased considerably and further reduction has little economic benefit. Payment for slaughter pigs in Australia is based on weight and backfat. Penalties apply once certain threshold values are exceeded. Economic values for backfat depend on the proportion of pigs exceeding threshold levels and are therefore affected by the mean and variation in fat depth (Hermesch 2005). Substantial economic differences can also be associated with variability in individual primal cut weights at a fixed carcase weight and fat depth (Mérour *et al.* 2009), and these may also need to be considered in breeding objectives.

Number born alive remains the most economically important reproductive trait of the sow. In some maternal lines average piglet weight at birth is used to improve pre-weaning survival of piglets and litter weight. Following recent analyses (Bunter *et al.* 2010) sow weight and fat depth may also need to be included in breeding objectives.

Comment. There are some differences between the species in the traits included in breeding objectives, in the level of distinction made between those traits and the measures taken on seedstock, and in how breeding objective derivation has evolved. The differences are explained in part by production and nucleus level environments being more similar in pigs than in the other species, and by the industries differing in structure (van der Steen 2007). An important consequence, however, is that comparison of rates of genetic gain between the species is problematic. Differences in the number and nature of the traits specified in the breeding objective affects the variance of objectives and hence the comparison of gains expressed in genetic standard deviations of the objective. Differing amounts of distinction between breeding objective traits and the measures on seedstock also makes comparison unequal as it changes index accuracy and thus the amount of genetic change that it is possible to observe. These differences, along with species biological differences affecting generation interval, need to be borne in mind when across species comparisons of genetic gain are contemplated.

NEW DEVELOPMENTS AND OTHER ISSUES FOR BREEDING

Availability of genomic information. The availability of genomic information should not in itself change breeding objectives as neither the traits that are of direct economic importance to the production sector nor the level of detail at which they are valued (the economic level) is expected to be affected. The practical importance of genomic information is especially in its potential to lift accuracy of selection, including at early ages, with benefit to genetic gain and the trait composition of gain. Incorporation of genomic information in EBVs, as considered by Johnston *et al.* (2011) for beef cattle, is a required focus for genetic evaluation across the industries, with the enhanced EBVs then needing to be utilised (e.g. in $Indexes) in selection for the whole breeding objective.

There are other possibilities for genomic information to affect breeding objectives. The availability of SNP tests (or other markers) for particular disease conditions or abnormalities could allow additions to breeding objectives that previously could not be defined or valued. This might occur, for example, where it is more cost effective for industry to manage occurrence of an abnormality rather than to eliminate it. Greater knowledge of how genotype maps to phenotype could require changed procedures for assessing economic values for specific traits. Widespread adoption of genomic selection might change industry structure and cause seedstock enterprise returns and costs to be given more attention in breeding objectives. The possibility of this departure from usual breeding objective practice is considered a little further below.

Societal concerns. Increases in productivity are central to increasing economic merit and required in the interest of world food security (Cribb 2008). In addition to increasing productivity, breeding has to consider societal concerns for animal welfare, human health, and for management of the environment. These have assumed greater importance as consumers have become more able to influence products and practices. Current examples are societal concerns about mulesing in sheep, use of farrowing crates in pigs, and the use of growth promotants in beef cattle. The impacts of societal concerns on breeding objectives are usually through the changed management they may require, affecting costs and thus trait economic values and potentially relativities. However the impacts can also be through requiring additional traits and elements of trait value to be considered. Concern for animal welfare is an important reason for including fertility and other fitness traits in objectives that is additional to their effects on productivity (Oltenacu and Broom 2010). In the mulesing case, concern for welfare may require flystrike resistance to be included in objectives, and it may or may not otherwise have been specifically included.

Climate change. The predicted consequences of climate change, including elevated environmental temperatures, increased costs of production, and declining and more variable production environments, have potentially large ramifications for breeding. Choice of breed, fertility, and other aspects of adaptation are likely to increase in importance, and they could increase the need for methods of combining and utilising between and within-breed differences. Increased costs of production will affect trait economic values and potentially relativities. Greenhouse gas emission traits may ultimately be able to be included in objectives (Hegarty and McEwan 2010). A first approach, however, could be to cost the emissions associated with the feed intake needed for production against the economic values of other traits. This would account for the main genetic variation in emissions associated with production traits, but not for any variation that is independent of that.

Environment-level effects on trait genetic relationships. The ability of breeding to respond to changed environments is limited by a lack of knowledge of how trait genetic relationships vary at differing levels of environment. There are some understandings from evolutionary genetics (Houle 1991) and from resource allocation modelling (van der Waaij 2004). Knowledge is particularly needed for extensively grazed species and in regard to relationships with traits of breeding females. This is especially relevant in Australia, where environments are very variable and where pressure on land use is likely to see breeding females forced into more marginal environments. The need for this knowledge is expected to be further increased under climate change.

Integration of genetics and management. Use of improved genetics can require management to also change, especially concerning provision of feed. A limitation on providing guidance on this in grazing animals has been the difficulty in anticipating feed intake at pasture. Figure 1 illustrates some inter-relations between genetic improvement, stocking rate and $ per ha. An increased feed requirement per head is expected to accompany genetically increased productivity (here assuming no increase in feed efficiency), so the curve for 'improved genetics' moves upwards and to the left (Figure 1a). If current stocking rate is low, using improved genetics lifts feed utilisation and makes the stocking rate closer to the new optimum. If current stocking rate is high, perhaps near the optimum, the full benefit from using improved genetics may only be realised if it is recognised that stocking rate also has to change (be reduced). Note that if feed efficiency can also be improved, the dependency described is expected to be largely removed (Figure 1b).

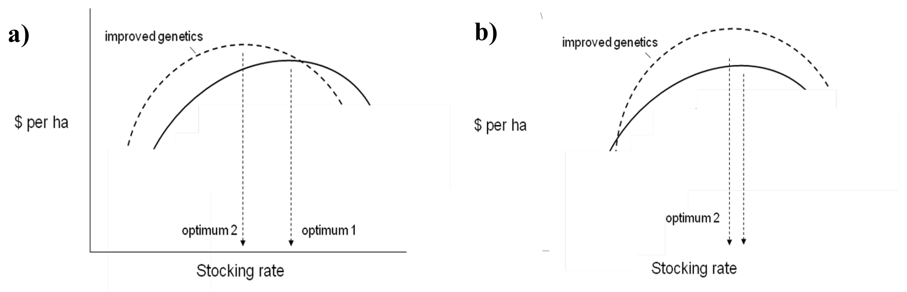

Figure 1. The inter-relation of stocking rate, genetic improvement, and $ per ha, (a) without and (b) with simultaneous improvement of feed efficiency (schematic)

BREEDING OBJECTIVE NEEDS FOR THE FUTURE

Here we suggest areas where more attention is needed, and where the framework for deriving breeding objectives may need to be extended in breeding objectives for the future.

Genetic parameter knowledge for breeding objective traits. Breeding objective traits (of commercial animals in relevant production systems) are much less studied than are potential selection criteria, with the result that there are deficiencies in the genetic parameter knowledge available. This is especially so for traits that need to be understood in different environments (e.g. traits of breeding females) and that are difficult to study experimentally (e.g. feed intake at pasture). This knowledge is also needed for any potential new objective traits. Inadequate knowledge at the level of these genetic parameters limits the effectiveness of all breeding and the benefit there can be from having genomic information or other new selection criteria available.

Including the processor and consumer. The usual framework for deriving breeding objectives includes valuing traits in the commercial production system up to the point of sale from the farm or 'finisher' level of the system. Where traits relevant to processors and consumers (e.g. yield and product quality traits) are included, at least in beef cattle, they are valued according to the price paid at this point of sale. There could be advantages in extending this to include the further value differences that accrue to processors and consumers. This would allow more accurate pricing of ultimate differences, accounting of processor costs that are not currently considered, and a fuller capturing of differences in total economic merit. It may also be necessary for valuing other consumer-oriented traits (e.g. healthfulness traits, such as iron content of meat) that could need inclusion in the future.

Combining enterprises and enterprise pathways. The commercial production system in which traits are valued can include more than one enterprise or enterprise pathway. The principle in calculating trait economic values is to sum over all of the enterprises where the improvement will be expressed. Where there is more than one enterprise pathway involved and this is known in advance (e.g. when breeders have clients producing for different markets), the different pathways can be either treated as different production systems or combined. However, when it is not possible to know in advance which enterprise pathway will apply, the likelihood that each will be encountered should be considered and the pathways combined. Improvement that flows through purebred and then possible crossbred enterprises is an example (Wolfova *et al.* 2011).

Trait value differences for specific roles. Trait improvement can be of greater value to the breeder than to the commercial producer because of the potential there is for the seedstock breeder to multiply the expressions of improvement that will ultimately occur in commercial production. This applies especially for breeders who have other seedstock breeders as clients. Providing breeders with overall merit predictions that are more specific to their role, perhaps separated also for sires and dams, could aid understanding and improve selection and investment decisions.

Including the seedstock breeder. A case can also be made for including the returns and costs of the seedstock enterprise (breeding company) itself in valuing breeding objective traits (see also Barwick and Hammond 1990). The principle to be followed is to sum values accruing over the seedstock enterprise and all other enterprises encountered in commercial production. This formulation would be relevant to the seedstock breeder specifically rather than to industry generally, though it may still be well correlated with broader industry objectives.

Valuing trait improvement at the trait x animal level. Trait improvement may in future be valued more at the trait x animal level than trait level. This change would allow account to be taken of the non-constancy of trait value that occurs across the range of some traits (Barwick and Henzell 2003). It would also increase customisability, and facilitate and enhance genetic evaluation where there are important non-additive components of trait value involved. This potentially includes evaluation that involves mixes of breeds and crosses, evaluation of mating pairs for mate selection, and evaluation that involves genes of large effect.

CONCLUDING REMARKS

The shift in focus achieved in industries from single traits towards selection for overall economic merit has been a very important development. Rates of genetic gain in overall merit are increasing, though much greater gains are possible. Breeding objectives need to be regularly revisited so consideration can be given to the further issues that are demanding the attention of breeders. Some extensions may be needed to the framework for deriving breeding objectives. It is important that all issues are able to continue to be considered within a consistent framework and industries are able to maintain focus on selection for the whole breeding objective.

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