Breeding objectives in an era of transformational breeding technologies

T.J. Byrne¹ & P.R. Amer²

¹AbacusBio International Limited, Roslin Innovation Centre, The University of Edinburgh Easter Bush Campus, EH25 9RG, Edinburgh, United Kingdom
²AbacusBio Limited, P O Box 5585, Dunedin 9058, New Zealand
tbyrne@abacusbio.co.uk (Corresponding Author)

Summary

While the area of breeding objective development already plays a critical role in many aspects of breeding program design and operation, we argue that this role is likely to increase in importance with the advent of transformational technologies that impact on genetic improvement programs.

The advent of genomic selection technology hasn’t necessarily changed the role of breeding objectives, but with the speed and direction of genetic gain changing in the genomic era, appropriately designed and well-constructed breeding objectives are ever more important. Furthermore, new traits which rely primarily on genomic prediction information are rapidly being added to breeding objectives. These often require a “retrofit” to existing indexes, and commonly there is no appetite to completely review and restructure the breeding objective model.

In some industries, a focus on environmental (e.g. greenhouse gases, and nitrate leaching) and/or animal welfare outcomes is likely to increase in importance. Effective implementation of these traits is also likely to be dependent on new technologies, particularly genomic selection, and they often introduce substantial philosophical shifts in the way the breeding objective needs to be constructed.

As there is a shift towards market driven investment in genetic improvement, in some cases market pull for improved genotypes will be key to justifying investment in the new traits and technologies. Breeding objectives will play a significant role in supporting investment decisions, because they underpin the valuation of traits and technologies that increase rates of genetic gain; this valuation is a prerequisite for market driven investment.

As technology becomes more advanced, the tools needed to evaluate it (both economic and other) must be adapted. This will ensure that investment is made in the best technology to increase genetic gain for traits of high economic and social importance.

Keywords: breeding objectives, genomics, new traits, economic evaluation.

Introduction

Breeding objectives can play an important, but not exclusive, role in determining the optimal size and direction of genetic changes in traits in a breeding program (Amer, 2006). They enable both breeders and commercial producers to direct breeding emphasis towards specific market outcomes or address key performance aspects of their production system. In the design of a breeding programme, breeding objectives also have a significant influence on the optimisation of many aspects of the breeding programme including: which traits to record to increase profitability, the choice of animals to be the parents of the next generation, the
choice of breeds or lines to introduce into the production system, and the evaluation of different investments in the breeding programme, by providing criterion by which to quantify return on investment (Goddard, 1998).

Several new breeding technologies are already impacting many genetic improvement pipelines. The advent of genomic selection technology doesn’t necessarily change the role of breeding objectives, but with the speed and direction of genetic gain changing in the genomic era, appropriately designed and well-constructed breeding objectives are ever more important. Genomic selection has however disrupted the business structures of breeding companies, perhaps more so than the breeding strategies within those companies. Since the global financial crisis of 2008, there has been a flood of available capital for investment. This has created an invigoration of venture capital investment markets; investments in gene editing technology by private companies is a good example, as is investment in alternative protein sources, such as those from plants or lab grown meat.

This paper considers the role of breeding objectives in a new animal breeding era that we anticipate will be increasingly influenced by disruptive technologies. A key role of breeding objectives methodology will be its integration with investment analysis to guide and inform decisions about investment in the current, and potentially many new, disruptive technologies.

**New genomic traits in breeding objectives**

Genomic selection strategies are contributing to an ongoing trend of broadening of breeding goals which have been in existence over at least the last 3 to 4 decades. As well as generating more information on exiting traits under selection, genomic technology has enabled the improvement of a raft of new traits of economic importance. These traits are commonly referred to as hard-to-measure traits such as, for example, feed intake, greenhouse gas emissions, various forms of product quality, and late in life traits such as longevity.

For efficient multi-trait selection, these new traits need to be added to breeding objectives. This may simply require a new set of profit calculations, for a product quality trait for example. However, in some situations where the novel trait affects feed requirements more widely (e.g. feed intake), the addition of the trait to the breeding objective requires more complex considerations. This is because feed cost implications are already accounted for within the economic values of traits such as milk production, growth (or size), and reproductive efficiency. These challenges, along with the desirability to retrofit the new traits into existing selection indexes, have been discussed by Amer et al. 2017, and Meyer et al 2017. There are many opportunities for double counting in the integration of new traits, and often confusion over whether a trait is a selection criterion, or alternatively if it fully represents the relevant component of the breeding goal with a genetic correlation of one.

**Direction and speed – balancing priorities**

Genomic selection has increased rates of genetic gain through increases in accuracy of prediction and shortening of generation interval. While the application of genomic selection is usually targeted at hard-to-measure traits, genomic prediction is also included for traits that are recorded on many individuals with high accuracy (like milk production in dairy cattle). This is inevitable, given that the principle of genomic prediction hinges on genotypes on well-recorded animals. The outcome of this is that genomic selection risks favouring traits recorded with high accuracy; those with a clear definition and measurable phenotype. Traits
where the phenotype is less well defined, there are multiple biological components (which we often do not understand), and records are available on fewer animals (like feed intake in dairy cattle) are disadvantaged in a multi-trait genomic selection setting.

In this context, breeding objectives are key to managing the direction and speed of change through the accurate evaluation and integration of economic consequences. This represents good management of the risks associated with trait selection complexes. In particular, this is pertinent when there are risks associated with the deterioration of important fitness traits that are not well recorded, when genomic selection increases accuracy of production traits.

**Valuing genetics technology - major genes and gene editing**

Several major gene effects (or at least QTLs) have been available in selective breeding programmes across species (e.g. DGAT-1 – milk production, GDF-8 – meat production, and numerous major genes affecting the prolificacy of sheep) for years. However, the economic effect of these major genes is seldom accounted for in breeding objectives. Sometimes the objective is to maximise selection towards homozygosity (sometimes for the wild type because of real or perceived associations with deleterious side effects, in addition to their favourable impacts on the initial target trait), and this supersedes any formal economic prioritisation. For major genes with non-additive impacts on the breeding goal, the value of animals with specific genotypes depends on the existing, and expected future, gene frequency in the target population (Kearney et al. 2005), and so it is hard to account for them in a conventional breeding goal.

With gene editing now being technically feasible, there is a need to evaluate the potential payback of this technology if applied in livestock breeding programs. Large scale editing of potential selection candidates where selection of edited individuals is based only on parent average information is likely to be required to avoid inbreeding, and to avoid a substantial trade-off in lost selection intensity for conventional traits. Thus, initial implementation costs, potentially coupled with ongoing royalties, will mean that deployment will need to be based on a sound commercial proposition and associated industry value. Clear demonstration of the magnitude of benefits may also be a key factor to persuade regulatory bodies that the technology is worth approving for widespread use.

**Value propositions and new technology evaluation**

The current market valuation of Illumina is approximately US$29 billion; providing an example of the huge value seen within technology companies that at least in part support livestock genetic improvement. In recent years, stimulatory monetary policies by most central government organisations, have led to a surge in funds looking for investment. Venture capital initiatives are thriving, including many targeting agricultural and animal genetic technologies. Venture capitalists rationalise their investments in technology companies based on accepted rates of success, effectively playing a numbers game, in the absence of detailed domain knowledge and the true market opportunity.

As there is a shift towards market driven investment in genetic improvement, in some cases market pull for improved genotypes will be key to justifying investment in the new traits and technologies. Breeding objectives will play a significant role in supporting investment decisions because they underpin the valuation of traits and technologies that increase rates of genetic gain; this valuation is a prerequisite for market driven investment.
Market survey approaches are also likely to become increasingly important, because they better capture the demand pull and appetite for improvements from buyers of gene stocks, when compared to bioeconomic models. Surveys which support farmer typology development (e.g. Martin-Collado et al., 2015) can provide market segmentation information and intelligence to support investment. This is particularly the case as we see social impact traits such as greenhouse gas emissions, nitrate leaching, and animal welfare outcomes becoming more prevalent in breeding programs globally.

As technology becomes more advanced, the tools needed to evaluate it (both economic and other) must be adapted. This will ensure that investment is made in the best technology to increase the genetic gain for traits of high economic and social importance.

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