Using preference survey approaches to define breeding goals

T. J. Byrne[1], P. R. Amer[1], K. F. Smith[2], P. F. Fennessy[1], P. Hansen[3]

[1]AbacusBio Limited, P O Box 5585, Dunedin 9058, New Zealand
[2]AbacusBio Pty Limited, Olveston, 331 Penshurst Road, Byaduk, VIC 3301, Australia
[3]Department of Economics, University of Otago, PO Box 56, Dunedin, New Zealand

Abstract

Breeding objectives are usually derived using bio-economic models. However preference-based approaches offer another means of assessing the appropriate values of desirable traits in breeding programmes. They are especially useful when considering traits that have no clear economic values.

We have used the internet-based software *1000Minds* to derive economic values in the definition of breeding objectives and to test whether current breeding objectives align to industry expectations, by surveying breeders and farmers to determine their assessments of the relative values of traits. We have applied these methods to sheep in Ireland and Australia, dairy cattle in New Zealand, and pasture plants in Australia. In particular, we have devised ways to express the part-worth utilities in financial terms.

The most critical issue in developing such approaches is a clear definition of traits and the use of realistic ranges of variation in trait performance in the creation of alternatives. Conversion of part-worth utilities into economic terms requires that the economic value is generated within the survey by providing respondents with options that relate to traits which must be defined in tangible economic terms. In presenting alternatives with the aim of calculating economic values, application of discounted gene-flow principles to breeding objectives in preference-based methods depends on the way questions are asked. It is apparent that respondents' understanding of a trait (namely trait definition), and experience with the traits are very important in using preference-based approaches.

Preference-based methods have proven extremely useful for industry engagement and for quantifying the range and perceptions of trait priorities of commercial farmers. We see it as particularly useful in deriving the inputs for desired gains selection indexes. However we have found some limitations to their use for the calculation of economic values and the definition of animal breeding objectives related to separation of true differences in preferences, confounding, and double counting.

Introduction

Traditional methodologies for deriving breeding objectives involve the use of profit functions which calculate the impact on farm profit of changes in each trait. However, it is also important that breeding objectives reflect the farming philosophies of the breeders and commercial farmers for whom they are designed.

The increasing importance of environmental (Olesen *et al.*, 2000) and animal-welfare (Fisher and Webster, 2009; Nielsen *et al.*, 2011) traits preferred by consumers, which may impact on market access, has driven developed livestock industries to account for aspects of production systems beyond those that can be defined economically. Similarly, as developing countries build genetic-improvement programmes (e.g. Kosgey (2006)), breeding objectives must be defined for production systems where price and cost data are not readily available. A further challenge in defining breeding objectives in developing countries is that animal value often encompasses intangible factors such as prestige, financing, insurance, or as a means of cultural and ceremonial functions (Kosgey *et al.*, 2004). Therefore, there is an increasing recognition of the need to incorporate the perceptions of industry stakeholders in breeding objectives.

This paper describes the application of the internet-based software *1000Minds* to derive economic values in the definition of breeding objectives and to test whether current breeding objectives align to industry expectations, by surveying breeders and farmers to determine their assessments of the relative values of traits. We have applied these methods to sheep in Ireland and Australia, dairy cattle in New Zealand, and pasture plants in Australia. In particular, we have devised ways to express the part-worth utilities in financial terms.

Materials and methods

Application of *1000Minds*

In a preference-based experiment, respondents are asked a series of paired statements/ questions; each statement features two alternatives differentiated on a set of attributes (with differing levels of performance) (Caussade *et al.*, 2005). This representation of options in terms of a set of attributes is consistent with Lancaster's theory of consumer demand whereby consumers derive utility not from the goods themselves but rather from the good's underlying characteristics (Lancaster, 1966). In the context of animal breeding, this approach involves analysing farmers' preferences in terms of the benefits that they perceive will arise from changes in genetic traits (Tano *et al.*, 2003). For example, Wurzinger *et al*. (2006) and Tano *et al*. (2003) used choice experiments to value cattle traits in Africa based on farmers' preferences when production and price data were not readily available. Scarpa *et al*. (2003) estimated preference values for genetic traits in pastoralists' cattle populations in Kenya that would be desirable for future breeding or conservation programmes. Sy *et al*. (1997) evaluated the preferences of parts of the Canadian beef production system for beef cattle characteristics, and von Rohr *et al*. (1999) surveyed meat quality experts in Switzerland to derive estimates of price changes attributable to quality difference in pig carcases. We have applied preference-based experiments to meat sheep, wool sheep, dairy cattle, and pasture cultivars.

The *1000Minds* software used to implement the survey applies a method for deriving part-worth utilities known by the acronym PAPRIKA (**P**otentially **A**ll **P**airwise **R**an**K**ings of all possible **A**lternatives) (Hansen, 2009). In the present context, respondents are asked to trade-off a series of hypothetical alternatives. These relate to the most desirable features when (1) selecting a flock of meat sheep, (2) selecting a flock of fine wool sheep, (3) selecting a herd of dairy cows, or (4) renewing a pasture under a particular set of environmental conditions. The alternatives were defined in terms of either one (surveys 2 and 3) or two and three (surveys 1 and 4) traits at-a-time. Examples of a question are presented for meat sheep (Figure 1) (Byrne *et al.*, In press) and dairy cows (Figure 2), respectively.

Which of these (hypothetical) flocks of sheep do you prefer?
(given they are identical in all other respects)

(left)
Value per lamb at the meat processor
€2 more
Average days to slaughter of lambs
2 weeks earlier

OR

(right)
Value per lamb at the meat processor
€4 more
Average days to slaughter of lambs
1 week earlier

This one | They're equal | This one
This one is impossible | Skip this one for now | This one is impossible

Figure 1. A question presented for meat sheep defined in terms of two traits at-a-time.

Which of these (hypothetical) herd do you prefer?
(given they are identical in all other respects)

(left)
5 **less** calving difficulty cases per 100 cows per year

OR

(right)
25 kg **more** milksolids per hectare

This one | They're equal | This one
This one is impossible | Skip this one for now | This one is impossible

Figure 2. A question presented for dairy cows defined in terms of one trait at-a-time.

The number of such questions (and the burden on respondents) is minimised because each time a question is answered, PAPRIKA eliminates all other possible questions that are implicitly answered as corollaries of those already answered (via the logical property of 'transitivity'). From the respondent's answers (individual or group consensus), the software applies mathematical methods to calculate part-worth utilities which represent the relative importance of the attributes to the respondent(s). In this approach, part-worth utilities are expressed as percentages such that the ideal hypothetical alternative (as per the highest-ranked levels on all traits) has a total score of 100% (the maximum hypothetically possible). The output of the *1000Minds* software represents the mean part-worth utility for each level within each trait.

Survey development

The most critical issue in developing preference-based approaches is the clear definition of traits and the use of realistic ranges of variation in trait performance in order to define the alternatives. It is also necessary to define the logical (or 'natural') ranking of the least-preferred to the most-preferred levels for each trait. Consultation and the application of pilot surveys (involving experts) to test assumptions and to obtain feedback particularly around the clarity of the questions or alternatives were invaluable.

The trait must be clearly defined such that the levels of performance can be quantified. However this is not always straight-forward and it can be very difficult to parameterise some traits – pest resistance and survival over summer in pasture, and lamb survival are examples. The comparison of the current situation with a future option using terms such as per 100 cows (Figure 2) has enabled an adequate parameterisation in the dairy model in practice and using terms such as ALWAYS has enabled an adequate parameterisation in the pasture renewal model in practice. Two examples from the separate user/farmer survey of priorities to be considered in wool sheep flock selection (fleece weight) and pasture renewal (pasture survival) are presented in Table 1.

Table 1. Examples (from separate studies) of parameterisation of traits (Byrne, unpublished, (Smith and Fennessy, 2011).

Adult clean fleece weight
Increase adult clean fleece weight by 0.5 kg
Pasture survival
Pasture survival in **hot dry summer** is **same as now**
Pasture **always survives** in **hot dry summer**

In the meat sheep study, the levels for each trait were based on meaningful variations in trait performance consistent with farmer experience in the context of the Irish production-system. For example, one week of lamb growth represents 0.5 to 0.7 kg of carcase weight gain and is worth, in gross economic terms, approximately €2 per lamb; hence levels of 1 week and 2 weeks earlier to slaughter were applied. In the dairy cattle study, the description of the trait attempted to ensure that the financial impact in the New Zealand production system was approximately the same for each trait change in all descriptions, while in the wool sheep study, the levels for each trait were based on a change of approximately one phenotypic standard deviation in each trait, based on genetic parameters for Australian Merino sheep genetic evaluation. Thus, we have used different approaches to choosing the levels in each application.

Derivation of economic values

Importantly, to derive economic values using preference-based methodologies, the economic value must be generated within the survey by providing respondents with an option concerning a trait defined in tangible monetary terms (Orme, 2010). To avoid bias in the respondents' interpretation of each question (and therefore the part-worth utility), it is important that the monetary trait definition is independent of a change in the performance of any trait included in the survey (otherwise this will cause double-counting). There must also be a reasonable expectation that the trait chosen as the monetary benchmark will exhibit linearity of value. An example of a question including a monetary trait (Byrne *et al.*, 2011) is presented in Figure 1. In a recent pasture renewal study, the monetary attribute was defined in terms of the cost of grain (Smith and Fennessy, unpublished). The price of grain, as a cost parameter, is widely understood, as purchasing of grain in times of feed deficit is common.

The average (across trait levels in the survey) preferences expressed per unit change in a trait of interest are computed from the part-worth utilities output from the *1000Minds* software. The average preference expressed per unit change in the trait is then multiplied by the equivalent preference for a single monetary value trait, effectively establishing how much reward for the monetary trait that the respondent would be prepared to sacrifice in order to realise improvement in the trait of interest.

The derivation of economic weights in breeding objectives requires that differences in the timing and frequency of expression of different traits are accounted for (McClintock and Cunningham, 1974). In animal breeding terms when using survey-based methodology, Nielsen and Amer (2007) commented on the implications of the way in which animal group definitions are formulated when presenting alternatives to respondents, and suggested that the application of discounted gene-flow principles to breeding objectives in survey-based methods depends explicitly on the way the questions are asked. The survey for sheep in Ireland posed the following question in relation to a number of alternative features of a hypothetical flock of sheep: *Which of these (hypothetical) sheep flocks do you prefer?* (Figure 1). Presented in this way, the question prompts the respondent to choose his or her preferred alternative flock from the two on offer, assuming the implications of the choice will occur to the respondent instantaneously, on reading the alternatives. This approach leaves the application of discounted gene-flow principles to a second step of the process, rather than requiring respondents to implicitly account for the differences.

Considerations

In the current studies (for dairy cattle in New Zealand and sheep in Australia and Ireland) this type of approach has been used to test whether current breeding objectives align to industry expectations. Changing breeding objectives tends to be inherently unpopular with breeders and can heavily influence the relative values of breeds, and also the relative value of stocks of different breeding companies. Therefore the use of preference-based methodologies enables gathering of information from industry stake-holders, to provide a mandate for change. In this respect, Figure 3 provides an overview of the application of the *1000Minds* approach in the context of the generalised design of genetic improvement programmes for production animals.

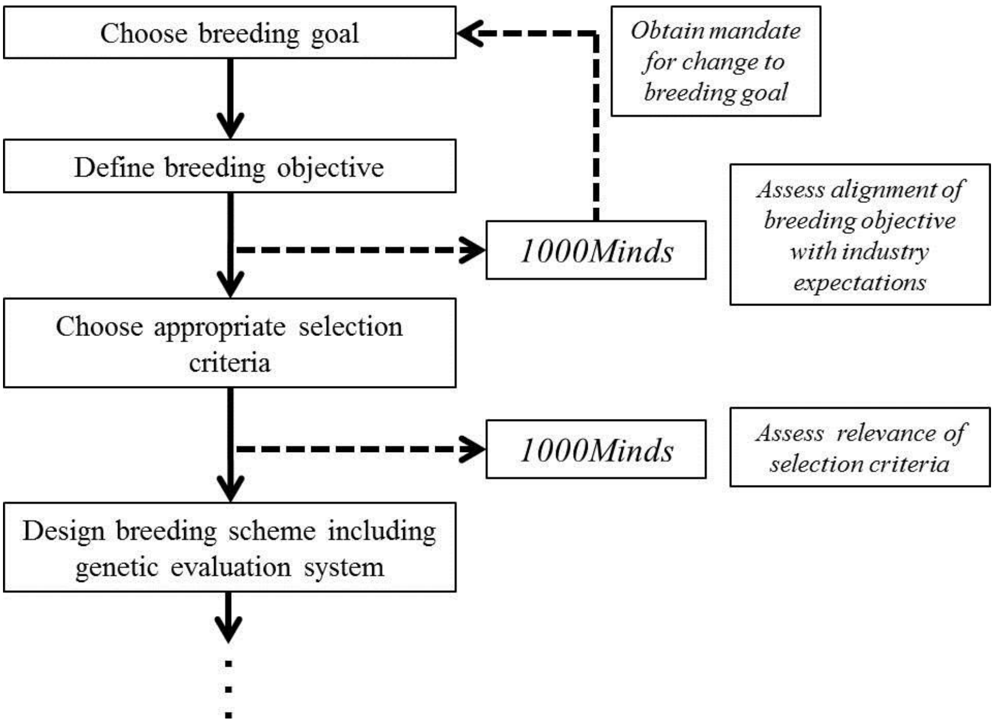

Figure 3. The use of 1000Minds in the design of genetic improvement programmes for production animals.

Hazel (1943) argued that partial EVs must be used in developing breeding objectives. Doing so ensures that the economic implications of genetic changes in a trait are calculated independently of genetic changes in other traits; i.e. genetic and phenotypic correlations between traits are ignored. The assumption that part-worth utilities are truly partial EVs is a potential limitation of the use of a preference-based methodology to calculate EVs. It could be argued that any economic consequences arising from a trait change that are the result of a correlation assumed by the respondent between performances in other traits (i.e. impartiality that results in double counting) are useful in terms of defining a breeding goal (Smith and Fennessy, 2011). However, this potential for impartiality suggests that caution is required when using preference-based methods to formulate EVs for traits in which respondents are expected to struggle to identify independent consequences of genetic changes.

The calculation of EVs in a breeding objective should focus on the economic implications of changes in the trait rather than on the genetic variation in that trait (Hazel, 1943). One problem when using preference-based methodology to calculate EVs is that participants can confound the economic implications of changes in a trait with the level of variation in the trait. This confounding phenomenon means that the respondents include components of the variance (namely heritability and phenotypic standard deviation), in choice decisions. Confounding represents the respondent's intuition about how easily improvements can be made in the trait and may present a challenge to the use of preference-based methods for calculating EVs in the traditional way.

These studies have shown that the specification of the survey itself (trait definitions and trait levels) was a critical aspect in developing preference-based surveys to define breeding objectives; it was particularly important that participants were presented with realistic alternatives with respect to trait variation. Moreover, it is critical that when offered a trade-off, each respondent understands and correctly interprets the definition of each trait, and therefore provides a valid response. To obtain a valid response, unambiguous trait definitions must be included in the survey.

Conclusion

Preference-based methods have proven extremely useful for industry engagement and for quantifying the range and perceptions of trait priorities of industry stake-holders. We see it as particularly useful in deriving the inputs for desired gains selection indexes. These studies have highlighted the potential use of *1000Minds* to assess the importance of traits to the industry (whether a trait should be included in the breeding objective), assess whether current breeding objectives align to industry expectations, help prioritise research into new recording and genetic evaluation methods, and define industry breeding goals.

References

Byrne, T.J., Amer, P.R., Fennessy, P.F., Hansen, P., Wickham, B.W., In press. A preference-based approach to deriving breeding objectives: applied to sheep breeding. animal. 10.1017/S1751731111002060

Byrne, T.J., Fennessy, P.F., Smith, K.F., Hansen, P., Amer, P.R., 2011. Preference-based approaches to deriving breeding objectives: Application to sheep and plant breeding, Proceedings of the Association for the Advancement of Animal Breeding and Genetics, Perth, Australia, pp. 35-38

Caussade, S., Ortúzar, J.d.D., Rizzi, L.I., Hensher, D.A., 2005. Assessing the influence of design dimensions on stated choice experiment estimates. Transportation Research Part B: Methodological 39, 621-640.

Fisher, M.W., Webster, A.J.F., 2009. Breeding and Selection Goals and Animal Welfare. Proceedings of the New Zealand Society of Animal Production 69, 135-139.

Hansen, P., Ombler, F., 2009. A New Method for Scoring Additive Multi-attribute Value Models Using Pairwise Rankings of Alternatives. Journal of Multi-criteria Decision Analysis 15, 87-107.

Hazel, L.N., 1943. The genetic basis for constructing selection indexes. Genetics 28, 476-490.

Kosgey, I.S., Baker, R.L., Udo, H.M.J., Van Arendonk, J.A.M., 2006. Successes and failures of small ruminant breeding programmes in the tropics: a review. Small Ruminant Research 61, 13-28.

Kosgey, I.S., Van Arendonk, J.A.M., Baker, R.L., 2004. Economic values for traits in breeding objectives for sheep in the tropics: impact of tangible and intangible benefits. Livestock Production Science 88, 143-160.

Lancaster, K.J., 1966. A New Approach to ConsumerTtheory. Journal of Political Economy 74, 132.

McClintock, A.E., Cunningham, E.P., 1974. Selection in dual purpose cattle populations: defining the breeding objective. Animal production 18, 237-247.

Nielsen, H., Olesen, I., Navrud, S., Kolstad, K., Amer, P., 2011. How to Consider the Value of Farm Animals in Breeding Goals. A Review of Current Status and Future Challenges. Journal of Agricultural and Environmental Ethics, To be confirmed.

Nielsen, H.M., Amer, P.R., 2007. An approach to derive economic weights in breeding objectives using partial profile choice experiments. animal 1, 1254-1262.

Olesen, I., Groen, A.F., Gjerde, B., 2000. Definition of animal breeding goals for sustainable production systems. Journal of Animal Science 78, 570.

Orme, B.K., 2010. Interpreting the Results of Conjoint Analysis. In: Orme, B.K. (Ed.), Getting Started with Conjoint Analysis: Strategies for Product Design and Pricing Research. Research Publishers LLC, Madison, pp. 77-88.

Scarpa, R., Ruto, E.S.K., Kristjanson, P., Radeny, M., Drucker, A.G., Rege, J.E.O., 2003. Valuing indigenous cattle breeds in Kenya: an empirical comparison of stated and revealed preference value estimates. Ecological Economics 45, 409-426.

Smith, K.F., Fennessy, P.F., 2011. The use of conjoint analysis to determine the relative importance of specific traits as selection criteria for the improvement of perennial pasture species in Australia. Crop and Pasture Science 62, 355-365.

Sy, H.A., Faminow, M.D., 1997. Estimating the values of cattle characteristics using an Ordered Probit Model. American Journal of Agricultural Economics 79, 463.

Tano, K., Kamuanga, M., Faminow, M.D., Swallow, B., 2003. Using conjoint analysis to estimate farmer's preferences for cattle traits in West Africa. Ecological Economics 45, 393-407.

von Rohr, P., Hofer, A., Kunzi, N., 1999. Economic values for meat quality traits in pigs. J. Anim Sci. 77, 2633-2640.

Wurzinger, M., Ndumu, D., Baumung, R., Drucker, A.G., Okeyo, A.M., Semambo, D.K., Sölkner, J., 2006. Assessing stated preferences through the use of choice experiments: valuing (re)production v. aesthetics in the breeding goals of Ugandan Ankole cattle breeders, Proceedings of the Eighth World Congress on Genetics Applied to Livestock Production. World Congress on Genetics Applied to Livestock Production, Belo Horizonte, Brazil, pp. 4. CD-ROM: 31_439-608.pdf. . 13–18 August, 2006