ECO NOMIC EVALUATION OF BREEDING OBJECTIVES IN SHEEP AND GOATS
- GENERAL CONSIDERATIONS

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Kensington, Australia, 2033.

SUMMARY

The procedures to be followed and some of the problems which arise in defining breeding objectives are discussed. Special emphasis is given to attempts to reconcile conflicts between different bases of evaluation, and it is concluded that from a long-term viewpoint, efficiency should be the goal of the breeder, where efficiency is measured as the ratio of the value of all inputs to the value of all outputs. In the shorter term, or where artificial distortions of markets occur, other objectives may be preferred. Goals should be clearly distinguished from selection criteria, and this will be more likely to be achieved if careful attention is given to the level of analysis which is employed.

INTRODUCTION

Sheep and goats are used for meat and fibre production, and to a lesser extent for milk production, in a wide range of environments throughout the world. The relative importance of meat and fibre changes greatly from one production system to another, with the result that there are many different objectives at which breeders may aim, and many breeds and strains which are genetically very different. Some stocks are used in systems with very high inputs, as in European sheepmeat production, while others, such as sheep and goats in many lesser developed countries and in arid zones, must produce from very low inputs. The diversity of genotypes provides the producer with a wide choice of breeds or strains for use in a given production/marketing system, and in making a choice between available stocks he needs to have a specific objective in order to evaluate their relative merits. In addition, further improvement of existing stocks will be efficiently pursued only if appropriate directions of change can be identified. As production systems change over time, all breeding objectives are to some extent speculative, being based on predictions of economic and technological conditions at the time when results of current decisions come into effect. This uncertainty is a greater problem for future improvement than for choice among existing stocks, because of the longer lags involved. In this paper, I shall concentrate on the general problems of defining breeding objectives in sheep and goats. More detailed reviews can be found in Ponzoni (1982) and Bradford and Meyer (1986).

SELECTION AMONG STOCKS

While decisions on which breed or strain or crossbred to use are sometimes made for aesthetic or sentimental reasons, only economically based decisions will be considered in this paper. Thus it will be assumed that a producer aims to maximise his economic well-being when he chooses his animals. Though few would carry out a fully detailed analysis, in principle producers would assess what costs and what returns would be achieved with each available genotype. In most instances, a farmer would regard his land as a fixed part of his system, though inputs of fertiliser (for example) might be equivalent to expanding his land.
holding. His final decision on the most profitable type of sheep or goat would then be made on the basis of which gave (say) the highest gross margin, not necessarily under current conditions, but under conditions which he expects to apply over the next few years. He may apply some restraints in making his comparisons, such as specifying that no further borrowing will be done at existing interest rates. Such analyses are regularly made in deciding whether to run Merino sheep for apparel wool, crossbred sheep for meat, or Angora goats for mohair (for an Australian example). Such comparisons are normally based on somewhat simplified assumptions, and on approximations to the genetic differences between breeds or species, which have seldom been accurately determined under comparable conditions. However, such calculations are generally regarded as the most rational method of choice in such situations.

**SELECTION WITHIN STOCKS**

In discussing selection among stocks, it was assumed that the producer was operating within a defined system, and though there might be some uncertainties, he was acting for his own benefit. When we come to selection within stocks, this simple assumption is not so useful. In most livestock breeds, there is a hierarchy, and the genetic change in the breed is determined largely by selection decisions made in elite studs (Robertson and Asker, 1951), the results of which eventually flow through to ordinary flocks, with a lag of variable length (Bichard, 1971).

In such a structure, the economic consequences of selection decisions may be different at different levels of the hierarchy, and frequently the relevant information is either not readily available or not efficiently transferred to the decision makers in elite studs. A similar consideration applies to the overall industry structure. For instance, it is now widely recognised that many consumers regard lamb as overfat, but lamb producers are not penalised for overfat lambs when they sell animals for slaughter, but rather tend to be rewarded. Producers thus face a dilemma in defining what is genetic improvement. The tendency is to take a longer-term view and assume that consumer wishes will eventually affect the market. The introduction of objective measurement in wool selling has greatly improved the ability of breeders to define realistic breeding objectives.

**Breeding objectives and selection criteria**

One source of confusion which must be avoided is the failure to distinguish between objectives and selection criteria (James, 1982). The breeding objective is the combination of traits which we wish to improve, and should be decided on purely economic grounds. The fact that a trait may have a very low heritability, or may be extremely difficult to measure (e.g., feed consumption in extensively grazing sheep or goats) has no relevance to whether or not the trait should be considered as part of the objective. On the other hand, such considerations are entirely relevant in choosing selection criteria — those traits on the basis of which the breeder makes selection decisions. The breeding objective must be defined in terms of what we would like to improve, not what we can improve. The improvements which are possible depend on genetic factors and practical questions about the design of the breeding program, and can only be properly considered after the objective has been defined. Failure to observe this distinction is likely to lead to confusion between means and ends, and consequently to less progress than might have been achieved.

Once one has defined a breeding objective in strictly economic terms,
genetical assumptions can be introduced, and on the basis of these the results of any breeding program can be predicted, and by use of the breeding objective, the economic value of the genetic changes can be assessed. Thus the role of economics is to define what is desirable; the role of biology is to predict the consequences of a breeding program. The combination of economics and biology allows the choice of the optimum program from among those possible. If the two are not kept separate until the final stage, the full range of possibilities may not be explored.

Who benefits?

Moav (1973) raised the very important question of whose interests are to be served by a breeding program, and showed by a simple example that the relative economic weights to be given to different traits depended on the viewpoint taken. From a national (consumer) viewpoint, what is desirable may be the production of the desired amount of high quality meat and fibre at the lowest possible cost, with a surplus for export if suitable prices can be obtained. On the other hand, a farmer with a fixed land holding and no access to borrowed money may be concerned solely with maximising output from his property, even if this is achieved at a higher cost per unit product, since he will be compensated by the greater amount of product. This problem will often be exacerbated by government regulations or subsidies, which may considerably increase the discrepancies between the goals of different sections of the whole production system. Experience has shown that what can be established by legislation can also be dismantled by legislation, and for a long-term activity such as livestock improvement it may be unwise to base objectives on the assumption that existing government interventions will continue indefinitely.

On the other hand, a breeder who elected to disregard "artificial" market structures in choosing a breeding objective could find that he could not sell stock in competition with other breeders who did breed strains adapted to current conditions, and go out of business before the animals he has bred come into demand. As emphasised by James (1980), the profitability of a given enterprise will depend on its efficiency relative to competitive enterprises, and thus producers will be concerned to buy breeding stock which will maximise their current profit. In buying sires, they are concerned with those available at the time, and the direction of change being made in any strain will be of little concern in choosing between sources of sires, though the rate of genetic gain will be important in determining sire replacement rates.

Combining returns and costs

On an enterprise basis, we can write a profit equation in the form

\[ P = R - C \]  

(1)

where \( P \) is profit, \( R \) is total returns, and \( C \) is total costs. An alternative, used by Dickerson (1970) and others, is the ratio

\[ Q = \frac{C}{R}. \]  

(2)

It was shown by James (1982), using a simple example, that relative economic values derived from (1) and from (2) could be very different. In (1) the enterprise is used as the basis, while in (2) the value of output is used as the basis. Other examples of the way in which the relative economic values depend on the basis of calculation were given by Moav (1973) and Brascamp, Smith and Guy (1985). The latter authors then showed that if \( P \) is set equal to zero, the basis on which the calculation is made no longer affects relative economic
values. At first sight, this may appear artificial, but if "normal profit" is included as a cost of production, setting $P$ to zero appears to be quite reasonable. But if profit is not to be increased, what is the justification for seeking genetic improvement? One way of answering this question is to say that competition with meat and fibre production from other breeds or species guarantees that profit will in fact decline if improvement is not made. Nevertheless, setting profit to zero may not always be a convincing way of resolving the problem of varying economic values as the basis of calculation changes.

Smith, James and Brascamp (1986) have advanced another argument as a way of reconciling these differences. The economic value for a given trait $y$ would be calculated as follows. The change in profit from a small change $dy$ would be given by

$$\frac{dP}{dy} = \frac{dR}{dy} dy - \frac{dC}{dy} dy$$

On this basis, the economic value for $y$ would be

$$a_y = \frac{dP}{dy} = \frac{dR}{dy} - \frac{dC}{dy}$$

Thus the value of $a_y$ consists of two parts: a change in outputs and a change in inputs. However, it would be possible to match the change in output by using currently available animals simply by scaling up the enterprise. This scaling approach, with $R$ being changed by $\frac{dR}{dy} dy$, would bring a corresponding change in costs of $\frac{C}{R} \frac{dR}{dy} dy$, so the change in profits from scaling would be

$$\delta P = \frac{dR}{dy} dy - \frac{C}{R} \frac{dR}{dy} dy$$

Since this change in profit could be achieved without genetic improvement, they argue that the value of genetic improvement is $dP - \delta P$, from which the relative economic value for $y$ is given by

$$a_y = \frac{C}{R} \frac{dR}{dy} - \frac{dC}{dy}$$

The value of genetic improvement is then the saving in costs which are needed for the increased output.

If we write $\phi = \frac{R}{C} = \frac{Q}{Q}$, then

$$\frac{d\phi}{dy} = \frac{C}{R} \frac{dR}{dy} - \frac{dC}{dy}$$

and

$$a_y = CQ \frac{d\phi}{dy} = -R \frac{dQ}{dy}$$

Thus the economic value of a trait, apart from a factor which is the same for all traits, is the same as would be given by use of $\phi$ or $Q$. If we consider changes in costs, these could be matched by scaling of the enterprise, and the value of genetic improvement is given by the extra output from the same change in costs. Again, the enterprise could be scaled to give the same change in profit, in which case the value of genetic improvement is the reduction in inputs needed to achieve the same change in profit. These approaches lead to values of $a_y$ which are proportional to those given in (7).

In this approach there are no fixed costs, so it is a long-term one, and it is assumed that there are no artificial barriers to proper allocation of resources. The elimination of fixed costs makes the derivation of economic
values somewhat more difficult, as the costs of all resources used in the enter-
prise must be included. When there are no fixed costs, it is not possible to
make genetic gains simply by increasing output and thus spreading fixed costs
over a greater volume of products. Of course, in the short term many products
will have fixed costs, and an increase in production will benefit them. However,
as shown above, in the long term what is important on an industry-wide basis is
efficiency of production, measured by either $\phi$ or $Q$. Given the freedom to vary
the scale of the enterprise, only changes in efficiency can be regarded as
genetic improvement.

If it is decided that the ratio of costs and returns should constitute the
breeding objective, some further problems must be considered. What constitutes
a cost, and what constitutes a return? For example, wool is normally sold at
auction. One way of calculating returns and costs would be to take returns from
wool as the amount of wool sold multiplied by the average price of the wool.
Costs of selling the wool (transport, handling, brokerage, etc.) would then be
added to costs. On the other hand, such charges could be subtracted to give a
net return from wool sales, and these charges would then not be counted as costs.
Different cost/return ratios could be obtained from the two approaches, though
in practice the difference might not be large.

Applying constraints

Let us denote by $H$ the breeding objective which is chosen, whether it be
$P$, $Q$, $\phi$ or some other. It may be that the breeder wishes to apply some con-
straint to the objective. For example, a sheep producer in a semi-arid zone
would perhaps wish to specify that the total grazing pressure on his land should
not change, since an increase could lead to pasture degradation while a decrease
would mean that resources were not fully utilised.

Suppose there are $n$ traits to be considered. Then

$$ H = H(y_1, y_2, \ldots, y_n) $$

and the constraint will have the form

$$ K(y_1, y_2, \ldots, y_n) = \text{constant} $$

Then on denoting

$$ \frac{\partial K}{\partial y_j} = K(j) $$

we must have

$$ K(1)dy_1 + K(2)dy_2 + \ldots + K(n)dy_n = 0 $$

from which

$$ dy_n = -\frac{K(1)}{K(n)}dy_1 - \frac{K(2)}{K(n)}dy_2 - \ldots - \frac{K(n-1)}{K(n)}dy_{n-1} $$

and on substituting this expression into

$$ dH = \frac{\partial H}{\partial y_1}dy_1 + \frac{\partial H}{\partial y_2}dy_2 + \ldots + \frac{\partial H}{\partial y_n}dy_n $$

we find

$$ dH = \sum_{j=1}^{n-1} \left( \frac{\partial H}{\partial y_j} \frac{K(1)}{K(n)} \right) dy_j $$

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This is the approach taken by Jones (1982) in defining a breeding objective for merino sheep with a fixed total amount of grazing available.

It can be shown that if the restriction is imposed that total outputs are fixed or that total inputs are fixed, we are led to the conclusion that the correct definition of the breeding objective is $Q$ or $\phi$, since if (say) $R$ is fixed, any genetic improvement will be by reduction of $C$, and with fixed $R$, this means a reduction of $Q$ or an increase of $\phi$. Thus it may sometimes be convenient to consider fixed inputs or outputs in defining breeding objectives, and this may be done rather than allowing both $R$ and $C$ to vary if this simplifies the determination of economic values.

Specification of traits

Appendix A shows there is no unique way of specifying the breeding objective in terms of a given set of traits. Weight gain and feed consumption can be replaced by weight gain and feed conversion ratio without altering the breeding objective, though its expression would be different. How should we choose the set of traits to be represented? In the example just cited, it does not seem to matter, though many breeders would prefer the use of feed conversion ratio to feed consumption, since it gives relatively less value to weight gain, which is evaluated at the same feed conversion ratio rather than at the same feed consumption.

On the other hand, we could consider returns from wool as simply amount of wool times average price, or attempt to specify average price as a function of fleece characters such as average fibre diameter, colour, tenderness, etc. If the first approach is taken, the specification of the objective is simplified. However, in predicting responses to selection, the genetic parameters connecting price and physical characteristics of the fleece would be required, and these would have to be deduced from the same type of analysis as used to include the traits in the breeding objective. It would then seem that there is nothing to choose between the two methods. However, one possible disadvantage with more detailed specification is the difficulty of ensuring that analysis into components is pursued to the same depth in all cases, with the possible result that economic weights for some traits are based on incomplete analyses. A compensating possible advantage is a more thorough understanding of the nature of genetic improvement when the detailed specification is used. I believe that development of a breeding objective should begin with a specification of all items of income and expenditure. Once this has been done, it is not necessary to proceed further. However, if desired, each item may then be analysed as a function of the relevant traits, it being essential to ensure that all relevant traits are included in the analysis of each item. Clearly there is a limit to the depth to which such analyses should be pursued; they would be expected to stop short of basic physiological processes, and certainly could not be pursued to the gene locus level.

Such analyses do not always avoid confusion. It is, for example, not uncommon for the value of increased meat production to be discounted for an assumed increase in feed consumption. This may be appropriate if the objective is designed to include feed conversion ratio, as pointed out earlier. However, frequently the purpose is to avoid including feed consumption in the objective, because it cannot be measured in practice, and as shown by Gjedrem (1972) omitting an important trait from the objective may have serious consequences. My own preference is for feed consumption to be included explicitly, perhaps divided into different components (Ponzoni, pers. comm.), but there can never be a valid
objective which does not properly include such a major component of costs.

A difficulty may sometimes arise with what may be called secondary effects. It is well known that an increase in twinning rate in ewes will lead to reduced wool production. How should this effect be included in the objective? Three ways suggest themselves. (1) Discount the value of the extra lambs produced by the value of the loss in value of wool. (2) In estimating genetic parameters, do not correct for twinning status in estimating variances and covariances, so that such a reduction in fleece production occurs as a correlated response to changes in twinning rate. (3) Introduce a new variable, wool loss due to reproduction. The second procedure, though possible, is likely to prove difficult to apply in practice, while the first is similar to the discounting of weight gain for increased feed consumption. The third method seems simplest and best.

Discounted cash flows

Discounted cash flow methods have been used on occasion in definition of breeding objectives, as by McClintock and Cunningham (1974) and James (1978). In some circumstances, such as the problem considered by James of combining current generation and future generation gains, they appear essential. In the economic evaluation of investment in breeding programs such procedures are also necessary (Hill, 1971). Application of discounting may also be desirable in defining a selection objective in general, but in sheep and goat breeding would probably not make a great difference to the relative economic values determined from analysis of costs and returns within a single year. Certainly, returns from slaughter for meat occur only once in an animal's life, while returns from fibre will accrue at regular intervals. Returns from meat in animals slaughtered young will accrue before returns from fibre are realised, but returns from meat of animals slaughtered at advanced ages will accrue after returns from fibre production, and so will probably average out in their effects. Of course, one would probably keep returns at these ages separate in the breeding objective, so that with discounting meat of young animals would be relatively more valuable than without discounting, but the consequences in a breeding program would probably be small. Another problem in principle which would probably not be of much practical importance concerns non-linearity of the objective. In finding relative economic values, partial differentiation is used, effectively linearising the function. This is done on the grounds that genetic changes are slow, so that over a short period the function will be essentially linear. Over a longer period, as genetic changes accumulate, it would be necessary to redefine the linear version of the objective to allow for the effect of the changes. Using discounting, this would imply that in order to define the objective, one would have to know what changes in means would be expected over future time periods, and these would only be known after a breeding program had been defined on the basis of the selection objective, and so on. But as returns accruing far in the future are substantially discounted, the errors arising from ignoring such a complication are likely to be small.

CONCLUSION

Only recently have animal breeders devoted a lot of attention to careful formal definition of breeding objectives. The general approach which should be taken is still subject to some disagreement, since the definition of an objective may depend on the perspective of the person making the definition. However, it does appear that if a long-term view is taken, the efficiency of production, measured as cost per unit return or its reciprocal, is the appropriate criterion of economic advance. For this it is essential that all costs
and returns be treated as variable, depending on the scale of the enterprise, and that any temporary distortions in the market be disregarded.

Even if all breeders agreed on how an objective should be defined, there would still be a multiplicity of objectives in the sheep and goat industries because of the variability of environments and markets. And even within an environment and market, many breeders will differ in their expectations of future developments, so that even further variation in objectives is to be expected. It is therefore important that large-scale performance recording schemes should allow for flexibility in the objectives pursued by breeders making use of the schemes.

REFERENCES


Consider a simple profit function

\[ P = n(aw - bf) \]  

where \( w \) is weight gain, \( f \) is feed consumed, \( n \) is number of animals, and \( a \) and \( b \) are prices. Let us take \( P \) as the breeding objective. Then the economic values for \( w \) and \( f \) are found to be \( na \) and \( -nb \) respectively. However, we could write \( e = f/w \), where \( e \) is feed conversion ratio, and then

\[ P = n(aw - be)w \]  

Then the economic values for \( w \) and \( e \) are \( n(a - be) \) and \(-nbw\) respectively.

The breeding objective is the same, but it has been expressed differently, and the economic value for \( w \) has changed from \( na \) to \( n(a - be) \). This is because economic values are partial derivatives, and are derived holding the values of other variables constant. Increasing weight gain while holding feed conversion ratio constant is less valuable than making the same change holding feed consumption constant. Thus one can talk of the economic value of any trait only when all other traits in the objective have been specified.