There is a range of production-marketing systems in practice and different current breeding stocks are used to maximise economic benefits. Several stocks may be used in one system, to benefit from heterosis, to complement each other and to fill specialised roles. In genetic improvement, the interests of the different sections of industry in an efficient market are not at variance (Moav, 1973) but are all met by reducing costs per unit of product value (Dickerson, 1970, Smith, James and Brascamp, 1986). The scope for genetic improvement in one or many stocks is considered, both for current sets of objectives and for uncertain future conditions. If the overall economic benefits are high relative to the cost of improving one stock, there will be considerable scope and increased benefits from selecting different stocks for different sets of objectives, to provide flexibility and insurance for the future. The dilemma is posed that improvement in the national interest has much scope for variety but is usually constrained, while the scope for independent breeders is restricted, yet they endeavour to breed and market a range of breeding stocks.

**INTRODUCTION**

**Need for a variety of breeding stocks**

There is a range in production and marketing systems, and competition among them in the economic production of pig meat. The situation is not static but is continually changing, and the conditions and needs for the future are not certain. There may thus be a need for a variety of breeding stocks to meet the range in production-marketing systems. Some of the range is shown in Table 1. Depending on costs, production may be intensive or extensive, on low or high density diets, at low or high feeding levels, at moderate or high health status, and stock performance may interact with the production system. The market payment system will also affect the production system, with a balance between output and quality, and competing products (e.g., poultry meat) will be relevant. The economic merit of a breeding stock thus depends on the production-marketing system on which it is assessed. Also maximum economic benefits, or minimum cost per unit of product value, may be obtained by crossing with other stocks to benefit from heterosis and complementarity. The selection objectives in a stock will thus depend on its role, (as discussed by Bennett and Tess, 1986), and the selection criteria on the feasibility and cost in measurement. There is also uncertainty about the efficacy of different selection systems in terms of selection criteria (e.g., Fowler, Bichard and Pease 1976) and in testing systems used (e.g., Webb 1983). Finally, there is uncertainty about conditions in the future and there may be merit in developing stocks selected for different sets of objectives to provide flexibility, and to give insurance for changed conditions in the future.
serve all sections of the production-marketing chain. However it has been shown by Smith, James and Brascamp (1986) that Moav's result was due to anomalies in the profit equation approach. They argued that changes which correct previous inefficiencies in the production system should not be counted (in effect putting fixed costs like variable costs on a per animal basis) and that extra profits which could be matched by rescaling the size of the production unit should not be counted. With these two conditions the economic weights derived from any aspect (scaled or fixed output value, inputs or profit; or per product unit, animal, producer, investor or consumer) are identical. They are also equivalent to those derived from the economic efficiency ratio (Dickerson, 1970) for the cost per unit of product value. These results depend on an efficient market, distributing costs and benefits equitably over the production-marketing chain, otherwise temporary sectional interests may exist. The results also have implications for selection for growth, size, appetite and output as economic traits in their right, rather than only through their effects on economic efficiency.

**SCOPE FOR SEVERAL SELECTION STOCKS**

In pig production there is usually a range of production-marketing systems and a series of breeding stocks to serve them. But consider first the simple case of one system, one stock and one set of breeding objectives.

One set of objectives. Let $C$ be the cost of selection in one stock in one year and $R$ be the undiscounted value of the returns in one year of one year of genetic improvement. Due to lag in dissemination, the returns are first recouped at year $t$ and continue to be recouped until year $n$. With $r$ the inflation-free discount rate, and the discount factor $d = (1/(1+r))$, the discounted benefits from one year of selection are

\[ R(d^t + d^{t+1} + \ldots + d^n) - C \]

\[ = R(d^t - d^{n+1})/(1 - d) - C \]

\[ = D - C. \]

The benefit/cost ratio is then

\[ (D - C)/C = D/C - 1. \]

Estimates of the return ($R$) to the cost ($C$) were made for the possible rate of genetic improvement of economic efficiency in the U.K. pig industry (Smith, 1985) with $R/C$ ranging from 200 to 500. With a discount rate of 0.05, a lag of 5 years and last returns at 10, 20 and 50 years, the discounting terms are 3.6, 8.6 and 14.6, respectively. The $D/C$ values thus range from 700 to 7,000, and show the very high benefit cost ratio possible on a national scale for genetic improvement in a single breeding stock. If several breeding stocks are required for the production system, then the benefit cost ratios fall proportionally. However, the objective is usually to maximise benefits and since costs are low relative to total returns, benefits are not much reduced by having several stocks as necessary parts of the production system, if there are gains from heterosis and complementarity or flexibility.

**Two sets of objectives.** How different do two sets of objectives have to be before it is worthwhile selecting two different stocks. If $r_H$ is the correlation between the sets of objectives, the benefits with one selected stock will be:

\[ B_1 = (1 + r_H)D/2 - C. \]
If two stocks are selected, one for each set of objectives, the benefits would be

\[ B_2 = D - 2C. \]

It would be worthwhile to have two selection stocks when \( B_2 \) exceeds \( B_1 \), and the proportional extra benefits are

\[ \frac{(B_2 - B_1)}{B_1}. \]

These are shown in Table 2. For high values of \( D/C \), modest (but worthwhile) gains in benefits are obtained if the sets of objectives are similar, with increasing gains as the correlation falls and they become dissimilar. If one set of objectives refers to a larger proportion of production than the other, then the gains are reduced proportionally. With zero or negative correlations among sets of objectives, the advantage of a second selection stock is obvious.

However the situation changes appreciably as \( D/C \) falls. This will be the case for private breeders and breeding firms, who benefit only from sale of breeding stock (rather than all commercial production), who are in competition with other breeders, have a short term outlook and a cash flow problem. Their discount rates (with uncertainty from many factors) may be higher (0.075 to 0.15). So, the returns (R) are less and the discount term smaller (2 - 4). \( D/C \) values from 2 to 50 have been used to represent these cases. With small \( D/C \) values, there are no benefits from having two lines, unless the correlation between sets of objectives is quite low (less than 0.5).

Several sets of objectives. With several sets of objectives, there would be different correlations among the various sets which would be difficult to model. A guide to the benefits if there are several sets to be accommodated may be obtained by assuming the same correlation between each set of objectives. With one stock selected the benefits are

\[ B_1 = \frac{(1+(n-1)r_H)D}{n} - C \]

and with \( n \) stocks selected

\[ B_2 = D - nC \]

with the proportional gain as before. Again, there are only substantial gains (Table 3) with high \( D/C \) values and low or moderate correlations among sets of objectives. With unequal use of the different selected stocks, the proportional gains will again be reduced.

**FUTURE UNCERTAINTY**

There is uncertainty about future market needs and production systems, and so about objectives in selection. Thus the breeding objectives and stocks selected for current conditions may be less appropriate than expected in future conditions. For example, the attention to pay to size and appetite versus efficiency, to meat quality and carcass composition, to early sexual maturity, mothering ability and longevity is uncertain. In the past there were many stocks to choose from, but with effective evaluation and selection schemes, the choice is reduced. There may thus be scope for developing alternative stocks selected for different sets of objectives to cover a wider range of breeding goals, and so reduce the uncertainty inherent in relying on currently successful stocks.

An attempt was made (Smith, 1985) to model the uncertainty by adding a term to the discount rate, so assuming that uncertainty increases with time. However if several stocks were selected for different sets of objectives, the uncertainty would be reduced, and several algebraic functions modelling the reduction were
considered. The results (Smith, 1985) showed that for large D/C values, large numbers of alternative stocks could be developed with useful gains in total benefits over time. But, as for current sets of objectives, when D/C values are low, the scope for having alternative lines is quite limited, and any extra benefits are low.

The problem remains of how best to choose sets of objectives for alternative stocks to cover a range of possible future needs. From the results in Tables 2 and 3, it would appear that the sets of alternative objectives should not be highly correlated with each other. So benefits may come from moderate to extremes in diversity, rather than minor variations of the current themes. Of course, the more diverse the set of objectives from the current set, the less likely it will be to come about, but it may be worthwhile to cover for that possibility. Since returns would be uncertain and long term, development of such stocks would have to be subsidised in the long term national interest.

GENERAL DISCUSSION

Current production marketing systems often depend on and exploit differences among current stocks, recouping benefits from heterosis, complementarity and flexibility (e.g., in use of terminal sire lines). The improvement system must then deal with all the component stocks. If the stocks have specialised roles, they will be selected for these roles, and become even more specialised and extreme, relative to other stocks. Thus the pattern of breeding and selection has been set by initial historical (and selection) differences between stocks, and the improvement may be locked into the initial system.

How different are the sets of objectives among stocks with different breeding roles. Consider the three main roles 1) general purpose (or rotational), 2) maternal and 3) terminal stocks. Correlations among these three sets of objectives for UK pig production are estimated as (1, 2) 0.95, (1, 3) 0.89 and (2, 3) 0.71. The high values are due to the part-whole correlations and to the high economic value of lean meat and food efficiency in all lines. These correspond to the values in correlated responses found by Smith, Dickerson, Tess and Bennett (1983) for economic efficiency of lean meat production for US pig production. However for production of live weight, rather than lean, the correlated responses in maternal and terminal lines were low (0.24 to 0.68). By contrast, the correlations among National Swine Improvement Federation (1985) recommended selection indices for the 3 types in the USA are all over 0.98 and seem quite anomalous. (A. Schinckel, personal communication).

The question here is whether it is worthwhile to create additional diversity in performance traits, to develop stocks for alternative current production marketing systems and create stocks of little value in current systems but which might be useful in the future if needs and conditions change. On a national (and global) scale the possible benefits are large relative to the costs, and the development of such stocks seems very worthwhile. But the development would have to be subsidised since these would be no returns in the short term. However, national programmes of pig improvement have usually been conservative, selecting general purpose stocks for current economic conditions with little specialisation on development of alternate types. Instead most farmer-breeders and breeds have been advised to use one set of breeding objectives in state supported national improvement schemes. This represents much duplication for effort among breeds and breeders which seems unnecessary. Such state support might be better spent in maximising rates of change (e.g., by intense selection and embryo transfer) in nucleus stocks each selected for a different set of objectives of
current or possible future value.

In contrast with the national interest, pig breeding firms usually have low D/C ratios, as discussed earlier, and will have much less scope for developing alternative lines. Yet they often maintain and select a series of stocks to better fit their customers' needs and the range of production marketing systems. There may be, of course, related sales in other services and commodities which would increase their returns. However, these are unlikely to materially change the balance of their returns and costs. The competitive nature and high risk aspects are reflected in low survival rates of commercial breeding companies, as shown over the past decades in the poultry industry, and may well apply to pig breeding groups in the future. The important question to resolve is how the consumer is best served by the genetic improvement system in the long term, rather than that it be dictated by short term events.

REFERENCES


National Swine Improvement Federation. 1985. Pork value seedstock improvement programmes. NSIF. Univ. of Minnesota. U.S.A.


Table 1  
Need for variety in breeding stocks due to the range of production and marketing conditions, both current and future.

Production systems

Intensive or extensive
Diet density, feeding level
Weight, age or composition end-point
Housing, health, behaviour, welfare
Costs
Genetic environment interactions

Market requirements

Payment system and differentials for
Composition
Conformation
Quality
Competing products

Breeding stocks

Economic merit depends on the production marketing system
Heterosis
Specialised stocks
Complementarity

Improvement system

Selection objectives depend on breed role
Selection criteria, accuracy, costs
Selection methods
Station or field test; individual, family or progeny test
Diet, feeding level, ages.

Uncertainty

Current conditions variable and dynamic
Future conditions uncertain
Table 2. Proportional gain (x 100) in benefits by selecting two stocks, rather than one stock, if there are two sets of breeding objectives with a correlation $r_H$ between them.

<table>
<thead>
<tr>
<th>BREEDING COMPANY</th>
<th>NATIONAL INTEREST</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cumulated discounted returns</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Correlation</td>
<td></td>
</tr>
<tr>
<td>0.95</td>
<td>1</td>
</tr>
<tr>
<td>0.90</td>
<td>3</td>
</tr>
<tr>
<td>0.80</td>
<td>9</td>
</tr>
<tr>
<td>0.50</td>
<td>9</td>
</tr>
<tr>
<td>0.20</td>
<td>50</td>
</tr>
<tr>
<td>0.00, -ve†</td>
<td>100</td>
</tr>
</tbody>
</table>

† For negative $r_H$, use unselected stock for second objective in $B_1$, then $B_2 = 2B_1$.

---

Table 3. Proportional gain (x 100) in benefits by selecting stocks for each set of breeding objectives, rather than one stock, with a correlation $r_H$ among sets of breeding objectives.

<table>
<thead>
<tr>
<th>BREEDING COMPANY</th>
<th>NATIONAL INTEREST</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cumulated discounted returns</td>
</tr>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Sets of objectives (n)</td>
<td>5</td>
</tr>
<tr>
<td>Correlation</td>
<td></td>
</tr>
<tr>
<td>0.95</td>
<td>10</td>
</tr>
<tr>
<td>0.90</td>
<td>15</td>
</tr>
<tr>
<td>0.80</td>
<td>15</td>
</tr>
<tr>
<td>0.50</td>
<td>55</td>
</tr>
<tr>
<td>0.20</td>
<td>165</td>
</tr>
<tr>
<td>0.00†</td>
<td>253</td>
</tr>
</tbody>
</table>

† Proportional gain = $(n - 1)$.