# Application of Mate Selection to Pig Breeding Programs

K. L. Bunter, T. Long and B. Tier

## Introduction

The selection policies in a breeding program may be considered as a two stage process: the selection of replacement breeding stock based on estimates of each individual's genetic merit, and the choice of which animals to mate together (the mating system). Selecting individuals of high genetic merit is typically considered independently of their potential mates and the mating system, although the method of genetic evaluation may influence the likelihood of selected individuals being related. Once the choice of replacement breeding stock has been made, the level of inbreeding associated with a breeding program is then determined by the mating system applied to selected individuals. This poses the question of whether animals selected using independent two stage selection decisions are best suited to the long-term improvement of the breeding herd, where long-term potential gains in genetic merit may be offset by elevated levels of inbreeding.

Best Linear Unbiased Prediction (BLUP) is the most accurate method of genetic evaluation currently available to animal breeders, with great potential for improving rates of genetic gain. BLUP increases the accuracy of genetic evaluation by making more efficient use of family information than other methods. As a result, it is likely that when a small group of animals are selected for breeding, compared with the population - as is done in the pig industry - they will be more closely related than if evaluation was done with a less accurate method. It is this feature which may lead to increased rates of inbreeding associated with BLUP over alternative genetic evaluation methods if these changes are not suitably accommodated in the mating program.

This is particularly evident for traits of low heritability, sex limited expression and single trait selection. However, the level of inbreeding associated with the use of BLUP depends on herd size, selection and mating decisions, with small, intensively selected, closed herds likely to be most affected over long time horizons. It is unlikely that current methods for controlling inbreeding in small herds will be as effective with the use of BLUP. Similarly, the extra response obtained with BLUP also depends on herd size.

Several researchers have shown elevated levels of inbreeding associated with BLUP for single trait selection (e.g. Belonsky and Kennedy, 1988: Sorensen, 1988) and in the multiple trait situation (Rohe *et al* 1990) for mating systems which do not account for degree of relationship when determining mating pairs (e.g. random mating). For producers of breeding stock concerns over rates of inbreeding, and its cumulative effects, are likely to slow the development of more effective pig breeding programs, despite the fact that BLUP facilitates better design. Inbreeding may result in loss of genetic variance, inbreeding depression, reduced selection intensity, and lower accuracy of genetic evaluation. Hence, inbreeding will act as an antagonist to selection, but is unavoidable in small populations where natural selection may also occur.

Breeding operations practise classical approaches to controlling inbreeding. These methods vary in effectiveness and ease of implementation, some of which include:

- maintenance of large numbers of families;
- reducing variance of family size;
- within family selection;
- reducing selection intensities;

- increasing generation interval (slowing turnover);
- avoidance and rotational mating systems;
- ignoring some family information (more recently); and
- bringing in outside breeding stock.

Unfortunately, all these approaches reduce the amount of genetic gain, working through a combination of reduced selection intensity or accuracy of selection, as well as maintaining less desirable families in terms of the traits of interest. For breeders introducing outside stock, there is the added risk that the genetic merit of introduced animals may be inferior to their own breeding stock, which may negate several years of sound selection policies.

From an industry perspective it is desirable that high rates of genetic gain are achieved by breeders, since they determine genetic progress for the entire industry. Even if nucleus herds/lines become inbred, only a very small proportion of pigs in the industry will display inbreeding depression, due to line crossing and the use of cross-breds in the commercial sector of the industry. The main concern about the effects of inbreeding to the industry is, therefore, through slowing of rates of genetic improvement made by breeders, and their viability, in the long term. Should breeders modify mating policies to control inbreeding at the expense of improved genetic gain, substantial reductions in performance would be experienced by the industry. Ideally producers need to make high levels of genetic gain while limiting inbreeding to acceptable levels over the time horizon of their breeding programs.

## Maximising genetic gain

Choice of method of genetic evaluation (e.g. BLUP vs. selection on individual performance) and selection policies (e.g. proportion selected and turnover rate) have well recognised effects on the efficiency of a breeding program. Less considered is the potential role that mating systems may have for improving rates of genetic gain.

Positive assortative mating (mating best to best) is one mating system which has been shown to enable significant improvements in genetic gain when accuracy of selection is high. Unfortunately, facilitating matings between individuals of similar genetic merit leads to increased matings of related individuals and higher levels of inbreeding. It appears that this approach will not facilitate high levels of genetic gain if inbreeding is to be managed at acceptable levels.

An alternative to assortative mating is to use an approach known as mate selection. In this context, mate selection refers to the selection of mating pairs or groups subject to the expected genetic merit and inbreeding coefficients of potential progeny. To a large part, choice of mating pairs or groups is determined by the sows currently in the breeding herd, since they must be bred post-weaning in discrete mating groups. Using mate selection strategies, mating partners may be *specifically* chosen for boars with the availability of suitable sows for a boar, and his own genetic merit, determining his *total* merit relative to the current breeding herd. The use of mate selection may, therefore, be considered as an extension in the second stage in the selection process, where the total merit of boars selected is determined by both their genetic merit and their relatedness to sows already in the breeding herd.

## An example of mate selection

Consider a simple example of three boars available to be mated to five sows, where each boar is capable of servicing three sows for a week's matings. The estimated breeding values (EBV) for each boar and sow is bolded in brackets, and it is easy to derive the array of expected progeny breeding values as the average of both potential parents EBVs (Table 1).

The coefficients of inbreeding (F) for potential progeny of these matings, expressed as a percentage, are shown in Table 2.

Table 1. Expected average breeding value of potential progeny for all possible matings

| Sow no: | | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|
| EBV: | | **+15** | **+20** | **+30** | **+32** | **+40** |
| Boar no. | EBV | | | | | |
| 1 | (+40) | 27.5 | 30.0 | 35.0 | 36.0 | 40.0 |
| 2 | (+40) | 27.5 | 30.0 | 35.0 | 36.0 | 40.0 |
| 3 | (+45) | 30.0 | 32.5 | 37.5 | 38.5 | 42.5 |

Table 2. Percentage inbreeding of potential progeny for all possible matings

| Sow no: | | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|
| EBV: | | **+15** | **+20** | **+30** | **+32** | **+40** |
| Boar no. | EBV | | | | | |
| 1 | (+40) | 0.0 | 6.25 | 0.0 | 0.0 | 50.0 |
| 2 | (+40) | 0.0 | 0.0 | 12.5 | 0.0 | 0.0 |
| 3 | (+45) | 12.5 | 0.0 | 0.0 | 12.5 | 12.5 |

By ranking boars and sows simply on EBV, boar 3 would mate sows 6, 7 and 8, while either boar 1 or 2 could mate sows 4 and 5. Regardless, the total genetic merit of the progeny (GMP) would be 176 (sum of the progeny's expected breeding values), with average level of inbreeding (AF) at 6.25% for additional mating pairs (1,4: 1,5) or 5.0% (2,4: 2,5 or 1,4: 2,5). For this example GMP=176 is the maximum level achievable given the constraints. In the majority of practical situations, ranking for mating in this way will not result in achieving maximum GMP either in the short or long term, due to lost opportunities for specific matings, and provides no integration for managing inbreeding.

Using mate selection we evaluate appropriate mating pairs, using both information on EBVs and F to define a value (R) for all possible matings. R defines the total merit of each mating pair as a function of genetic merit of the parents and their relatedness. The long-term objective is then to improve overall response by maximising GMP and minimising the level of inbreeding, where R is defined as:

$$R_{ij} = EBV_{ij} - gF_{ij}$$

and

$R_{ij}$ = aggregate return for progeny from parents i and j

$EBV_{ij}$ = average EBV of parents i and j

g = penalty applied against level of inbreeding

The objective for this example must be achieved within the constraints that each boar is allowed up to three matings, and each sow must only be bred to one boar. This process is simplified by using appropriate linear programming techniques. Table 3 shows recommended mating pairs for this example, determined by the emphasis placed on the importance of F, and the expected genetic merit and average percentage inbreeding of progeny produced from these matings.

From the example in Table 3, when the penalty (g) against inbreeding is very low (e.g. 0.1), application of mate selection results in the better ranking solution option mentioned above, selecting boar 2 in preference to boar 1 as he is less related to sow 5. Increasing g to 1.0 results in the same high level of genetic merit while reducing average level of inbreeding. When g equals 10.0 inbreeding may be avoided with a slight reduction in total GMP. If considering only F to determine mating pairs a substantial reduction in genetic gain results. There seems little value in pursuing an option for controlling inbreeding which greatly reduces genetic gain (e.g. F alone) when the same level of inbreeding may be attained with only small reductions in genetic gain (e.g. g=10.0). Alternatively, breeders may find an intermediate approach which maximises genetic gain more appropriate, and accept a low level of inbreeding as its cost.

Table 3. Expected total genetic merit (GMP) and average percentage inbreeding (AF) of progeny produced from matings determined by mate selection, with different penalties (g) placed on level of inbreeding in the progeny generation

| Penalty (g) | Mating pairs | GMP | AF |
|---|---|---|---|
| 0.1 | 2,4:2,5:3,6:3,7:3,8 | 176 | 50% |
| 1.0 | 2,7:2,8:3,4:3,5:3,6 | 176 | 2.5% |
| 10.0 | 2,4:2,7:2,8:3,5:3,6 | 173.5 | 0.0% |
| F alone* | 1,4:1,6:1,7:2,5:2,8 | 168.5 | 0.0% |

* Considering only F to determine mating pairs.

An important feature to note is the re-ranking of boars for total merit which is determined by their genetic merit, their relatedness to the available sows, and the emphasis placed on information relating to F. For evaluating boars on EBV alone (e.g. first stage of selection), boar 3 ranks highest and boars 1 and 2 rank equivalently. However, using a measure of relatedness to the female breeding herd (F of progeny) in addition to individual genetic merit, would establish boar 2 as superior to boar 1 due to better coordination of his use with boar 3. Should level of inbreeding be the only criterion for evaluation, boars 1 and 2 rank higher than boar 3. In the short term (e.g. determining matings for one week) this approach may be considered simply as an optimum method of allocating mates. However, when boar use trends continue over time, mate selection will result in greater use of boars more suited to the structure of their current breeding herd and the exclusion of unsuitable individuals.

Even with a very simple example, considered for only one set of constraints for one week's matings, the use of mate selection may help reduce levels of inbreeding while maintaining high levels of response. With further constraints, such as number of services capable by boars of different ages, letting the computer determine optimum matings for the breeder makes sense, particularly when a large number of matings must be determined each week.

The more relevant question, however, is whether mate selection has any influence in the long term. Applying mate selection to a simulated breeding herd, undergoing continuous selection and mating, has shown it to be effective in the long term for maintaining high levels of genetic response while reducing levels of inbreeding below that achieved under random mating.

## Conclusions

As currently evaluated, mate selection is a powerful tool which has the potential to manage inbreeding while retaining the advantages of using BLUP. This is possible due to the high accuracy of BLUP, which ensures the relative emphasis between EBV and relatedness with available mates correctly modifies the contributions of boars to future generations. For practical application, the emphasis placed on information relating to inbreeding will need to be established from both a genetic and economic viewpoint.

Mate selection approaches would not be appropriate when accuracy of selection is low due to interactions between selection and mating systems. As such its application is appropriate only for mass selection programs involving moderately to highly heritable traits, or index selection where the accuracy of the index is moderate to high. This emphasises the need for breeders to consider the development of selection and mating systems concurrently. Further investigation of this approach for practical implementation is desirable.

## References

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