SWINE BREEDING GOALS, SHORT- AND LONG-TERM CONSIDERATIONS

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SUMMARY

The aim of this paper was to examine how breeding programmes can maximally contribute to an efficient and acceptable pork industry. Attention is given to short-term as well as to long-term implications. Topics addressed are: (1) the perspective to be taken; (2) production environment; (3) traits to be included in the breeding goal; and (4) their impact.

It was concluded that due to competition, many pig breeding organizations (even national schemes) are forced to give emphasis to short-term effects. This, however, may be suboptimal for the long-term perspective of the industry.

The long-term breeding goal for growing performance should not only include growth rate and carcass quality, but also feed intake capacity, digestibility and (activity-related) maintenance requirements. Reproduction performance should include longevity and oestrus traits in addition to litter size. Apart from quality of the product, also attention should be given to the quality of production, since this will improve public acceptance of the pig industry.

Level-dependency of economic values gives some theoretical problems, but for most of these problems appropriate techniques are available.

INTRODUCTION

Breeding goals in swine improvement schemes keep getting attention, in practice as well as in research. A plausible reason is that a proper definition of the breeding goal is crucial, since it determines the future direction of the population and the testing systems to be applied. Thus, it should always be one of the first steps in the design of a breeding programme (Harris et al, 1984). Furthermore, regular redefinitions of the breeding goal appear to be necessary due to changing production and market environments (N-output constraints, increased emphasis on quality, etc.). The scientific interest in breeding goals can merely be explained from the complexities with deriving optimal weights for the breeding goal traits.

Suboptimal breeding goals lead to reduced efficiency of the genetic improvement scheme. Usually the efficiency losses are small, as shown by Vandepitte and Hazel (1977). However, with antagonistic traits in the breeding goal, appropriate weights of the traits are of primary importance. The relative weights of meat quality and carcass leanness in populations with the halothane gene, may serve as an example.

With selection index theory (Hazel, 1943), the aggregate genotype (H) is defined as a (linear) combination of economic weights of traits and their breeding value. For practical reasons, H is often limited to heritable traits of high (long-term) economic importance. The breeding goal of an improvement scheme is usually broader than the formalized aggregate genotype (Gibson, 1992). As a result, a quantitative description of the entire breeding goal is generally lacking (Brascamp and De Vries, 1992). Breeding goal traits not included in the aggregate genotype (e.g. physical soundness, meat quality, aggressiveness) might be improved in secondary selection steps (independent culling) or weighed subjectively in multitrait selection decisions.

Almost all optimization studies in the past focused on breeding goals that were optimal in the short-term. Additional profit or cost reduction (per herd or per animal) at actual production and market conditions was used as the optimization criterion (e.g. Tess et al., 1983; De Vries, 1989a; Stewart et al., 1990). There is growing belief, however, that long-term consequences (a.o. environmental pollution, genetic diversity) should be included as well. In this way, breeding can contribute to a more sustainable pig production (Kanis, 1993). Another aspect to consider for long-term improvement is that breeding goal traits may have economic values that are not fixed in time (level-dependency), which implies that their long-term values may differ from their short-term values.

The aim of this paper is to examine how breeding programmes can maximally contribute to an efficient and acceptable pork industry. Attention will be given to short-term as well as to long-term implications. Relevant research will be reviewed based on four topics: (1) the perspective to be taken; (2) production environment; (3) traits to be included in the breeding goal; and (4) their impact.

PERSPECTIVES

Overall benefit

When financed from taxes, a national breeding programme should take the entire production chain into account, i.e. all parts of the chain should be able to benefit from the programme. As soon as it was stressed that pig improvement should not only include growth performance but also prolificacy (e.g. Lush, 1940; Dickerson and Hazel, 1944), the question of "which perspective to be taken" arose. This topic was especially relevant for industries with specialized sow and fattening herds.

At first sight, relative economic weights of growth and litter size seem to depend upon the perspective taken, since a weaner producer will usually have a constrained number of sows, whereas the grower will have a constrained fattening capacity (Brascamp et al., 1985; Brascamp and De Vries, 1992). Thus, in the weaner producer's viewpoint the economic value of an extra piglet born also encompasses the profit (or loss) per weaner, whereas for the grower its value is limited to cost reduction. People were probably elated when Brascamp et al. (1985) forwarded their zero-profit concept stating that returns equal total production costs, since this concept removed all differences in relative economic values between perspectives taken. Even for the economy as a whole (which might face constrained output) it lead to the same relative economic values as the values at sow or grower levels. The same convenient results were derived from the approach of Smith et al. (1986), who considered that only returns from selection should be taken into account which could not as well be achieved by rescaling the operation. Furthermore, they showed that economic weights based on this rescaling approach were equal to the relative weights derived from efficiency equations.

The convenient approaches of Brascamp et al. (1985) and Smith et al. (1986), however, did not stay without debate, as was recently reviewed by Brascamp and De Vries (1992). E.g., Amer and Fox (1992) stated that economic weights should be defined as the change in farm profit under optimized output levels of the farm. Brascamp and De Vries (1992), however, again exploiting the nice features of the zero-profit concept, could show that zero-profit implies that economic values are not affected by optimized output levels. Unfortunately, the zero-profit concept has not been completely accepted. E.g., Groen (1989) states that the price mechanism that should lead to zero-profit does not work perfectly. Their idea is supported by economists who assume (based on the "agricultural treadmill theory") negative profits for the swine industry in the long-term, (Backus, pers. comm., 1994), or who report significant profit differences between exporting pig industries (with low added value) and special product industries in selfsupporting regions (Vard, 1993).

Breeder's benefit

A breeding goal should be optimal in the perspective of the decision-maker (Elsen et al., 1986). For a nationally operated breeding scheme, this may be devoted to the overall benefit of the industry and (finally) to the benefit of the consumers. In most countries, however, this is not anymore realistic, because of competing breeding companies on the same market, or due to opened borders between countries (e.g. within the EU). On such a market (unless full vertical integration is established), breeders within a national scheme are in direct competition with other (groups of) breeders. Thus, a national scheme will sooner or later operate in the same way as a private breeding company.

In a competitive situation, investments in the breeding programme have to be recouped from their impact on market share (De Vries, 1989b). As a result, competition has a number of consequences for the breeding goal:

(1) At the level of potential clients/users, there is no full compensation between a weakness in one trait and the strength in another trait (Schultz, 1986). This leads to priorities for traits at a relatively low level (catch-up breeding). De Vries (1989b) gives an objective method based on a marketing model, to take competitive position optimally into account.

(2) Short-term effects are more important than long-term effects. This is due to the risk for a competitive business of not staying in the market. Therefore, risk needs to be included when discounting projected returns to year of investment (Smith, 1978).

(3) It may take a long time before the merits of genetic improvement are passed on to the decision-maker (the breeder), especially when the trait is expressed in the last parts of the production chain (slaughter house, retailer, etc.). A national programme without competition (with overall benefit as its perspective), only has to consider the genetic time-lag, i.e. the time between genetic improvement and expression of a trait. A competitive breeder, however, also faces an economic time-lag. This is due to the fact that it takes some time before potential users get aware of changed qualities of a product, such that it affects their buying behaviour. Note that methods for discounting genetic time-lags are available (GFLOW). Similar methods should probably be used for economic time-lags.

The conclusion from this paragraph is that many pig breeding organizations are forced to give emphasis to short-term effects, which may be conflicting with long-term overall benefit.

PRODUCTION ENVIRONMENTS

Breeding goals should be such that they maximize the profit of the breeding organization. Nevertheless, they should be tuned at the level of the group of potential users of the breeding stock. A problem is that there may be different users with different production environments for their herds. Within a country, such variation is merely limited to technical differences (feeding system, husbandry conditions, etc.). Between countries, one also faces economic differences together with contrasts in legislations, public acceptance and special product requirements (e.g. carcass weight).

There has been quite some worrying about interactions between genotype and production environment, since such interactions may lead to dissimilar ranking of aggregate genotypes (H) in different environments (H x E). In this context two topics are addressed: (1) environmental effects on expression of breeding goal traits (g x e); and environment dependent economic values of traits (v x e). Both lead to H x E, and although often not realized, theoretically they can be treated as similar problems. The similarity can be shown when describing a trait, just like H, as the weighted sum of its composite traits ($g=w_1a_1+w_2a_2+..+w_na_n$). A simple example is growth rate when considering (conform nutritional modelling) feed intake capacity as one of its driving variables (a_i). It will be clear then that the contribution (w_i) of this driving variable heavily depends on the production environment (ad lib vs. restricted feeding), thus causing v x e, which at the level of growth rate is expressed as g x e.

The use of a variety of lines with different breeding goals may be seen as a strategy to accommodate for H x E. Ollivier et al. (1990) demonstrated this with an example of two specific vs. one general selection line for two distinct economic environments. Exploitation of multiple lines increases costs of the breeding programme or decreases selection intensity. Nevertheless, different breeding goals and selection programmes for different economic environments are probably justified (Brascamp and De Vries, 1992). Note that having a variety of lines also has a direct advantage, because it enables to exploit breed differences. In this way, the competitive position on several markets can be improved quickly by selling combinations of lines specific for each market.

Within a country, the economic environment is rather similar for all herds. Thus, a national breeding organization only has to consider technical differences (e.g. feeding system) that might cause g x e. Brascamp and De Vries (1992) stated that such differences between herds (within one market) generally do not justify multiple lines with different breeding goals, because groups of similar environments are too small. Thus, solutions should come then mainly from adapted management.

The conclusion from above discussions may be that H x E and g x e are of concern only for breeding organizations that work on different markets.

RELEVANT TRAITS

Efficiency of lean deposition

Definition of a breeding goal starts with formulating the relevant traits. The traits chosen by most pig breeders usually align the primary aim of the pig industry, namely the efficient conversion of feed into edible lean.

De Vries and Kanis (1994) describe the contribution of breeding schemes in the improvement of efficiency of lean deposition. They list realized phenotypic and genetic trends in commercial and experimental populations in several countries, and roughly estimate a genetic improvement of 1% per annum for feed efficiency. Most of this improvement appears to be achieved from increased growth rate (GR) and lower backfat thickness (BF). In biological terms, these trends can be described as reduced rate of lipid deposition (Ld) and increased protein deposition rate (Pd).

According to many authors, optimal levels of BF will soon be reached, especially in countries without castration and with low carcass weights. Therefore, the contribution of reduced Ld to feed efficiency improvement is expected to diminish. However, some other routes to improve feed efficiency can be exploited, which are shown in Table 1.

Table 1. Routes to improve efficiency of lean deposition by feeding system (at commercial level) and level of feed intake capacity (FIC) relative to optimum intake (FI_o) (De Vries and Kanis, 1992; Kanis and De Vries (1992).

	Level of FIC		
Feeding system	$FIC > FI_o$	$FIC < FI_o$	FIC not relevant
Ad libitum	↓ FIC / ↓ Ld ↑ Pdmax	↑ FIC ↓ R	↓ RFI
Restricted	↑ Pdmax	↑ FIC ↓ R	↓ RFI

Pdmax: maximum protein deposition rate (Pd); Ld: lipid deposition rate; R: minimum Ld/Pd; RFI: residual feed intake.

The linear/plateau model for protein deposition (Pd) and feed intake (FI) (Whittemore, 1983), results in two different situations: (1) feed intake capacity is higher than optimal ($FIC > FI_o$) and (2) FIC is lower that optimal ($FIC < FI_o$). In the first situation, selection for lower FIC seems relevant, provided that the commercial fattening pigs are fed ad libitum (Table 1). According to the linear/plateau model, this will reduce Ld while Pd will stay at its maximum (Pdmax). It is questionable, however, whether reduced FIC indeed has an economic value, since feed intake can also be controlled or adapted by management (restricted instead of ad lib feeding), although this may give some higher costs. Such reasoning follows from Smith et al. (1986), who stated that trait changes that correct for previous inefficiencies of a herd should not be included when deriving economic values.

In a situation with $FIC < FI_o$ (Table 1), increased FIC is required to increase GR, both under ad lib and restricted conditions. Other routes for improved efficiency are a decreased ratio (R) for minimum Ld/Pd (when $FIC < FI_o$) or an increased maximum protein deposition (when $FIC > FI_o$). A remaining possibility, not dependent on FIC level or the feeding system, is the reduction of nutritional requirements without affecting GR or BF. This is referred to as residual feed intake (RFI), since it reflects the residual variation in FI (of an ad lib fed population) after correcting for GR and BF differences.

Including RFI instead of FI in the breeding goal of commercial lines makes no sense (Kennedy et al., 1993), but calculation of its genetic parameters or use of this trait in experimental lines (e.g. Luiting, 1990) can be worthwhile. A number of studies have shown that RFI has a rather high genetic variance within breeds ($h^2 = 0.3$-0.4) (a.o. Foster et al., 1983), whereas also differences between breeds have been found. Interpretation of genetic variation in RFI is still difficult. Some studies have demonstrated variation between breeds in traits like feed digestibility (Elbers et al., 1989), activity levels (Henken et al., 1991) as well as in eating pattern (De Haer and De Vries, 1993b). De Haer et al. (1992) estimated phenotypic correlations of eating pattern traits with RFI, and found that 47% of the variation in RFI could be explained by daily eating time and frequency. Assuming that eating activity is a proper reflection of overall activity, their results indicate that (overall) activity-related maintenance is an important component of RFI variation. Research with larger data sets is needed to quantify within-breed genetic variance of RFI and its covariances with underlying traits (De Vries and Kanis, 1994).

Efficiency of reproduction

Weaner costs can be reduced from increased litter size and sow longevity in dam lines. Furthermore, efficiency improvement can be achieved from a lower age at first oestrus and shorter weaning-oestrus interval. Possibilities for improving litter size born (LSB) are well-documented (e.g. Johnson, 1992; Haley and Lee, 1992). Similar to growth modelling, LSB can be seen as the result of interacting component traits like ovulation rate, uterine capacity and embryonic survival.

Limited knowledge is available on the genetic variance of sow longevity. Also because of its late expression, this trait is usually not included in the aggregate genotype for index selection. Indirect responses is expected to come from independent culling at young age on traits describing leg and udder quality (Van Steenbergen, 1990).

The attention paid to oestrus traits is growing. In a selection experiment on interval weaning-oestrus (IWOE) with 1st parity sows (Ten Napel et al., 1994), this trait appeared to have a high genetic variance. Selection was found to be successful in reducing the proportion of animals with a delayed onset of oestrus after the first litter (Ten Napel and De Vries, 1994). The selection response, however, was less expressed in multiparous sows (De Vries et al., 1992a). Therefore, it is speculated that delayed oestrus might be partly related to body composition.

Product quality

Carcass quality is included in most pig breeding schemes. Usually, the attention to this trait is limited to subcutaneous fat content. Reaching low levels of this fat depot, other (visible) fat depots will become relevant (abdominal and intermuscular fat). Measurement of these depots on live animals is troublesome, but indirect responses are likely to be achieved from selection on feed efficiency.

In addition to lean/fat ratio, also attention can be given to lean/bone ratio in the carcass. This ratio can then be described in classification terms as used in slaughterhouses (conformation, carcass type, etc.). The differences in classification systems between countries show that the relative value of this attribute is extremely market-dependent.

Lean meat quality involves two groups of traits: (1) pH related traits (waterbinding, colour, etc.); and (2) intramuscular fat content (IMF). The first group has moderate h^2's and seems rather unrelated to growth rate and backfat thickness in halothane negative populations (De Vries et al., 1992b; 1994a). IMF has a high h^2 and a strong relationship with backfat thickness (Schwörer et al., 1990; Hovenier et al., 1992). Although the costs can be high and returns are riskful, some Dutch breeding organizations have now included these quality traits in their breeding goal (De Vries et al., 1993).

Despite its decreasing volume, the attributes of fat tissue also need to be considered, because consumer perception appears to be affected by a.o. saturatedness of fat (Cameron, 1990). On the other hand, some authors claim that fat quality problems can be avoided by adequate composition of diet fat (Metz, 1985) or increased feed intake (Whittemore, 1984).

Production quality / Public acceptance

The importance of a trait is usually derived from its direct economic impact. When a breeding organization aims at long-term benefits of the whole industry, the effects on public image should be taken into account, since public acceptance is one of the main conditions for a sustainable pork production (Kanis, 1993). This requires special attention to the quality of production. Production methods can positively be influenced when breeding organizations give more attention to traits like disease resistance, sow longevity and behaviour (aggressiveness, cannibalism). Also oestrus traits should get more attention, since inducing oestrus routinely by hormones is undesirable with respect to public image (De Vries et al., 1992b).

DERIVATION OF ECONOMIC WEIGHTS

When defining the aggregate genotype (Hazel, 1943), the economic weight represents the value of the change in the trait while keeping the other traits in the aggregate genotype constant. This means that a trait correlated to other relevant traits does not have one single value. E.g., when comparing breeding goals between national schemes, the economic weight of growth rate depends on whether feed conversion or daily feed intake has been included in the breeding goal.

The values of most traits can be derived using profit or cost equations that are based on easy accessible economic and technical parameters. For some groups of traits, however, special problems arise:

(1) Categorical traits (e.g. carcass grading) or all-or-none traits (disease). These types of traits were discussed by a.o. Danell (1980). Assuming an underlying normal distribution, use can be made of a threshold model (Danell and Rönningen, 1981) that gives estimates for the relative shifts in class distributions from the truncation point heights. E.g., De Vries (1989a) used this method for deriving the value of carcass type.

(2) A number of traits have level-dependent economic values (e.g. meat colour). Furthermore, the value of a trait may depend on the levels of other traits (e.g. appetite, as illustrated in Table 1). In such situations, it is clear that performance levels at the commercial level should be used. Also the variation between herds and animals at this level should be taken into account. E.g., most populations will be a mix of animals with $FIC>FI_0$ and animals with $FIC<FI_0$ (Table 1).

(3) For some traits no objective economic evaluation is available. Examples are exterior traits and meat quality. A nice approach to overcome this problem was recently applied by Hovenier et al. (1993). They (subjectively) defined optimal ranges for the levels of meat quality traits, and then derived economic values of trait changes from their effects on the fractions of carcasses categorized as optimal. Important assumptions for their approach are that variances of traits are not affected by selection, and that effects of individual traits on buyers' attitude are independent. The latter implies full compensation between a weakness in one trait and the strength in another. However, similar to the effects on saleability of breeding stock, as discussed when dealing with competitive effects, this assumption might not hold. Therefore the approach of Hovenier et al. (1993) should probably be combined with a marketing model, as used by De Vries (1989b). This is expected to result in more emphasis on "weak" traits.

DISCUSSION

The breeding goal can include different combinations of traits. For fattening performance, it may include the "observed" traits like GR, BF and FIC. However, to accommodate for the linear/plateau relationships of protein deposition with FI, it may be better to include "biological" traits like Pdmax, R and FIC (Table 1), although the genetic parameters of these component traits are not known. A further improvement would be to account for changes in FIC and energy requirements during the growth period. The simple model of De Vries and Kanis (1992), who simulated the average fattening day, considered FIC as one of the driving variables throughout the growing period. It is clear, however, that appetite is only partly determined by mechanical constraints. Based on daily data from electronic feeders and automatic weighers, the growing period of selection candidates can probably be split up in three successive stages: (1) FIC determined by mechanical constraints (FIC_{MCH}) with $FIC<FI_0$; (2) FIC_{MCH} with $FIC>FI_0$; and (3) FIC determined by metabolic constraints (FIC_{MT}) with $FIC>FI_0$. The metabolic constraint should be regarded as a negative feedback mechanism to defend body composition and weight (Steffens et al., 1990). Therefore, BF can be seen as the indicator trait for FIC_{MT}. Data on FIC in the first two parts of the growing period might be used to estimate "daily appetite gain". Adding the latter trait to the breeding goal is probably valuable in the long-term, since a low level would hamper further improvement of lean growth rate.

Increased appetite may have some more benefits, especially in the context of sustainable production. As mentioned earlier, it may have a positive effect on sow fertility (onset of oestrus), thus contributing to a more "natural" production. Furthermore, intake capacity (FIC_{MCH}) may be positively associated with feed digestibility. This would be very relevant for reducing environmental pollution (per fattening herd) or it may enable the use of lower quality feedstuff.

Similar to fattening performance, "observed" litter size may also be described by underlying "biological" traits in the breeding goal. However, as long as these traits (ovulation rate, etc.) are not measured, this will not have any benefit. New reproduction technology, however, may change this situation. Beeren et al. (1994) studied the genetic and economic effects of embryo transplantation combined with cloning in pigs. When such technology is exploited at commercial level, the breeding goal for the recipient lines (fostering embryo's from specialized fattening lines), should not include litter size, but uterine capacity.

Breeding goals usually aim at the genetic improvement of additive effects. However, recent literature show significant non-direct genetic or non-additive effects. For growth rate and backfat, maternal effects (Bryner et al., 1992) and parental gametic imprinted effects (De Vries et al., 1994b) have been found. These genetic effects are expressed only through one of the two parents of the commercial fattening pig, which should be reflected in the breeding goal for specialized sire and dam lines. The same holds for specialized grandparental lines that produce F1-sows, i.e. heritable maternal effects for litter size should be taken into account only for selection of the grandmaternal line (Roehe and Kennedy, 1993).

In the present review, a number of traits were discussed with level-dependent economic values (e.g. feed intake capacity, meat quality). Marginal economic values of these traits only optimize the short-term breeding goal, and can be highly inefficient for the long-term. In such a situation, optimization across multiple generations is needed. Recently, techniques for this purpose have been developed (Pasternak and Weller, 1992).

CONCLUSIONS

- The necessity of considering long-term implications for the definition of the breeding goal is widely perceived. Many pig breeding organizations (even national schemes), however, are forced to take competition effects into account, which implies emphasis on short-term effects.
- Opened borders and special markets will require different breeding goals and a variety of selection lines.
- The breeding goal for growing performance should not only include growth rate and carcass quality, but also feed intake capacity, digestibility and (activity-related) maintenance requirements. Reproduction performance should include longevity and oestrus traits in addition to litter size.
- For the long-term benefit of the industry, public acceptance should be taken into account. This implies that not only attention should be given to quality of the product, but also to quality of production (e.g. disease resistance).
- For a number of breeding goal traits, some theoretical problems arise for defining their economic weight. However, for most of these problems appropriate techniques are available.

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