New phenotypes for new breeding goals in pigs

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Introduction

An essential step in any genetic improvement program is the definition of the overall breeding objective or breeding goal. This includes traits of interest, relative significance of each trait and the direction of improvement. The traits included in the breeding goal depend upon the expected market requirements of the end product. In pig breeding, this means consumer expectations when the pork from genetically improved breeding stock will be sold. It can take several years depending upon the generation interval and genetic lag. Therefore a good prediction of the future trends is required. Further, like any successful enterprise, the breeding goals should also be specific, measurable, attainable, realistic and timely (SMART). The specific traits included in the breeding goals should also be chosen carefully as the amount of genetic progress for each trait is inversely proportional to the number of traits. Further, technology should be available to record the associated trait phenotypes in a cost effective manner. In spite of these challenges, pig breeders have successfully selected and adapted their breeding stock to changing market requirements over the past centuries and decades, and should be able to do so even if the requirements are changing more rapidly and the times are more challenging.
In this paper, the trends and factors that influence pig breeding goals and the desired phenotypes are presented and discussed.

Pig breeding during the past century

During the early part of last century, prizes were given to elite breeding stock based on the breed characteristics and physical appearance. Hence, the breeding goals and phenotypes focused more on exterior traits, and the emphasis was on recording these phenotypes and maintenance of pedigree records and herd books. Later, during the past 60 years crossbreeding and specialized sire and dam lines were introduced. Moreover, the increasing demand for leaner pork, resulted in breeding goals that focused more on reduction in backfat and improvement in growth rate or days to market to provide the required quality at lowest price. During the last 100 years there was a remarkable genetic progress in reducing backfat (-75%) for carcass quality and improving growth rate (+100%) for production efficiency, while very small or negligible gains were made in reproduction traits during the past century (Merks, 2000). A majority of these changes were as a result of improvements in performance recording and genetic evaluation methods. Since the 1990's genetic progress has also been made in reproduction traits especially litter size at birth. Further developments have taken place to include more phenotypes such as easy cycling, number of teats, meat colour, water binding capacity and marbling. The question then is where will these lead to? Will these trends continue almost linearly leading to an average daily gain of about 1.5 kg/day, 20 piglets born per litter and backfat as low as 8 mm by 2050 or will the trends be slower? The answers certainly depend upon the developments in the pork chain, breeding goals, technology available and realised genetic progress.

Developments in the pork chain

The pork chain includes all players involved in pork production, from genetics suppliers and pig producers to the slaughter houses and retail outlets that bring the final products to the pork consumers. Until recently (20th century), the pig producers strived for lower cost of production, the slaughter houses demanded more uniformity, the retail outlets need more efficient processing while the consumers value reliable quality. However, in the 21st century the chain is becoming more complex than that (Figure 1). Nowadays, the producers need to maximize value over costs along among others: (1) better lean tissue feed conversion to minimise cost per kilogram of carcass and (2) maintain *optimum* levels of backfat and loin depth for carcass quality and to maximise payment from the slaughter houses. The slaughter houses and retail outlets need more uniformity in the carcass cuts, more at the same time differentiation in products as well as no risk of food borne diseases or residues. The pork consumers and citizens in general expect no zoonosis, a low carbon foot print, proper animal welfare and pig farms possibly far away from cities and villages. This all can be summarized as sustainable pork production.

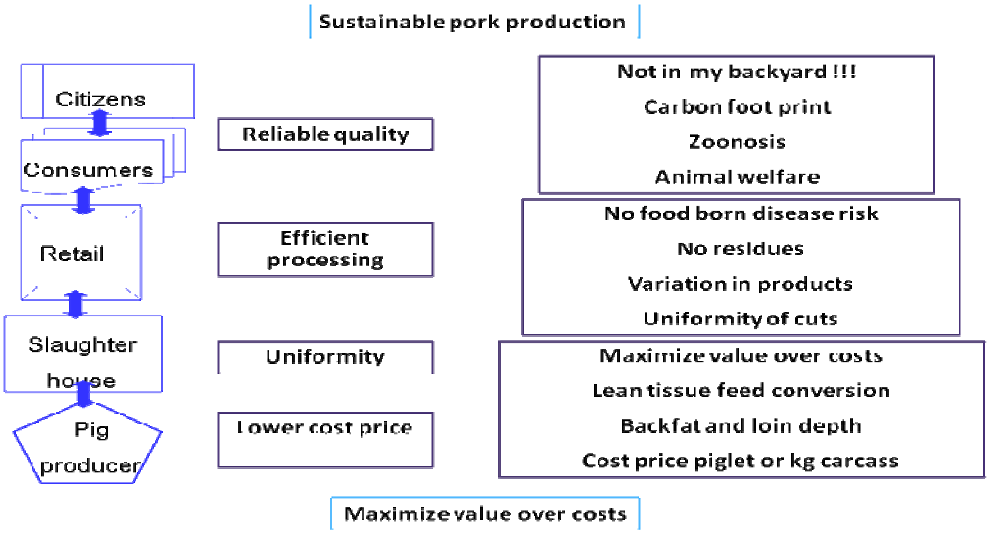

Figure 1: Pork chain from 20th to 21st century

The next decades pig breeding organisations need rapid genetic progress that will maximize value over costs but also improve health and welfare of the pigs and produce pig carcasses with added value for the pork chain. The progress needs to be balanced: sustainable pork production.

New Phenotypes

New phenotypes are necessary to target and attain new breeding goals according to the requirement of pork value chain partners and the expectations of consumers and citizens. Results of interactions among farmers, citizens, governments and food industry have resulted in the need for new phenotypes. We foresee 4 main pillars: vitality, uniformity, robustness and societal trends while keeping up the production efficiency.

(a) Vitality from birth to slaughter.
The intent is to have an undisturbed pig production from birth to slaughter house. During nursery and finishing phases this should yield pigs which are vital without human interference. This should also lead to reduction in the number of sows culled after first parity and lower mortality as well as lower disease problems in older sows. Improvement in vitality requires reduction in losses during the different phases of development from ovulation, embryonic development, birth, weaning and finishing to slaughter. Genetic trends over the past ten years by TOPIGS have already shown the possibilities of increasing litter size at birth and reducing mortality of piglets at the same time (Figure 2).

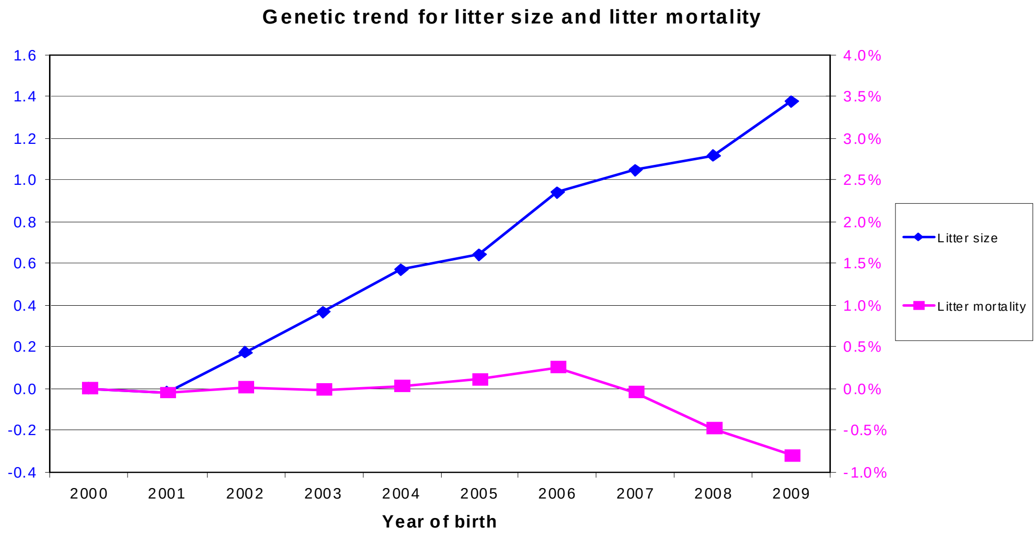

Figure 2: Genetic trend for litter size and litter mortality in the TOPIGS breeding program.

Taking care of the less vital piglets can be labour intensive. Consequently, genetically improved vitality will contribute to a reduction of the amount and cost of labour. Analysis of the trends over the past 15 years in the Netherlands (Landelijk Biggenprijzenschema 1997-2009) suggest that substantial gains have been made in reducing the time spent per piglet: from 42 minutes/weaned pig in 1997 to 20 minutes in 2009. Genetically better vitality from birth to slaughter will therefore contribute to a further reduction in human assistance or labour/pig.

(b) Uniformity at different levels of production
There is an increasing demand for more uniformity in pork cuts from the slaughter houses, retail and consumers. In fact uniformity is desirable at all levels of pig production. The uniformity in litter size at birth is useful for more efficient management. Uniformity in birth weight is useful to decrease mortality. This is especially important as the litter sizes increase. Table 1 shows the effect of variation in birth weight for the daily gain later in life of the pigs. A difference of 500 grams in birth weight results in a difference in daily gain from birth to slaughter of 30 grams/day.
Further increase in uniformity during finishing would help increase protein efficiency. Uniformity in slaughter weight at shipment and carcass length would help increase slaughter plant efficiency. Finally, uniformity in size and weights of pork chops and uniformity in meat colour, marbling and drip loss is useful for retail shelves and consumers. Uniformity at all these levels means avoiding extremes in low or high in birth weights, slaughter weights and pork quality resulting into products that are average good and are uniform.

	Small	Normal	Large
Distribution	17%	68%	15%
Birth weight, kg	1.0	1.5	2.0
Start weight, kg	25.8	26.7	28.1
End weight, kg	112.0	113.1	114.3
Carcass weight, kg	87.0	87.6	88.5
Age at slaughter, d	176.2	170.5	166.1
Carcass gain, g/d	493	512	532
HGP lean, %	56.6	56.5	56.3
Lean gain, g/d	278	289	299

Table 1. The effect of birth weight on daily gain and lean meat%.

(c) Robustness

In addition to vitality and uniformity in pig production there is a need for more robustness. The definition of robustness is the ability of pigs to adapt to different stressors without stress. Or better: strong and healthy pigs that continue to perform well in presence of various stressors. These stressors can be disease challenges, extremely hot or cold temperatures, low quality feed or challenges due to changes in housing or management e.g. more group than individual housing.

As pig breeding is becoming more and more a global business, robustness to heat in tropical environments or cold in some of the temperate regions is necessary. It has been shown that there are genetic differences between sow lines with respect to heat tolerance at time of insemination (Bloemhof et al., 2008). As an example (Figure 3), one sow line showed a reduction in farrowing rate and litter size as the temperatures on the day of insemination rose above the 20◦ C, while there was hardly any effect on the other line.

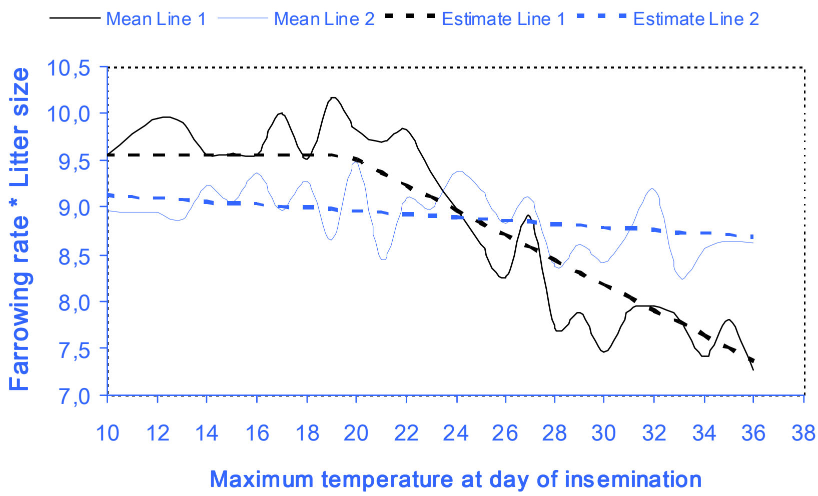

Figure 3: Genetic differences in heat tolerance (Bloemhof et al. 2008)

The differences between lines can be used either to select lines for specific environments or lines with generalised heat tolerance. More generally, if the genetic correlation between the performance in two environments is lower than 0.4-0.6, then separate lines become necessary (Mulder and Bijma, 2006) that involves additional costs. In most cases it is desirable to have lines that are robust and are able to perform well in spite of extreme changes in temperature or climate.

(d) Society driven trends

Society expects better animal welfare, less use of antibiotics, reduction of the carbon foot print as well as adequate organic next to conventional pork production. A ban on castration is expected in most European countries. However, if the castration is stopped there is a risk of boar taint from some entire males such that pork from any entire male can be considered as full of risk for pork processors. Since the boar taint compounds have relatively high heritabilities, there are opportunities to reduce or eliminate boar taint through genetic selection (Knol et al., 2010; Merks et al., 2010).

Group housing and non-tail docking necessitate insight in behavioural mechanisms. There is considerable genetic variation in effects of social behaviour on gain and feed intake (Bergsma et al., 2008). However, further investigations are required to evaluate the correlations of these traits with the phenotypes related to behaviour such as tail biting or male sexual behaviour.

In addition, worries about zoonosis require increasing disease resistance while the use of antibiotics has to be lowered to avoid resistance of bacteria and viruses for antibiotics that are also used in human medicine. Opportunities for selection for higher disease resistance or tolerance have been revealed in several studies. Studies by Doeschl-Wilson et al. (2009), Ait-Ali et al. (2007), Vincent et al.(2006) Opriessnig et al., (2006), Halbur et al. (1998) suggest differences in host genetic response with respect to PRRS and PMWS.

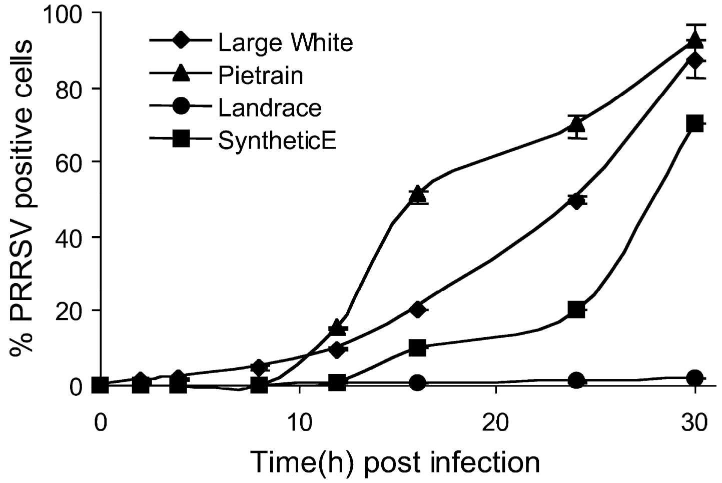

Figure 4: Infected cells after in vitro infection
Source: Ait-Ali et al. (2007)

However, a majority of disease resistance studies are based on challenge experiments which are expensive and difficult to do on large number of pigs. Therefore, the main issue is identification of phenotypes that can be easily measured for effective genetic selection.

New technologies

New technologies are also becoming available to set and support new breeding goals. Modern pig breeding is actually evolving as a technology based industry, making use of advancements in housing, feeding and management of pigs, genomics and improvement of statistical models.

The completion of the pig genome sequencing and availability of the Porcine Illumina SNP60 BeadChip (Ramos et al., 2009) has opened doors for new opportunities. Genome wide association studies using the 60K SNP chip can be especially useful for traits that are difficult and expensive to measure. In addition, it has opened up possibilities for selection for traits of animal welfare and societal significance. An example is selection against boar taint compounds to stop castration. A Genome-wide association study using the 60K chip has revealed a cluster of candidate genes associated with androstenone levels (Duijvesteijn, et al.,2010). This provides further opportunities for selection against boar taint in addition to quantitative selection.

New developments in data recording and automatic transfer of data from the weighing scale to the central database has made it possible to record new birth phenotypes. (Knol and Mathur, 2010). An example is recording of individual birth weights on hundreds of thousands of piglets and direct transfer of data to central database to help selection for vitality and uniformity in addition to production efficiency.

New and improved statistical models are now developed for taking into account new phenotypes in multi trait BLUP evaluations. In addition, new models and evaluation methods are being developed to account for social interactions in group housing (Bijma et al., 2007). Combined with technological advancements in management allowing for group housing of large number of pigs, these will be useful for selection on associate or social effects to improve animal welfare.

More developments are taking place in analysis of molecular data and genomic selection (Meuwissen et al., 2001). Along with these developments there is an increasing need for good, sound observations and phenotypes preferably corrected for external factors as herd, year, season etc.. Theoretical studies have shown that much larger training data sets including several thousands individuals with genotypes and phenotypes are needed than indicated by the initial simulation results (Goddard, 2009, Meuwissen, 2009), creating mixture models combining existing quantitative approaches with the use of molecular data.

However, technology is just a tool to support new phenotypes and breeding goals. Technology is for pig breeding not a goal on itself.

Conclusions

The generalized breeding goal for pigs was quality pork against the lowest cost price. This has changed into sustainable pork production which maximises value over costs.

Clearly, there is a need for not only a higher production efficiency but also more quality to meet the expectations of the value chain partners, pork consumers and citizens. This will require new phenotypes and new breeding goals related to vitality from birth to slaughter, uniformity from birth weight to pork chops and robustness. The breeding goals will not only be driven by economic considerations but also by societal trends and expectations. Special consideration needs to be given to the upcoming ban on castration of male piglets, improving general disease resistance, reducing use of antibiotics and reducing carbon foot print. There are several developments in the technology to support the new breeding goals and recording of the related phenotypes. However, it has to be very clear that technology is just a tool not the breeding goal.

Until recently, the breeding goals mainly focused on litter size at birth and at weaning, daily gain from birth to slaughter, meat percentage and feed conversion. The breeding goals for the future will include vitality from birth to slaughter without human interference, uniformity from birth to pork, reduced use of antibiotics and improved food safety.

Simplicity and straightforwardness of the breeding goal has to be weighed against completeness and complexity.

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