One century of genetic changes in pigs and the future needs
Jan W.M. Merks,
IPG, Institute for Pig Genetics B.V., P.O. Box 43, 6640 AA Beuningen, the Netherlands (e-mail: Jan_Merks@ipg.nl)

Abstract
Breeding programmes and improved knowledge of genetics have resulted in gradually increased genetic changes in pigs. In this paper the genetic changes in the European pig during the last century are analysed and compared with societal needs for the following decades. Dutch data are used to support the general trend in Europe and results of an EC project on breeding and society are used to identify societal needs.

Genetic changes in pigs started early this century, mainly in Northern Europe, by the gradual set up of local and regional breeding programmes. In the first 60 years the goal of these programmes was focussed only on leanness and feed efficiency. However, type, leg quality and breed characteristics were of utmost importance in these years for some breeding programmes. During these decades the genetic changes were negligible for reproduction traits. Progress was achieved especially for breed characteristics like type and colour and later also backfat thickness, daily gain and consequently improved feed efficiency.

With the introduction of crosses in the early 60’s, specialisation in dam and sire lines but moreover in breeding programmes arose in the pig industry. This specialisation resulted rapidly in increased genetic changes, more breeds and/or lines and breeding goals that supported efficient lean meat production systems. Especially in the sire lines, this specialisation resulted in increased progress for daily gain, backfat thickness and feed efficiency. Improved knowledge of genetics increased genetic changes in leanness and feed efficiency during the last few decades, but at the same time attention could be and was paid to fertility and vitality. During the last decade most European pig breeding programmes realised annual genetic progress for daily gain of +20 g/day, lean meat % of +0.5% and litter size of +0.2 piglet/litter. Molecular genetics does not enable more genetic change for these traits, but does so especially for expensive or difficult to measure traits, e.g. meat quality, health and longevity. In commercial pig breeding programmes selection limits have not been reached yet. Nevertheless, there are experimental results that indicate unintended side effects of the present breeding goals.

Next to changes in breeding possibilities, the societal needs have also changed. During the first 80-90 years of the century, pig producers were aiming at production of lean meat at low(er) prices. In this period low prices were more important than quality and/or welfare of the pigs. Nowadays, diversification in consumers’ needs is growing and quality of the product (including production circumstances) is important in Western Europe. The market for pork is changing from a market of producers into a market of (potential) buyers. Clearly, the success of any pig breeding programme next century will be judged by the consumer. Where a newly bred, or genetically modified, variety of animal fails to provide something people are prepared to buy, the breeding programme will be judged a failure. In this respect ethical issues are also becoming more important. Modern breeding techniques can threaten animal welfare; a very fast increase in one or a few traits can easily result in an insufficient increase or adaptation of the organs and skeleton. Animal integrity is another important issue, especially related to genetically modified animals. Clearly, the relationship between animal and human interests is central to any view.

From the analysis of genetic changes in pigs and the present and foreseen changes in market demands, it may be concluded that the pig breeding programmes were very successful; but they will have to change their goals. Less emphasis will be needed on low cost price and more emphasis on product quality, biodiversity and well balanced genetic changes for economically important traits.

Introduction
Breeding programmes and improved knowledge of genetics have resulted in gradually increased genetic changes in pigs. These genetic changes are mainly desired changes, but some of the genetic alterations made
in pursuit of breeding goals seem to have unintended side-effects. The goal of this paper is to analyse one century of pig breeding with societal needs in the background.

In the first part, the genetic changes in the European pig during the last century are analysed. For this analysis three periods will be distinguished: 1) until 1950, 2) between 1950 and 1990, and 3) the last decade. These periods mark substantial changes in pig breeding programmes. Dutch data are used to support the general trend in Europe. Further, the genetic changes are used to reflect on our breeding goals and to indicate potential selection limits.

Nowadays, the opinion of the farmers about the quality of their product is not important for animal breeders, but the opinion of society and the “licence to produce” determines the goal of farm animal selection and reproduction. This greatly affects the future of pig breeding and consequently realised and planned genetic progress must comply with societal needs for the next decade. These aspects will be discussed in the last part of the paper based on results of the EU-project “The future developments in farm animal breeding and reproduction and their ethical, legal and consumer’s implications” (Neeteson et al., 1999).

Genetic changes and trends during this century

Before 1950

Since mankind started domestication of farm animals, we have been trying to get progeny from the animals that seemed best fit for the purpose we had in mind. Docility and breed characteristics like colour and size were favoured. The pig was seen as a waste converter that was able to produce high valuable food. The fat and manure of pigs were rewarded by farmer and government.

Early this century, herdbooks were set up for the different breeds in most European countries. This work was initiated by national governments and implemented regionally. This was also the period in which central testing was initiated, first by the Danish pig breeders in 1907 (Grøn Pedersen, 1997) and later followed with similar set ups in other countries. The goal of central testing was the comparison of genetic value for daily gain, feed conversion and backfat thickness under standardised (management) circumstances. All herdbooks focussed on pure-bred selection and breeding for efficient pork production. Selection indices were introduced.

From 1950 until 1990

This period is characterised by cross breeding and the start-up of pig breeding companies. The work of Dickerson (1952, 1973) on crossbreeding in poultry and plants also raised the interest of pig breeders. The work of Smith (1964) and Moav (1966) on specialised sire and dam lines clearly started the present pig breeding programmes. Breeds were grouped into sire and dam lines or, as in the Netherlands for the Dutch Great Yorkshire, split up into a sire and dam line (Knap, 1990). Index selection was still focussed on production traits. In Table 1 the phenotypic trend in central test results from 1930 until 1990 in the Netherlands is shown for Dutch Landrace and Dutch Yorkshire. Backfat thickness was reduced by almost 50%, daily gain increased by more than 50% and consequently the feed efficiency was improved to a large extent.

Table 1. Phenotypic trends in central test results in the Netherlands (1930 – 1990).

<table>
<thead>
<tr>
<th>Race</th>
<th>Daily gain (g/d)</th>
<th>Feed efficiency (kg/kg)</th>
<th>Backfat thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dutch Landrace</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1930</td>
<td>500</td>
<td>3.5</td>
<td>45</td>
</tr>
<tr>
<td>1947</td>
<td>650</td>
<td>3.4</td>
<td>33</td>
</tr>
<tr>
<td>1972</td>
<td>788</td>
<td>2.6</td>
<td>26</td>
</tr>
<tr>
<td>1990</td>
<td>840</td>
<td>2.8</td>
<td>24</td>
</tr>
<tr>
<td>Great Yorkshire</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1930</td>
<td>550</td>
<td>3.4</td>
<td>48</td>
</tr>
<tr>
<td>1947</td>
<td>680</td>
<td>3.2</td>
<td>35</td>
</tr>
</tbody>
</table>
By the end of the 80’s family selection had been introduced in the dam lines to select for litter size (Haley et al., 1986), whereas until then selection for reproduction was not expected to be profitable. In Figure 1 the phenotypic trend of litter size for Dutch Landrace and Great Yorkshire is illustrated. From 1981 the Great Yorkshire is split up into a dam (D) and sire (S) line.

![Figure 1. Phenotypic trend for the litter size in second and higher parities in the Dutch Landrace (DL) and in the Great Yorkshire (GY) dam line (GY-D) and sire line (GY-S) from 1969 to 1991.](image)

In addition to specialisation on sire and dam lines, breeders also became specialised. Specialised breeding farms for pure breeding, multiplication and crossbreeding and commercial farms for piglet production and fattening were set up. The commercial farms bought gilts and boars from the breeding farms instead of breeding these gilts and boars themselves. The introduction of artificial insemination (AI) enhanced further specialisation.

*From 1990 until 1999*

In the last decade, improved knowledge of genetics led to increased genetic progress in both sire and dam lines for production and reproduction traits. Firstly, the application of BLUP (Best Linear Unbiased Prediction) was an important step (e.g. Tribout et al., 1998). This resulted in clear genetic progress for litter size.
size in the dam lines as indicated in Figure 2. Family selection (Figure 1) realised a progress of 0.5 piglets in 10 years; application of BLUP realised the same progress in less than 5 years (Figure 2).

The difference in progress between sire and dam lines is also remarkable. In Figure 3 the genetic trend for litter size is indicated for a Dalland sire (080) and dam (020) line, while in Figure 4 this is done for backfat thickness. Both are a result of differences in breeding goal between the dam and sire lines, and clearly illustrate the effect of specialised lines.

The last decade is also characterised by widening of breeding goals and introduction of molecular genetics. Breeding goals are now based not only on economically profitable traits like daily gain, feed efficiency and litter size but also increasingly on traits like meat quality (drip loss, colour) and vitality of piglets (Knol, 1998), and on strategies to overcome genotype x environment interaction (Andersen et al., 1998; Merks and Hanenberg, 1998) and inbreeding (Meuwissen, 1998). These new breeding goals are not only a result of improved data recording and statistical methods but merely the result of a target level approach at commercial level over a given time-frame. An example is selection for piglet vitality in Dalland populations (Knol, 1998). Piglet vitality is defined as survival from birth until weaning, expecting all piglets to be born alive. Selection for this trait started in 1994 by detailed registration and the genetic trend is shown in Figure 5.
Figure 3. Genetic trend for litter size in Dalland 20 (dam) and Dalland 80 (sire) line from 1984 to 1998.

Figure 4. Genetic trend for ultrasonic backfat thickness in Dalland 20 (dam) and Dalland 80 (sire) line from 1984 to 1998.
Molecular genetics methods (Rothschild, 1998) were introduced to pig breeding early in this decade by the DNA test (Fuji et al., 1991) for halothane sensitivity. However, further application of molecular genetics is limited and mainly expected to be of interest for disease resistance and meat quality traits (Visscher and Haley, 1998) unless the traits are sex-limited or expensive to measure in a commercial environment.

Figure 5. Genetic trend for piglet vitality (in % survival) in Dalland 20 (dam) and Dalland 80 (sire) line from 1994 to 1998.
Main trends in the century
In Figure 6 a schematic description is given of the main genetic trends in the century, including only daily gain, backfat thickness and litter size. Genetic improvement is only significant for daily gain and backfat thickness. During the last decade genetic progress was speeded up enormously. Most European pig breeding programmes now realise an annual genetic progress of +20 day, lean meat % of +0.5% and litter size of +0.2 piglet/litter.

Present state of the art
The pig breeding programmes have been very successful in effecting genetic improvement of economically important traits, especially daily gain, backfat thickness, feed efficiency and, during the last decade, litter size. However, this is not enough for the future. Breeding goals have been or are presently being set up more broadly. Breeding is aiming at efficient production under all relevant circumstances and adequate management. This means finding an adequate strategy to overcome genotype x environment interaction and also selection pressure for traits that are of negligible economical importance or of less interest. Examples include number of piglets born dead, interval between weaning and first oestrus, longevity of sows, vitality of pigs until slaughter weight, meat colour, drip loss, etc. Further, due to the concentration and increasing scale of pig production, the health of the pigs is becoming more important. This means not only setting up high health breeding farms (minimal disease level) but also selection for general disease resistance under commercial conditions. New technologies like genomics and reproduction technology may be helpful, especially for traits that are difficult to measure phenotypically (e.g. longevity and disease resistance) or which can be measured only after slaughter (e.g. meat quality traits) or many years (e.g. persistency in litter size).
In commercial pig breeding programmes selection limits have not been reached yet. The first limit may be backfat thickness due to physiological reasons, but in most breeding programmes selection for this trait has already stopped because of having reached the desired or optimal level. Nevertheless, there are experimental results that indicate unintended side effects of the present breeding goals.

The selection experiment of Johnson et al. (1999) on increased litter size showed undesirable genetic effects on number of stillborn and mummified pigs. Similar negative genetic relationships are reported by Hanenberg et al. (1999) in a commercial Dutch Landrace population. In Table 2 the heritability estimates of Hanenberg et al. (1999) are tabulated. Based on these heritabilities and the estimated genetic correlations, they compared different breeding goals for reproduction. In Table 3 the expected genetic progress is indicated for 3 alternatives: 1) maximum progress for total born, 2) economic optimum, and 3) extra selection emphasis on litter mortality and interval from weaning to oestrus. The effect of these three strategies on total born and litter mortality (born death + death loss until weaning) is clearly indicated. By small changes in selection pressure, negative side effects can easily be avoided.

Table 2. Heritability estimates for reproduction traits in Dutch Landrace (Hanenberg et al., 1999)

<table>
<thead>
<tr>
<th>Trait</th>
<th>1st parity</th>
<th>other parities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total born</td>
<td>0.09</td>
<td>0.10</td>
</tr>
<tr>
<td>Born alive</td>
<td>0.08</td>
<td>0.09</td>
</tr>
<tr>
<td>Stillborn</td>
<td>0.02</td>
<td>0.05</td>
</tr>
<tr>
<td>Mothering ability</td>
<td>0.02</td>
<td>0.03</td>
</tr>
<tr>
<td>Interval weaning-oestrus</td>
<td>0.10</td>
<td>0.05</td>
</tr>
<tr>
<td>Interval = 7 days</td>
<td>0.21</td>
<td>0.12</td>
</tr>
<tr>
<td>Interval logarithmic scale</td>
<td>0.14</td>
<td>0.07</td>
</tr>
<tr>
<td>Nonreturn%</td>
<td>0.06</td>
<td>0.03</td>
</tr>
<tr>
<td>Gestation length</td>
<td>0.25</td>
<td>0.29</td>
</tr>
<tr>
<td>Age 1st service</td>
<td>0.32</td>
<td></td>
</tr>
</tbody>
</table>

Another interesting experiment was recently reported by Eissen et al., (1999). The effect of extreme high levels of litter size on lactating primiparous sows of three genotypes (one purebred and two crossbred) was tested. In total 300 primiparous sows were randomly assigned to litter size of 8, 11 or 14 piglets by crossfostering within three days after farrowing. Sows were fed ad libitum while piglets had no access to creep feeding. The effect of these litter sizes on sows’ performance is summarised in Table 4. Up to a litter size of 11 piglets, primiparous sows are reasonably able to rear their litter without clear negative effects. However, if litter size is increased up to 14 piglets, primiparous sows are not adequately equipped for that job: having inadequate feed intake and consequently relatively large loss of weight, backfat thickness and litter growth. These results clearly indicate that increasing litter size also needs increased feed intake capacity of sows and the management of these sows.

These experimental results clearly indicate that selection limits have not yet been reached but easily can be reached soon because of physiological limitations and / or unintended side effects.
Table 3. Expected genetic progress from different selection strategies for fertility traits (Hanenberg et al., 1999)

<table>
<thead>
<tr>
<th>Trait</th>
<th>Average</th>
<th>Index 1</th>
<th>Index 2</th>
<th>Index 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total born</td>
<td>10.85</td>
<td>+0.15</td>
<td>+0.14</td>
<td>+0.12</td>
</tr>
<tr>
<td>Stillborn</td>
<td>0.85</td>
<td>+0.02</td>
<td>+0.02</td>
<td>+0.01</td>
</tr>
<tr>
<td>Litter mortality (%)</td>
<td>8.22</td>
<td>+0.15</td>
<td>+0.11</td>
<td>+0.03</td>
</tr>
<tr>
<td>Interval weaning to insemination &gt;7 days</td>
<td>15.98</td>
<td>-0.09</td>
<td>-0.17</td>
<td>-0.15</td>
</tr>
<tr>
<td>(%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Litters / sow / year</td>
<td>2.37</td>
<td>+0.00</td>
<td>+0.00</td>
<td>+0.00</td>
</tr>
<tr>
<td>Weaned piglets / litter</td>
<td>9.42</td>
<td>+0.10</td>
<td>+0.11</td>
<td>+0.10</td>
</tr>
<tr>
<td>Weaned per sow / year</td>
<td>22.35</td>
<td>+0.25</td>
<td>+0.26</td>
<td>+0.23</td>
</tr>
</tbody>
</table>

1Index 1: Maximum progress for total born
2Index 2: Economic optimum
3Index 3: Extra emphasis on litter mortality and interval weaning-insemination

Table 4. Effect of different litter sizes on sow performance traits during lactation (Eissen et al., 1999)

<table>
<thead>
<tr>
<th>Trait</th>
<th>Number of piglets</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>14</td>
</tr>
<tr>
<td>Feed intake (kg/d)</td>
<td>4.8</td>
</tr>
<tr>
<td>Backfat loss (d10 to 28)</td>
<td>2.1</td>
</tr>
<tr>
<td>Backfat loss (mm/d)</td>
<td>0.12</td>
</tr>
<tr>
<td>Weight loss (d10 to 28)</td>
<td>14.7</td>
</tr>
<tr>
<td>Weight loss (kg/day)</td>
<td>0.8</td>
</tr>
<tr>
<td>Litter growth (d10 to 28)</td>
<td>38.4</td>
</tr>
</tbody>
</table>

Societal needs

During the first 80 – 90 years of the century, pig producers aimed at production of lean meat at low(er) prices. In this period low prices were more important than quality and / or welfare of pigs. Consequently, the present cost of pork is almost the same as it was at the beginning of the century. Gradually, the national and international market for pork is changing from a market of producers into a market of (potential) buyers. Diversification in consumers’ needs is growing and quality of the product (including production circumstances) is increasingly important. Pig breeding programmes, at the very beginning of the food production chain, have to deal with this new situation in which awareness of the demand of the consumer and the license to produce of society plays a considerable role.

In general, the breeding of farm animals is not an issue that appeals to the regular consumers, because it is an activity that is not clearly visible at the beginning of a production chain (Van Genderen and De Vriend, 1999). The quality of the pork is of more importance to them than the way in which those products are produced. Consumers, however, have clear opinions about the large-scale introduction of e.g. cloning, sexing and genetic modification. It is therefore important to discuss what breeding goals and reproductive tools for pigs are acceptable to society.

Some of the genetic alterations realised in pursuit of breeding goals may have unintended negative side-effects on animal welfare and integrity. The fact that we are aware of the potentially harmful consequences of breeding and genetics and the fact that we are able to control these places an ethical responsibility on society. Despite the growing awareness of this responsibility people today take quite different views about what is acceptable in farm animal breeding (Christiansen and Sandoe, 1999). On the one hand there are concerns towards animals, humans, the environment or biotechnology itself: unintended negative side effects can be in conflict with animal welfare, animal integrity, human health, genetic diversity and the environment. On the other hand the positive applications represent an obligation not to dismiss these options.
Conclusions
One century of pig breeding clearly resulted in genetic changes. The main features are the progress in daily gain (+100%) and in backfat thickness (-75%). During the last decade, genetic progress was accelerated enormously by further specialisation and improved statistical methods (and computers), especially in reproduction traits. At present, most European pig breeding programmes realise annual genetic progress for daily gain of +20 g/day, lean meat % of +0.5% and litter size of +0.2 piglet/litter. In commercial pig breeding programmes selection limits have not been reached yet. Nevertheless, there are experimental results that indicate unintended side effects of the present breeding goals. In general, more genetic progress for a single trait increases the potential risk for the biological balance of the pig. Clearly, the success of any pig breeding programme next century will be judged by the consumer. Where a newly bred, or genetically modified, variety of animals fails to provide something people are prepared to buy, the breeding programme will be judged a failure. Next to quality of the product, animal integrity and welfare will also be judged. Only improved production levels without affect on health or metabolic balance of the animal seem to be accepted by society.

References

Rothschild, M.F. 1998. Identification of quantitative trait loci and interesting candidate genes in the pig: progress and prospects. 6th WCGALP, Australia, 26: 403 - 409


Van Genderen A. and De Vriend H. 1999. Farm animal breeding and the consumer. In: The future developments in farm animal breeding and reproduction and their ethical, legal and consumer implications, Neeteson A.N. (e.d.) page 66 - 84