Strategies to manage inbreeding accumulation in swine breeding company nucleus herds: Some case studies

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Abstract

Modern swine breeding is undergoing a series of changes that affect the underlying strategies for genetic improvement. Increased competition among fewer breeding companies requires rapid genetic improvement to maintain competitive advantage. The result is intense selection pressure within swine industry nucleus populations. Selection pressure is enhanced through the use of artificial insemination, embryo transfer, and, potentially, marker-assisted selection. This increased selection pressure raises concerns due to the more rapid accumulation of inbreeding within these populations. The current strategies used to control the accumulation of inbreeding are somewhat simplistic. The methods often include arbitrary restrictions on the percentage of sows mated to a single sire, the number of sires retained from a full and half-sib family, the avoidance of matings between closely related individuals, and elimination of families presumed to be segregating for alleles with deleterious effects on fitness. As demonstrated by classic genetic theory, when the previously listed methods to minimize inbreeding are used, inbreeding is delayed, but it is inevitably accumulated within nucleus herds. The rate of accumulation typically is between 0.3 and 0.6% per annum. Composite lines addressing specific market needs, particularly for terminal sires, may offer short-term solutions for nucleus level inbreeding. Most parent and terminal products are produced from line crosses wherein inbreeding is eliminated in the resulting progeny. Understanding the causes of inbreeding depression continues to be important in order to improve the performance of purelines in multiplication, leading to more efficient transfer of genetic improvement.

Key Words: Pigs, Inbreeding, Selection

Introduction

In order to address the topic of inbreeding in swine seedstock herds, I have relied almost exclusively on experience working with the nucleus herds of Danbred (Danbred USA, L.L.C., Dorchester, NE) and our close relationship to the National Pig Breeding Program administered in Denmark by Danske Slagterier (Danske Slagterier, Copenhagen, Denmark). The general trends for inbreeding within these populations illustrate what typically might be found in any nucleus level herd undergoing intense selection. The objective of this paper is to present a detailed description of several closed nucleus herds and the results for average inbreeding within those populations. In addition, this paper will include a brief discussion of the economic forces that exist in the swine industry and their effect on opportunities to control inbreeding, the need for inbreeding control from the perspective of a seedstock supplier, and some of the questions that remain concerning the long-term impact of current selection strategies.

Business Forces in the Seedstock Industry and Their Effect on Inbreeding Control

Swine breeding stock suppliers typically own and operate nucleus level populations or lines. The matings within nucleus populations are controlled in such a way that only animals predicted to produce progeny with superior performance are permitted to contribute their DNA to subsequent generations. Several existing (e.g., BLUP) and emerging (e.g., marker-assisted selection) technologies are used to identify animals that, when mated, will produce genetic improvement in the population. No matter the methods employed, the breeding company seeks to transfer increasingly superior combinations of alleles to the commercial production segment of the pork chain.

The number of lines maintained varies among companies, but most companies maintain lines having selection programs specialized toward maternal or terminal traits. Maternal traits include those associated with reproductive performance, such as the number of pigs born or litter weight at birth. Terminal traits are associated with carcass quality, growth, feed efficiency, and meat quality. Maternal line selection programs often include evaluation of several terminal traits, but performance measures for terminal traits receive less weighting in a selection decision compared with maternal traits.

The genetic improvement that occurs at the nucleus level is often transferred to commercial swine producers by using a multiplication system. The multiplication system includes herds that are composed of one or more nucleus level lines or crosses of nucleus lines. A typical system that produces females for use by the commercial producer would be a Landrace multiplication herd that is mated to Yorkshire males. The multiplication system uses the improved nucleus level animals to produce a crossbred animal for use by the commercial producer. The commercial producer would then mate this crossbred female with a terminal line boar to produce market animals for slaughter.

Given the system described above, there are a few concepts that affect decisions on inbreeding control that should be noted. First, the expense of producing the genetic gain at the nucleus level and the cost of maintaining nucleus and multiplication level herds typically contributes somewhere between $1 and $4 to the cost of production per market pig at the commercial level. The actual cost at the commercial level is influenced by several decisions made by the commercial customer. For example, cost to a customer purchasing gilts is generally higher than that to a customer willing to operate a closed system wherein the genetic company supplies improved genetics via semen from the nucleus herd, bypassing the expense of the multiplication system. This is due, at least in part, to the increased production risk and investment required by the genetics company at the multiplication level.

Second, many genetics companies are product-driven. A product-driven company seeks to produce a low-cost, innovative product that meets the needs of the industry. Genetic suppliers essentially produce a population of nucleus animals that possess a combination of alleles capable of producing some measurable increase in performance compared with animals produced in prior years. Customers of genetics companies are, thus, willing to pay for access to the DNA from the improving population of nucleus animals. The methods to produce the improved combination of alleles vary, but, inevitably, the means have to provide for the highest financial returns within the current confines of what commercial swine producers expect to pay for genetic value as described in the previous paragraph. Competition among genetics companies is largely determined by the speed and efficiency of producing genetic progress. Customers will purchase from companies providing the best value, defined by the amount of improvement achieved at the nucleus level relative to the cost to the commercial producer.

Third, the swine industry is undergoing rapid changes, and the main decision power over product requirements is becoming increasingly concentrated in consumers. This change to a consumer-driven industry tends to concentrate economic power in the companies closest to the consumers. In the pork industry, such companies include retail grocery chains and meat processors. These companies will create a demand for unique pork products that have the characteristics that are required to compete both within and between protein sources. The genetics company must, therefore, be adaptable and flexible to meet the demands of unique product streams. The requirement to maintain competitive advantage will be the ability to rapidly adapt lines and selection programs to produce the performance characteristics required by the industry and to maintain competitive genetic gain relative to other protein sources.

The concepts presented above are important to a discussion of inbreeding because of the underlying implication that genetics suppliers cannot afford to compromise short-term genetic gain in order to maintain the accumulation of inbreeding within closed nucleus herds at extremely low levels. In addition, genetics suppliers must be cautious with the application of new and currently expensive technology (e.g., marker-assisted selection) to produce this progress without first subjecting that decision to a cost:benefit analysis. Obviously, a compromise must be reached between short-term and long-term demands from a genetic improvement program.

Reasons for Avoiding Inbreeding

Despite the short-term needs of the industry, most swine breeding companies apply simple rules to control the accumulation of inbreeding within nucleus herds. Inbreeding control is necessary to limit the impact of deleterious alleles, to control production risk due to inbreeding depression, and to help maintain genetic variation within a nucleus population over the long term (i.e., long-term risk management).

Nicholas (1998) wrote an extensive review of inherited disorders in swine. Although the disorders described by Nicholas (1998) are not caused by inbreeding, certainly the increase in homozygosity associated with higher levels of inbreeding creates more opportunity for these alleles, often recessive in effect, to exhibit their associated phenotypes. The concept of risk management is important when considering deleterious alleles. Inbreeding control programs often require that a single sire be allowed to mate only a small fraction (e.g., 5%) of the total female population. This limits the extent to which a sire that is carrying a deleterious allele can spread that allele in the nucleus population.

Many swine genetics companies produce a Yorkshire × Landrace crossbred female for use in commercial production systems. This program requires the use of a purebred female in multiplication. It is very important that multiplication be operated in a highly efficient manner to produce as many high-quality animals as possible. Increasing levels of inbreeding are often associated with a depression in animal performance that is of concern in a program that uses purebred animals in multiplication. Johnson (1990) assembled a summary of numerous research studies that had evaluated the effects of inbreeding on performance. Table 1 contains a description of the depression in performance for a female that has an inbreeding coefficient of 0.1. In general, there is a depression in litter size and a reduction in the ability of a sow to raise her litter. This is shown by a reduction in the number of liveborn pigs of 0.3, a reduction in litter weaning weight of approximately 1 kg, and a decrease in the preweaning survival rate of pigs (–2.5%). These reductions in performance will increase the cost of production at the multiplication level as inbreeding accumulates within purebred populations. It should be noted that the commercial level is relatively unaffected by inbreeding depression due to the use of crossbred parent females and terminal pigs.

For this review, no attempt was made to predict the effects of inbreeding on genetic variation or on the long-term response to selection for economically important traits. Most swine breeding programs include efforts to maintain some constant or minimum level of effective population size. This would help to limit the effects of drift on random loss of alleles from the population. However, there is concern among industry geneticists about the effects of current selection strategies on the ability to maintain adequate long-term genetic gain within closed nucleus populations. The gradual loss of genetic variation associated with the accumulation of inbreeding may reduce competitive advantage for breeding companies or, more importantly, negatively affect our ability to meet the growing worldwide demand for protein due to slower genetic improvement. Inbreeding depression, because of negative effects on performance, could make some populations difficult or expensive to maintain. Several questions, addressed later in this paper, point toward additional research that could be undertaken to address this issue.

Examples of Inbreeding in Industry Populations

The following section contains several examples of the accumulation of inbreeding within swine seedstock herds. Each of the examples includes a brief description of population size and structure, a description of the testing and selection program, a listing of rules applied at the sow farm to minimize inbreeding accumulation, and the resulting rates of inbreeding within the populations. These results from these herds are typical of what would be expected from most closed nucleus herds.

Danbred Population

Danbred USA operates a closed set of nucleus herds composed of 1,250 Landrace, 500 Yorkshire, and 600 Duroc sows. In addition, there are 800 sows within a closed composite terminal line. The farm managers within these units are employees of the corporation; thus, Danbred has the unique opportunity to be able to enforce rules that quite easily delay and limit the accumulation of inbreeding. It is important that the rules be easily understood by personnel working at the nucleus farm. Complex approaches to minimize inbreeding are often too cumbersome to carry out on a routine basis, although the increasingly common applications of information systems at the farm level may change this. The first example presented herein is from Danbred's Yorkshire population.

This population is composed of 500 purebred Yorkshire sows. This herd has been completely closed to introduction of outside breeding stock since the fall of 1995. To limit testing costs, only a percentage of the total production of males (25%) and females (50%) is performance-tested. The animals entering the performance test are initially selected based on the index of the litter from which they came. Approximately 2,500 gilts and 1,200 boars are tested annually.

All matings on the sow farm are performed using artificial insemination. We maintain approximately a 60% replacement rate in this herd each year. All voluntary culling of sows (i.e., sows not culled for reasons such as crippling and morbidity) is based exclusively on the index value. In other words, a sow is culled if a gilt with a higher index is available to replace her. In this way, very high indexing sows can remain in the herd as long as they are contributing to genetic gain. We also include reproductive performance in the genetic analysis from the pureline sows located at several multiplication farms (currently 3,000 additional sows). More multiplication sows will be added as we develop our information system to incorporate their data efficiently. No transfer of breeding stock occurs from the multiplication level to the nucleus.

The index that is used for selection includes the following traits: number of pigs born alive (**NBA**), litter weight adjusted for the number of liveborn pigs (**LBW**), backfat and loin depth (**LED**) adjusted for weight, and weight adjusted for age. The majority of the emphasis in this index is placed on born live and litter birth weight. Weight has an economic value that is sufficient to maintain growth rate at its current level. Table 2 contains the genetic trends for this population. The general conclusions are that NBA increased by 0.58 pigs and LBW by 335 g from 1995 to 1999. Improvement in backfat (–0.73 mm) and loin depth (+.84 mm) were also noted, and weight remained relatively unchanged (–0.28 kg).

We observe the following rules to control the rate of accumulation of inbreeding:

A single sire is allowed to produce a litter from only 5% of the sow base. The result of this is that within our 500-sow Yorkshire population 50 to 60 half-sib families are produced each year. Some half-sib families may be produced from sires that are themselves half-sibs.

Only a single sire is selected per full-sib family. Two sires from the same litter can occasionally be selected, but they are treated as a single sire for mating purposes.

Matings between full- and half-sib family members are avoided. Matings between animals with common grandparents are avoided whenever possible.

There is no arbitrary restriction on the number of males and females selected from a single sire. However, we will restrict this amount subjectively if a sire would tend to leave an unusually high number of progeny.

The results for inbreeding in this population are shown in Table 3. These results are the culmination of the inbreeding control measures, selection program, and population structure that was described previously. Using 1995 as the base, inbreeding accumulated roughly 0.3 to 0.4% per year, and it currently stands at 1.4% within the population of animals born in 1999. I did not calculate the average expected inbreeding coefficient given the effective population size for this population; however, these results are within the expected range of inbreeding in terms of rate of change per annum in populations that would be expected to have similar effective sizes (Hubbard et al., 1990; Kuhlers and Jungst, 1991.). Also interesting is the percentage of the population that is inbred. Currently 61% of the animals tested during 1999 and 2000 have an inbreeding coefficient greater than zero. These results suggest that at approximately five generations after the closing of the herd to outside introductions of animals, all animals will have inbreeding levels greater than zero.

The Danish System

The Danish breeding system maintains approximately 2,600 Landrace, 2,200 Yorkshire, 1,400 Duroc, and 400

Hampshire sows within the nucleus populations. These sows are distributed over 40 to 50 privately owned breeder farms. A given farm may house several herds. Table 4 shows the number of herds by breed, the number of litters produced, and the number of animals that undergo performance testing. The performance-testing program is extensive, including every boar and gilt produced at the nucleus level. Currently, the top 10 to 15% of the boars are selected at weaning, based on the predicted index value for the litter, to enter a central test station for performance testing. The remaining boars and all gilts are tested on the farm. Boars at the station are evaluated for the same traits as those on the farm, with the exception that individual feed intake is recorded. In addition, pH is measured in the loin of slaughtered non-select boars from the test station. These data on pH are currently used to predict breeding values for the remaining population. This approach to selecting for meat quality is likely to change in the near future with the development of a biopsy allowing measurements of meat quality traits to be made on muscle tissue from individual animals (color, pH, and intramuscular fat). Virtually 100% of the matings are performed using artificial insemination, allowing for very high selection intensity to be placed on males.

The maternal populations are selected based on these criteria: total number of fully-formed pigs born, average daily gain from 0 to 30 kg, average daily gain from 30 to 100 kg, feed efficiency, percentage lean, conformation, and pH. The terminal lines are selected for average daily gain from 0 to 30 kg, average daily gain from 30 to 100 kg, feed efficiency, percentage lean, weight of slaughter loss, conformation, and pH. The primary emphasis in the maternal lines is pigs born, followed by daily gain. In the terminal lines, the primary emphasis is daily gain, followed by feed efficiency. The genetic trends for these populations can be found in Tables 5 to 8.

Within the Danish breeding herds, the following rules are followed in order to minimize inbreeding:

Landrace: A maximum of 12 sons may be retained per AI sire. These boars must be half-sibs, unless the boars originate from a rare pedigree. A rare pedigree is defined for a sire that, during the course of his time on stud, leaves very few sons. An arbitrary allowance is made in that situation for retention of full-sibs. A maximum of 4% of the litters may be produced from any single AI sire.

Yorkshire: A maximum of 18 sons per AI sire may be retained. These boars must be half-sibs unless they originate from a rare pedigree. A maximum of 4% of the litters may be produced by any single sire.

Duroc: No restrictions are placed on the number of sires retained due to demand for Duroc semen for terminal matings. A maximum of 5% of the litters within the breed may be produced from any single AI sire.

Hampshire: A maximum of 10 half-sib sons may be selected from any single AI sire. Only 5% of the litters may be produced from any single AI sire.

Due to the increased use of AI within the nucleus farms, a new set of inbreeding controls is currently under discussion and would include the following:

No change for the Hampshire population.

Duroc: Reduce the 5% limit on litters per sire to 1.5% and limit the number of females that may be selected to three per litter.

Landrace: Reduce the 4% limit on litters per sire to 2% and increase the number of sons from 12 to 18 per AI sire. In addition, breeders may only select three females per litter.

Yorkshire: Reduce the 4% limit on litters per sire to 2% and allow a maximum of three females to be selected per litter.

The results for inbreeding in the Danish populations are shown in Table 9 (Anders Vernersen, personal communication). Again, these results are the culmination of the current inbreeding control measures, selection program, and population structure that were described for these herds. Using a five-generation frame of reference, inbreeding accumulated at roughly 0.3 to 0.5% per year; the five-generation cumulative total ranged from 1.9 to 3.7%. These results agree closely with predictions from population genetics theory in terms of rate of change per annum or generation in herds that would have a similar effective size.

Discussion

The results above demonstrate that inbreeding is accumulating within swine nucleus herds. Theoretical research has been done that demonstrates the negative long-term effects of inbreeding on response to selection (Robertson, 1960). This is mainly thought to be due to the random loss of alleles from the population causing a reduction in the available variation for selection. Some questions come to mind with respect to the long-term implication of our current selection strategies.

First, in swine, the selection objective changes over a relatively short time horizon. Examples of this include the traits percentage lean and, in some cases, litter size. Percentage lean reaches a minimum acceptable threshold due to undesirable correlation with other traits (e.g., some meat quality traits). Therefore, it becomes desirable to initiate selection within alternative traits while holding lean constant. The same may be true for litter size and its effect on birth weight. The use of multiple-trait selection procedures may reduce the negative long-term impact of selection and population size on genetic variation. It becomes important to answer the question of what impact these changes to the selection program have on variation within traits receiving different economic weightings over time.

An additional question involves how well our current strategies for computing inbreeding truly reflect changes in homozygosity that occur at the gene level (“realized” inbreeding; Christensen et al., 1994). The theoretical range in inbreeding coefficient is from zero to one. As inbreeding accumulates within populations, those animals that have more underlying heterozygosity may potentially have a performance advantage compared to those individuals with higher levels of homozygosity and thus may be more likely to be selected. This may well maintain a certain level of variation within the population due to the effects of selection pressure on maintaining desirable alleles in the population. A better understanding is required of how to manage selection programs to help maintain desirable alleles within the population for many economically important traits.

Implications

Most swine seedstock suppliers use relatively simple rules to control inbreeding within closed populations undergoing intense selection. In nucleus herds of 400 or more sows, inbreeding increases at a rate of approximately 0.3 to 0.6% per year. The rate may be higher within smaller herds. This accumulation in inbreeding at the nucleus level has little effect on performance at the commercial level due to the use of crossbred animals. This is in contrast with other species, such as dairy cattle, where purebred animals are used by the commercial segment of the industry. The current strategies to control inbreeding are mainly the result of a need to control risk from deleterious alleles and to maintain high productivity in the nucleus and multiplication herds. A better understanding is required of the complex relationships between selection, population structure, and loss of variation in order to develop strategies to avoid the loss in opportunity to improve new traits.

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Notes

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Table 1. Reduction in performance for females with an inbreeding coefficient of 0.10

Trait	Reduction in performance
Number of fully formed pigs born	-0.4 pigs
Number of pigs born alive	-0.3 pigs
Number of pigs weaned	-0.22 pigs
Survival rate of pigs to 21 d of age	-2.5%
Litter weaning weight at 21 d	-0.99 kg

Table 2. Line 500 genetic trends[a,b]

		Average breeding value				
Year of birth	n	NBA	LBW, g	Backfat, mm	LED, mm	Weight, kg
1995	673	-0.04	79.45	-0.13	0.05	0.14
1996	1,995	0.03	84.44	-0.33	0.10	-0.30
1997	2,707	0.22	65.31	-0.71	0.46	-0.40
1998	2,595	0.42	221.55	-0.84	0.79	-0.11
1999	1,735	0.54	414.50	-0.86	0.89	-0.14
Change 1995-99		0.58	335.05	-0.73	0.84	-0.28

[a] Values presented are average EBV.

[b] NBA = number of pigs born alive; LBW = total weight of all pigs born alive; backfat = mean of five backfat measurements taken between the last and 10th rib at approximately 110 kg body weight; LED = mean of five loin depth measurements taken between the last and 10th rib at approximately 110 kg body weight; and weight = body weight at the completion of the performance test period adjusted for age.

Table 3. Average inbreeding within the Line 500 nucleus

Year of birth	Population inbreeding coefficient, %	Average coefficient of inbred animals, %	Percentage of animals with inbreeding > 0, %	Percentage change in inbreeding coefficient, %
1995	0.0	0.00	0	—
1996	0.31	3.80	8	0.31
1997	0.66	3.52	19	0.35
1998	0.98	2.07	48	0.32
1999	1.39	2.26	61	0.41

Table 4. Population structure of the Danish nucleus herds

Breed	Number of herds	Litters produced per year	Number of pigs undergoing performance testing annually		
			Test station boars	Boars on-farm	Gilts on-farm
Landrace	24	6,200	1,044	16,756	23,000
Yorkshire	22	4,800	1,038	12,620	14,693
Duroc	23	3,600	1,341	8,358	9,612
Hampshire	7	1,000	692	1,501	2,244

Table 5. Danish nucleus genetic trends for the Duroc breed[b,c]

Year of birth	ADG, g (0–30 kg)	ADG, g (30–100 kg)	F/G	% Lean	Dressing loss, kg	Conformation points	pH
95/96	3.1	26.6	-0.04	0.11	0.10	0.04	-0.001
96/97	7.4	52.5	-0.08	0.15	0.11	0.05	0.001
97/98	8.8	73.6	-0.12	0.28	0.27	0.06	0.0[a]
98/99	10.8	97.9	-0.16	0.48	0.22	0.11	0.002
Change 1995–99	7.7	71.3	-0.12	0.37	0.12	0.07	0.003

[a] Year in which selection for this trait was initiated.

[b] Values presented are average EBV.

[c] ADG (0–30) = average daily gain in grams from birth to 30 kg; ADG (30–100) = average daily gain in grams from 30 to 100 kg body weight; F/G = ratio of weight of feed consumed per weight of gain (kg/kg) between 30 and 100 kg body weight; % lean = percentage of carcass weight represented as lean meat; TNB = total of live born and stillborn pigs; conformation points = score for soundness and body conformation on a 1 to 5 scale; and pH = pH measurement taken within the loin muscle 24 h after slaughter.

Table 6. Danish nucleus genetic trends for the Hampshire breed[b,c]

Year of birth	ADG, g (0–30)	ADG, g (30–100)	F/G	% Lean	Dressing loss, kg	Conformation points	pH
95/96	1.6	11.8	-0.03	0.24	0.05	0.02	-0.001
96/97	2.3	23.8	-0.06	0.48	0.04	0.03	0.001
97/98	4.0[a]	44.4	-0.10	0.60	0.15	0.06	0.002[a]
98/99	7.6	64.6	-0.14	0.71	0.12[a]	0.09	0.005
Change 1995–1999	6.0	52.8	-0.11	0.47	0.07	0.07	0.006

[a] Year in which selection for this trait was initiated.

[b] Values presented are average EBV's. [c] ADG (0–30) = average daily gain in grams from birth to 30 kg; ADG (30–100) = average daily gain in grams from 30 to 100 kg body weight; F/G = ratio of weight of feed consumed per weight of gain (kg/kg) between 30 and 100 kg body weight; % lean = percentage of carcass weight represented as lean meat; TNB = total of live born and stillborn pigs; conformation points = score for soundness and body conformation on a 1 to 5 scale; and pH = pH measurement taken within the loin muscle 24 h after slaughter.

Table 7. Danish nucleus genetic trends for the Landrace breed[b,c]

Year of birth	ADG, g (0–30)	ADG, g (30–100)	F/G	% Lean	TNB	Conformation points	pH
95/96	2.3	19.1	-0.03	0.05	0.23	0	-0.002
96/97	-0.9	47.1	-0.06	0.05	0.64	0.04	0.003
97/98	-1.1[a]	62.7	-0.07	-0.12	1.22	0.09	-0.001[a]
98/99	-5.1	82.0	-0.09	-0.14	1.77	0.18	0.009
Change 1995–1999	-7.4	62.9	-0.06	-0.19	1.54	0.18	0.011

[a] Year in which selection for this trait was initiated.

[b] Values presented are average EBV.

[c] ADG (0–30) = average daily gain in grams from birth to 30 kg; ADG (30–100) = average daily gain in grams from 30 to 100 kg body weight; F/G = ratio of weight of feed consumed per weight of gain (kg/kg) between 30 and 100 kg body weight; % lean = percentage of carcass weight represented as lean meat; TNB = total of live born and stillborn pigs; conformation points = score for soundness and body conformation on a 1 to 5 scale; and pH = pH measurement taken within the loin muscle 24 h after slaughter.

Table 8. Danish nucleus genetic trends for the Yorkshire breed[b,c]

Year of birth	ADG, g (0–30)	ADG, g (30–100)	F/G	% Lean	TNB	Conformation points	pH
95/96	1.5	15.6	-0.02	0.02	0.44	-0.04	0.006
96/97	0.7	32.4	-0.04	-0.01	0.67	0.01	0.007
97/98	-1.7[a]	42.5	-0.05	-0.01	0.82	0.08	0.009[a]
98/99	-1.8	56.4	-0.06	0	1.00	0.18	0.007
Change 1995–1999	-3.3	40.8	-0.04	-0.02	0.56	0.22	0.001

[a] Year in which selection for this trait was initiated.

[b] Values presented are average EBV.

[c] ADG (0–30) = average daily gain in grams from birth to 30 kg; ADG (30–100) = average daily gain in grams from 30 to 100 kg body weight; F/G = ratio of weight of feed consumed per weight of gain (kg/kg) between 30 and 100 kg body weight; % lean = percentage of carcass weight represented as lean meat; TNB = total of live born and stillborn pigs; conformation points = score for soundness and body conformation on a 1 to 5 scale; and pH = pH measurement taken within the loin muscle 24 h after slaughter.

Table 9. Rates of inbreeding within Danish nucleus herds over five generations

Breed	Total inbreeding, %	Average change per generation, %	Average change per year[a], %
Landrace	3.7	0.74	0.53
Yorkshire	1.9	0.38	0.27
Duroc	3.5	0.7	0.5
Hampshire	3.7	0.74	0.53

[a] Generation interval = 1.4 yr.