

# Working with Variance: Hassle or Help in Developing Breeding Management Programs

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## ■ Introduction

The demands of particular markets for pork products will likely result in specific genotypes, managed in specific production systems, becoming the norm in our industry. Among the advantages of adopting such a strategy would be a minimal lag time in bringing the best genetics to the production level, minimal biosecurity risks, and great uniformity of production generation pigs. By comparison, present systems involving selection at nucleus level, and the transfer of these genetics through existing multiplication systems to the production level, are logistically more difficult, involve much greater genetic lag and biosecurity risks, and produce much greater variability at production level. We have also known for many years that the environment (nutrition, housing, welfare, health status, etc) limits the extent to which the genetic merit of the dam and sire are expressed in the phenotypic characteristics of their offspring (the "G x E" interaction). Collectively, these environmental effects create the enormous variation in performance that is evident in existing breeding herds and their progeny. The first purpose of this presentation is to identify the variance that exists in our breeding herds and the possible origin of this variability. Ways of addressing this variability in breeding populations to build better breeding management programs will then be considered, accepting that variability may be both a "help" and a "hassle" in achieving this goal.

In the area of breeding herd management, standardized production flow and maximized output are still major drivers of management decisions, with little time or effort apparently spent in considering the true economics of alternative production systems. We already have the technology and knowledge to adopt several different strategies for improving breeding herd performance, yet decisions about a particular component of the breeding program often seem to be taken in isolation, and not as part of an integrated economic analysis of the potential benefits of implementing changes. Such analysis would be very

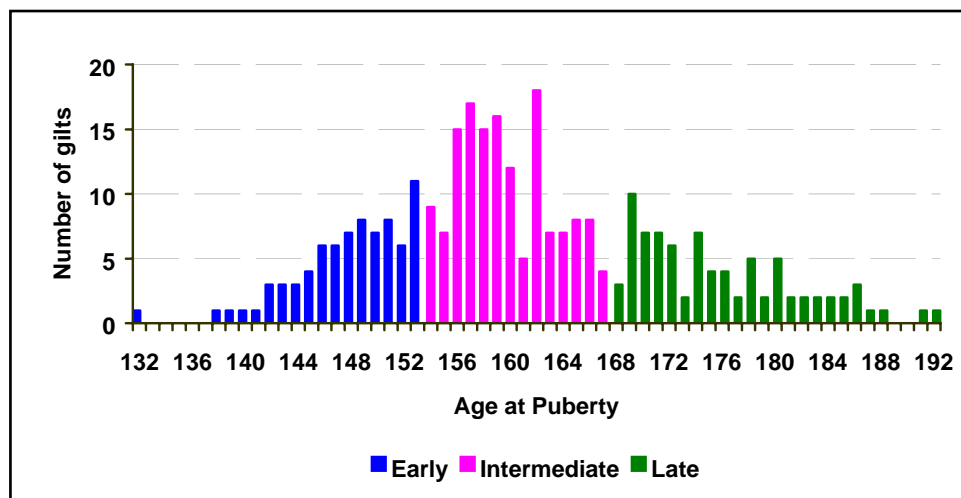
valuable, not only to guide the development of optimal production systems, but also to help direct R & D activity into the most meaningful directions from an industry perspective.

## ■ Aspects of Replacement Gilt Management

### Growth and Nutrition

Growth is not usually a constraint to sexual development of replacement gilts. In existing commercial, dam-line, genotypes there is virtually no relationship between growth rates in gilts (0.55 to over 0.8 kg per day from birth to selection for entry to the gilt pool) and the age (130 to 200 days) at which gilts can exhibit first estrus if provided direct contact with mature boars at an early age (Figure 1). However, when we consider the growth performance of potential replacement gilts, there are three important aspects of variation that need consideration.

**Figure 1. Number of gilts per day showing pubertal estrus after stimulation with direct boar contact from approximately 140 days of age and 100kg body weight. (Prairie Swine Research Centre, University of Alberta Swine Research & Technology Centre; unpublished data, 2002)**



### *Variation among genotypes in terms of tissue deposition*

It seems that the selection of existing lean dam-line females has resulted in a much more labile fat depots, that may be harder to increase during gilt development, but are also fairly resistant to change during lactation. In recent studies in the literature, a major focus has developed on the importance of the protein mass of the sow as the primary factor in lactation performance and post-weaning fertility. In these experiments, major changes in protein mass during lactation, imposed by different nutritional regimens, and closely linked to fertility of the sow after weaning, are associated with non-significant changes in backfat (**Table 1**). From the perspective of the metabolic regulation of the reproductive axis, this immediately begs the question as to whether fat mobilization is an important regulator of sow fertility.

**Table 1. Sow and nutrient variables in first-parity sows that lost a low, moderate, or high amount of body protein during lactation (From Clowes et al., 2003a)**

| Sow lactation intake: | Protein Loss in Lactation |                          |                          | P     |
|-----------------------|---------------------------|--------------------------|--------------------------|-------|
|                       | Low                       | Moderate                 | High                     |       |
| Feed, kg/d            | 4.49 ± 0.14 <sup>a</sup>  | 4.33 ± 0.14              | 4.03 ± 0.13              | 0.103 |
| Energy, MJ ME/d       | 63.7 ± 1.93               | 61.0 ± 2.01              | 56.9 ± 1.91              | 0.089 |
| CP, g/d               | 878 ± 19 <sup>z</sup>     | 647 ± 19 <sup>y</sup>    | 491 ± 18 <sup>x</sup>    | 0.001 |
| Lysine, g/d           | 50.2 ± 1.06 <sup>z</sup>  | 34.6 ± 1.10 <sup>y</sup> | 24.2 ± 1.04 <sup>x</sup> | 0.001 |
| <b>Weight, kg:</b>    |                           |                          |                          |       |
| Farrow                | 195 ± 3.6                 | 197 ± 3.8                | 200 ± 3.4                | 0.516 |
| Loss in lactation     | 12.9 ± 2.3 <sup>x</sup>   | 16.9 ± 2.4 <sup>x</sup>  | 28.4 ± 2.1 <sup>y</sup>  | 0.001 |
| <b>Backfat, mm:</b>   |                           |                          |                          |       |
| Farrow                | 15.4 ± 1.18               | 15.0 ± 1.24              | 16.3 ± 1.10              | 0.712 |
| Loss in lactation     | 0.89 ± 0.32               | 1.45 ± 0.34              | 1.57 ± 0.30              | 0.340 |

<sup>a</sup> Least-square means ± standard error of the mean

<sup>xyz</sup> Within a row, means without a common superscript letter differ by the significance level in that row.

If these observations lead to the conclusion that lean tissue mass is the most critical determinant of sow fertility, and protein mass changes much more dramatically than body fat during lactation, this raises several questions.

- Irrespective of protein mass, what minimal level of body fat (or fatness) is still needed for good reproductive performance, and to provide the necessary physical protection to the sow to prevent culling for lameness and injury?
- If high, unrestricted, growth rates in gilts produce overweight animals at breeding, yet these animals are still deficient in body fat, how do we address this problem?
  - through extremes of nutritional management
  - through use of a more appropriate dam-line

### *Variation in protein mass at breeding*

Recent data from well-controlled sow studies suggest that increased protein mass at farrowing can be protective against the loss of protein mass that is still seen in many genotypes during the first lactation (see **Table 2**).

**Table 2. Body weight and back fat loss, and reproductive characteristics, at weaning in first-parity sows that had a standard or high body mass at parturition and lost a moderate amount of protein during lactation (after Clowes et al., 2003b)**

| Parturition Body Mass (PM)                                 | Standard<br>(165 kg) | High<br>(193 kg) | Significance |
|--|----------------------|------------------|--------------|
| B. Wt. Loss (kg)   | 17.6 ± 2.2           | 21.3 ± 2.4       | <0.05        |
| Backfat loss (mm)  | 4.6 ± 0.8            | 5.7 ± 0.9        | NS           |
| Uterine weight, kg   | 0.22 ± 0.02          | 0.30 ± 0.02      | 0.06         |
| % follicles ≤ 3.5mm diameter                               | 61.4                 | 41.7             | <0.05        |
| Diam. (mm) largest 16 follicles                            | 3.3 ± 0.26           | 3.9 ± 0.27       | 0.06         |
| Foll. fluid E <sub>2</sub> (ng/mL) largest<br>16 follicles | 0.29 ± 0.10          | 0.65 ± 0.10      | <0.05        |

Values are Least-square mean ± standard error of the mean.

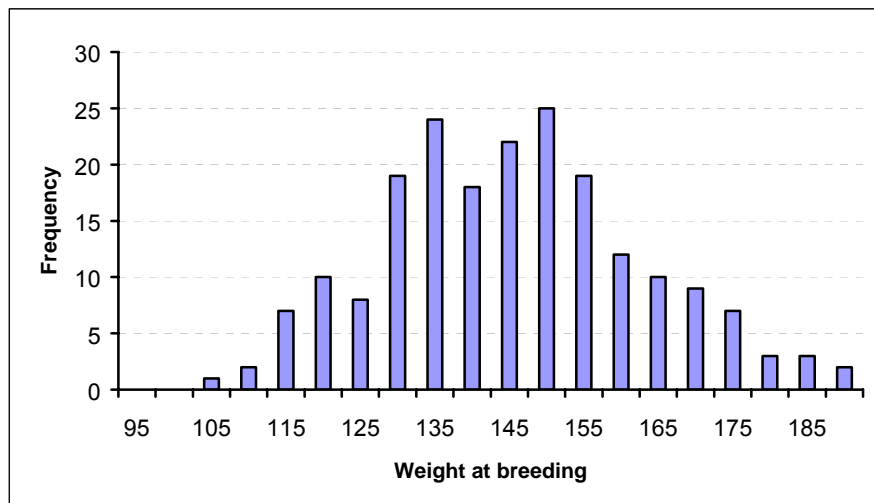
It is unclear where the threshold for this protective protein mass lies, but a body weight at farrowing of 175 kg or greater may emerge as the possible recommendation. Assuming that the targeted weight gain during the first

gestation will be 35-40kg, this sets targeted breeding weights at around 135-140kg. Given the achievable growth rates of contemporary dam-line gilts, this range of body weight at breeding can be easily achieved, especially if we generally aim to breed gilts at second estrus in well-managed gilt conditioning programs. Generally, we must move towards much better, genotype-specific, recommendations for the appropriate body state of gilts at breeding and farrowing, taking account of expected feed intake and milk production in lactation. But we must also try and reduce variability in protein mass as a key driver of lactation and post-weaning performance.

### *How do we manage the variation in growth performance.*

Our most recent data from a study of gilt development under typical commercial conditions suggest that the variability in growth rate is a major problem in standardizing the pool of bred gilts that enter production units. In this study gilts were only selected for breeding if they showed a pubertal response to boar stimulation within 40 days, starting at 140 days of age. They were then bred at third heat after being moved to production units during their first cycle. Weights at first estrus ranged from less than 90, to over 140kg, and at breeding the range of weight (98 to 186 kg) and backfat (8 to 24 mm) was even more extreme (**Figure 2**).

**Figure 2.** Range of breeding weights in gilts first stimulated with direct boar contact at 140 d of age and bred at third estrus. (Patterson et al., 2002, unpublished data)



In a previous study in which we attempted to slow growth in gilts with high fibre diets from 50 kg until puberty induction (Patterson et al., 2002), we had very little impact on bodyweight at first estrus. However, experience in commercial practice suggests that modified "conditioning" diets can have an impact on body fat stores in lean gilts. We have also explored the possibility that by inducing early pubertal estrus using direct contact with boars, we might slow down subsequent growth compared to un-stimulated littermates. Although boar exposure in this study decreased age at first estrus by some 15 days, we have been unable to establish any effect on subsequent growth (Willis et al., 2002, unpublished data).

These results suggest that there is a need to identify and manage the variation in gilt growth and development from an early age.

- We believe that both high and low extremes of body weight at breeding will result in sows being culled from the breeding herd early in their productive life.

To overcome the problems caused by variation in growth rate in gilts, it may be essential to sort gilts by weight and growth performance at an early stage, and then use specific nutrition and management programs to bring different categories of gilts to a more uniform condition at breeding. The techniques and facility design needed to achieve this with minimal additional labor must be addressed. ***However, a need to weigh and directly measure tissue composition in gilts at some point in the development program seems unavoidable.***

It is also possible to reduce the range of breeding weights by adopting flexible recommendations for the estrus at which gilts are to be bred.

- Heavier and faster growing gilts that mature late will be bred at first estrus
- For slower growing and leaner gilts that cycle early, breeding may need to be delayed until third or even fourth estrus.

However, even if these adjustments are made, the variation in growth performance during the following gestation period will also need to be considered to try and reduce the variability in weight at farrowing. The benefits of such programs will be a higher retention rate of gilts in the breeding herd and less variable reproductive performance after weaning the first litter. This approach should also minimize "Entry-to-first-service" intervals.

## ■ Variation in sexual maturation as a "selection" criterion for replacement gilts

It is definitely possible to take advantage of the inherent variability in contemporary gilt pools to produce more uniform, and higher quality, production females. All the data published in the last twenty years indicate that age at first estrus is normally distributed when growth restriction is not a concern. The full extent of this variation in age at first estrus is most apparent if gilts are exposed to boar stimuli at an early age (say 140 days as in the study presented in Figure 1). Even when stimulation is delayed to 160 or even 180 days, it is always possible to identify a proportion of 10 to 20% of gilts that do not respond to boar stimuli within a set period of time (say 20, 30 or 40 days). In the study for which data are presented in Figure 2, 63% of the gilts were recorded as showing standing estrus within 30 days, and 79% within 40 days, of initial boar contact starting at 140 days.

There are sound biological reasons, and increasing amounts of production data, to support the suggestion that late maturing gilts will have reduced lifetime fertility.

- This leads to the obvious suggestion that response to a standardized protocol of boar stimulation can be used to identify the 75-80% of gilts that are likely to be most fertile.

Although there is nothing preventing us from taking this step forward in reproductive management, a major problem is the high body weight of "non-select" gilts if puberty induction starts at a late age.

- For this reason, early stimulation with mature boars is recommended to avoid the economic penalty of culling non-select gilts from the gilt pool.

Even in the system of early puberty induction used in our most recent studies, 82% of the gilts that were still non-cyclic by 180 days of age, were already above market weight. There would, therefore, still be a financial penalty to culling these gilts. However, retention of these gilts within the herd would;

- incur costs of unknown numbers of additional non-productive days
- represent less efficient use of pen space within the gilt pool
- still not guarantee that gilts would eventually cycle

Also, remember, even if these gilts were bred, their expected fertility would be low. Given these concerns, it seems preferable to use relatively early stimulation with boars as an effective technique for identifying the most reproductively "fit" replacements, whilst avoiding the financial penalty of adopting this more rigorous "selection" procedure.

## ■ Variability in lactating and weaned sows

The metabolic demands of lactation in the context of the tissue reserves needed by the first parity sow as she enters lactation have already been discussed. The solution to the problem of depressed fertility after weaning the first litter will probably largely be addressed by 1), decreasing the variability in the body state of sows as they enter lactation, and 2), using genetic selection and further advances in sow nutrition to meet the nutrient demands of lactation from adequate nutrient intake. However, a further challenge will still be to reduce the variability in reproductive performance after weaning to the point that all sows will be successfully re-bred within a five-day period. This does not suggest that this 5-day period will necessarily be day 1 to day 5 after weaning. Part of the problem with variable reproductive performance in weaned sows lies in the population of sows that are either showing estrus before weaning, or initiating the growth of potential pre-ovulatory follicles very close to weaning. Although this results in a minimal weaning-to-estrus interval, there is evidence that these follicles may not be optimally mature at the time of ovulation. As a result, the earliest returning sows do not necessarily show the highest fertility

A practical method of reducing variability in ovarian development in the weaned sow requires further study. However, with the application of new techniques of molecular genetics (such as micro-array analysis) and large-scale proteomic analysis of the regulators of ovarian follicular development, it is likely that our understanding of the key regulators of follicular development in the sow will rapidly advance. Such studies are already in progress at the Swine Research & Technology Centre. Combined with the extensive use of ultrasonography to track the complex dynamics of follicular growth in the sow, this will enable us to evaluate production and other techniques, aimed at standardizing the pattern of ovarian follicular development immediately before weaning. If this can be achieved, there would be an immediate improvement in the synchrony with which sows return to estrus after weaning and in the fertility of the sows bred during this period.

The pattern of follicular development observed during lactation reflects the pattern of gonadotrophin secretion. A number of large ovarian follicles may be present immediately after farrowing but a week later follicular development is minimal. Then, as lactation progresses there is a gradual increase in the number of medium- to large-sized follicles. This gradual increase in ovarian follicular development is related to the gradual decline in the inhibitory effects of suckling, related to a gradual increase in the interval between suckling episodes in later lactation.

- This is why manipulation of litter size before weaning (split-weaning) can be an effective management tool for increasing ovarian development at final weaning, and consequently, sow fertility.

Because the gonadotrophin response to split weaning is transient, it has been suggested that split weaning should only occur 2 to 3 days before final weaning. However, we believe this recommendation needs further evaluation, and any period of reduced suckling input may give beneficial results. Further research on split-weaning strategies is a focus of current collaborative studies between the University of Alberta and Prairie Swine Centre.

In addition to the effects of suckling *per se*, the pattern of follicular development in lactation is very sensitive to effects of catabolism, as shown in a number of experiments (Zak et al., 1997; Yang et al., 2000; Clowes et al., 2003a,b). Because of this, inadequate voluntary feed intake during lactation in first parity sows is still a major problem.

- In particular, differences in metabolic state of sows of different parities emphasizes the need to consider different management strategies for primiparous, as compared to multiparous, sows.

It is imperative to understand the characteristics of individual genotypes in the farm environment in order to make informed decisions about the management of the early-weaned sow. It appears that once a sow mobilizes more than around 10% of her protein reserves at farrowing, there will be negative effects on the reproductive system, resulting in fewer and poorer quality ovarian follicles at weaning. As discussed earlier, initial data also suggest that there may be an interaction between size at farrowing and the amount of tissue that can be mobilized before milk production and fertility is affected, particularly at the lower end of farrowing weights (150 – 180kg) and when excessive weight loss (more than 10 to 15% of farrowing weight) is present.

- Although more information is needed on this subject, we should aim to have management systems in place that would avoid both the factors that would drive sows over the threshold in terms of excessive tissue loss in lactation.

### **Reproductive status after weaning**

Variability in the weaning-to-estrus interval is a major problem in sows breeding management. Extensive delays the onset of estrus increase non-productive days. Variation in WEI makes it difficult to meet breeding targets and to concentrate breeding management into defined periods. In recent years, work from The Netherlands has focused attention on the relationship between onset of estrus, estrus duration and the timing of ovulation. Key factors that have been identified are;

- ability to detect standing heat and estimates of heat duration vary greatly between farms
- ovulation occurs approximately 70% of the way through the estrous period
- WEI and estrus duration are inversely related

Based on this information it is recommended that farms should obtain information about estrus duration in their weaned sows and use this information to develop specific breeding strategies. However, in general, breeding should be delayed in early returning sows (Monday, Tuesday, Wednesday sows in a Thursday weaning program) but should take place as soon as estrus is detected in later returning (Thursday, Friday and weekend) sows. This will give the best chance of mating in the optimal 12-20 hour period before ovulation.

In other words, as with many of the issues discussed in this paper, ***having reliable data on existing variability in particular production systems is the first essential step to finding ways to manage this variability.***

### **Management options for reducing variability in post-weaning fertility**

First, we must define the response of particular genotypes to particular patterns of management, and in particular the response to early weaning. Only then can we make sensible suggestions about strategies to improve weaned sow fertility. However, it is likely that in all genotypes, early weaning will result in some increase in the WEI, and WEI will be more variable. Additionally, most primiparous sows will show reduced fertility in terms of conception rate and litter size. Depending on the genotype and its response to early weaning, this may be associated with increased early embryonic mortality after weaning, a decrease in ovulation rate, or both. Therefore, an imposed delay in the return to estrus would be expected to improve fertility after weaning early. The extra non-productive days, and slight decrease in litters/sow/year, may be more than offset by an increase in litter size born. Several options exist:

- The impressive response of primiparous sows to “skip-a -heat” breeding, even at the expense of 21 non-productive days, may be financially justified
- If sows show an extended, but predictable, weaning-to-estrous interval, then the best option may be to simply breed at this estrus and accept that fertility may be reduced compared to higher parity sows
- If there is either an unacceptable increase in the weaning-to-estrous interval, or problems with variability, then treatment with PG600 at, or on the day after weaning, can be effective in increasing the number of sows bred by a specific target day
- If an inconsistent pattern of weaning-to-service intervals disrupts breeding programs, or if a delay to first breeding is needed to enhance overall fertility or move sows to a different breeding week, then another

strategy is to feed sows Regumate from the day of weaning until 5 days before sows are required to be bred. This will block the onset of estrus and provide good heat synchrony after withdrawal.

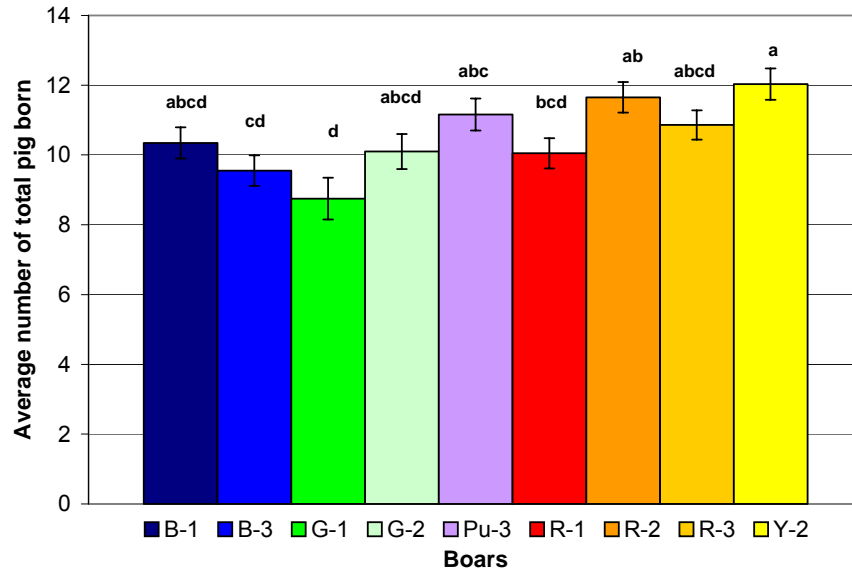
- In all early weaned situations, producers should consider the potential advantages of enhancing fertility with split weaning. The number of days over which to reduce litter size before final weaning needs evaluation in each management system.
- Innovative management protocols involving both split-weaning and Regumate treatment may also provide benefits in terms of both synchrony in the breeding week and improvements in fertility due to an imposed increase in the WEI.

Finally, producers should always try and design their breeding barns to take advantage of the stimulatory effect of boars and high feed (energy) intake from weaning to re-breeding on subsequent fertility. As the boars are likely present anyway, it makes good sense to design facilities to take advantage of this extra contribution to breeding herd performance.

### ■ **Variability in Boar Fertility.**

A number of laboratories have published good evidence to suggest that selection of AI boars can be substantially improved. Dr. Billy Flowers and his colleagues have provided evidence that "dominant" boars can be identified that have superior performance in competitive insemination programs, even though they could not be identified as being superior by routine laboratory analysis of sperm motility and morphology. Our own group has produced similar data by comparing boars on the basis of proven fertility when using relatively low sperm numbers for AI (**Figure 3**). Our data suggests that 10-20% of boars identified as being fertile by existing techniques, may be sub-fertile if low sperm numbers are used for AI. We can assume that even with higher sperm numbers per AI dose, the performance of these boars will be a problem if breeding conditions are not ideal. Although the relatively lower performance of these boars may be masked by the use of pooled semen, there is little purpose in covering the maintenance and collection costs of these boars if they are not contributing to the production of progeny.

**Figure 3. Total born per litter size for for nine boars based on at least 50 breedings per boar using 1.5 billion sperm per AI dose over a four-month period. LSM ( $\pm$ SEM) with different letters are significantly different ( $P < 0.05$ ). Boar G-1 was identified as being consistently less fertile.**



- If we wish to move towards the use of lower sperm numbers and less inseminations, we must identify the most fertile boars in our populations as part of this process.

Our recent data suggest that it will be possible to develop fertility evaluation protocols that could involve as few as 20 single-boar matings during the training and early collection period and that reliable data on the predicted fertility of these boars could be available by day 30 of gestation. Several groups also continue to look for other markers of boar fertility and semen quality that would be even more immediately available in production units. Preliminary results indicate that analysis of the protein profile of seminal plasma may be one such approach.

### **Reducing the number of sperm per insemination**

Reducing sperm number per insemination would be a key factor in producing more breedings per boar per year and thus allowing a reduction in the number of boars maintained at stud. This has obvious advantages in terms of efficiency in boar stud management, but is unlikely to have a major impact on the semen cost allocated per bred female. This is particularly true if the boar stud is an

independent unit selling semen to a variety of commercial producers. ***However, if the reduction in the number of boars at stud is associated with a proportional increase in the genetic merit of these boars for important production and carcass traits, then there is a major economic benefit to the whole production chain.***

Clearly, variability in boar fertility and semen quality exists. Reducing this variability will help in meeting regular production targets, will reduce days to market and feed conversion efficiency in terminal line offspring, and will increase the genetic value of the carcass sold.

## ■ Closing Comments

Variability exists in all aspects of the breeding herd. Generally, it is a paradox that the very variation that we rely on to make genetic progress at the nucleus level, produces major challenges in efficient production at the commercial level. Variability can be both a "help" and a "hassle" in developing effective breeding programs. However, by measuring and working with variability, it is possible that the advantages can outweigh the disadvantages and modified breeding management programs can bring a benefit to the whole production chain. However, the overall economic benefits of adopting more innovative breeding management strategies need to be clearly established.

## ■ Acknowledgements

The financial and in-kind support of the research reported in this paper from the Natural Sciences and Engineering Research Council, the Canada Research Chairs Program, Alberta Agricultural Research Institute, Alberta Pork, Sask Pork, Saskatchewan ADF, Genex Swine Group, PIC Canada Ltd. and Alberta Swine Genetics Corporation is acknowledged.

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