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Recognizing the characteristics of our new dam lines

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Introduction

It is possible to set ambitious benchmarks for breeding herd performance using available commercial dam-line females. With attention to good gilt management, excellent lifetime performance of sows in the breeding herd is achievable. However, these targets can only be achieved by recognizing the key physiological characteristics of contemporary dam-line females, and particularly their exceptional lean growth potential. By controlling body condition (particularly overall body mass rather than "fatness") and relative sexual maturity, producers can maximize first litter performance of gilts and improve their lifetime performance as mature sows in the breeding herd.

One of the great failures of the North American pork production industry has been an inability to capture the true production potential of the excellent dam-lines already available. Perhaps the most disappointing aspect of these inefficiencies is that they represent cost/benefit advantages that could be captured at the primary production level. To correct these deficiencies, appropriate and achievable key performance indicators (KPI) should drive breeding herd management. These KPI should relate closely to known characteristics of commercial dam-line sows, and be both measurable and economically meaningful.

Defining "optimal" as opposed to "maximal" sow productivity when considering the characteristics of available dam-lines

"Maximal sow productivity" is still usually defined as the number of pigs weaned per sow per year, and considerable attention is presently being paid to the goal of "30 pigs weaned per sow per year" as the benchmark of modern breeding herd productivity. However, in an industry that is likely to increasingly focus on, 1) product quality, and 2) the constraints that welfare and environmental issues will place on pork producers, the quality and cost of producing each kg of product sold, as well as the total number of weaned pigs, needs to be considered when determining the best economic returns from the sow breeding farm.

The real or perceived impacts of pork production on the environment are an increasing challenge to the industry. Therefore, an approach to measuring the environmental impact of production systems, in addition to more traditional measures of production efficiency and growth performance, challenges us to adopt a totally integrated approach to measuring the relative efficiency of food-animal production. The ultimate measure of annual sow productivity should ultimately reflect the margin between 1) total production costs + environmental costs incurred by the sow and her litters, and 2) revenues received for total kilos of product marketed from that sow. Environmental costs would include a measure of the land footprint needed for production, recognizing both efficiency of nutrient utilization (land area for feed production, plus land area, or alternative handling costs, of incorporation manure based nutrients and food-animal processing wastes into arable land with zero impact of the environment. The implementation of processes for recycling water and using manure digesters for production of "green" energy, represent future opportunities for offsetting the costs of pork production. If such advances in production efficiency can be implemented, and audited in pork production chains that allow full traceability at retail level, this would allow more efficient pork production enterprises to be differentiated from the larger scale, more commodity-based and "less environmentally friendly" production systems, with which they compete in the retail (export) market.

Given this integrated view of "optimized" pork production which is likely to become increasingly important in pork production systems in the future, the characteristics of dam-line females that are associated with high numbers of weaned pigs per year, must be weighed against their ability to produce terminal line offspring that have high feed conversion efficiencies and high quality carcasses that will attract premium prices (or avoid packer discounts). Consistency in both the number and quality of weaned pig produced over the sow's productive lifetime may therefore offer the best economic returns and simplest management systems in the long-term. Conversely, the use of extremely prolific dam-lines that may produce more total weaned pigs per lifetime, but increase the cost of product sold due to increased variability in weaned pig performance, may not be the optimal choice in future pork production systems.

When comparing the characteristics of available commercial dam-line sows, it is often unclear whether standard measures of sow productivity are being offered for comparison. In some cases the count of gilt NPD can be extremely low and it appears that age at first service is taken as the day the gilt is placed on the breeding farm inventory. In other words, the entry-to-service interval (ESI) is entered as zero days, and the gilt NPD only includes the cost of returns to estrus after first service and gilts that fail to farrow. In other cases, it is often unclear what NPD contribution is included for gilts never bred, but moved to the sow farms and on in our opinion on inventory. Statements that more than 95% of all gilts arriving at the farms are eventually routinely bred, seems to be inconsistent with some of the counts of gilt NPD provided and real-life experience of the high NPD costs of not identifying truly "select" gilts before entry to the breeding herd. Objective estimates of gilt NPD should include an ESI that is counted from the day that gilts in a finishing system would, on average, exceed optimum market weight (around 170 days in Canada, and perhaps 185 days in the USA finished-pig market). The count of NPD must include days accumulated by gilts entered but never bred.

Defining measurable and meaningful indicators of breeding herd performance?

Given the above comments, the key indicators of breeding herd performance need to be carefully defined, and should reflect the most meaningful measures in terms of overall economic performance. Our producers are trying to make money, and should not be encouraged to see a simplistic measure of productivity like maximal numbers of pigs produced, at any cost, as a worthwhile goal. If a production system is not fully integrated, the terms of contracts at each level of the production chain should reflect the value of the pigs produced. Indeed, recognition of the need for a correct balance between the quality and the number of weaned pigs produced is not always apparent in the contracts agreed. Consequently, this is often also not reflected in the priorities given to improving breeding herd performance. In terms of producing a reliable supply of weaned pigs at the critical nursery stage of production, the most important breeding herd key performance indicators (KPI) are probably; 1) uniform numbers of pigs weaned per week, 2) the weight and age of the pigs weaned, and 3) the least variation possible in age and weight at weaning. In turn, if properly rewarded, these KPIs determine the key factors that will be the focus of the breeding herd. As has been repeatedly emphasized in the assessment of key determinants of the number of pigs born and weaned per week, the single biggest factor needing attention is meeting breeding targets, with the second largest risk factor being farrowing rate. As shown in **Table 1**, these factors far outweigh the impact of achieving overall increases in the number of pigs born/litter, or variations in pre-weaning mortality. Thus, the primary focus of the breeding herd should be identifying the gilts and sows available on a weekly basis to meet projected breeding targets and to improving the breeding management of these gilts and sows.

Table 1: The relative importance (%) of different components of breeding herd efficiency for achieving a uniform weaned pig flow to the nursery (after Dial, 2002).

Component of breeding herd efficiency	%
Number of sows served	60
Farrowing rate	30
Number born alive per litter	5
Mortality of pigs born alive	5

In the "push" concept of breeding herd management, a focus on establishing a well managed Gilt Development Unit (GDU) ensures a constant supply of gilts per week, and at the same time improves breeding management within the GDU. A constant input of high quality gilts into the breeding herd, with increased longevity, in turn stabilizes the parity structure of the breeding herd. This helps in preventing the somewhat erratic contribution that weaned sows are often seen to make to weekly breeding targets. A constant input of "select" gilts to the breeding herd also prevents the tendency for a reduction in the voluntary culling of sows to achieve weekly breeding targets. All these factors will prevent breeding farms from entering the "death spiral" that is frequently seen in many of our larger production systems (Williams et al., 2005).

The key management practices that will best serve our industry, and the characteristics of the dam-lines that best suit these practices, will be the focus of the rest of this discussion.

Understanding the phenotype of commercial dam-line sows

The major changes in the lean growth potential, and associated changes in the overall tissue metabolism of contemporary dam-line sows is not adequately recognized. Compared to selection for reproductive merit, the much greater heritability of growth traits has resulted in improvements lean growth performance in terminal line pigs that is the very basis of a competitive pork production industry in world meat markets. Inevitably, existing dam-lines carry these same traits to a greater or lesser degree. In the major dam-lines used in contemporary pork production in North America, inadequate attention is paid to the changes in basic sow metabolism resulting from this increased potential for lean tissue deposition and an associated lack of fatness in our current dam-lines. Traditional management practices that were established even 20 years ago need to be re-evaluated, if we are to capture the full economic potential of the modern breeding sow and her offspring, in terms of greatly improved nutrient utilization.

In terms of the threshold growth rates needed to sure that growth rate per se is not limiting the onset of sexual maturation in the gilt, the earlier data of Beltranena et al. (1991) suggested that only when growth rate was below 0.55kg/day from birth to onset of boar stimulation at 160 days of age, was there any delay in onset of pubertal estrus (**Figure 1**).

The more recent data presented in **Figure 2**, from a study of Genex grandparent females and their F1 progeny at the University of Alberta, support these conclusions. This leads to the generalization that with unrestricted feeding during the grow/finish phase, and recommended space allocations to gilts during development, it is unlikely that growth rate in commercial dam-line gilts will limit age at the onset of first estrus. Furthermore, the data in **Figure 2** emphasize that age at first estrus is very largely dependent on the age at which effective stimulation with boar pheromones and direct boar contact is applied. Recent comments that pubertal estrus is occurring at older ages in today's commercial dam-lines seems to us to have little substance, unless of course boar stimulation is delayed.

Figure 1: Relationship between growth rate and age at pubertal estrus in gilts first stimulated with boars at 140 days of age. (After Beltranena et al., 1991). Feed restriction in gilts achieving a lower growth rate was associated with a delay in the onset of puberty.

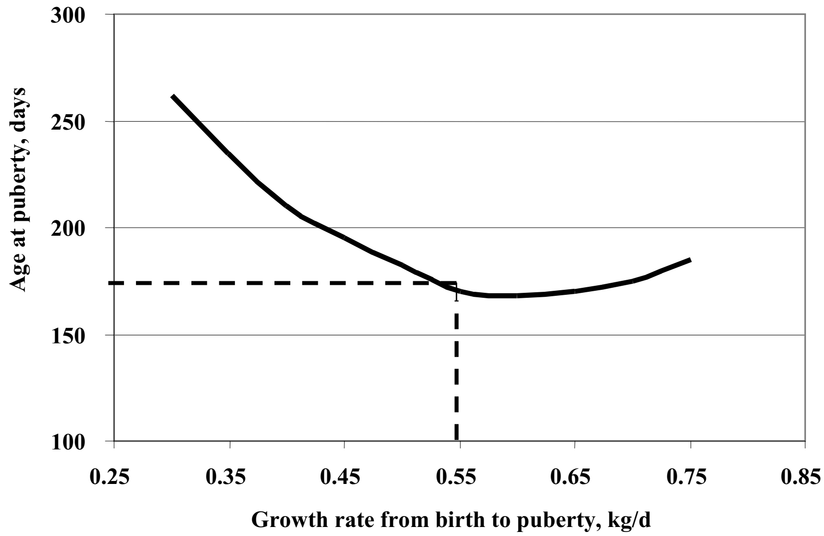
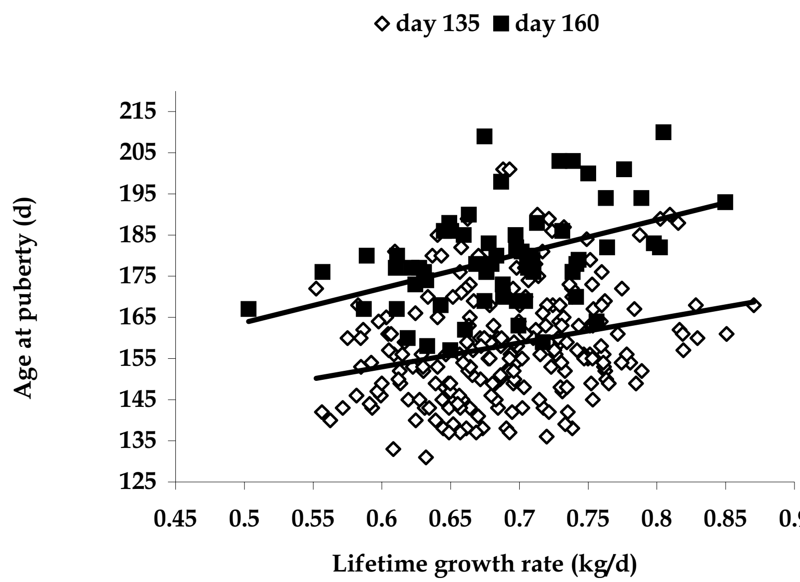


Figure 2: Effect of puberty stimulation in the gilt commencing either at 160 d (Closed squares; _) or 135 d (Open diamonds;) of age. Both sets of data indicate that the highest growth rates achieved by feeding gilts ad libitum with diets aimed to maximize lean growth potential may result in a delay in the onset of first estrus (Data from Patterson, 2001).



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The true distribution of age at first estrus is clearly evident when one re-plots the data in **Figure 2** for the F1 gilts that were first exposed to boar contact at 135 days of age, as in **Figure 3**. Age at pubertal estrus is now seen to almost normally distributed, with some gilts reaching puberty within days of first boar contact, whilst other gilts may only not show pubertal estrus after 50 days of continuous boar contact. However, the data in **Figure 3** seem to support the curvilinear "best fit" to the data shown in **Figure 1**, suggesting a tendency for the highest growth rates to be associated with a marginal delay in pubertal estrus. This may be problematic, in that late maturing and fast growing gilts may become overweight by the time they are bred, and as discussed later, this is one of the major risk factors for poor retention in the breeding herd (Williams et al., 2005).

Finally, data from another dam-line genotype shown in **Figure 4** reinforces the view that growth performance of most commercial dam-line gilts is unlikely to place any constraint on the age at pubertal estrus, and that pubertal estrus can still be induced at a relatively early age with good boar stimulation.

The data in **Figure 4** show comparable data from a gilt re-population study conducted in collaboration with the Prairie Swine Centre Inc., involving PIC Camborough 22 gilts, provided good boar contact from a pen average of 140 days. These data also serve to demonstrate the total

Figure 3: Normal distribution of age at first recorded heat (pubertal estrus) in Genex F1 gilts provided good boar contact from 135 days of age (Data from Patterson, 2002).

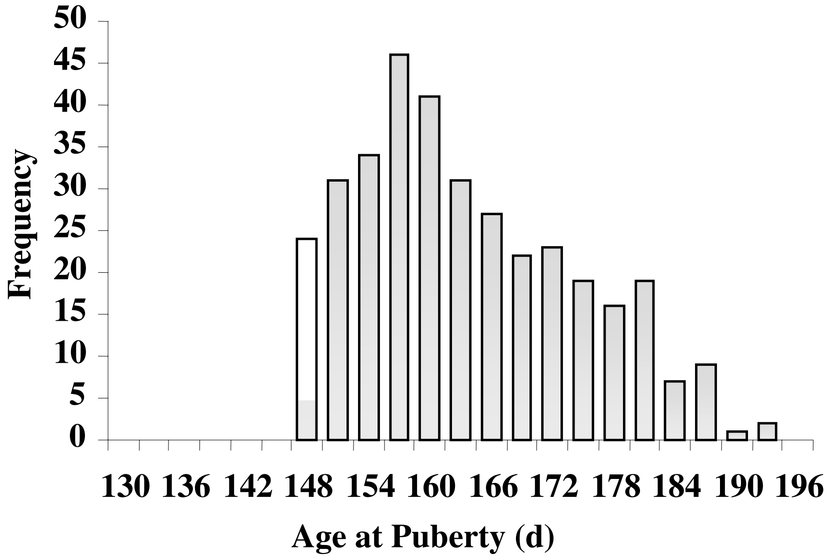
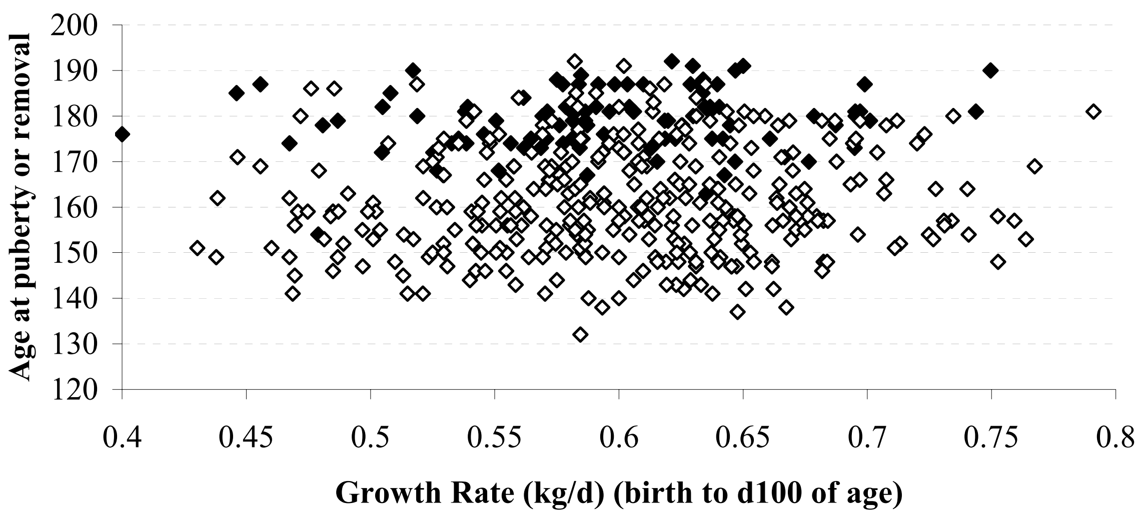


Figure 4: Relationship between growth rate and age at puberty in response to daily boar stimulation from 140 days of age (open diamonds). Gilts not recorded in estrus by 180 days were designated Non-Responders (closed diamonds). (Prairie Swine Centre and University of Alberta, Swine Technology and Research Centre, unpublished data, 2003).



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lack of any relationship between growth rate and the population of gilts that did, or did not, have a recorded pubertal estrus within 40 days of commencing boar stimulation.

Finally, because of the considerable variability in growth performance within a group of gilts, it is wrong for producers to assume that some arbitrary age will effectively define the physical development of gilts at stimulation or breeding. Gilt pool managers seem to ignore the enormous variation in growth rate among groups of gilts, and also the rather uncertain relationship between weight and back-fat. The extremes that were encountered at the time of first recorded estrus in the gilts that produced the data shown in **Figure 3** are shown in **Figure 5**.

The extremes of age at sexual maturity and growth rate, result in gilts with induced first estrus soon after commencing stimulation with mature boars at around 130 days of age but only a threshold growth rate of 0.64 kg/d (**Figure 5a**), compared with gilts with first recorded estrus at 189 days of age and the highest growth rates recorded at 0.80 kg/d (**Figure 5b**). These extremes result in first estrus gilts differing in body weight by as much as 73 kg. In terms of gilt conditioning for physical fitness and longevity in the breeding herd, early maturing/slower growing gilts would need to be provided with high energy "fattening" diets to achieve 135 kg body weight and at least 18 mm of back-fat at breeding. In contrast, late maturing/fast growing gilts probably need to be subjected to restrict feeding during development to prevent excessive growth being a cause of lameness and eventual culling. The unavoidable conclusion from these data is that age is not a good measure of weight or fatness, and the only way to be certain that gilts are at target weight for breeding is to weigh them!

As age at sexual maturity can also vary from 130 to over 200 days (**Figure 5c**), it is impossible to set some

Figures 5a (top) and 5b (bottom):. An illustration of the extremes of growth performance within a contemporary group of commercial dam-line gilts provided with direct boar contact from 135 days of age to stimulate onset of first estrus (Data from Patterson, 2001).

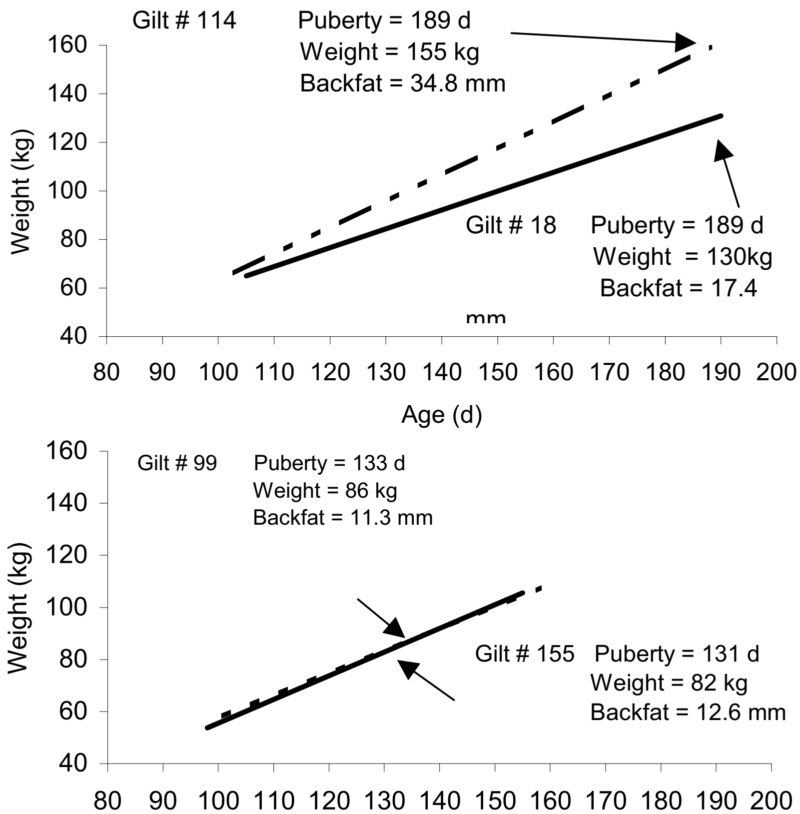


Figure 5c: Actual weight and growth rate at 140 days of age shown in relation to the observed and independent age at which pubertal estrus was observed. The number of estrus cycles needed to bring each category of gilt to a target breeding weight of 135 – m150 kg is then indicated. (Prairie Swine Centre, and University of Alberta, Swine Research & Technology Centre, unpublished data 2003).

Growth Rate (kg/d) at 140 d of Age	Weight (kg) at 140 Days of Age	Age at Puberty 160	165	170	175	180	185	190
0.50	70	143	135	138	140	143	145	148
0.55	77	146	137	140	142	145	136	139
0.60	84	146	137	140	143	146	136	139
0.65	91	145	135	138	141	144	148	137
0.70	98	141	145	148	137	141	144	148
0.75	105	136	140	143	147	135	139	143
0.80	112	145	149	136	140	144	148	152
0.85	119	136	140	145	149	153	157	162
0.90	126	144	149	153	158	162	167	171

Predicted Estrus at Breeding

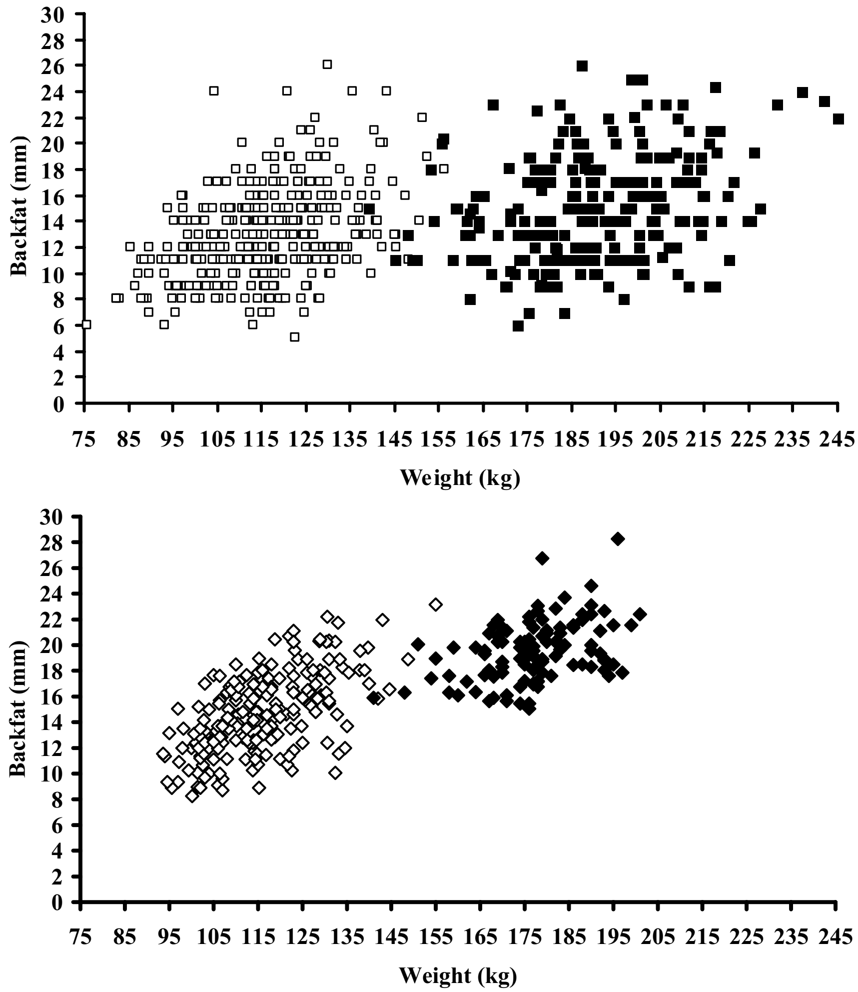
1st estrus ■ 2nd estrus ▒ 3rd estrus □ 4th estrus ▒ 5th estrus ▒ 6th estrus ▒ 7th estrus ▒

arbitrary age and assume that this defines some general level of sexual maturity. Clearly, by starting to assess whether gilts will show a standing heat in response to boar contact at over 200 days of age, there is little opportunity to determine the relative sexual maturity of individual females. The only benefit from introducing boar contact at such a late stage is the very short period over which pubertal estrus will be observed. However, very efficient boar stimulation programs can involve relatively little labor input per gilt bred, and yet increase the lifetime performance of truly "select" gilts substantially.

The lack of any reliable association between age, and onset of sexual maturity or body weight, implies that these essential benchmarks must be assessed independently in a well-managed GDU and used to allocate gilts to appropriate breeding groups. The aim should be to have gilts as sexually mature as possible before target breeding weight is reached, with the minimal requirement that breeding occurs at least at second estrus. Even excluding slower growing gilts before the start of puberty stimulation may also be cost effective, because, as shown in **Figure 6**, the number of NPD required to bring these gilts to a target breeding weight can be substantial.

Interestingly, the earlier studies of Beltranena et al. (1993) already indicated that the fatness of the gilt was unrelated to the rate of sexual maturity, and this conclusion has also been supported in subsequent experiments. Moreover, in most gilt pools, there is usually a very weak association between weight and measured back-fat, as shown in **Figures 6** to **8**. From a management perspective, simply relying on an increase in overall body weight to produce a predictable change in back-fat in all gilts, or to assume that some arbitrary age will be associated with target levels of back-fat in all gilts, is unrealistic. Equally, back-fat can in no way be interpreted as indicating the likely body weight of a replacement gilt.

Figures 6a (top) and 6b (bottom): Associated changes in sow body weight and back-fat in (a) Camborough 22 and (b) Genex gilts between breeding and farrowing. Dashed lines indicate average weight and back-fat at each time (Unpublished data, University of Alberta, 2005).



Consideration of differences among dam-lines (genotypes)

Breeding companies producing a wide variety of high index dam-line gilts, have generally failed to provide adequate data about the key performance characteristics of even major commercially used dam-lines. Based on recent collaborative studies with two major commercial dam-lines, we conclude that the phenotype of the gilts and first parity sows clearly reflects the extent to which selection for increased lean tissue gain is reflected in these terminal dam-lines. As can be seen in **Figure 6**, the level of fatness (back-fat measured at the P2 position in both cases) during gilt development tends to be different. Furthermore a maternal weight gain of 50 kg from breeding to farrowing results in a very different response in back-fat gain.

The critical question then becomes, to what extent is this relative leanness of the terminal dam-line likely to affect lifetime productivity of the sow? From

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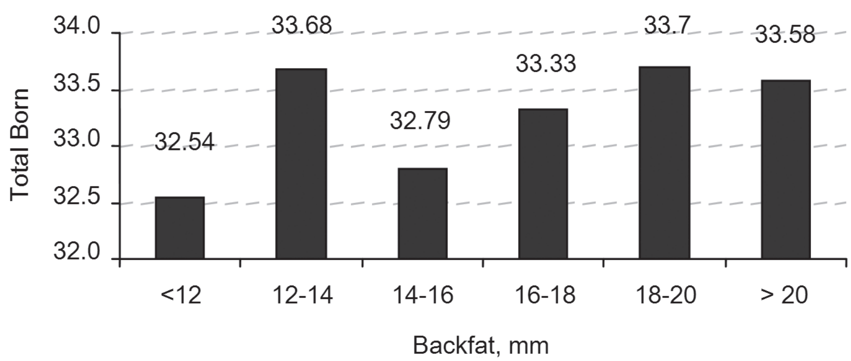
existing data, it is hard to suggest that there are any inherent differences in lifetime reproductive performance that can be ascribed to the relative fatness of the sows per se (Williams et al., 2005; **Figure 7**).

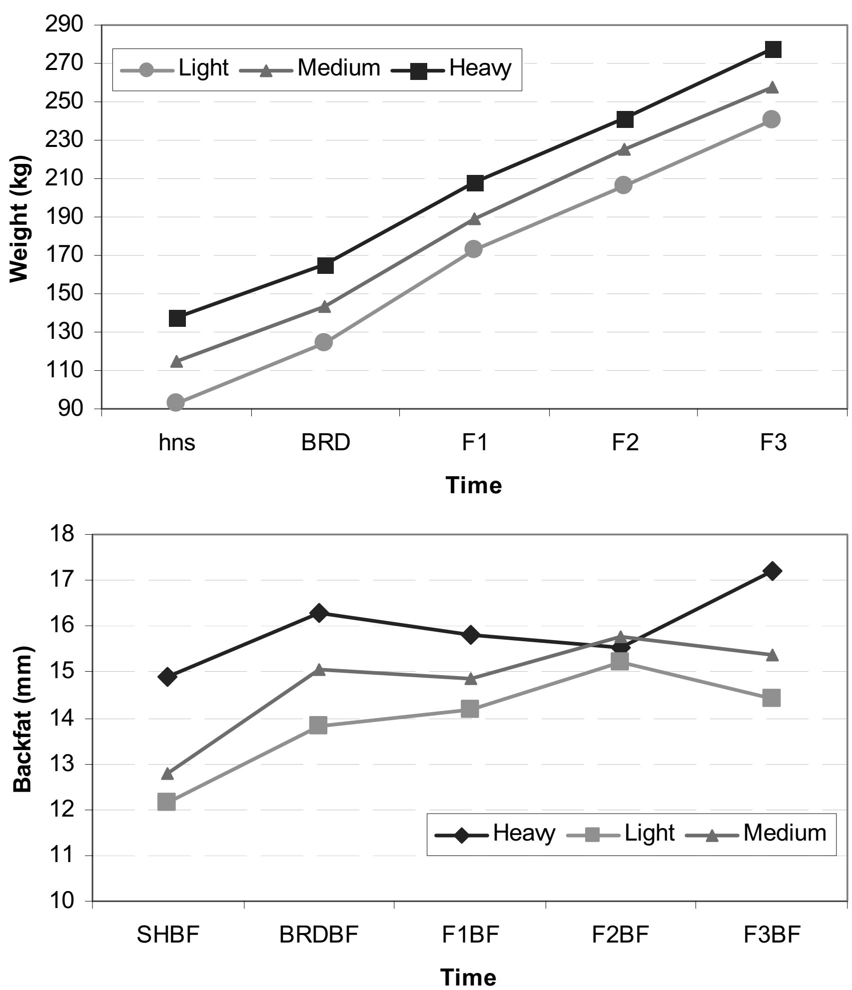
Similar data were reported for the relationship between initial breeding weight and productivity over three parities (Williams et al., 2005). The lack of a consistent relationship between overall sow body weight and back-fat thickness is also seen in data collected over three parities from the gilts shown in **Figure 6a**. The changes in sow body weight and back-fat over three successive parities, for those sows that were available to record data on each occasion are shown in **Figure 8a** and **8b**, respectively. As can be seen, because gilts were bred by design at third estrus, and there was a lack of any relationship between body weight and rate of sexual maturity once the critical threshold has been passed, this resulted in a wide range of body weights at breeding at immediately after these gilts farrowed their first litter. In general, the pattern of increase in lean body mass over successive parities would meet most conventional targets (**Figure 8a**), and the changes in measured back-fat were variable and lower that would be suggested as ideal even for the Camborough sow (**Figure 8b**). However, as discussed earlier, the lower than targeted levels of back-fat do not seem to be critical for sow longevity in the breeding herd, or for sow lifetime productivity.

A notable feature of the data shown in **Figure 8a** is the persistent difference in sow body weight over three parities, despite the fact that management practices in this herd would allow feed intake in gestation to vary with respect to perceived weight and body condition of the sows after breeding. This emphasizes the need to focus on entering gilts into the breeding herd at known and recorded weights, as probably the only reliable way of insuring that lifetime changes in sow weight will be consistent with

Figure 7: Impact of back-fat at first service on total born through three parities in a large-scale study of Camborough gilts (Williams et al., 2005).



Figures 8a (top) and 8b (bottom): Mean body weights of gilts bred at third estrus, regardless of body weight, with the data representing the body weight (a) and back-fat (b), respectively, for the lowest, the middle and the highest 10% of gilt weights when first recorded as heat-no-serve after introducing direct contact with boars at 140 days of age when first bred.



longevity and good lifetime productivity.

Physiological limitations to maximizing lifetime productivity

As shown in **Tables 2** and **3**, the performance of contemporary dam-line sows is truly astounding! Their ability to tolerate serious loss of body tissues as a result of experimentally imposed feed restriction at peak lactation, with relatively little effect on many measures of post-weaning fertility, needs to be recognized. Equally, the reality that sows can deposit and mobilize lean tissue, with little impact on fat tissue depots, requires us to accept a new biological paradigm and to mange these sows accordingly.

These results are typical of similar experiments conducted in lactating and weaned sows in our laboratory over the last 10 years and show the extent to which lean tissue is mobilized to meet the demands of milk production during the first lactation, and in comparison, the small and usually non-significant changes in back fat. Compared to earlier reported impacts of the "thin sow syndrome" on subsequent fertility, contemporary first parity weaned sows show very different responses. The relatively minor impact of sow tissue catabolism on the weaning-to-estrus interval, with often no effects on ovulation rate, shows the resilience of these sows from a reproductive perspective. Second parity litter size is usually decreased in sows that are catabolic at weaning due to increased embryonic loss, but within a single estrous cycle, sows subjected to "skip-a-heat" breeding show excellent productivity (Clowes et al., 1994).

Parallel selection for improved lean growth performance and sow fertility seems to have resulted in a fairly characteristic response to lactational catabolism in contemporary dam-lines. The tendency for only a marginal delay in the return to estrus results in inadequate follicular development by the time that ovulation is triggered (Zak et al., 1997a). The associated lack of oocyte maturity and endocrine changes over the peri-estrous period are key contributors to reduced litter size (Zak et al., 1997b). A recent series of detailed endocrine studies in the lactating and weaned first parity sow is providing a valuable insight as to the changes in gonadotrophic hormone secretion that underlie these changes in post-weaning performance after weaning the first litter.

Table 2: Sow and litter production data for a recent experiment to study the mechanisms mediating effects of tissue catabolism in first parity sows subjected to restricted feed intake from day 14 – 21 of lactation (Restrict) or fed close to appetite until weaning (Controls) on subsequent fertility. (Data are Means ± SEM). (Unpublished data of Vinsky et al., Swine Reproduction-Development Program, University of Alberta, 2004)

Item	Control (n=17)	Restrict (n=17)	P value
Sow data			
Farrow weight (kg)	189.8±12.4	189.1±14.3	0.89
Farrow backfat (mm)	19.8±3.0	20.5±3.0	0.49
Weight loss (kg)	9.17±6.66	22.35±7.73	<0.0001
Lactation backfat loss (mm)	1.29±2.51	2.74±2.09	<0.08
Litter data			
Litter size (piglets)	9.41±0.80	9.47±0.72	0.82
Initial weight per pig (kg)	1.46±0.29	1.36±0.20	0.20
Total weight gain per pig (kg)	5.05±0.53	4.63±0.51	<0.03

Table 3: Embryonic survival and other reproductive characteristics in sows at day 30 of gestation. Data are from the same experiment for which production data are presented in Table 3 and all sows were bred using standard artificial insemination procedures are the same pooled semen after weaning. (Data are Least square means ± SEM).

Item	Control (n=16)	Restrict (n=17)	P value
Wean-to-estrus interval (days)	5.29±1.26	5.41±1.33	0.79
Ovulation rate	18.25±0.65	18.24±0.63	0.99
Live embryos	14.43±0.78	12.29±0.76	<0.06
Embryonic survival to d30 (%)	97.59±6.76A	77.34±6.56*	<0.04
Number of males	7.75±0.59	7.53±0.57	0.79
Number of females	6.50±0.57	4.71±0.56	<0.04
Proportion of male embryos (%)	58.34±4.52*	67.47±4.38*	0.16

[A]Arcsin transformed data are presented

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Management strategies for the breeding sow herd must increasingly recognize the changes in lean growth performance in contemporary dam-line sows (see Willis et al., 2003), and the changes to even traditional hormone therapies that would historically be expected to improve weaned sow fertility (for example see Kirkwood et al., 1998; Foxcroft, 2004). Accepting the risk of being considered some what heretical, most of our recent experiments with the lactating and weaned sow lead to the conclusion "that from a fertility and prolificacy perspective, fatness is simply not the key risk factor"! In contrast, lean tissue mass is a key consideration for correct management of the gilt, and the lactating and weaned sow, and the experimental evidence to support this contention has been clearly established (Clowes, 2003a,b; Quesnel et al, 2003).

Conclusions

Implementing an effective gilt pool management strategy will allow producers to meet targets for body condition (weight, back fat) and physiological maturity (age at first estrus, and estrus at breeding), to reduce annual replacement rates (target for top 30% of breeding herds should be <50%) by improving sow "fitness" and reducing sow death losses, and increase labor efficiency and space utilization. All these advantages can ultimately be achieved whilst maintaining economic efficiencies of smaller, well managed, breeding herds. A comprehensive understanding of the characteristics of specific dam-lines is however, essential, when developing the"optimized" breeding management programs of the future.

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