Maximizing Growth Rate - Weaning to Market
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While many factors contribute to the overall profitability of a given pork production facility, throughput would be high on most manager’s lists. Faster growth rate, and thus increased building throughput, reduces both fixed and variable costs of production. Faster growing pigs not only use less barn space in their lifetime, but they also eat less feed and usually require less care. Furthermore, it has been amply demonstrated that faster growing pigs can produce pork that is of at least equal quality to that produced by slower growing pigs (Ellis and Keith, 1993); thus, there is no penalty in pork quality for achieving more rapid gains.

At its simplest, growth rate is affected by two factors, namely feed intake and the efficiency with which that feed is utilized for growth. Assuming feed efficiency remains essentially constant, increasing feed intake will increase growth rate; conversely, if feed intake remains the same, improving feed efficiency will improve growth rate. This intimate relationship among growth rate, feed intake and feed efficiency provides insight into the factors that drive growth rate.

At the same time, the interrelationship among the three can create confusion, because it is difficult to differentiate the primary as opposed to secondary effects on each component. In other words, if growth rate in a given barn is poor, it takes detailed analysis of the situation to determine if pigs are growing slowly because they are not eating, or are not eating because they are growing slowly!

Growth Defined

Before discussing the factors that affect growth in the pig, it is important to understand some of the basic principles of growth. Modelling growth is a relatively recent undertaking, having been pioneered by Whittemore and Fawcett (1976) less than a quarter century ago. In general terms, growth in the pig consists of three components: lean tissue (largely protein and water), lipid and ash. Protein accretion increases linearly as dietary protein supply increases, until another nutrient, generally energy, becomes limiting. Dietary protein supplied in excess of this upper limit is wasted, as it cannot be retained as protein tissue per se. It is generally accepted that under all but the most ideal circumstances, maximal protein accretion is below the intrinsic maximum of the animal (Whittemore, 1998). However, feed intake may not be the factor preventing the pig from achieving its genetic potential for growth (Patience et al., 2001).

Predicting growth under commercial conditions has proven to be more difficult than initially imagined. In order to predict growth, five pieces of information are required: 1) the intrinsic (genetic) potential of the pig for protein deposition at a given weight or point in time, 2) the maintenance requirement for energy and amino acids, 3) the partitioning of energy intake in excess of maintenance between protein and lipid accretion, 4) daily nutrient intake and 5) the efficiency with which energy and amino acids are utilized for growth (adapted from Schinkel and de Lange, 1996). Unfortunately, this information is often not readily available on many farms. For example, most genotypes are poorly characterized with respect to their potential for protein deposition and feed intake under commercial conditions is rarely readily available, at least not with sufficient accuracy for these purposes. The maintenance requirement for energy and amino acids has been defined with a reasonable degree of accuracy, although further clarification of some issues is required. The metabolic parameters, namely the nature of partitioning of energy between adipose and lean tissue, and the efficiency with which amino acids and energy are utilized for growth are poorly defined. Predicting animal performance under commercial conditions has been frustrating, although there are a number of laboratories around the world working on this important topic.

There are at least two intrinsic limitations to protein accretion. First, there appears to be a minimum lipid:protein ratio that is applied to growth, and which appears to differ among genotypes. In modern genotypes, under conditions of excellent feed intake, the lipid:protein ratio in the empty body rise from 1.0 at 50 kg to 1.6 to 1.8 at 120 kg. Under conditions of less ideal feed intake, the lipid:protein ratio at 120 kg is only about 1.3 to 1.5:1 (Patience et al., 2001). Second, there is an intrinsic upper limit to protein accretion, which is not only characteristic of individual genotypes, but which is also affected by gender. Energy supplied in excess of that required to maximize protein deposition and the intrinsic minimum lipid:protein ratio will be used for fat deposition (Gerrits, 1996).

It has been estimated that only about one-third of the protein consumed in the diet will be retained in the body as
protein. The rest will contribute to the circulating nitrogen pool, most of which is eliminated in the urine, and to the energy currency of the body.

In summary, growth in the pig is normally measured as body weight gain; however, the gain consists of three components: lean, fat (lipid) and minerals (ash). Energy is required to drive growth; energy in the diet is first used for maintenance purposes, with excess supply used for a blend of protein and fat gain. If additional or excess energy is available, this will go directly to increased fat in the carcass.

Genetics

With the tremendous improvements in the genetic make-up of the modern pig, it is sometimes hard to accept that with this progress, we may have also inherited some constraints to performance. For example, it is well understood that selection for leanness, if not linked to selection for feed intake, can lead to animals with reduced appetite, and thus growth potential.

Interestingly, selection for leanness also tends to select for animals with a higher mature body weight. Selection for younger age at puberty tends to select for animals with a lower mature body weight (Currie, 1988). Since modern pork production seeks leaner animals, but also selects for animals that achieve puberty at a younger age, conflicting objectives emerge. This is one reason – but not the only one – why breeding companies have distinct sire and dam lines available for sale.

Current genetic improvements have resulted in an increase in the lean growth rate of up to 3% per year (Hall et al., 2000). As the lean content of the pig increases, feed efficiency improves. In order to support this increased growth, the supply of nutrients must also increase, through either increased feed intake or the use of more nutrient dense diets (Hall et al. 2000).

Physical Environment

The pig’s physical environment is clearly a major determinant of growth rate. The pig’s “physical” environment can be broken down into two components: thermal (e.g. temperature, humidity, air speed) and non-thermal (e.g. air contaminants, floor space).

The thermal comfort zone is the range in temperature between which the animal maintains a constant core temperature, maintains normal contact with other pigs (no huddling due to chilling), maintains a normal feed intake and does not shiver or pant. The thermal comfort zone is about 10°C wide.

Please note the term “feed intake is normal” as opposed to “constant.” Across the 10°C thermal comfort zone, feed intake will change. When selecting a temperature for our barns, we want to remain within the thermal comfort zone, and in fact, fall within the part of the thermal comfort zone that maximizes feed intake without adversely affecting growth rate. In other words, we want to select the “optimum” temperature for the pig. The figure (above) summarizes the optimum temperature for the growing pig.

We must remember that the pig produces a certain amount of heat as a consequence of normal basal metabolism; the digestion of feed, the breakdown of nutrients in the feed, movement of muscles and a host of other normal activities in the pig all create heat. When the temperature in the barn is cool, this heat helps to keep the pig warm; when the temperature in the barn is too hot, such as in warm weather, this heat produced by the pig compounds the effects of heat stress. This is why feed intake declines in hot weather. The pig tries to reduce its basal heat production by digesting and metabolizing less feed.

There are also obligatory losses of heat from the body of the pig. Indeed, this must occur, because if the metabolic heat was not removed, body temperature would rise and ultimately the pig would die. The objective of pig housing is to balance heat production with heat losses, to maintain the pig in a comfortable environment.

The nature and extent of heat loss from the pig is often misunderstood. For example, the pig loses heat to its surroundings by both sensible (radiation, convection, conduction) and insensible (evaporation) mechanisms. Certain losses or gain of heat, such as through radiation, are diffi---

### Average growth rate and feed conversion in Dutch (NL) and Norwegian (N) pigs from 1980 to 1995

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<tr>
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<tbody>
<tr>
<td>Growth (g/d) (NL)</td>
<td>646</td>
<td>654</td>
<td>693</td>
<td>718</td>
<td>717</td>
<td>729</td>
</tr>
<tr>
<td>Growth (g/d) (N)</td>
<td>835</td>
<td>868</td>
<td>897</td>
<td>936</td>
<td>960</td>
<td>956</td>
</tr>
<tr>
<td>FC (NL)</td>
<td>6.15</td>
<td>3.08</td>
<td>2.98</td>
<td>2.93</td>
<td>2.87</td>
<td>2.79</td>
</tr>
<tr>
<td>FC (N)</td>
<td>2.54</td>
<td>2.45</td>
<td>2.31</td>
<td>2.26</td>
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Adapted from Rauw et al. 1998

### Heat Loss from the Pig

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Conduction</td>
<td>Via solid materials in contact with the pig’s body</td>
</tr>
<tr>
<td></td>
<td>eg. concrete floor</td>
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<tr>
<td>Convection</td>
<td>Via air movement across the surface of the pig’s body</td>
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<tr>
<td></td>
<td>eg. drafts</td>
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<tr>
<td>Evaporation</td>
<td>Via conversion of water from a liquid to water vapour</td>
</tr>
<tr>
<td></td>
<td>eg. panting, laying in wet manure</td>
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<tr>
<td>Radiation</td>
<td>From pig’s warm body to a surrounding cold body not in contact with the pig</td>
</tr>
<tr>
<td></td>
<td>eg. to uninsulated or poorly insulated walls</td>
</tr>
</tbody>
</table>

### Optimal Barn Temperatures Versus Pig Weight

<table>
<thead>
<tr>
<th>Weight, kg</th>
<th>Temperature, ºC</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>28</td>
</tr>
<tr>
<td>20</td>
<td>25</td>
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<tr>
<td>25</td>
<td>23</td>
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<td>35</td>
<td>20</td>
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<tr>
<td>45</td>
<td>17</td>
</tr>
<tr>
<td>55</td>
<td>16</td>
</tr>
<tr>
<td>65</td>
<td>15</td>
</tr>
<tr>
<td>To market</td>
<td>15</td>
</tr>
</tbody>
</table>

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cult to measure, and therefore not as obvious as conductive and convective mechanisms. Even the latter are often poorly understood. For example, while many people refer to subcutaneous fat as highly protective against chilling, the reality is that fat tissue is 16 times more effective than air in conducting heat (Currie, 1988). The impact of adipose tissue rests more with its poor blood supply than its insulation properties.

Under practical conditions, one should be considering the “effective” ambient temperature when considering the effects of elevated temperature. As an example, wet floors and slats have the effect of lowering the effective ambient temperature by 5 to 10°C. On the other hand, the presence of dry bedding elevates effective ambient temperature by about 4°C (Verstegen et al., 1984). For this reason, simply reading the temperature from a thermometer is not sufficient; similarly, assuming the ventilation controller with associated temperature sensors is going to “automatically” maintain thermal comfort in the pig is also dangerous.

Heat Stress

The single most important effect of heat stress is reduced feed intake, leading to a drop in growth rate (Lopez et al., 1991a,b; Hyun et al., 1998; Becker et al., 1993). Heat stress also increases heart rate and thus increases the maintenance requirement for energy.

While temperatures above the thermal comfort zone reduce feed intake, changes in feed intake can also alter the thermal comfort zone! For example, pigs with a reduced feed intake experience a higher thermal comfort zone, due to the reduction in metabolic heat production. This becomes a particular concern in newly-weaned pigs, which due to a temporary reduction in feed intake, often become chilled at temperatures that would otherwise provide adequate comfort. For this reason, in order to get young, newly-weaned pigs off to a good start, a slightly higher temperature is recommended for the first few days off the sow. Maintaining this elevated temperature for too long a period, however, will lower feed intake.

The impact of thermal stress will affect, and be affected by, the presence of other stressors. For example, a study by Hyun et al. (1998) showed that the effects of different stressors (high temperature, restricted space allowance and regrouping) on average daily gain, feed intake and feed conversion, when presented together, are additive.

Cold Stress

Verstegen et al. (1984) suggest that the main factor influencing growth and development of young pigs is feed intake, which is increased as temperature decreases. If feed intake is not allowed to increase, the result is a reduced rate of gain as the cold increases heat loss and therefore energy gain. Herpin et al. (1987) suggest that heat production is increased as environmental temperatures fall, which has the effect of reducing fuels available for growth.

Typically, lower average daily gains and higher feed intake occurs among pigs in a cold environment (Lopez et al., 1991). However, in some studies, notably in younger pigs, low temperatures did not affect feed intake, so that only growth rate and feed conversion were compromised (Maenz et al., 1994). As a thumb rule, one can estimate that for every Centigrade degree below the thermal comfort zone, growth rate will decline by 10 to 22 g/d (Verstegen et al., 1984).

Social Interaction

Space Allocation

While the response to floor space by pigs in confinement appears to have received considerable attention, many questions remain. It is well understood that reducing floor space allowance reduces both feed intake and growth rate and also leads to behavioural vices, such as tail-biting (Edmonds et al., 1998). However, the changing nature of pig housing combined with a more thorough investigation of the subject has resulted in more questions arising on this topic. New information on floor space allowance is becoming available, and will be reported in my presentation at the Symposium.

While crowding is known to reduce growth rate and feed intake, increasing the density of the diet to achieve equivalent daily nutrient intake is not successful in returning the performance of crowded pigs to that achieved by non-crowded pigs (Brumm and Miller, 1996).

Health

In response to pathogens, the immune system is activated to synthesize the components of the defense mechanism. These processes require energy; thus, the health of the animal becomes important not only in the growth of the animal but also in the efficiency of that growth. The increase in cytokine production decreases feed intake and consequently reduces feed efficiency (Williams et al., 1997). Minimizing the level of chronic immune system activation can enhance the rate and efficiency of pig growth (Williams et al., 1997). Williams et al. (1997) suggested that pigs with a highly activated immune system are more affected by dietary amino acid requirements above that needed to meet the lean tissue growth rate than pigs with a low level of immune system activation.

<table>
<thead>
<tr>
<th>Lysine Level</th>
<th>Low Immune System Activation</th>
<th>High Immune System Activation</th>
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</thead>
<tbody>
<tr>
<td>%</td>
<td>BW (kg)</td>
<td>BW (kg)</td>
</tr>
<tr>
<td>1.20</td>
<td>7.256</td>
<td>6.806</td>
</tr>
<tr>
<td>1.50</td>
<td>6.845</td>
<td>6.395</td>
</tr>
<tr>
<td>1.80</td>
<td>6.566</td>
<td>6.116</td>
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Adapted from Williams et al., 1997.
Diet

Diet Composition

Clearly, diet composition is one of the most easily altered aspects of pork production, as nutritionists seek to enhance performance at the lowest possible cost. However, it is an over-simplification to assume that increasing nutrient density will increase performance; while this is certainly true in some instances, it is not universal and care must be taken to avoid the temptation to increase nutrient density – and thus feed cost – to overcome other more fundamental constraints in the production system. Not only is it costly, it may be ineffective.

Considerable attention is directed at selecting the appropriate nutrient levels in the diet, but there appears to be less interest in addressing how those nutrient specifications will be met. This may be a more serious matter than previously thought. For example, Fairbairn et al. (1999) reported that the energy concentration in barley varies by 15% or more; other studies have revealed similar or larger variation in other ingredients. Clearly, the same degree of precision must be applied to meeting nutrient specifications as was applied in the development of those specifications.

Diet Processing

The reduction in particle size of feed ingredients improves feed efficiency and nutrient digestibility (Wondra et al., 1995a, 1995b). Efforts are still being made to find the optimum particle size of grain ingredients. Healy et al. (1994) found that optimum particle size of the diet was 600 μm in nursery pigs and Wondra et al. (1995a) found that a particle size of 600 μm, or slightly less, was optimal for corn in diets for finishing pigs. The reduction of particle size exposes more surface area to enzymes in the gut of the pig, allowing more of the nutrients to be digested and absorbed. However, there is an increased incidence of gastric ulcers with decreased particle size (Wondra et al, 1995a, 1995b) that must be considered when determining the optimum particle size of grains in a diet.

Benefits of using pelleted diets include decreased segregation, increased bulk density, reduced dustiness, improved handling and transportation characteristics, improved palatability and thermal modification of starch and protein (Chae and Han, 1998). Wondra et al. (1995a) found that pigs fed pelleted diets digested 3% more dry matter and 10% more protein each day than pigs fed meal diets. The improvement was attributed to the increased digestibility of dry matter and protein, rather than increased daily intake of these nutrients, because ADFI was actually less for the pigs fed pelleted diets.

Water Quality

Water quality can affect performance, and is generally described in terms of dissolved solids (TDS), suspended solids (organic matter) and microbiological content. Microbial contamination of water can result in pathogen transmission to an animal and therefore affect productivity. Water hardness increases with mineral content (TDS) (McLeese et al., 1991).

Water is often blamed for poor performance, but the data supporting these claims is often lacking. Wahlstrom (1981) reported that at TDS levels as high as 6900 ppm, water consumption increased, but salinity had no effect on gain, feed consumption or feed efficiency. This is in agreement with an earlier study by Paterson et al. (1979) which found no significant differences in average daily gain or feed efficiency between pigs drinking water with 3000 ppm added sulfate and those provided water with no added sulfate. Adding nitrate to drinking water up to a rate of 2000 ppm had no negative effects on growth, feed intake or feed utilization (Sorensen et al., 1993). Maenz et al. (1994), Patience (1997) and Patience et al., (1997a,b) reported that water with very high levels of sulphate result in an osmotic diarrhea, but has no effect on animal performance.

Antinutritional Factors

Increasing average daily feed intake through the use of palatable ingredients for pigs will ultimately increase average daily feed intake. However, many ingredients used in swine diets have antinutritional factors (ANFs) associated with them, which will impede the performance of the pig by affecting ADFI and feed efficiency.

Known ANFs present in peas, common beans and soybeans are protease inhibitors, haemagglutinins or lectins, tannins, alpha-amylase inhibitors, allergens or antigenic proteins, phytases, goitrogens, antivitamins and saponins. Antinutritional factors decrease feed intake as well as decrease feed efficiency through interference in the digestive process.

Summary

In summary, a multitude of intrinsic and extrinsic factors affect growth in the pig. It is only by addressing each, individually and as a whole, that animal growth can be optimized. What is clear is that pork production, while achieving extraordinary gains in the past 4 decades, has yet to fully utilize the tremendous genetic potential of the pig. This is apparent by the variation in performance which occurs among groups of pigs within a barn, and by the diversity of results experienced among producers. It is equally clear that the financial returns that will accrue from achieving higher levels of performance are substantive.

References


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