RECENT ADVANCES IN SOW NUTRITION

Mike Tokach and Márcio Gonçalves

Kansas State University, Manhattan, KS, U.S.A

1.- INTRODUCTION

Sow productivity has increased dramatically in the last 15 years. Pigs per sow per year continues to increase at 0.40 to 0.45 pigs/year. The improvement has been driven by large increases in pigs born per litter. The increased litter size has led to a precipitous decline in birth weight of pigs. These changes have led producers and nutritionists to question whether current feeding programs are meeting the needs of the sow and whether there are strategies to increase birth weight through the diet or other means.

The purpose of this review is to discuss recent nutrition research with gestating and lactating sows and briefly discuss the approach that is taken to feeding highly prolific sows in the U.S., South America, and E.U.

2.- HISTORICAL BASELINE

The overall goals for feeding sows have not changed greatly over time. During gestation, the goal is to obtain the desired body condition as quickly as possible after mating and maintain the sow in proper body condition throughout gestation without allowing her to become too thin or too fat. A properly formulated gestation diet would allow the sow to meet her daily requirements for amino acids, vitamins, and minerals while being fed at varying levels required to achieve the desired body condition. The energy level of the diet varies greatly based on the cost of ingredients in the particular region.
where the sows are being fed. After farrowing, a lactation diet is fed at rates to allow high feed intake to minimize loss of body weight during lactation while allowing for high milk production for litter growth and to prepare the sow to return to estrous promptly after weaning with high ovulation rate for a large subsequent litter. The question is how much changes in productivity have changed the sow’s requirements and whether recent research indicates that feeding programs must be different for current sows than historically.

3.- ESTIMATES OF REQUIREMENTS

Using the NRC (2012) model, Standardized Ileal Digestible (SID) lysine requirements of gestating sows are low from d 0 to 90 of gestation at 9.2 to 10.2 g/d regardless of litter size (Table 1). The estimated requirements increase dramatically during the last 3 weeks of gestation and are influenced more by litter size with requirement estimates increasing from 16.4 g/d at 10 total born to 18.4 g/d for 16 total born. During lactation, the requirements increase much more dramatically as litter size increases (Table 2). With 10 pigs nursed, the requirement is 51 to 53 g/d. At 16 pigs nursed, the requirement is 64 to 67 g/d.

Table 1.- Estimated SID lysine requirement (g/d) of first parity sows during gestation

<table>
<thead>
<tr>
<th>Total born, n</th>
<th>Gestation, d</th>
<th>1 to 45</th>
<th>45 to 90</th>
<th>90 to 114</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td></td>
<td>9.3</td>
<td>9.2</td>
<td>16.4</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>9.4</td>
<td>9.6</td>
<td>17.1</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>9.4</td>
<td>9.9</td>
<td>17.7</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>9.4</td>
<td>10.2</td>
<td>18.4</td>
</tr>
</tbody>
</table>

1Feeding level of 1.83 kg/d from d 1 to 90 and 2.4 kg/d from d 90 to 114 (diet containing 2,530 kcal NE/kg).

Table 2. Estimated SID lysine requirement (g/d) of first parity sows during lactation

<table>
<thead>
<tr>
<th>Total born, n</th>
<th>Weaning weight, kg</th>
<th>5.8</th>
<th>6.0</th>
<th>6.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td></td>
<td>51.3</td>
<td>52.1</td>
<td>52.8</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>55.5</td>
<td>56.4</td>
<td>57.3</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>59.7</td>
<td>60.8</td>
<td>61.8</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>64.0</td>
<td>65.3</td>
<td>66.5</td>
</tr>
</tbody>
</table>

1Feeding level of 6.0 kg/d of a diet containing 2,565 kcal NE/kg in a 21 d lactation.
4.- RECENT SOW NUTRITION RESEARCH

**Feeding from weaning to estrus.** In a large unpublished observational study (670 sows) by PIC in 2014, increasing feeding level from 2.6 to 4.2 kg/d from weaning to mating reduced wean to estrus interval from 5.3 to 4.4 d, increased percentage of sows bred by d 7 from 92.8 to 97.5%, and increased subsequent litter size by a full pig from 12.9 to 13.9. Graham et al. (2015) used 637 sows to test this hypothesis. They fed sows 2.7, 3.6, or 5.4 kg/d of a diet containing approximately 2.44 Mcal NE/kg from weaning to estrus. They achieved NE intakes of 6.5, 8.6, and 12.6 Mcal per day. They found no difference in wean to estrus interval (5.1, 5.0, or 5.0 d), conception rate (95.6, 95.6, or 94.7%), farrowing rate (85.4, 87.0, and 82.3%), or born alive (13.1, 12.9, or 12.9) for sows fed the 2.7, 3.6, or 5.4 kg/d, respectively. Parity of the sow did not influence the response to feeding level. Graham et al. suggested that the improved body condition scores of sows in their study (> 2.75 on scale of 1 to 5) may have limited the benefit and that thin sows may still benefit from higher feeding levels. However, their data clearly showed that sows in good body condition at weaning did not benefit from receiving high feeding levels from weaning to estrus. More research is needed in this area.

**Feeding during most of gestation.** A recent review of data from over 11,000 farrowings confirmed historical data demonstrating that as backfat levels at farrowing increase, feed intake linearly decreases, which leads to a linear increase in body weight and backfat loss during lactation (Kim et al., 2015). Litter weight gain was reduced when backfat exceeded 20 mm at farrowing with the reduction being particularly great when sows exceeded 25 mm of backfat at farrowing.

Although number of gilts were too limited to clearly demonstrate, data from Amdi et al. (2014) showed that feeding lower levels of feed (1.8 kg/d) to thin gilts (12 mm backfat) reduced birth weight by 100 g/pig, whereas the same feeding level had no impact on birth weight in fat gilts (19 mm backfat).

These trials demonstrate that sows can be fed to a range of backfat and body conditions as long as extremes (12 mm or less in parity 1 or > 22 mm of backfat in all sows) are avoided with relatively little impact on sow or offspring performance.

**Feeding the last two to three weeks before farrowing.** Increasing feed intake in late gestation during the phase of rapid fetal development (bump feeding) is practiced in many parts of the world. There is thought that feeding during this period has increased in importance with larger litter sizes and that the quantity of feed should be increased over previous recommendations as a means to increase birth weight. The factorial estimates of
requirements from NRC (2012) as presented in Table 2 also suggest that increasing amino acid intake may be beneficial.

Several experiments have been conducted over the years to examine feeding levels in late gestation. These research trials clearly demonstrate that sow body weight is increased with increasing feeding level in late gestation, with the impact on piglet birthweight being more variable. Most of the research has examined increases in feed intake which increases amino acids and energy. Thus, Gonçalves et al. (2015) fed 2 levels of amino acids (10.7 vs 20 g of SID lysine/d) and 2 levels of energy (4.50 or 6.75 Mcal NE/d) in a 2 x 2 factorial to 1,102 sows starting on d 90 of gestation. Their results indicated amino acid and energy intake influenced sow weight gain with a greater increase in body weight gain when amino acids and energy were increased together rather than when increased alone. Concerning birth weight of live born pigs, increasing amino acids had no impact, but increasing energy intake increased piglet birth weight by 30 g/pig (1.33 vs 1.36 kg) with a similar response in gilts and sows. Increasing energy intake in the sows also increased stillbirth rate (4.4 vs. 6.5%), but had no effect on stillbirths in gilts (3.4 vs 3.4%). The researchers concluded that 1) body weight gain of gilts and sows depends not only on energy but also Lys intake levels, 2) sows fed increased amount of energy had increased stillborn rate, 3) the positive effect during late gestation on individual piglet birth weight was due to increased energy rather than amino acid intake; however, the impact of increased energy intake during late gestation on piglet birth weight was modest. Total born was 14.2 pigs for gilts and 15.2 pigs for sows coupled with birthweights of less than 1.4 kg/pig providing an ample opportunity for the nutrient intake to demonstrate a response.

In a metanalysis, Gonçalves reviewed the existing literature on bump feeding and found that each 1 kg increase in daily feed allowance during late gestation is associated with approximately 7 kg of additional body weight gain for gilts and sows. The analysis also concluded that energy intake provides the response rather than amino acid intake and piglets on bump feeding treatments were on average 28 g heavier than piglets from sows that were not bump fed.

Some have postulated that increasing feed intake in late gestation would help reduce preweaning mortality because it increased glycogen reserves in the baby pig; however, preweaning mortality has not been improved by increasing late gestation intake. In an excellent review, Theil et al. (2014) discussed that low feed intake increases fat mobilization, which may actually help colostrum production and quality. Thus, low feed intake in late gestation may increase fat mobilization and offset the benefits of increased glycogen reserves from high feed intake in late gestation.
Peripartum feeding just before and after farrowing. Two recent papers examined feeding around farrowing. Traditionally, intake has been limited to 3 kg or less for the last few days before farrowing and sows were stepped up on intake after farrowing to avoid having sows “go off feed”. As many farms have transitioned to feeding systems that eliminate hand feeding and allow ad libitum intake during lactation, the practice of limiting feed around parturition has been re-examined.

Decaluwe et al. (2014) provided either 1.5 or 4.5 kg/d from d 108 of gestation until farrowing. Sows that were fed 1.5 kg/d during late gestation were increased to 3 kg on d 1 and 4.5 kg on d 2 after farrowing. All sows were provided similar feed availability after d 2. Sows that were fed 4.5 kg/d in late gestation numerically consumed less feed during lactation (5.3 vs 5.8 kg/d); however, they consumed more total feed from d 108 until weaning (129 vs 117 kg). Thus, they lost less backfat. The extra feed prior to farrowing also increased colostrum yield and the lactose content of the colostrum, which increased piglet weight gain during the first day of life. The immunoglobulin levels were not altered and weaning weight and subsequent sow performance were not influenced by feeding level prior to farrowing.

In another study by the same research team, Cools et al. (2014) fed sows a traditional step down/step up program around farrowing (limit fed) or provided sows with ad libitum intake starting on d 105 of gestation (Figure 1). By design, the feeding program influenced feed intake prior to d 7 of lactation, but did not influence intake from d 7 to weaning. Similar to the research by Decaluwe et al. (2014), providing extra feed intake around farrowing reduced backfat loss, although sow weight change was not affected. Interesting, the researchers found that providing ad libitum intake resulted in higher piglet weaning weight and growth for lean (< 22 mm) and moderately conditioned (18 to 22 mm) sows, but ad libitum intake prior to farrowing reduced weaning weight and piglet growth of litters from fat sows (> 22 mm backfat).

Together, these research projects suggest that, when sows are below 22 mm in backfat, providing ad libitum feed intake upon placement in the farrowing room (within last week prior to farrowing) will increase total feed consumption prior to weaning and, thus, reduce loss of body reserves and improve litter growth and weaning weight. The data also again show the importance of not having sows excessively fat (> 22 mm) at farrowing.
Feeding during lactation. Xue et al. (2012) conducted two experiments investigating the energy and lysine:ME ratio required by lactating sows. In the first experiment, they fed energy levels ranging from 3.06 to 3.40 Mcal ME/kg (approximately 2.30 to 2.55 Mcal NE/kg). Similar to earlier research, feed intake and litter weight gain were reduced when dietary energy was less than 3.2 Mcal ME/kg (approximately 2.4 Mcal NE/kg). In the second experiment, increasing SID lysine:ME ratio from 2.1 to 3.3 g/Mcal ME linearly increased litter weight gain with the greatest increase through 3.0 g/Mcal ME (4.1 g/Mcal NE). This coincided with a daily intake of 61 g/d of SID lysine intake. Litter weight gain was 2.4 kg/d for sows fed the higher lysine:ME ratios in this experiment. For sows with higher production, higher levels of amino acids would be required. Sows require approximately 22 g/d of SID lysine per kg of litter weight gain.

Source of energy has not been studied in many recent studies, but historical trials demonstrate that lower fiber, higher starch diets encourage greater energy intake. Attempts to further increase intake with sucrose or other specialty carbohydrate sources have not been able to demonstrate improved feed intake (Johnston et al., 2003).
5.- RECENT RESEARCH WITH OTHER NUTRIENTS OR INGREDIENTS

**Essential fatty acids.** There has been renewed interest in essential fatty acids in recent years. These efforts have come from two directions. First, historic research demonstrating benefits in sow productivity with additions of omega-3 fatty acids to the diet from fish oil sources or from flax or linseed oil. Second, many typical diets have high ratios of n-6:n-3 fatty acids causing a concern that there may be an imbalance of pro-inflammatory to anti-inflammatory eicosanoids. Recent data from Rosero (2015) suggests that lactating sows should consume at least 100 g/d of linoleic acid for optimal subsequent reproductive performance. Further data is needed to validate this response. Some research with protected fish oil products as a source of omega-3 fatty acids have shown promise; however, a protected source must be used and costs are often prohibitive.

**Mannan oligosaccharide.** Studies have found that including mannan oligosaccharides in the diet of sows in late gestation has been associated with an approximate 60 g increase in piglet birth weight (Landeau and Le Dividich, 2013; Taylor-Pickard, 2015). Although more peer-reviewed research may be needed to further validate this response, some production systems include mannan products in their diets for this potential benefit.

**L-Carnitine.** Eder et al. (2001) supplemented 125 mg per day for sows from weaning to farrowing and observed an improvement of 8% and 7% in litter birth weight of gilts and sows, respectively. These results were further supported by later research. However, it would be valuable to re-evaluate these effects at larger litter size (i.e., > 14 total born).

**Arginine.** Mateo et al. (2007) observed an increase in piglet birth weight through L-arginine supplementation. However, seven follow-up studies did not find differences in birth weight.

6.- APPROACHES TO MEETING SOW NUTRIENT REQUIREMENTS AROUND THE WORLD

Excellent sow productivity can be found in farms around the globe even under systems with large differences in feed delivery methods, nutrient levels, and ingredients. We will briefly review major differences between nutrient levels and feeding methods in the U.S., Brazil, and Spain.
**United States.** The greatest difference between nutrient levels of gestation and lactation diets is found in the United States. During gestation, sows are fed a low lysine (ex. 0.56% SID lysine) diet with a relatively high NE content. The high NE content is because corn, dried distiller grains (DDGS), and soybean meal are often the most economical diet that can be fed. During lactation, the energy level is slightly higher than the gestation diet because a low level of fat is often added and the DDGS level is typically lower than in the gestation diet. Although increasing levels of feed-grade amino acids are used in the lactation diet, the crude protein level is usually considerably higher than most lactation diets in Spain. The SID lysine level will range from 1.0 to 1.2% depending on the productivity level of the farm. The philosophy is to provide a diet to meet the needs of the first parity sows and, thus, the diet may be over the requirement for older sows.

Because the energy levels are relatively high, gestating sows are fed a low level of feed during gestation (2.0 to 2.2 kg/d) with feeding rates adjusted based on body condition or backfat. Most farms will increase feed intake by 0.9 kg for 2 to 3 weeks prior to farrowing. Immediately after farrowing, sows are allowed ad libitum feed intake through automatic feeders. This has resulted in a dramatic change in feeding practices in farrowing houses in the US, where it has become relatively uncommon to observe empty lactation feeders. Numerous different automatic feeding systems are used in the industry and feed is almost always provided in dry form.

**Brazil.** The main difference compared to U.S. is that diets in Brazil are formulated to higher lysine levels during gestation and lower lysine levels during lactation. During gestation, sows are fed a high lysine diet (ex. 0.65% SID Lys) with a smaller number of farms using a late gestation diet with even higher lysine levels (ex. 0.80% SID Lys). Energy levels per kg of diet during gestation and lactation are fairly comparable with U.S.; however, in general, the average feed allowance during gestation can be up to 0.4 kg/sow/d higher than U.S. mainly driven by a more aggressive use of bump feeding with a daily allowance of up to 3.3 kg/d of feed during late gestation.

During lactation, lysine ranges from 0.95 to 1.12%. Due to the lack of automatic feeders, some older farms still do not feed ad libitum from immediately after farrowing.

**Spain.** The main difference in comparing the diets in Spain to those in the U.S. or Brazil is that the diets are normally much lower in energy in Spain, especially during gestation. This makes sense because the higher fiber, lower energy ingredients are more economical relative to corn than in U.S. or Brazil. Ingredients with higher fiber content, such as sugar beet pulp, wheat bran, or sunflower meal are often used at low levels in the
lactation diet to maintain the same ingredients as used in gestation. As a result, lactation diets can often be lower in energy and higher in fiber than in the U.S. or Brazil.

7.- CONCLUSION

Requirements during gestation are higher with larger litter sizes; however because the maintenance requirement of the sow and needs for lean growth rate are so much higher than the needs for fetal gain, the nutrient requirements have not changed greatly. Increasing energy intake during late gestation will increase piglet birthweight by approximately 30 g/pig. Thus, it will be difficult using nutritional strategies to overcome the 130 to 150 g/pig reduction in birthweight of over the last 10 years that has been a result of genetic selection for increased litter size without selectioning for increased birth weight. Genetic selection for birthweight and viable pigs will be much more successful in addressing the concern with large litter sizes.

The requirement during lactation is another story. The increased demand for milk production from sows with more functioning mammary glands and increased piglets nursed require higher amino acid levels and feed intake. Nutritionists will continue to be challenged with formulating diets that allow farrowing house personnel to meet the increasing energy and amino acid demands of these high producing sows during lactation. Feeding systems must allow for feed to always be available to the sow to provide maximum intake.

The different feeding systems and diets used in major swine producing countries demonstrate that sows can be fed in a variety of manners while still achieving excellent productivity. Research should be used to challenge our current methods to determine if we can improve performance by using an alternative approach.

8.- REFERENCES

GONÇALVES, M.A.D., GOURLEY, K., DRITZ, S.S., TOKACH, M.D., BELLO, N.M.,
Sci. (Abstr.).
GRAHAM, A., NEILL, C., TOUCHEtte, K., CONNOR, J., TEGTMeyer, M. and
JOHNSTON, L.J., PETTIGREW, J.E., BAIDoo, S.K., SHURSON, G.C. and WALKER,
MATEO, R.D., WU, G., BAZER, F.W., PARK, J.C., SHINZATO, I. and KIM, S.W.