# New Energy and Amino Acid Requirements for Gestating Sows

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## ■ Take Home Message

Phase feeding of pregnant sows supplies the amino acids and energy needed just when the sows need them. This can result in reduced feed cost, better sow condition at farrowing, better rebreeding success and prolonged productive life of sows.

## ■ Introduction

In the last few years, our new research in sow nutrition has provided evidence that the feeding regimen of gestating sows needs revision. In particular, the change of amino acid requirements from early to late gestation and the energy deficit of young sows in late gestation give a strong indication that phase feeding of pregnant sows may be of advantage. This paper will review recent research, introduce future perspectives in sow nutrition and suggest options for feeding strategies for sows.

## ■ Gestation Feeding

Current recommendations for nutrient and energy intake during gestation are constant (NRC 1998). However, practical experience (Jackson 2009) has shown that feed and nutrient intake must be increased during late gestation to maintain performance and sow longevity.

Genetic improvement in lean yield and reproductive parameters such as litter size (CCSI, 2007) indicate that the AA requirements for sows should be re-evaluated. Currently, NRC (1998) recommends a constant value for amino acid requirements during gestation (NRC 1998), which assumes an equal distribution of nutrient demand throughout gestation. However; the metabolic focus of the sow changes from the recovery of sow body tissue following weaning to the synthesis of fetal tissue in late gestation (McPherson et al., 2004). Fetal weight, fetal protein content and mammary protein content increase 5-, 18- and 27-fold, respectively, in the last 45 d of gestation (McPherson et al., 2004; Ji et al., 2006). These dramatic increases in fetal weight and protein gain indicate that the requirement for AA must be greater in late gestation compared to early gestation. Ignoring these dynamics by applying a single phase feeding program will lead to overfeeding during early gestation and underfeeding during late gestation. Overfeeding in early gestation results in a waste of feed and money, while underfeeding in late gestation leads to sows entering lactation in a severe catabolic state.

## ▪ Amino Acid Requirements for Sows

Based on these physiological changes, amino acid requirement of pregnant sows were modeled by Kim et al. (2009) and a group from Germany (GfE 2008). Although the recommended levels of amino acid intake differ between authors, they agree that amino acid requirements in late gestation are greater than in early gestation. GfE (2008) proposed a change of diets on day 85 of gestation to accommodate the greater amino acid requirement caused by increased fetal growth. For example, GfE (2008) suggested true ileal digestible lysine intake of 9.4 g/d for day 1 to 85 of gestation and 14.6 g/d for day 85 to 115 in 2$^{nd}$ parity sows. The corresponding values for threonine, based on estimated amino acid ratios for sow maintenance and body protein growth, are 6.6 g/d and 9.6 g/d. Although we agree with the concepts used to derive these recommendations, these requirement estimates should be treated with caution until they are confirmed with experimental data.

Experimental data are now becoming available in support of the proposed change in amino acid requirements during gestation (**Table 1**). Srichana (2006) determined the total lysine requirement of gilts as 15.0 g/d in early and mid gestation and as 18.0 g/d in late gestation, based on nitrogen balance. Samuel et al. (2010), using the indicator amino acid oxidation technique, showed that the lysine requirement of 2$^{nd}$ parity sows was 13.1 g/d and 18.7 g/d in early and late gestation, respectively. For 3$^{rd}$ parity sows, the dietary total lysine requirement was 8.2 g/d and 13.0 g/d for early- and late-gestation, respectively (Samuel et al., 2010). Levesque et al. (2011a) found that second parity sows required 7.2 g/d total threonine in early gestation (day 35 to 53) and 13.6 g/d THR in late gestation (day 92 to 110) based on indicator amino acid oxidation. In multiparous sows (Levesque et al., 2011a), the total threonine requirement was more than doubled from 5.0 g/d in early gestation to 12.3 g/d in the last third of gestation. The requirement values (Levesque et al., 2011a; Samuel et al., 2010) were determined using Hypor sows weighing between 188 kg and 254 kg that achieved gestation weight gains of 550 g/d and an average litter size of 13.7 total born piglets. The weight loss in the lactation preceding a requirement study was moderate at 3.7 kg. If sows lose much more weight during lactation, the amino acid intakes prior to the following pregnancy may need adjustment. GfE (2008) suggested to increase the true ileal digestible lysine and threonine intake by 1.5 g/d and 0.9 g/d, respectively, throughout gestation for each 10 kg of body weight lost during the preceding lactation.

**Table 1. Total lysine[1] and threonine[2] requirements of gestating sows and resulting threonine to lysine ratios**

| | | 1st parity | 2nd parity | 3rd parity |
|---|---|---|---|---|
| Lysine | Early gestation | 15.0 | 13.1 | 8.1 |
| | Late gestation | 18.0 | 18.4 | 13.0 |
| Threonine | Early gestation | n/a[3] | 7.0 | 5.0 |
| | Late gestation | n/a | 13.6 | 12.3 |
| Threonine: lysine ratio | Early gestation | n/a | 53 | 62 |
| | Late gestation | n/a | 74 | 95 |

[1]Srichana (2006) for 1st parity, Samuel et al. (2010) for 2nd and 3rd parity

[2] Levesque et al. (2011a); [3] not available

These changes in amino acid requirement have several important consequences. First, these data show that the threonine to lysine ratio changes as pregnancy progresses and as sows age. Second, the magnitude of change in requirements makes it nearly impossible to satisfy the requirements using a single diet in gestation. Third, lysine may not be the first-limiting amino acid for older sows. This last point deserves further consideration in that the familiar order of limitation in growing finishing pigs may not apply to pregnant sows. In fact, Levesque et al. (2010) showed that threonine was likely the first limiting amino acid in multiparous sows in late gestation, tryptophan second limiting, and lysine and branched-chain amino acids third limiting, based on indicator amino acid oxidation and rates of protein turnover. Therefore, diet formulation for pregnant sows must account for markedly different ideal amino acid ratios compared to growing pigs, especially if confirmed by our current experiments to determine tryptophan and isoleucine requirements during pregnancy.

The requirement values determined for gestating sows comprise the factors maintenance and growth. The current estimates (NRC 1998) for lysine and threonine maintenance requirement of 36 mg/kg$^{0.75}$ and 55 mg/kg$^{0.75}$ body weight, respectively, were determined in growing pigs (Fuller et al., 1989) and may not be applicable for sows. In addition, the errors inherent in the nitrogen balance technique, i.e. overestimation of nitrogen retention, may result in maintenance requirements lower than the actual values. Recent results by Samuel et al. (2008) and Moehn et al. (2011) showed that the lysine and threonine maintenance requirements were appreciably greater at 49 mg/kg$^{0.75}$ and 98 mg/kg$^{0.75}$ body weight, respectively. The 2:1 ratio of threonine: lysine maintenance requirements may explain the greater threonine to lysine requirement ratios in older sows that experience comparatively little growth.

If a 2-phase feeding system is used in gestation, the question is when to change diets. McPherson et al. (2004) showed no change in fetal growth up to day 70 of gestation. Our results (Levesque et al. 2011b) indicate that the threonine requirement between day 63 and 73 of gestation was similar to that in early gestation, so that a change in gestation diets should occur after day 73. Therefore, the suggestion of GfE (2008) appears appropriate, i.e. to use an early gestation diet from breeding to day 84 of pregnancy, and a late gestation diet from day 85 to farrowing.

## ▪ Energy Requirements During Gestation

It can be expected that energy requirements increase as pregnancy progresses, predominantly because of the exponential growth of fetuses. At constant feed allowance, sows may develop insulin resistance to divert nutrients to the products of pregnancy. Bikker et al. (2007) showed that sows given a constant feed allowance during pregnancy developed insulin resistance in late gestation, whereas sows given a supplement of 540 g/d starch in late gestation did not. This clearly shows that insulin resistance in late gestation is a response to inadequate energy intake.

Close et al. (1985) showed that 1$^{st}$ litter gilts lost 140 g/d of body lipid when given a constant feed allowance. We recently found (Samuel et al. 2007) that 2$^{nd}$ parity sows increased their daily heat production by 4.0 MJ on day 105 vs. day 30 and 45 of gestation. This increase in heat production caused sows to be in negative energy balance at day 105 of gestation, which was supported by the loss of backfat observed between day 45 and 105 of gestation. Similarly, McMillan et al. (2011) found loss of backfat in late gestation in 2$^{nd}$ parity sows given a constant feed allowance, but not in 3$^{rd}$ parity sows. Ramonet et al. (2000) showed that multiparous sows maintained positive energy balance throughout gestation. It therefore appears that 1$^{st}$ and 2$^{nd}$

parity sows clearly need additional feed allowance in late gestation, while 3rd parity and older sows may need less adjustment to the feed allowance.

The GfE (2008) suggested to increase energy intake by 8 MJ/d metabolizable energy in late gestation for 1st to 3rd parity sows, and by 6 MJ/d for 4th parity sows. To prevent the lipid loss of 140 g/d reported by Close et al. (1985), an additional energy intake of approximately 7.5 MJ/d metabolizable energy would be needed. The additional heat produced by 2nd parity sows in late gestation (Samuel et al. 2007) consisted of 1.5 MJ of energy to cover the increased maintenance requirement of heavier sows in late gestation, and of 2.5 MJ of energy associated with maternal and fetal tissue gain. Applying the typical efficiency of energy retention of 0.70 (ARC 1981), this means that a 2nd parity sow would need approximately 6 MJ/d ME more during late gestation. Based on the above experimental results, the feed allowance of barley-based diets should be increased in late gestation by 600 g/d for gilts and by 500 g/d for 2nd parity sows. This differential approach to increasing feed allowance in late gestation is caused by the need of young sows, in their 1st and 2nd pregnancy, to grow to adult body size, which diminishes in older sows after their 3rd pregnancy. Therefore, increasing feed allowance should target primarily young sows while older sows should be given of an increase in feed allowance in late pregnancy.

The benefits of increasing feed allowance especially for young sows are not only the maintenance of sows' body reserves before parturition, but also reduced backfat loss during lactation (Miller et al. 2000) so that less feed may be needed in the next parity to enable the sows to regain body mass lost in lactation. As a consequence of reduced body mass loss in lactation, better rebreeding success can be expected as well. Indeed, Shelton et al. (2009) found that additional 2 lbs (0.9 kg) fed to gilts in late gestation increased the conception rate after weaning from 77% to 95%. This effect was not seen in older sows.

## ▪ Nutrient Availability for Sows

The data on digestibility of dietary amino acids have been obtained almost exclusively from research with growing-finishing pigs. Although age or body weight has long been recognized as a factor influencing protein and energy digestibility (Ball and Aherne 1987, CSIRO 1987), there are few studies of nutrient digestibility in sows. The greater true ileal digestibility of lysine and threonine in corn reported by Stein et al. (2001) has been confirmed by Levesque et al. (2011b) who showed that the availability of threonine in corn was greater by 6% in sows compared to growing pigs. However, Stein et al. (2001) found that the true amino acid digestibility in wheat, barley and canola meal was similar for growing pigs and sows. Conversely, Levesque et al.

(2011b) reported greater threonine availability in barley for sows than for growing pigs. This indicates a large degree of uncertainty regarding amino acid digestibility in sows compared to growing pigs. Therefore, it is safer to apply values for growing pigs in diet formulation for sows until more data for amino acid digestibility are available for sows.

The digestibility of energy, protein, lipids and fiber was shown to be greater in in sows compared to growing pigs (Le Goff and Noblet, 2001), resulting in greater energy content for the same feedstuff when fed to sows. The digestible energy content of the same diets was on average 0.6 MJ/kg greater in sows than in growing pigs, and this difference increased with increasing dietary fiber content (Le Goff and Noblet 2001). The increased urinary energy losses (affecting metabolizable energy) observed by Le Goff and Noblet (2001) in sows were probably caused by inadequate amino acid nutrition. It can be expected that the revised feeding regimen will improve sow amino acid nutrition so that increased energy losses can be avoided, and the full benefit of increased dietary energy content can be applied to sows. Noblet et al. (2003) proposed that the net energy content in feedstuffs was 2 – 4% greater for sows than for growing-finishing pigs. Applying a 3% greater energy content for diet formulation or feed allocation for gestating sows is justified.

## ▪ Feeding Recommendations

Because of the changes in energy and amino acid requirements during gestation, a single phase feeding program will lead to overfeeding during early gestation and underfeeding during late gestation. Overfeeding in early gestation results in a waste of feed and money, while underfeeding in late gestation leads to sows entering lactation in a severe catabolic state. Therefore, phase feeding gestating sows is necessary to supply nutrients in the right amount at the right time.

To control body condition, pregnant sows are fed restrictively. Therefore, energy intake is the limiting factor, and thus the feed allowance for energy needs to be considered first when devising a sow feeding regimen. Generally, the feed allowance of sows is based on body weight and sow condition so that heavier and leaner animals are given more feed. For the purpose of this recommendation, ideal body condition is assumed in the first instance.

Using the University of Alberta sow feeding schedule as a starting point, typical first-litter gilts would receive 2.2 kg/d of a barley-based diet throughout gestation. The typical feed allowances for a 2$^{nd}$ parity sow would be 2.4 kg/d, and for older sows 2.6 kg/d. These feed allowances are adequate to keep an average sow in good condition up to farrowing. However, when given a constant feed allowance in gestation, sows deposit body fat in early and mid gestation that is mobilized to supplement the inadequate energy intake in late gestation. This is energetically wasteful because both fat deposition and fat mobilization are less than 100% energy efficient. That means that the total feed eaten by a sow in gestation can be reduced slightly compared to a single feed allowance when introducing phase feeding, and still maintain the sow and allow the growth of the sow and her conceptus. When introducing phase feeding, it is therefore necessary to reduce the feed intake in early and mid gestation to accommodate an increase in feed allowance in late gestation while slightly reducing the total feed eaten by a pregnant sow. If the feed allowance for a 1$^{st}$ and 2$^{nd}$ parity sow is increased by 0.6 kg/d and 0.5 kg/d during the last 4 weeks of gestation, the daily feed offered needs to be reduced by 0.2 kg/d during the first two trimesters to achieve a small reduction in average gestation feed intake compared to constant feed allowance. These considerations lead to the feed amounts shown in **Table 2**. It must be noted that these feed amounts apply for sows of average body weight and condition; they should be modified for sows that are too lean or too fat, heavier or lighter than average, and more or less efficient in their nutrient utilization.

**Table 2. Daily feed allowance (kg/d) of a barley-based diet for average sows in good condition in early and late gestation.**

| | **1$^{st}$ parity** | **2$^{nd}$ parity** | **3$^{rd}$ parity and older** |
|---|---|---|---|
| Early gestation | 2.0 | 2.2 | 2.5 |
| Late gestation | 2.7 | 2.8 | 2.9 |
| **Average daily feed:** | | | |
| Phase feeding | 2.18 | 2.36 | 2.60 |
| Constant allowance | 2.20 | 2.40 | 2.60 |

Given these feed allowances, the amino acid contents needed to satisfy the daily requirements (**Table 1**) can be calculated. The necessary lysine and threonine contents (**Table 3**), respectively, range from 7.5 g/kg and 6.0 g/kg in early gestation gilts to 3.3 g/kg and 2.0 g/kg in 3$^{rd}$ parity sows in early pregnancy.

There are two viable strategies to supply the necessary amino acids at given feed allowances. One is to formulate a diet that contains the maximum amino acid concentration needed (’high’ diet), and one that contains the lowest amino acid concentration needed (‘low’ diet). For the intermediate amino acid concentration the ‘high’ and ‘low’ diets are then mixed in the appropriate ratios. The ‘high’ diet would need to contain a protein feedstuff, e.g. soybean meal or canola meal, while the ‘low’ diet would need no protein feedstuff at all, and could consist of barley only plus mineral and vitamin supplementation. A second option is to group the diets according to similar requirement. In this case, one diet would be used for gilts in early and late gestation and for 2nd parity sows in late gestation, while a second diet would be used for 2nd parity sows in early gestation and for older sows throughout pregnancy. From a nutrition and feed cost point of view, the option with 'high' and 'low' diets is preferable; however its implementation may be hampered by costs to upgrade existing feeding equipment. The second option can be implemented without doubling up the feeding equipment; it is sufficient to move the sows to the feed line that carries the appropriate ration.

**Table 3. Necessary dietary total lysine and threonine contents (g/kg) to satisfy the amino acid requirements given in Table 1 at the feed allowances given in Table 2.**

| | | 1st parity | 2nd parity | 3rd parity |
|---|---|---|---|---|
| **Early gestation** | Lysine | 7.5 | 6.0 | 3.2 |
| | Threonine | n/a | 3.2 | 2.0 |
| **Late gestation** | Lysine | 6.7 | 6.6 | 4.5 |
| | Threonine | n/a | 4.9 | 4.2 |

## Conclusions

The recent results for amino acid and energy requirements of sows strongly support the need for parity-segregated phase feeding of pregnant sows. The phase feeding program should consist of two diets that satisfy the higher and lower amino acid requirements. The feed amounts should be increased for the last four weeks of gestation. The increase in feed offered should be 0.6 kg/d for gilts, 0.5 kg/d for 2nd parity sows and approximately 0.4 kg/d for older sows. Such a feeding program supplies slightly less feed during gestation compared to single phase feeding but supplies amino acids and energy to the sows at the right amounts at the right time.

## Acknowledgements

Funding for this research has been received from: Alberta Pork, Ontario Pork, ALIDF, ACAAF and the Ajinomoto Amino Acid Research Program. Amino acids have been generously provided by Heartland Lysine (Ajinomoto).

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