

# **Establishing Nutrient Requirements for the Lactating Sow: A Summary of Recent Illinois Research**

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## **Introduction**

Genetic improvement of sows has been significant during the past two decades. Modern sows are not only leaner and heavier at maturity but also produce larger litters. A simple comparison of 1979 British national data (MLC, 1979) with similar data (MLC, 1998) 20 years later reveals a three-pig per year increase in pigs weaned per sow per year. Nutritionists are challenged to accurately estimate the nutrient needs of contemporary sows. Most efforts to date have been based on experimental results where birth weight, litter size, milk yield of the sow, and body condition of the sow have been measured in response to specific dietary treatments. We believe that further progress can be made by understanding how nutrients flow from the diet to storage and productive tissues in the body and how nutrients are mobilized from internal tissues and organs during periods of great nutrient demand such as lactation.

Conventional wisdom and some experimental data suggest that modern sows have less appetite in comparison to the animals that existed twenty or thirty years ago. At the same time, an improved capacity for milk production and the demands for milk by larger litters require that the sow either eat more or accelerate the extraction of nutrients from body tissues. The problem appears to be particularly acute in the lactating first-litter gilt. Inadequate feed intake during lactation affects return to estrus and subsequent litter size. Primiparous sows, bred younger than in the past, require nutrients for growth in addition to the demands for development of the conceptus and, post-partum, for milk production.

## **Models**

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Models are representations of reality. Good models facilitate the rapid comparison of a number of different scenarios. One approach to understanding sow nutrition is through the use of computational models that give considerations to key nutritional inputs and outputs. In order to develop such a model we began a series of experiments in the early 1990's designed to provide empirical data to use in the construction of a model of nutrient flow in the lactating sow. Specifically, we sought to understand: (1) the flow of nutrients among different organs and tissues during lactation, (2) the role of specific amino acids in controlling feed intake during lactation, (3) the appropriate approach for estimating availability of dietary amino acids for the lactating and gestating sow, (4) amino acid uptake by lactating mammary glands and subsequent utilization of nutrients for glandular growth and milk production and, (5) the effect of teat order, mammary capacity and nursing behavior on piglet growth. Using these data we created a dynamic simulation model to predict size and composition of organ tissues, growth of mammary glands and nursing pigs, and carcass size and composition in response to changes in diet composition, length of lactation, feed intake, and litter size.

Now, we will briefly summarize each of the projects.

### **Feed Intake**

Ultimately, nutrient requirements for lactating sows must include consideration of the sow's capacity for intake. Poor appetite is considered a constraint on performance in lactating primiparous sows (Lynch, 1988). Body condition at farrowing (O=Grady et al., 1985) and weight gain during gestation (Weldon et al., 1994) influence feed intake during lactation. Overfeeding sows during gestation can lead to excessive body fat and, consequently, low feed intake during lactation.

Trottier (1996) in our lab used primiparous sows to examine the relationship between low feed intake and increased weight loss during lactation and the alternative, increased gestation fat gain due to high energy intakes (Figure 2 and 3). Metabolic hormones were of particular interest. Plasma insulin and glucagon levels in primiparous sows fed a low-energy diet during gestation were higher than in counterpart sows fed a high energy diet (Figure 4). High insulin and low glucagon levels may reduce nutrient mobilization from body tissues and thus, increase appetite of the sows. Sows with a high energy intake during gestation exhibit low plasma insulin and elevated glucagon concentrations during early lactation. This is consistent with poor appetite

during lactation.

Feed intake during gestation should be high in order to maximize protein retention, yet directed to achieve optimum, not maximum, fat accretion. This strategy would maximize insulin release, minimize glucagon levels and, as a result, increase voluntary feed intake during lactation.

### **Digestibility of Amino Acids in Major Feed Ingredients by The Lactating Sow**

It is essential to know the extent to which the sow can extract nutrients from the diet that is provided. To date, the most widely utilized method for estimating nutrient digestibility is based on samples taken from the end of the small intestine, i.e., the terminal ileum. However, the digestibility values present in the scientific literature are based on samples taken from growing pigs, not from lactating sows. These digestibility values from growing pigs have been used for modeling nutrient requirements for lactating sows (Whittermore and Morgan, 1990; Pettigrew et al., 1992). Are digestibility values obtained with growing pigs representative of actual nutrient extraction in the sow? That hypothesis was tested in our next experiment.

Stein et al. (1999a) obtained ileal digestibility values for protein and amino acids for six feed ingredients, corn, soy bean meal, barley, wheat, canola meal, and meat and bone meal, in both growing pigs and sows during gestation and lactation (Table 1). The results indicate that lactating sows have higher apparent ileal digestibility values for most amino acids than growing pigs. This maybe because of elevated secretions of digestive enzymes or longer digestive tract. A reduced loss of endogenous protein at the distal ileum (Stein et al., 1999b) could be an another reason for the higher apparent ileal digestibility values obtained in lactating sows than in growing pigs. Gestating sows had a lower apparent ileal digestibility values than lactating sows.

### **Nutrient Mobilization in Lactating Sows**

Dietary nutrients are often insufficient to support milk production during lactation, especially in primiparous sows. Fortunately, sows are able to adapt to this situation by mobilizing nutrients from body tissues. Organs can become significant sources of nutrients and each organ may respond differently. Escobar (1998) and Kim (1999) investigated nutrient mobilization from different tissues during a 28-day lactation. On a percentage basis, the reproductive tract had the highest level of nutrient mobilization (Escobar, 1998). However, this is undoubtedly associated with normal postpartum regression. Kim (1999) demonstrated that the additional protein mobilization associated with an larger litters occurred primarily from the

reproductive tract. Interestingly, fat and protein mobilization occurred independently of each other in the different tissues (Escobar, 1998).

### **Nutrient Use by the Mammary Gland during Lactation**

It is essential that lactating sows provide adequate milk to nursing pigs. Thus, increasing milk yield has been one of the primary objectives for nutritionists. However, nutrient uptake and utilization by the porcine mammary gland has received little research attention. Concepts are largely based on extrapolations from studies with lactating cows.

Recent studies from our lab provide new information about sow lactation. The quantity of nutrients taken up from circulating blood by mammary glands was measured (Trottier et al., 1997; Nielsen et al., 1997) and the amount of nutrients used for mammary tissue growth was characterized (Kim et al., 1999a, b, and c).

In order to quantify nutrient uptake by mammary glands, it was necessary to develop procedure for measurement. Trottier et al., (1995) surgically fitted catheters in both the mammary vein and the carotid artery as a means of comparing arterial and venous concentrations. Using these comparisons the investigators found that almost 180 g of essential amino acids were taken up each day by mammary glands and of these 49 g were not secreted as a milk. These amino acids were apparently retained in the mammary gland (Table 2) for other functions. Thus, it was apparent to us that estimating amino acid needs based on output in milk can underestimate reality.

Kim et al. (1999a) conducted a follow-up experiment to investigate the amount of nutrients accumulated as a consequence of mammary tissue growth during lactation. That work indicated that there is a daily accumulation of seven grams of essential amino acids in sows nursing 10 pigs (Table 2). This amount represents 14.3% of essential amino acids that are taken up by the glands after milk secretion.

We have also attempted to characterize how mammary gland metabolism responds to litter size (Nielsen et al., 1997; Kim et al., 1999b). Experiments were conducted using sows nursing different numbers of piglets. Approximately 19 g of additional essential amino acids were taken up by mammary glands daily for each nursing pig during the 21-d lactation. The amount of essential amino acids additionally accumulated as mammary tissue proteins was .83 g daily with an additional nursing pig during 21-d lactation. When it is considered that 14.3% of

essential amino acids are retained in the mammary glands, the amount of essential amino acids used for mammary gland growth for nursing pig is 5.8 g per day. Thus, it can be predicted that sows with 10 nursing pigs need 49 g of essential amino acids each day for mammary gland growth (7 g accumulation) and as litter size increase sows need additional 5.8 g essential amino acids daily per nursing pigs (.83 g additional accumulation).

Amino acid needs of the mammary gland for growth have not been considered until now in the development of predictive models. As a result, the actual daily amino acid needs may be greater than predicted by the current NRC (1998) model. To test this hypothesis we conducted a practical study to determine the quantity of total daily amino acid intake that would maximize mammary gland growth (Kim et al., 1999c). Growth was maximized when sows received 55 g lysine daily; 8 g more than predicted by the NRC (1998) model for these sows. The studies from our lab (Kim et al., 1999a, b, and c) have indicated that consideration of mammary growth needs can contribute to better estimation of nutritional needs for lactating sows.

### **Summary and a Dynamic Model Nutrient Flow in Lactating Sows**

Providing optimum intake of nutrients to sows is essential if sow productivity is to be maximized and feed costs minimized. Establishing accurate nutrient requirements in lactating sows is not an easy process; it is a complex system. Understanding the flow of nutrients in the sow during lactation provides a basis for establishing nutrient requirements. Nutrient flow among various organs can be computed using our dynamic simulation model. Linear or nonlinear regression models were developed to relate information from the projects described above to create a dynamic model that simulates nutrient flow in sows during lactation (Kim et al., 1999d). Information used to construct the model included: apparent ileal digestibility of various protein sources in lactating sows (Stein et al., 1999) and nutrient mobilization in the sow's body as influenced by feed intake (Escobar, 1998) and litter size (Kim et al., 1999b), nutrient uptake by mammary gland (Trottier et al., 1997), nutrients need for mammary gland growth (Kim et al., 1999 a and c), and the growth of nursing pigs in response to maternal nutrient intake, litter size, and the location of suckled mammary glands (Kim et al., 2000). The model responds differently to inputs, such as day of lactation, daily nutrient intake, litter size, and the location of the suckled mammary gland. It is used to predict body composition and maternal weight changes during lactation, mammary gland growth during lactation, and growth of nursing pigs.

Our model predicts that when protein intake is decreased, sows will mobilize an increased amount of nutrients from the carcass and internal organs to minimize an effect on milk production (Kim, 1999). This results in small changes in ADG of nursing pigs. The NRC model (NRC, 1998), however, predicts that sows produce lower milk as protein intake decreases, resulting in a significant decrease in ADG of nursing pigs and an increase in maternal protein and fat (Table 3).

The present model can be applied in a practical situation to set a feeding plan for sows during lactation based on the litter growth and the sow body condition from the prediction at targeting weaning day in response to litter size. The present model can also be used to set a nutrient requirement in lactating sows with a concept on balancing optimal body condition of the sow with the maximal mammary gland growth and litter growth. The model will be further developed to use in the estimation of requirements.

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Table 1. Apparent ileal digestibility of some amino acids in major feed ingredients for the lactating sows<sup>1</sup>

	Corn	Barley	Wheat	Soybean meal	Canola meal	Meat and bone meal
n <sup>2</sup>	6	6	6	5	5	5
Crude protein	57.0 ± 2.9	60.2 ± 2.9	80.5 ± 2.9	71.7 ± 3.2	71.7 ± 3.2	61.3 ± 3.2
Lysine	60.5 ± 1.8	72.3 ± 1.8	79.4 ± 1.8	85.6 ± 2.0	85.6 ± 2.0	79.3 ± 2.0
Threonine	62.1 ± 2.5	60.3 ± 2.5	76.7 ± 2.5	76.3 ± 2.7	76.3 ± 2.7	70.2 ± 2.7
Tryptophan	76.9 ± 2.3	76.0 ± 2.3	86.1 ± 2.3	86.4 ± 2.5	86.4 ± 2.5	82.1 ± 2.5
Methionine	79.7 ± 1.4	78.1 ± 1.4	87.4 ± 1.4	82.5 ± 1.5	82.5 ± 1.5	84.0 ± 1.5

<sup>1</sup> Data were adapted from Stein et al. (1999)

<sup>2</sup> Number of sows

Table 2. Amount of amino acids taken up by mammary glands, retained in mammary glands, and accumulated in mammary glands during lactation in the sows

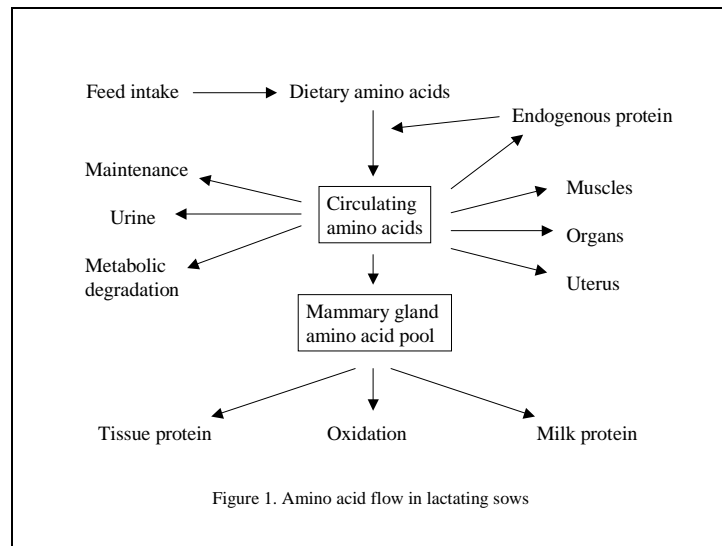
	Amino acids		
	Uptake <sup>1</sup> (g/day)	Retention <sup>1</sup> (g/day)	Tissue growth <sup>2</sup> (g/day)
Lysine	23.5 ± 6.0	1.4 ± 1.1	1.13
Threonine	16.0 ± 4.0	3.5 ± 1.1	0.63
Tryptophan	9.0 ± 1.0	-	0.16
Methionine	7.0 ± 1.5	1.4 ± 0.2	0.31
Leucine	37.0 ± 8.0	10.6 ± 2.4	1.29
Arginine	32.0 ± 7.0	16.5 ± 2.9	0.85
Valine	22.0 ± 4.0	5.5 ± 1.3	0.88
Isoleucine	18.0 ± 4.0	6.3 ± 1.1	0.64
Phenylalanine	15.5 ± 3.0	4.3 ± 1.2	0.70

<sup>1</sup> Data were adapted and modified from Trottier et al. (1997)

<sup>2</sup> Data were adapted and modified from Kim et al. (1999a)

Table 3. Comparison of outputs estimated from the Illinois model (Kim, 1999) and NRC model (NRC, 1998)

Inputs	Daily ME intake, Mcal	16.9	16.9	16.9
	Daily protein intake, g	906	850	790
	Litter size, pigs	10	10	10
<b>Outputs</b>				
Kim, 1999	Average daily gain, g/pig	142.7	141.1	139.1
	Maternal protein gain, g	-174.3	-344.7	445.1
	Maternal fat gain, g	-839.2	-620.4	-243.3
NRC, 1998	Average daily gain, g/pig	200	175	150
	Maternal protein gain, g	-900	1950	4800
	Maternal fat gain, g	-1530	2640	6810



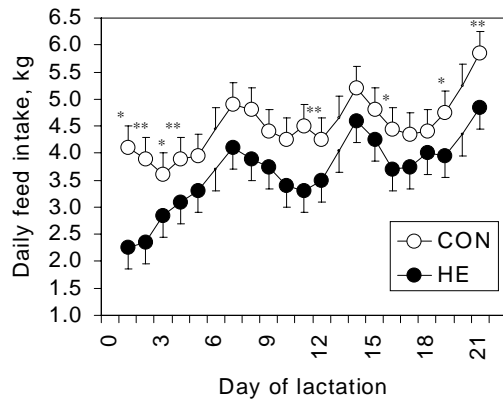


Figure 2. Daily feed intake during lactation in primiparous sows fed a control or a HE diet during gestation. \* P < .1 and \*\* P < .05 (Trottier, 1996)

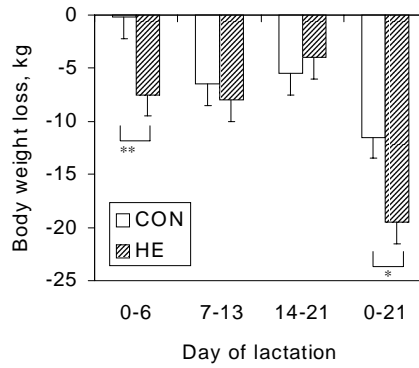


Figure 3. Weekly and total body weight loss during lactation in primiparous sows fed a control (empty bars) or a HE diet (hatched bars) during gestation. \* P < .1 and \*\* P < .05 (Trottier, 1996)

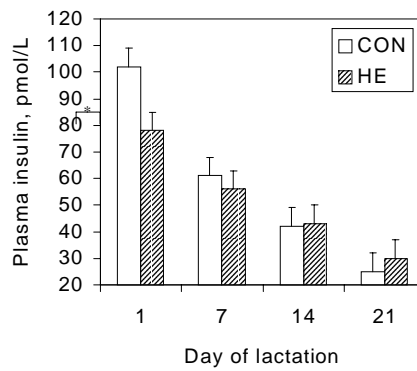


Figure 4. Plasma insulin concentration on d 1, 7, 14, and 21 of lactation in primiparous sows fed a control (empty bars) or a HE diet (hatched bars) during gestation. \* P < .1 (Trottier, 1996)