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The role of nutrition in piglet and milk production

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Introduction

Feeding lactating sows can best be described as art rather than science. From the scientific standpoint, numerous studies are conducted every year to evaluate specific nutrient requirements in order to maximize milk production and litter weaning weights as well as improve sow reproductive performance. Fortunately, producers are relatively quick to adopt this technology, as reflected in changes in lactation diet formulation. However, problems can arise when administering these precisely formulated sow diets. For example, we stress that sows should have unrestricted access to feed, yet how many times have you been in a farrowing house between 9:00 and 11:00 am and noticed that all the sow feeders are empty?

In the late 1980s, data from Swine Graphics Enterprises (as cited by Tokach and Dial[1]) demonstrated that lactation feed intake is much lower on commercial swine operations than observed in university research settings (**Figure 1**). The summary of lactation feed intake data from 120 farms indicated that average sow feed intake was well below the estimated 11.5 lb/day feed intake made by the 1988 NRC.[2] These data also indicate tremendous seasonal variation in lactation feed intake. Decreased feed intake during the summer months happens to coincide with poor breeding performance associated with seasonal infertility. It had been speculated that, with the gradual consolidation within the swine industry, much of the seasonal variation in sow reproductive performance would decrease. However, analysis of market hog slaughter by season over the past 25 years shows that this is not the case (**Figure 2**). Although the seasonal variation in hog marketings by quarter was greater in 1973 than in any of the 5-year increments since, the variation in 1998 marketings was still above average, and, regardless of year, fourth quarter marketings are always highest. This suggests that problems with seasonal infertility continue to plague the majority of sow farms in the US. This is not to suggest that feed intake is solely responsible for seasonal infertility. High ambient temperatures and photoperiod both contribute to reducing breeding performance, but low feed intake may be caused by misguided management strategies that can easily be corrected.

This is where the "art" of feeding lactating sows comes into play. We need to develop and implement procedures that encourage intake and provide feed to sows at all times. Therefore, the objectives of this paper are to:

- Review the importance of feed intake on sow and litter performance
- Demonstrate how feed intake records can be used to solve litter weight and reproductive problems
- Offer a guideline for feeding sows

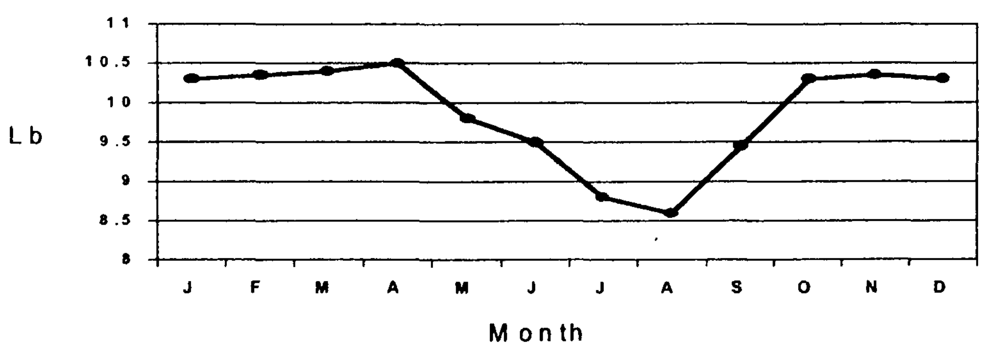

Figure 1. Composite lactation feed intake on 120 farms over three years. (Courtesy of Swine Graphics Enterprises, Inc. Webster City, IA

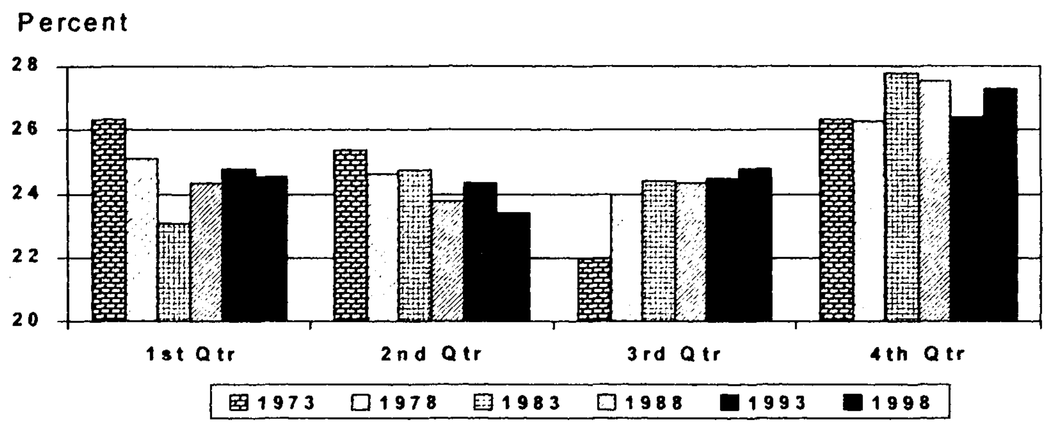

Figure 2. Commercial Hog Slaughter By Quarter. (U.S.D.A.)

Energy and amino acid intake

Restricting protein and/or energy intake during any period of lactation will reduce milk production and impair subsequent reproductive performance.[3,4,5] The negative influence on reproduction is particularly evident during summer months and can contribute to seasonal infertility. With the implementation of segregated early-weaning strategies, the importance of litter weaning weight also has increased because heavier pigs at weaning are easier to manage in the nursery.[6] Both amino acid and energy intake are important in influencing lactation and reproductive performance of the lactating sow (**Figure 3**).[7] At low energy intake (6.5 Mcal/d), increasing lysine intake from 9 to 45 g/d had little effect on milk yield. At an energy intake of 16.5 Mcal/d, however, increasing dietary lysine increased milk production markedly. These results reveal that milk yield is dependent on both lysine and energy intake because the response to one is contingent on the adequate intake of the other. Thus, energy intake must be considered when making lysine recommendations for lactating sows. Increasing dietary lysine as a remedy for low litter weaning weights will have no effect and only increase diet costs unless there is adequate energy intake to support milk production.

Energy and lysine intake also influence secretion of reproductive hormones and subsequent reproductive performance in an interactive manner (**Figure 4**).[7] At low energy intake (6.5 Mcal ME/d), increasing lysine intake had little influence on mean luteinizing hormone (LH).

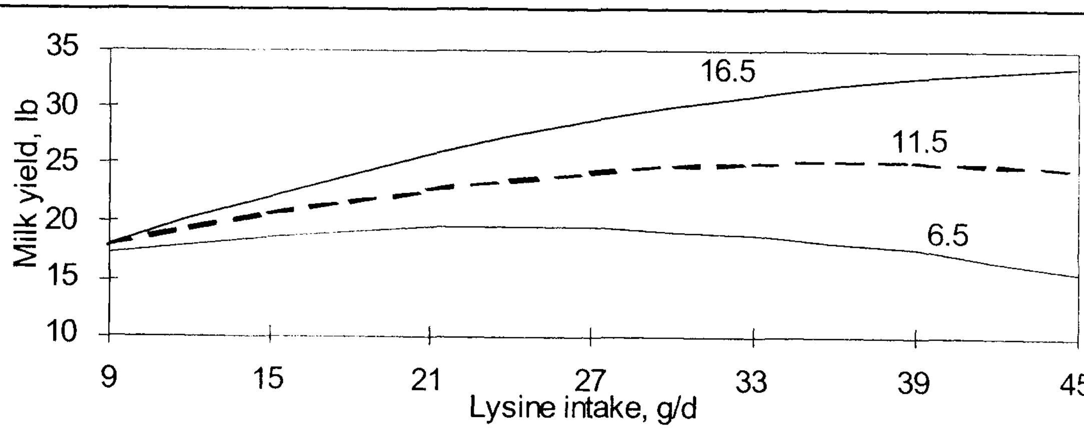

Figure 3. Influence of lysine and ME intakes on sow milk yield.

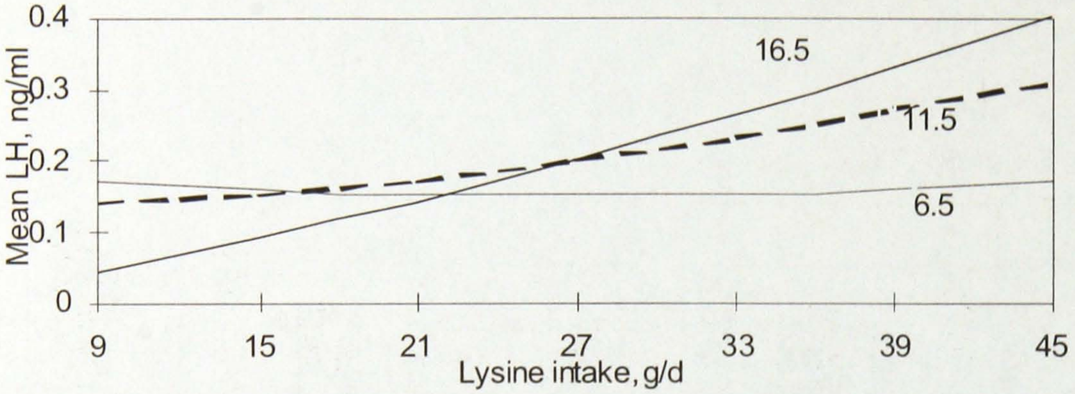

Figure 4. Influence of lysine and energy intake on LH secretion.

The influence of lysine intake on LH secretion increased as energy intake increased, however. These results reveal that LH secretion, similar to milk production, is reduced by restrictions of either lysine or energy intake. Recently Zak et al.[8] and Jones and Stahly[9] have also confirmed the correlation between total feed intake or amino acid intake, LH secretion and subsequent reproduction.

Weaning age also influences the relationship between nutrient intake and sow performance. High lactation feed intake becomes more critical as weaning age is reduced.[5] As lactation length decreases, sows with low feed intakes have decreased farrowing rate (**Figure 5**) and a longer weaning to service interval than sows with a high feed intake.

Application of these data indicate that all steps should be taken to increase total feed consumption during lactation before attempting to customize dietary lysine levels to a particular swine farm. Increased dietary lysine has little effect on sow and litter performance unless energy or feed intake is simultaneously increased. Therefore it is essential to do everything possible to maximize lactation feed intake.

The most practical method of increasing energy intake is to increase total food consumption. However, when decreased energy intake is a problem, sometimes high levels of fat (greater than 5%) are added to lactation diets to compensate for total low feed intake. It is important to remember that dietary fat is preferentially used by the mammary gland and results in production of "high fat" milk rather than being used by the sow as an energy source. Use of high dietary fat levels during lactation will improve litter weaning weights but may actually impair subsequent reproductive performance by reducing the number of LH peaks in early lactation.[10] Therefore, while some added fat (up to 4%) may be beneficial to improving litter

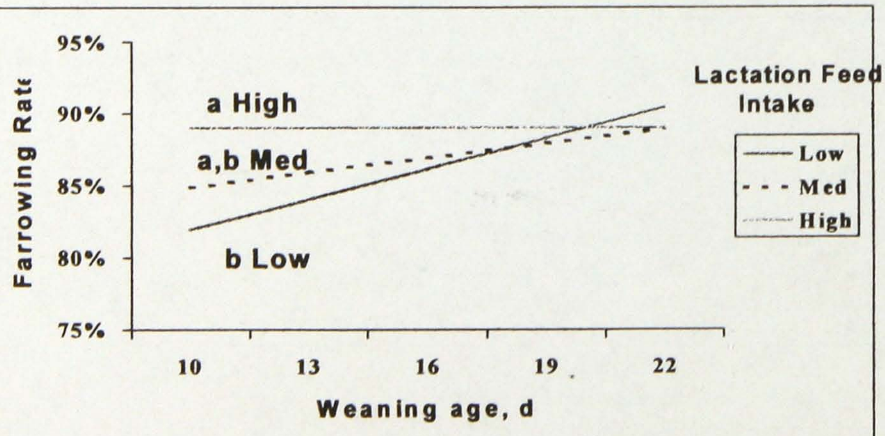

Figure 5. Influence of lactation feed intake on subsequent farrowing rate. a,b,c Lines lacking a common superscript letter differ ($P < .05$). Koketsu et al., 1997

performance, high levels of added dietary fat (greater than 5%) should not be used as a remedy for poor lactation feed intake.

While most nutritionists and veterinarians agree that maximal intake throughout lactation is the correct goal, considerable debate exists on the method to achieve maximal intake. The debate concerns how quickly feed intake should be increased in early lactation. Some advocate feeding extremely low levels of feed (2 lb/d or less) prior to and immediately after farrowing. Field experience indicates, however, that extremely low intake during this period limits the producer's ability to increase feed intake rapidly during early lactation. In extreme cases, ulcers can be created by the extended period of low intake around farrowing. After the long period without feed, sows often overeat if provided free access to feed. The sows will go off feed or have a noticeable dip in feed intake. Then, to compensate for this dip 5 to 10 days into lactation, people prescribe to limit feeding as a cure instead of correcting the management that originally caused the problem (that is, the extended period of little or no feed intake prior to and immediately after farrowing). Therefore, we recommend that prior to farrowing sows be fed at least 4 lb/d. Feed intake levels during other periods of gestation are also critical to promote maximum lactation intake. A review of these gestation-feeding patterns is provided by Tokach et al.[11]

Effects of dietary lysine on milk production

Our understanding of the amino acid requirements of lactating sows has improved greatly in recent years. As discussed above, we know that the lysine requirement during lactation is influenced by energy intake. Furthermore, recent data have suggested that the lysine requirement to minimize muscle loss and improve subsequent reproductive performance is higher than the requirement for maximum milk production. Amino acids other than lysine are also much more important for maximum milk production than previously thought.

Lysine is the amino acid that has been most intensely investigated. Research by Stahly et al.,[12] Johnston et al.,[13] and Tokach et al.[4] suggests that the lysine requirement is greater for high producing sows than previously thought. In all of these trials, total protein level of the diet was increased and lysine was considered to be the limiting amino acid. However, every experiment conducted has suggested different requirements for the lactating sow. The different recommendations from the various experiments are due largely to differences in sow productivity and feed intake. An excellent summary and explanation of the different recommendations for dietary lysine during lactation was presented by Pettigrew.[14] He indicated that the driving factor for the different lysine recommendations is the production level of the sows. Therefore, as litter growth rate increases, the grams of lysine required per day increases. Pettigrew[14] determined that 11.8 g of lysine is required for every pound of daily litter weight gain (26 g of lysine per kg of litter weight gain). A daily maintenance requirement (22 mg/lb$^{.75}$ BW or approximately 2 g/d of lysine for a 330 lb sow) should be added, while the lysine contributed from tissue breakdown (approximately 0.1 g lysine/kg (0.2 g lysine/lb) BW loss) should be subtracted from the requirement for litter gain to provide an estimate of the sow's requirement.

Based on expected feed intake, the grams/day requirement can be converted into a dietary percentage. For example, if a 330 lb sow weans a litter weighing 135 lb at 21 days, the litter birth weight was 35 lb, and the sow lost 10 lb during lactation, the sow would require 56 g dietary lysine/d.

100 lb litter gain/21 d = 4.76 lb/d
4.76 lb/d x 11.8 g lysine/lb = 56 g lysine for litter gain
56 g lysine for litter gain + 2 g lysine for maintenance - 2 g lysine from tissue breakdown = daily lysine need of 56 g

The values presented in **Table 1** have been derived using the lysine requirement estimates developed by Pettigrew[14] across a range of lactation feed intakes. Lactation feed intake can be determined from feed intake cards or from calculations based on monthly lactation feed deliveries. If the previous lactation diet is higher in lysine than the recommended level from the table, it may be possible to reduce the dietary lysine level without affecting performance. If the previous lysine level is lower or the same as the recommendation, the producer may want to increase the lysine (protein) level and reexamine performance records to determine whether litter weaning weight increases. This is a relatively simple approach that has worked well for us to customize sow lactation diets.

Once the optimal lysine level for litter weight gain has been determined, there still remains the question of sow longevity and the potential influence lactation feeding may have on subsequent reproduction. This question becomes critical when you consider that the lysine or protein requirement for optimal litter weight gain is lower than that required to minimize nitrogen loss and muscle catabolism during lactation. King et al.[15] reported that first litter gilts nursing nine pigs required a 1.08% lysine diet (40.5 g/d) to maximize litter growth rate when feed consumption was 8.3 lb. However, to minimize nitrogen loss, a 1.30% lysine diet (48.8 g/d) was required. These results are supported by Touchette et al.[16] where they demonstrated the lysine requirement for minimizing weight loss (54 g/d) or loin muscle loss (58 g/d) were considerably higher than the amount needed to maximize litter weaning weights.

Table 1: Dietary lysine level based upon litter weaning weight and sow feed intake

Adj. 21 day litter weaning Weight (lb)	Lactation feed intake (lb/day)								Lysine
	8	9	10	11	12	13	14	15	g/day
100	1.0	0.90	0.80	0.70	0.70				36
110	1.1	1.0	0.90	0.80	0.75	0.70			40
120	1.2	1.1	1.0	0.90	0.80	0.75	0.70		45
130		1.2	1.1	1.0	0.90	0.85	0.80	0.75	50
140			1.2	1.1	1.0	0.95	0.90	0.80	55
150				1.2	1.1	1.0	0.95	0.90	60

Research has demonstrated that NRC[1] lysine estimates are not adequate for lactating sows nursing large litters. The question then remains: to what levels should other amino acids be formulated as dietary lysine is increased? Research with the other amino acids was summarized by Tokach et al.[17] Researchers have demonstrated that the valine,[18] isoleucine,[19] and methionine[20] are much higher than previously predicted by NRC[1] or ARC.[21] More research is needed with these amino acids, as well as with tryptophan and threonine; however, results to date indicate these amino acids must be carefully considered in diet formulation to prevent costly limitations during lactation. In practical diet formulation, we formulate to meet the lysine requirement of the sow and attempt to maintain valine, isoleucine, and methionine as high as possible without incurring excess cost. Usually, this is accomplished by limiting the use of synthetic lysine in these diets. As more data become available, these amino acids may be added as standard ingredients in lactation diets, similar to the use of synthetic lysine in starter and grow-finish diets.

Measuring feed intake on the farm: Daily feed intake card accuracy

Recently Tokach et al. (1998)[6] demonstrated the potential problems with recording lactation feed intake using daily feed record cards. Briefly, the farm's daily feed cards showed an average feed intake of over 14 lb per day, but based on actual feed delivery, the actual feed consumption was more likely to be approximately 11 lb per day. We propose that rather than having employees spend time recording the number of feed scoops given to lactating sows each day, that this time be used to better observe the sows and/or increase the frequency of feeding. A more reliable method of monitoring sow lactation feed is by recording lactation feed delivery and dividing by crate days and lactation days. This data can then be charted and shared with farrowing house employees. Average lactation feed intake (ALFI) can be calculated by averaging the following two equations. The first is based on number of crate days according to the following formula:

ALFI=Total Feed Delivered / (No. of Crates (Days in the feed delivery period)

The second formula is based on the number of lactating days:

ALFI=Total Feed Delivered / (No. of Litters (Lactation Length)

The first method underestimates average lactation feed intake because of days that crates are empty or contain sows not yet lactating are included in the denominator. It assumes that all of the farrowing crates are occupied by lactating sows every day. The second number overestimates lactation feed intake because feed provided to prefarrowing sows is counted as feed fed to lactating sows.

Case study: Using feed intake calculations in diet formulation and feeding management

The manager of a 700 sow farrow-to-finish operation requested a review of the adequacy of their lactation diets relative to their litter weaning weights. The producer provided a summary of their production records detailing litter and sow reproductive performance as well as monthly lactation feed deliveries. We then calculated an estimated lactation feed intake using the two formulas discussed above. The average of these two calculations resulted in mean lactation feed intakes of: 10.66 lb/d from January through May; 7.66 lb/d from July through September; and 11.49 lb/d from October through December (**Figure 6**). Based on the seasonal shift in lactation feed intake, we expected to see a corresponding shift in litter weaning weights. However, litter weaning weights consistently averaged 84 lb (13.5 d lactation) despite the 30% reduction in feed intake. Therefore, sows must have been losing a considerable amount of weight during the summer months (confirmed by visual observation) to meet energy and amino acid requirements to support the litter weight gains. Further analysis indicated that percentage of repeat services increased from approximately 10% for the first quarter to 20% during the summer months following about a one month lag behind the decrease in sow feed intake. Farrowing rate also appears to be affected by sea-

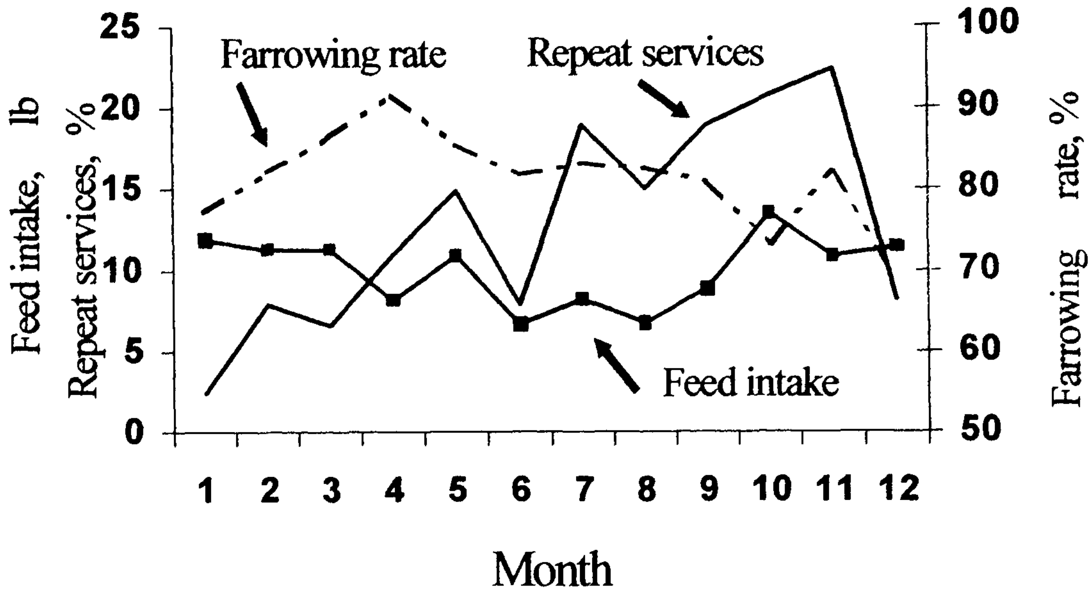

Figure 6. Seasonal effects on feed intake and reproduction

son and feed intake, with about a four month lag behind decreased feed intake. Results of this analysis indicated a revision of the producer's lactation diet formulation from the previous 1.1% lysine diet fed all year long, to a seasonal program where a 0.9% lysine diet is now being fed from October through May, and a 1.3% lysine diet being fed from June through September. We realize that if feed intake remains at the 7.5 lb average during the summer, energy will be first limiting milk production with the 1.3% lysine diet; however, our goal is to minimize sow muscle tissue loss and hopefully improve rebreeding performance.

In addition to changes in diet formulation, this analysis highlighted the issue of sow feed intake and emphasized the need for trying to improve feed intake, especially during the summer months. Strategies discussed included multiple feedings, with emphasis on providing extra feed with the afternoon feeding based on the theory that sows might shift their intake patterns to consume more feed at night. A review of environmental modifications such as increased air movement with stirring fans to improve the effectiveness of their drip cooling system was also discussed. Again, it is necessary to emphasize that the seasonal infertility problems observed in this herd cannot be entirely blamed on the seasonal change in feed intake. But by identifying the importance of feed intake and establishing a benchmark for the farm, changes in management might help offset a portion of the summer infertility by attempting to increase feed intake.

A practical method for maximizing lactation feed intake

Many different feeding methods will work to obtain maximum feed intake. The most important facet of any feeding method is to ensure that the sow always has access to feed. The simplest method we advocate is if the feeder is empty, put feed in it. We also advocate feeding sows at least three times per day. However, many producers are concerned with detecting sows that go off feed. Therefore, we advocate the following method as a simple procedure that can be introduced to a wide variety of personnel with a minimum amount of training that will ensure the early detection of sows that are off feed. To maximize sow feed intake, we suggest using the procedure shown in **Table 2** and outlined below.

Sows are fed zero, one, or two scoops (one scoop equals 4 lb) at each of three feedings during the day. If the feeder has significant feed left from the previous meal, no feed should be added to the feeder. If a small amount of feed is left, one scoop should be added. If the feeder is empty, two scoops should be fed. The only deviation from this pattern is for day zero to two after farrowing. During this time, the decision is to give zero or one scoop at each meal. The sows should not receive two scoops at a single feeding during this period. Following is an example of the decision process at each feeding.

Table 2: A suggested feeding procedure during lactation

Number of 4 lb scoops to feed at each feeding from day 0 to 2		
	Feeding	
Feed in Feeder	AM	PM
Empty	1	1
<2 lb	0	0.5
>2 lb	0	0

Number of 4 lb scoops to feed at each feeding from day 2 to weaning			
	Feeding		
Feed in Feeder	AM	Noon	PM
Empty	2	2	2
<2 lb	1	1	2
>2 lb	0	0	1

Morning feeding

All sows are fed one scoop if a small amount of feed is left in the feeder and two scoops if the feeder is empty.

Late-morning feeding

A second feeding is done later in the morning or immediately after lunch using the same scheme, (that is, one scoop if a small amount of feed remains and two scoops if the feeder is empty). If no feed has been consumed since the morning feeding, the sow is then investigated to determine if she has a fever, retained pig, or another detectable reason for being off feed.

Evening feeding

A similar scheme is used for the evening feeding; however, some judgment will have to be used if there is some feed left in the feeder. The sows that have had good appetites throughout the day but some feed remaining should receive two scoops. Sows that appear to be reaching appetite receive one scoop, and again if the feed has not been touched since the last feeding, the sow is investigated to see if there is a detectable reason for being off feed.

A key to this method of feeding is developing a communication method between various employees to indicate an individual sow's appetite history for the previous two or three meals. The communication is needed to determine how long the sow has been off-feed. Various methods are used including recording the daily feed intake, clipping clothes pins on the feeder according to an established code, or moving the farrowing card to different positions to indicate poor appetite in previous meals.

Conclusion

The scientific evidence is clear that maximizing lactation intake results in increased milk production and increased subsequent reproductive performance. However, as illustrated by the case studies presented, we commonly observe management induced lactation energy deficiency. We have proposed a method of lactation feeding that concentrates on providing multiple small meals each day during the lactation period. This method has been used successfully on several farms to increase lactation feed intake.

References

1. Tokach, M.D., and G.D. Dial. Managing the lactating sow for optimal weaning and rebreeding performance. In: Tubbs, R. and Leman, A. *Swine Reproduction.* Vol 8 No. 3 The Veterinary Clinics of North America – Food Animal Practice. W.B. Saunders Co. Philadelphia, PA; 1992 –559–573
2. NRC. 1988. *Nutrient Requirements of Swine.* Ninth Revised Edition. National Academy Press, Washington, DC.
3. King, R. H., and G. B. Martin. Relationships between protein intake during lactation, LH levels and oestrus activity in first-litter sows. *Anim. Reprod. Sci.* 1989; 19:283.
4. Tokach, M. D., et al., Quantitative influence of lysine and energy intake on yield of milk components in the primiparous sow. *J. Anim. Sci.* 1992; 70:1864.
5. Koketsu, Y., et al., Influence of various factors on farrowing rate on farms using early weaning. *J. Anim. Sci.* 1997; 75:2580.
6. Tokach, M. D., et al., Managing Variation on the Way In: Weaning Weight. *Proceedings of the Allen D. Leman Swine Conference.* Brooklyn Center, MN. 1998; 25:120–125.
7. Tokach, M. D., et al., Characterization of luteinizing hormone secretion in the primiparous, lactation sow: relationship to blood metabolites and return-to-estrus interval. *J. Anim. Sci.* 1992; 70:2195.
8. Zak et al., Pattern of feed intake and associated metabolic and endocrine changes differentially affect postweaning fertility in primiparous sows. *J. Anim. Sci.* 1997; 75:208.
9. Jones, D. B., and T. S. Stahly. Impact of amino acid nutrition during lactation on leutinizing hormone secretion and return to estrus in primiparious sows. *J. Anim. Sci.* 1999; 77:1523.
10. Kemp, B., et al., Effects of energy sourcce in the diet on reproductive hormones and insulin during lactation and subsequent estrus in multiparous sows. *J. Anim. Sci.* 1995; 73:3022.
11. Tokach, M.D., et al., Breeding herd recommendations for swine. *Kansas State University Swine Nutrition Guide* MF2302, 1997.
12. Stahly, T. S., et al., Lactational responses of sows nursing large litters to dietary lysine levels. *J. Anim. Sci.* 1990; 68(Suppl. 1):369(Abstr.).
13. Johnston, L. J., et al., Response of maternal-line sows to dietary protein concentration during lactation. *J. Anim. Sci.* 1991; 69(Suppl. 1):118(Abstr.).

14. Pettigrew. J. E. *Biokyowa Nutrition Update. Lactation requirements for the sow*. 1993. Biokyowa. Inc. Chesterfield. MO.
15. King. R. H., et al., The response of first-litter sows to dietary protein level during lactation. *J. Anim. Sci.* 1993; 71:2457.
16. Touchette. K.J., et al., Lysine requirement of the lactating primiparous sow. *J. Anim. Sci.* 1996; 74(Suppl. 1):63(Abstr.).
17. Tokach, M.D., et al., Amino acid requirements for lactating sows: new developments. *Compend. Contin. Educ. Pract* Vet. 1996; 18:S127.
18. Richert, B. T., et al., Valine requirement of the high-producing lactating sow. *J. Anim. Sci.* 1996: 74:1307.
19. Richert, B. T., et al., Increasing valine, isoleucine, and total branched-chain amino acids for lactating sows. *J. Anim. Sci.* 1997; 75:2117.
20. Schneider. R., et al.,. Futteraufnahme und lebendmasseentwicklung von sauen wahrend der laktation in abhangigkeit von der methioninversorgung. 1. mitteilung zum bedarflaktierender sauen an schwefelhaltigen aminosauren. *J. Anim. Phys Anim. Nutr.* 1992; 68:235.
21. ARC. 1981. The Nutrient Requirements of Pigs. Commonwealth Agricultural Bureaus. Slough. UK.