

Nutrition and Management of the Sow to Maximize Lifetime Productivity

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■ Introduction

A high level of weaned pig output can be maintained over the reproductive life of the sow if she consumes adequate amounts of energy and nutrients. First litter females are especially vulnerable to nutrition deficit, which typically occur during lactation. Adequate intake of amino acids during lactation is important for first litter females since excessive body protein loss results in a prolonged wean to estrus interval (WEI) and reduced subsequent litter size. A practical outcome of extended WEI is to cull for presumed reproductive failure.

This paper presents a brief review of Nutrition and Management practices that are important to lifetime productivity of the prolific sow. It places them in the context of a practical feeding strategy with the objective of maximum lifetime pig output at a profitable dietary input cost. Emerging opportunities are also cited for the young pig because of the potential impact on lifetime output of the sow and added financial reward.

■ Gilt Development for Longevity

The stages at which nutrition and management strategies tend to fail are in gilt development to first litter and feeding during first lactation. Proper nutrition and health acclimatization are fundamental, but the industry is still seeking the correct approach for replacement female production and introduction. Gilt development is a long-term process involving 4 phases:

- Controlled growth and health acclimatization begins early (25 kg).
- Puberty induction to promote physiological age prior to first breed.
- Growth in body mass to parturition and,
- First lactation and post-wean feeding to minimize body reserves loss.

Foundation Principles. Foxcroft and Aherne (2001) wrote a *seminal review* on the management of the replacement gilt. Key conclusions are:

- Significant time is required to achieve health acclimatization.
- Nutrition program that achieves physiological age without excess weight.
- Life-time growth rates exceeding 550 to 650 g/d produce heavier gilts and extra cost at first estrus and at breeding.
- Stimulate gilts to cycle at an early age.

Immune Development of Maiden Gilts

Moore (2001) emphasizes giving a low exposure to pathogens found in the system, early in life. There are different templates for gilt development but the common thread is deliberate introduction of challenge. Many problems that we face are mainly health related and have been minimized using a system that involves acclimatization and strategic vaccinations early in life that match health challenges in the target herd. Herds that have not achieved a PRRS stable status appear to be especially compromised and exhibit high sow mortality. This disease is devastating because it is immune suppressive.

Crew specialization for gilt development is important because of the processes that must be delivered on over a 'lifetime' (e.g., health challenge, puberty stimulation, proper breeding endpoints).

Nutrition and Growth of Bone

Proper development involves lifetime rearing with a mind to structural integrity, minimum body mass and immunity. Bones of first litter sows are weaker and more vulnerable to fracture than older sows (Geissemann et al., 1998). Changes in bone weight and strength during lactation were greater for young sows (Parity 1 > 2 > 5). Nutrition to optimize bone integrity of the maiden female should aim to maximize bone weight by the first two litters. The advantage of reduced growth rate prior to first breed on structural longevity remains unclear in pigs for a variety of reasons (Rozeboom, 1999).

Research is needed to relate lifetime growth rate to bone and cartilage integrity.

Pregnancy Growth for Minimum Body-size by Parturition

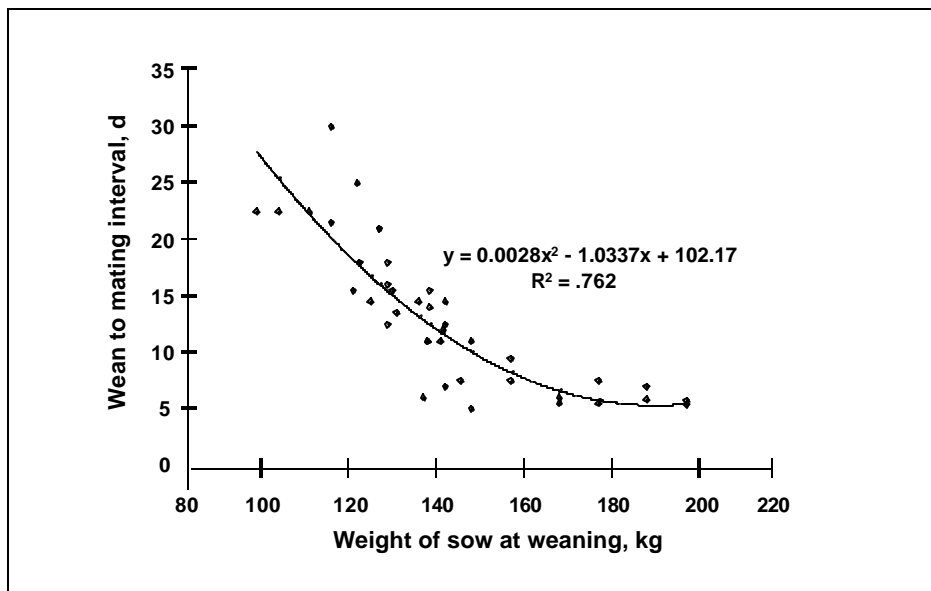
A complete reproductive cycle is one of the most Nutritionally expensive and challenging activities that a female can undertake. This is especially true for prolific first litter females since they have a smaller body mass. Nutritional strategy during first pregnancy may also impact reproductive ability for first litter females since there appears to be a minimum body size needed by the end of

pregnancy to support a rapid return to estrus. Williams and Mullan (1989) developed a relationship between female wean weight and WEI. It suggests that a wean weight of 150 kg or more minimizes wean to mating interval (Figure 1) and that a progressive increase in the WEI is predictable with lower body weight (greater weight loss). The insult of large body protein and (or) fat losses to support lactation is greatest for young sows because absolute body mass is low.

First Lactation

The process of gilt development is successfully completed when first litter females are fed to minimize the loss of body protein and fat. First litter females are especially vulnerable to nutrition deficit, which typically occur during lactation. Adequate intake of feed during lactation is important for first litter females since excessive loss of body fat and protein results in a prolonged wean to estrus interval and reduced subsequent litter size. This aspect is discussed later.

Figure 1. Primiparous sow weight at weaning and wean to mating interval (Williams and Mullan, 1989).



■ Feeding the Pregnant Sow

There are 3 stages of pregnancy that merit different feeding strategies. The *first* stage is early pregnancy and involves embryo survival and implantation.

The **second** stage is devoted to body growth and recovery of body reserves. Sows are fed to promote maternal gain and to recover body reserves that were mobilized during the previous lactation. The **third** phase is late pregnancy (last 35 d) and is characterized by exponential fetal and mammary growth. Our discussion will be restricted to practical feed levels for each stage and achieving proper end-points.

Maternal Growth

The feed requirement for pregnant sows can vary by 30-50% within a herd, depending on the attention given to body reserves. In practice, the main reason for differences in daily energy requirement are body condition and phase of pregnancy (e.g., first 72 h after mating, late pregnancy) and not body size. This is illustrated in Table 1. The NRC Sow model (1998) was used to generate energy and lysine needs for 7 parities during mid-pregnancy. Net maternal gain reflects reasonable expectations for tissue growth and yields the minimum expected body weight after 6 litters. Feed levels allow for moderate weight gain and assume that body condition is near optimum and that temperature is thermal-neutral.

Table 1. Predicted dietary energy and lysine needs to support different rates of growth during pregnancy over the life-cycle^a.

Litter No.	Body Weight at Mating	Net Pregnancy Gain	Diet Intake	Predicted NRC ME	Total Lysine
	kg	kg	kg/day	Kcal/day	g/day
First	125	35	2.15	6930	12.3
2	150	35	2.25	7250	12.5
3	175	25	2.25	7250	12.3
4	190	20	2.25	7250	11.9
5	200	15	2.20	7090	11.5
6	210	13	2.20	7090	11.4
7	218	11	2.20	7090	11.1

^a Computed using the 1998 NRC Gestation Model. Assumed 3225 Kcal NRC ME/kg diet and 12 fetuses (litters 1-2) or 14 fetuses (litters 3-7). Total lysine levels assume a Corn-Soy diet. Energy and feed amounts assume that no body reserves need to be recovered. Adjustments for body reserves are shown in Table 2. DE = ME / 0.96.

The objective with young females should be to increase body protein and fat mass without making them fat. The amount to be fed to first and second litter sows is similar to older, heavier sows because of declining net maternal gain with advancing age. The daily requirement for feed would need to be increased by about 60 g for each 1 C below the critical temperature for cold. This is approximately 18 C for sows in dry stalls and 14 C that are housed in groups. This would be higher for thin sows since their maintenance requirement is higher.

Feeding to Recover Body Reserves Lost During Lactation

Pregnancy feed level normally includes recovery of body reserves for 30-45 d. Absolute minimums for maintenance, late pregnancy and for body fat recovery are shown in Table 2. A reasonable endpoint for body condition is 2.5 to 3.0, which we equate to 16-18 mm P₂. Feeding strategies require ultrasonic validation on a herd basis. Fat depth is symbolic of energy input in relation to energy expenditure and the need for adipose recovery.

Table 2. Minimum feed levels required to reclaim body reserves and to support pregnancy in sows (assumes 182 kg sow).

Body Condition Score	Average P2 Fat depth, mm	Minimum Intake, kg/d
1	8 to 10	3.5 ^a
2	12 to 14	2.8 ^a
3	16 to 18	2.2
Maintenance		1.6
Maintenance + Growth (20 kg)		2.2
Maintenance + Conceptus + Mammary + Growth		2.8

^aComputed using NRC 98 Model. Assumed 2.0 kg fat = 1 mm fat depth. Corn-Soy diet.

Late Pregnancy Nutrition

Nutrient needs increase exponentially in late pregnancy. An increase in feed level during this phase will prevent loss of maternal body protein and fat that would otherwise be mobilized to support fetal and mammary growth. Sows will lose substantial amounts of body fat if energy intake is not sufficient. Sows fed at about maintenance (6.0 Mcal DE/d, 182 kg bw) were shown to be in negative energy balance in late pregnancy. We calculate that about 2.5 kg body fat would be mobilized if fed 6.0 Mcal/d from d 90. At least 7.5 Mcal DE/d is

needed to prevent this. It was estimated that up to 9.5 Mcal DE/d was needed from d 90 to parturition to maintain P₂ fat depth in sows (ref. cited in Boyd et al., 2000).

Protein needs increase during late pregnancy. Nitrogen retention is estimated to increase from 910 g/d at mid-pregnancy to 17-18 g/d in late pregnancy. Protein deposition rate increases 2-fold in the conceptus and 3-fold in mammary from d 100 to farrow (ref. cited in Boyd et al., 2000).

Excessive maternal gain and fatness can predispose the sow to dystocia at farrowing and decreased sow longevity (Dourmad et al., 1994). Thin sows are unable to mobilize adequate body reserves to support milk synthesis. Milk secretion may be reduced, especially if restrictively fed. A realistic minimum endpoint for body fatness is 16-18 mm P₂ fat. There is no advantage for having more than 22-24 P₂ mm fat depth and sows having ≤ 12 mm P₂ at farrow appear to be compromised (target, <12% of herd).

Phase Feeding in Pregnancy

A *phase feeding* strategy during pregnancy is advised (vs constant feed level throughout). It involves feeding the required amount of diet at each stage. Phase feeding accommodates (1) early pregnancy embryo viability (0-72 h minimum), (2) growth and recovery of body reserves (to 90 d pregnant) and (3) exponential fetal and mammary growth (90 d to -2 d pre-farrow). This can be accomplished with three feed levels in most cases (90%). Twice a day feeding is preferred.

■ Feeding the Lactating Sow

The feeding strategy during lactation should be to maximize feed consumption. Nutrient specification is critical but secondary. Feeder type and feeding method are too often inadequate for prolific sows. It is normal for lactating females to lose weight (<10 kg in 21 d), but excessive loss may result in prolonged WEI and decreased litter size.

Nutritional Burden of Lactation

The nutritional burden imposed by nursing a large litter was illustrated using prolific first litter females (Boyd et al., 2000). Sows weaned 10.2 pigs of 11 pigs placed per litter and nursed up to 21 d. A practical diet (0.95% total lysine) was fed with slight restriction for the first 5 d of lactation and then full-fed. Litter growth rate was determined at 5 d intervals to estimate milk output (Table 3).

Table 3. Predicted energy and lysine needs for prolific first litter sows^{a,b}

Item	Lactation Interval, days				Mean
	1-6	7-11	12-16	17-21	
Litter growth rate, kg/d	1.95	2.54	2.70	2.63	2.46
Calculated milk output, kg/d	7.80	10.16	10.80	10.52	9.84
Feed disappearance, kg/d	3.21	5.74	6.77	7.59	5.83
Energy balance, Mcal ME/d					
Required	20.43	24.96	26.19	25.65	24.30
Deficit	-9.59	-5.56	-3.31	0	-4.61
Lysine balance, g/d					
Required	55.9	71.5	75.8	73.9	69.3
Deficit	-25.4	-17.0	-11.5	-1.8	-13.9
Cumulative protein mobilized, kg	2.33	3.89	4.95	5.12	
Dietary lysine, % ^c	1.57	1.12	1.01	0.88	

^a Adapted from Boyd et al., 2000.

^b Assumptions: 30 females, 195 kg bw; fed conservatively 5 days then full fed @ 4 times/day; 10.2 pigs weaned/litter; 4 g milk per g piglet growth.

^c Dietary Lysine need assumes 90% of Lysine balance.

Milk output averaged nearly 10 kg/d for the 21 d lactation (assuming 4 g milk/g piglet gain). Almost 8 kg/d was produced during the initial 5 d (d 1-6). Energy balance was negative throughout but especially during d 1-6 when a conservative feed strategy was used. An estimated 10.4 kg of body fat would be mobilized to meet milk energy needs for 18 d of lactation (@ 0.58 kg/d). This would decrease to 8.5 kg if 9.2 pigs were nursed, which is an 18% decrease. Approximately 0.65 kg/d of feed would be needed for 60 d (d 5-65) to reclaim the extensive mobilization of body fat stores (10.4 kg).

The lysine and energy deficit suggests that feeding strategy and lysine level were inadequate. Conservative feeding during d 1-6 resulted in an extreme negative balance of energy and protein. We estimate that 45% of the total loss in body protein during the 21 d lactation (5.1 kg) was lost during the first 6 d. The insult to total body protein for the entire lactation is estimated to be 17.5%.

Feed Intake Targets Depend on Litter-size and Stage of Lactation

The amount of diet that must be consumed depends on litter-size and stage of lactation. This is illustrated in Table 4 for the first litter sow.

Table 4. Impact of litter-size and day of lactation on feed intake targets

No. Pigs Nursed	Daily feed level (kg/d) to achieve 85% energy balance ^a		
	Interval in Lactation d ^b		
	1-7	8-14	14-19
9	4.45	5.68	6.27
10	4.82	6.10	6.77
11	5.14	6.55	7.36

^a First litter 160 kg bw. Pig Growth Rate = 165, 230, and 265 g/d for weeks 1, 2 and 3.

^b Intake estimate based on: 3365 Kcal/kg (3506 DE), 85% of energy balance achieved.

Phase Feeding of Lactation Diets

Nutrition constrains litter size in the first litter female (Boyd et al., 2000). It appears that the first 10-12 d of lactation is very demanding and that the dietary requirement for lysine (% and other amino acids) may decline during lactation. Predicted dietary lysine need is relatively low late in lactation because milk output was maximized before 12 d (95%) and feed intake continued to increase throughout lactation.

Thus, a separate diet is warranted for first litter females and aggressive early feeding is especially important. In practice, implementation might involve either (1) a second diet or (2) a hand addition of soybean meal to the normal lactation diet for the first 12-14 d for first litter and thin sows.

■ Feeding from Post-weaning to Mating

Weaning is the time to assess the effectiveness of lactation feeding and to set objectives for recovery of body reserves. Limiting back fat loss to 2 mm from farrow to weaning (18-20 d) is evidence for good feeding management.

High post-weaning feed level has been reported to shorten the interval to service in first litter sows, which results in a higher percentage exhibiting estrus within 10 d of weaning. It has no such effect on more mature sows that are in relatively good body condition (Aherne and Kirkwood, 1985).

■ Segregated Production - First Litter Sows and Progeny

This part of the discussion addresses *Specialization* and *Segregation* because improved productivity and longevity result. Segregation of (1) first litter females allows for the specialization in nutrition and management that is required. Segregation of (2) parity 1 progeny into separate production flows is reasonable because of known differences in piglet wean weight and apparent differences in maternal immunity conferred by the sow. This may have consequences into the nursery and finish phases of growth.

Segregated and multi-site production techniques are part of modern pig production. There are reasons to extend the concept of segregation to the first litter female and her progeny. The idea is somewhat novel when health advantages are considered, but the benefits are more obvious for Nutrition and Management. There are financial rewards to the practice of keeping like 'things' together. Gilts and sows are simply different (Moore, 2001).

Nutritional Segregation of First Litter Sows

The sow herd is composed of two sow types with distinct differences in nutrient need: (1) First litter and thin sows and, (2) multiparous sows in proper body condition. The lysine requirement is higher for first litter sows. Preservation of body protein appears to be more important to WEI and subsequent litter-size (Boyd et al., 2000). Further, the effect of nutrient deficit on depression in second litter-size increases as first litter-size increases.

The choice to segregate first litter sows from other parity females also involves management considerations. Dedicated programs address differences in the need for farrowing assistance and customized diet. First litter sows don't respond the same at breeding (length of estrus). Their wean-to-first service interval tends to be longer and more variable (+ 1 to 2 d). There is the greater probability of return between d 8-12 post-weaning, which is noted for resulting in a low litter-size (Vesseur et al., 1994). The latter could be skipped 1 estrus cycle.

Progeny Segregation

Piglet weight at birth and weaning is less for gilts than for older sows. We are also beginning to understand that the health challenge faced by gilt progeny is greater than for progeny derived from mature sows. The younger sow would not be expected to confer the same degree of immune competence to her progeny because of differences in colostrum and perhaps in milk. Gilt progeny can be a destabilizing factor to health in the nursery and finish barn (Moore, 2001). All impact the efficiency of Finish barn utilization.

Table 5 shows the advantage that has been observed when progeny from Parity 1 (P 1) and Parity 2+ sows are kept segregated in different nursery and finish buildings. Moore (2001) reports more health problems in P-1 progeny in terms of mortality and medical cost. They tend to grow slightly slower in both phases. Segregated rearing presents the opportunity for strategic medication and vaccination. The advantage of segregated rearing of progeny is consistent with early results of a larger U.S. system (per. com., Hanor Company).

Table 5. Comparison of P1 and P2 progeny nursery – finish performance

Item	P1 progeny	P2+ progeny
Weaning weights (kg)	5.30	5.70
Nursery mortality (%)	3.17	2.55
Nursery ADG (g/day)	412	435
Nursery drug cost (CDN \$)	2.15	0.85
Finishing Mortality (%)	4.31	2.95
Finishing ADG (g/day)	735	765
Finishing drug cost (CDN \$)	1.82	1.01
Lungs with enzootic pneumonia lesions (%)	31	11

Adapted from Moore, 2001.

Influence of Maternal Age on Immune Competence

The influence of maternal age on the immune competence of progeny is best understood in dairy cattle. The first calf heifer does not confer the same degree of protection against pathogens as do older cows. There are also breed differences in (a) colostrum volume and (b) immunoglobulin concentration (Besser and Gay, 1994). First calf heifers, that have been Nutritionally deprived in late pregnancy, are likely to produce an insufficient volume of colostrum. Calves born after dystocia are often weakened and at higher risk of failing to receive adequate colostrum. With this in mind, it is an surprising that we often castrate 'newborn' pigs on the day of birth when nursing (for colostrum intake) should be the focus. Pendulous udders, large teats and ill-timed piglet transfer present additional challenges to adequate colostrum intake.

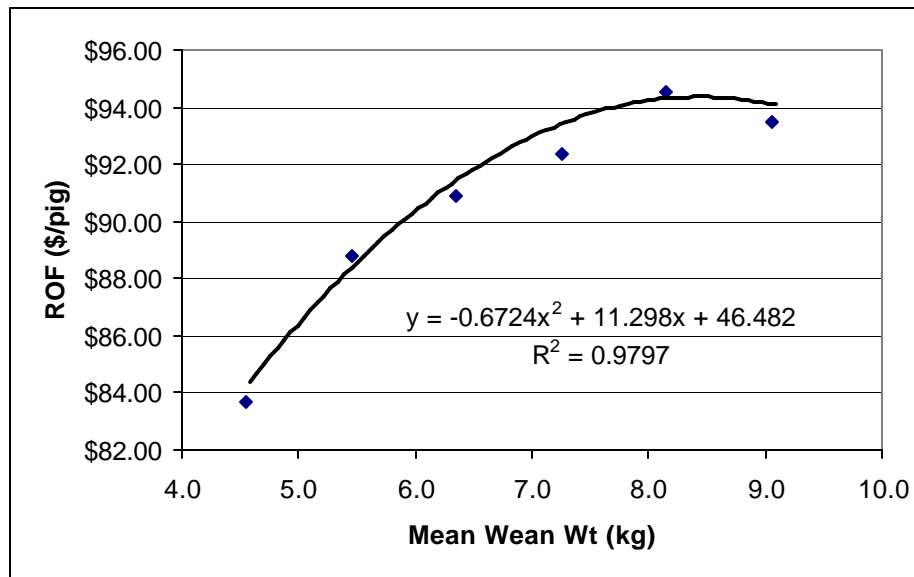
It appears that the sow influences immune competence of her progeny beyond the period of colostrum intake. Substances in sow milk are known to exert an

influence on intestinal cell growth and perhaps early development of the immune response (Blecha et al., 1983). This was illustrated in a practical study by comparing growth rates of pigs receiving sow milk to weaning to that of pigs allowed to nurse the sow for 2 d and then provided a good milk supplement in the same environment to weaning. The former grew faster from weaning to 125 kg than the latter when reared in the same pens (Cabrera et al., 2001).

Impact of Wean Weight on Subsequent Growth Performance

The financial reward of rapid growth through the Nursery and Finish unit and of decreasing variation is large because Finish barn use is more efficient (Figure 2, adapted from Cabrera et al., 2001). Segregating first litter progeny to separate production flows might further benefit more efficient Finish barn use by (1) decreasing the percent of smaller weaned pigs and, (2) by eliminating the further impact of gilt-derived pigs with a less developed immune system.

Figure 2. U.S. \$ Return Above Feed Cost vs. Average Wean Weight



■ Conclusion

A high level of weaned pig output can be maintained over the reproductive life of the prolific sow if she is developed properly and then is fed and managed properly. Gilt development is one of the most disappointing aspects that we observe. It is a long-term process that begins early and completes upon

weaning the first litter and re-breed. Critical control *points* that are too often inadequate are:

- Immune development and health acclimatization,
- controlled growth to proper body size by first litter, and
- early estrus stimulation to promote physiological age.

We are still seeking to understand the impact of growth rate on cartilage integrity. Proper development cannot protect against poor lactation feeding and 'unfriendly' facilities that injure.

The underlying theme of this paper is *Specialization and Segregation*. There are known differences in the management and nutritional needs of first litter sows. There are known differences in piglet wean weight and apparent differences in maternal immunity conferred by the first litter sow compared to older counterparts. These have consequences into nursery and finish phases. There are financial rewards to providing specialized, and in some cases, segregated rearing. Improved sow longevity and progeny performance result.

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