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Nutritional management of seasonal infertility

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Introduction

The objective of this review is to provide an overview of nutritional management strategies that can be used to help maximize reproductive performance of gilts and sows during the summer and autumn months that coincide with the period in which seasonal infertility is most often observed. In a related paper, Dr. Kirkwood discusses more broadly causes and treatments of seasonal infertility. However, we do feel that a brief discussion on this topic is warranted as an introduction.

"Seasonal infertility" refers to the reduction in reproductive performance of sows and gilts often observed during the months of late summer and early autumn. The European wild boar is a seasonal breeder (Mauget, 1982), and the period of late summer/early autumn during which seasonal infertility is generally observed in the domestic pig coincides with the natural period of seasonal anoestrus in the European wild boar (Claus and Weiler, 1985). The most common symptoms of seasonal infertility reported from case studies include: increased age of gilts at first mating, extended interval between weaning and mating, and reduced farrowing rate (Hennessy and Williamson, 1984; Love, 1978; Xue et al., 1994; Peltoniemi et al., 1999a, 1999b). As a consequence, non-productive sow days and culling rates associated with seasonal infertility have a significant economic impact in problem herds (Leman, 1992). Unfortunately, the etiology of seasonal infertility is poorly understood, thereby making management difficult. The two primary causative factors associated with seasonal infertility seem to be: seasonal changes in day length and high ambient temperatures resulting in heat stress in lactation and early gestation (for review see Love et al., 1993; Prunier et al., 1996). However, as Hennessy and Williamson (1984) state in regard to seasonal infertility "whether reduced fertility is due to heat stress *per se* or to photoperiod or to heat stress in conjunction with other stressors can not be easily ascertained. It is reasonable to assume that many factors such as the social environment, management, nutrition, and the physical and thermal environments of the sow acting on the central nervous system as stressors may combine and contribute to a total and detrimental stress to sows both before and during mating and in early pregnancy." In other words, management of sows to minimize seasonal infertility requires a systems approach.

Each component of the production system must be designed to minimize the animal's biological responses to natural seasonal stressors that coincide with seasonal infertility. In the following sections we provide an overview of management strategies, with a focus on nutrition during pregnancy and lactation, that can be used in a systems approach to facilitate maximal reproductive success in summer and autumn.

Housing and feeding level during pregnancy

It has been suggested from studies conducted in the U.S. (Leman, 1992), Australia (Love et al., 1993) and Europe (Peltoniemi et al., 1999b) that individual housing reduces the seasonal effects on fertility compared to group housing. It is not clear how individual housing protects against seasonal effects on fertility. Love et al. (1995) suggest it is likely associated with uniform feed intake and reduced stress, particularly the social stress invoked by group-housing of sows.

However, group housing of sows is the only alternative for swine producers in many European countries because of government bans on the use of gestation crates, and this trend is gaining support in the U.S. as evidenced by the recent ban on the use of gestation crates in Florida, with similar attempts being unsuccessful in California and Oregon. This trend, combined with the increased susceptibility of group-housed sows to seasonal effects on fertility, warrants further discussion on nutritional management of seasonal infertility in group-housed sows during pregnancy.

Love et al. (1995) reported a beneficial effect of a high feeding level during the first four weeks of pregnancy on farrowing rates of group-housed sows in each of two trials conducted at separate Australian pig production units during the summer-autumn period which coincides with the period of seasonal infertility in these locations. However, the protective effect of a high feeding level in early pregnancy on farrowing rates was not observed during the winter-spring period.

Production

In trial 1, group-housed multiparous sows (22–23 sows per pen) were mated in February and March (week 5 to week 11 of the year), so that pregnancy coincided with the summer-autumn period in Australia, or they were mated in July and August (week 26 to week 36), so that pregnancy would coincide with the winter-spring period in Australia. Groups of sows mated during each period were fed a low, moderate, or high feeding level during the first four weeks of pregnancy, followed by a moderate level of feeding during the remainder of pregnancy (Table 1). During the summer-autumn period, farrowing rate was higher for groups of sows fed the high feeding level compared to groups of sows fed the low feeding level (Table 2). However, the low feeding level, associated with low fertility (50.0%) in this trial during the summer-autumn period, supported a high farrowing rate (87.0%) during the winter-spring period. The moderate level of feeding supported a farrowing rate in sows similar to that of the high feeding level (69.0% versus 64%) (Table 2).

Trial 2 was similar to trial 1, except gilts were included in the study. The results of this trial were similar to those of trial 1. The high feeding level in early pregnancy improved farrowing rates in gilts and sows mated during the summer-autumn period compared to gilts and sows fed the low feeding level (81.2% versus 71.3%, $P<.05$) during this same period, and the low level of feeding supported a high farrowing rate (89.0%) in gilts and sows

Table 1. Feeding levels during early pregnancy (Trial 1)*

Season	Week of Mating	Feeding rate (kg per sow per day)		
		Weeks of Gestation		
		1 and 2	3 and 4	5–16
Summer-Autumn	7, 9–11	1.6	1.8	2.5
	6, 8	2.5	2.5	2.5
	6–11	>3.7	>3.7	2.5
Winter-Spring	26, 29–36	1.7	2.0	2.7
	26, 29–36	>3.7	>3.7	2.7

Summer-Autumn diet specification: 3,346 kcal DE, 170g crude protein kg^{-1} diet
Winter-Spring diet specification: 3,107 kcal DE, 136g crude protein kg^{-1} diet
*from Love et al., 1995

Table 2. Effect of feeding level during the first four weeks post-mating and season on farrowing rate of group-housed sows (Trial 1)*

Season	Week Mated	Feeding rate					
		Low		Moderate		High	
Summer-Autumn	6			64.3^{a}	(41)	58.5^{b}	(54)
	7	48.8^{a}	(41)			77.3^{b}	(55)
	8			73.3	(46)	68.1	(49)
	9	43.2^{a}	(44)			75.6^{b}	(60)
	10	56.8^{a}	(44)			65.0^{a}	(56)
	11	51.1^{a}	(45)			77.8^{b}	(67)
	6,8			69.0	(87)	63.6	(103)
	7,9,10,11	$50.0^{a,e}$	(174)			$74.1^{b,g}$	(174)
Winter-Spring	26, 29–36	$87.0^{a,f}$	(169)			$87.5^{a,f}$	(209)

^{a,b} Within rows, different subscripts indicate significant differences ($P<.05$) associated with feeding level.
^{e,f,g,h} Within columns, different subscripts indicate significant differences ($P<.05$) associated with season
Figures in parentheses indicate number of sows mated
*from Love et al., 1995

mated during the winter-spring period. Interestingly, litter size was not affected by season or feeding level in either trial. Therefore, the authors suggest that the increased feeding level has a protective effect on maintenance of pregnancy in group-housed sows, and that the loss in pregnancy associated with seasonal infertility seems to be an all-or-nothing response.

Generally, it has been suggested that a high level of feeding during early pregnancy is associated with increased embryo mortality (Einarsson and Rojkittikhun, 1993). Because of this, it is generally recommended to feed sows liberally prior to mating, and then restrict-feed sows post-mating, which has been shown to facilitate embryo survival (Ashworth, 1998). However, the majority of this research has been conducted in production systems in which sows are housed in individual stalls.

The current hypothesis for the mechanism by which restricted feeding reduces farrowing rate in group-housed sows is that the reduction in LH secretion characteristic of summer-autumn (Peltoniemi et al., 1997) is amplified by restricted feeding post-mating, and this causes a suppression in progesterone secretion by the CL, resulting in inadequate embryonic signaling which ultimately leads to embryonic mortality (Peltoniemi et al., 2000).

From these data, it is evident that the effects of season must be considered when developing feeding programs for group-housed sows. Very low feeding levels should be avoided during early pregnancy to facilitate maintenance of pregnancy in summer and autumn months.

Feed intake in lactation

In the U.S., the period of seasonal infertility (mid-summer, early fall) coincides with the hottest time of the year. Although heat stress may not be the primary cause of seasonal infertility, it is a contributing factor (Love, 1978; Hennessy and Williamson, 1984; Leman, 1992; Xue et al., 1994). The most notable symptom of seasonal heat stress on fertility is a prolonged weaning to estrus interval, which is closely associated with a reduction in appetite induced by heat stress, resulting in low feed intake during lactation (Prunier et al., 1996). Other consequences of low feed intake during lactation include reduced milk yield and increased mobilization of body tissues.

Therefore, management strategies that facilitate a high feed intake during lactation are critical, especially during summer and autumn months, for the available data make it quite clear that a high level of feed intake by sows during lactation is essential for good subsequent reproductive performance (Aherne et al., 1999; Koketsu and Dial, 1997; Pettigrew, 1998).

In order to facilitate a high level of feed intake by lactating sows during summer and autumn, a systems approach that employs environmental, feeding management, and diet formulation practices discussed in the following sections is recommended.

Environmental management practices for lactating sows

Maintaining a comfortable environment for the lactating sow during seasonal periods of high ambient temperatures can be achieved by employing management practices designed to facilitate heat loss from the sow's body.

Adequate ventilation is essential for removal of heat and moisture from facilities generated by animals in commercial production systems. Ventilation may be provided by wind, by gravity, or by fans. However, regardless of the system, it must be well designed and well managed, so that all areas within the production unit are continually supplied with fresh air. To facilitate proper management of ventilation systems in commercial production units, it is recommended that detailed protocols outlining specific ventilation settings for seasonal fluctuations in temperature be used.

Both drip cooling and evaporative cooling systems have also been shown to be effective facilitators of sow body heat loss during seasonal periods of high ambient temperatures.

Beneficial effects of drip coolers include improved feed intake (Table 3), reduced respiration rate (Murphy et al., 1987; Harp and Hunke 1991; Romero, 1991; Sandoval, 1995), increased litter weaning weight (Sandoval, 1995; Stansbury et al., 1986; McGlone et al., 1988), lower pre-weaning mortality (Romero, 1991), and reduced sow weight loss during lactation (Murphy et al., 1987; Sandoval, 1995; McGlone et al., 1988). However, drip cooling should only be used in farrowing facilities with open-type flooring to avoid detrimental effects of wetting piglets (Stansbury et al., 1986; McGlone et al., 1988).

In a study conducted to compare the efficacy of evaporative cooling and drip cooling systems to alleviate heat stress of lactating sows, sow weight loss, litter weaning weights, and the number of pigs weaned per sow were similar for each cooling system (Harp and Huhnke, 1991).

Snout cooling is another management practice that can be used to alleviate seasonal heat stress, and improve feed intake (Stansbury et al., 1987). However it does not appear to be as effective as drip cooling (McGlone et al., 1988)

Another factor that should be consider, is the type of flooring. Research conducted at Texas Tech University (Johnston et al., 1987; McGlone et al., 1988) and the University of Minnesota (Koketsu, 1994) has demonstrated that the conductive properties of flooring impact feed intake by lactating sows; sows housed on materials

Table 3. Effect of drip cooling on daily feed intake of heat-stressed lactating sows*

Reference	Daily feed intake, kg/day				
	Control	Drip	Difference	% of Control	*P*<
Murphy et al., 1987	4.79	5.74	0.95	+25.0	.05
Sandoval, 1985	6.10	5.50	0.60	+11.0	.001
Romero, 1991	6.31	6.41	0.10	+1.6	NS
Stansbury et al., 1986					
Trial 1	4.24	5.74	1.50	+35.4	.05
Trial 2	4.98	6.61	1.63	+32.7	.001
McGlone et al., 1988					
Trial 1, Plastic floor	3.09	5.89	2.80	+90.6	.0001
Trial 2, Concrete floor	3.99	5.29	1.30	+32.6	.0001
Trial 2, No Fat	5.33	7.03	1.70	+37.5	.01
Trial 2, 7.5% added fat	4.63	6.19	1.56	+33.7	
Mean Response	4.82	6.04	1.22	+25.3	

*adapted from Pettigrew and Esnaola, 2000.

that conduct heat (concrete, metal) consume more feed and have better reproductive performance (Johnston et al., 1987) than those housed on floors that do not conduct heat (plastic-coated expanded metal).

Feeding management practices for lactating sows

The primary objective of a lactation feeding program during lactation is to maximize daily sow feed intake, especially during seasonal periods of high ambient temperature. Important factors associated with sow feed intake include the frequency and time of feedings, feeding level, water intake, and type of feeding method.

First, it is recommended that sows be fed more frequently than once per day. It has been well established, through a wealth of practical experience, that sows should be fed frequently in order to achieve maximum feed intake. The actual number of daily feedings needed to achieve maximal feed intake is not clear; however, we suggest that sows be fed at least three times per day. In addition, a shift to evening or nighttime feedings has beneficial effects on feed intake. However, labor costs associated with more frequent feeding must be balanced against the expected improvements in sow and litter performance associated with increased feed intake.

Secondly, it is recommended that sows in lactation are allowed ad libitum access to feed. The primary advantage of ad libitum feeding is that it ensures that feed is available to the sow during night when heat is less intense, so the sow may eat more. A controlled study in a well managed farm in the U.S. showed feed consumption and performance of sows allowed ad libitum consumption equal to those fed more traditionally (Connor, 1999).

Thirdly, adequate water intake is essential during lactation, especially during periods of heat stress. Sows like other animals, will reduce their consumption of feed if water supply is not adequate. Water flow rate of nipple drinkers often is not adequate, and the sow will not spend enough time drinking to obtain the quantity of water required to support the metabolic processes of lactation (Leibbrandt et al., 2001). Restricting the flow rate of nipple waterers from 700ml/min to 70ml/min reduced sow feed intake in lactation by 0.21kg/d in summer (Leibbrandt et al., 2001). A larger decline in feed intake was expected; however, a nipple flow rate of 700ml/min would be considered by most to be inadequate, particularly in hot environments. Currently it is not clear what the flow rate needs to be, but 2 liters per minute seems to be adequate.

Another alternative to nipple waterers are cup waterers. Koketsu (1994) found that lactating sows on commercial farms with cup waterers consumed about a half kilogram more feed per day than sows on farms with nipple waters. It is recommended that cup waterers be used. However, if nipple waterers are used, considerable attention is needed to ensure an adequate water flow rate.

Fourthly, wet feeding practices can be used to improve feed intake of heat stressed sows during lactation. Two common methods of wet feeding include adding water on top of the feed, and mixing the feed and water before offering it to the sow. Mixing of feed and water prior to feeding is the recommended practice, for it allows better control of the feed:water ratio, however the labor involved is more extensive.

Diet formulation considerations for lactating sows in hot environments

As a first principle, it is essential to provide an adequate amount of each of the essential amino acids to lactating sows. The amounts of amino acids needed vary among sows and among situations, largely because of variation in the amount of milk produced. An approach to estimating the amounts of amino acids needed in specific situations has been proposed by Pettigrew (1993) and by NRC (1998).

One complication associated with amino acid intake by heat-stressed sows is that excess amino acids must be metabolized for excretion of the nitrogen as urea, which generates metabolic heat. The heat generated through this process adds to the heat load on the sow's body, increasing the degree of heat stress and reducing feed intake. It is possible to provide an adequate amount of each essential amino acid in relatively low-protein diets by use of crystalline amino acids, and that practice appears to be more beneficial in hot conditions.

The results of a regional collaborative experiment conducted by several universities in the Midwestern U.S. (Table 4; Johnston et al., 1999) suggest that reducing the protein level and using crystalline amino acids may be beneficial in a hot environment, but detrimental in a thermoneutral environment. The hot environment had large detrimental effects on all criteria, and the effects of diet were subtle. However, it is clear that litter weaning weight responded differently to the dietary treatments in the two environments. Reducing the protein level and using crystalline amino acids was detrimental in the absence of heat stress, perhaps because of an inadequate supply of the amino acid valine, which was not supplemented. This same treatment provided a small advantage in heat-stressed sows, probably by reducing the heat increment of feeding.

It is recommended to minimize the heat load on heat-stressed lactating sows by using crystalline amino acids and lowering the dietary protein level. The improvement in litter weaning weight is modest, but economically significant.

The previous section dealt with the high heat increment of dietary protein, which contributes to the heat load. It was shown that reducing the heat increment appears beneficial during heat stress. There are other variations in heat increment, notably that fat has a lower heat increment than carbohydrate. Therefore, providing some of the dietary energy as fat rather than as cereals can reduce the heat increment and benefit the animal (Table 5). Note especially the effect of dietary fat versus starch on ME intake in heat-stressed sows.

From a broader view, supplemental fat added to the diet of the lactating sow reliably increases the ME intake, but reduces the amount of feed consumed (kg) in sows not heat-stressed (Pettigrew and Moser, 1991). The increase in ME intake is bigger in heat-stressed sows. Provision of some of the dietary ME as fat increases the transfer of energy from the sow to the litter, and results in greater litter weaning weights.

As described above, increasing ME intake of sows during lactation usually improves the subsequent reproductive performance. However, there remains a question about whether that relationship holds when the increase in ME is largely from fat. There is a growing body of evidence that the hormone insulin mediates at least part of the improvement in reproductive performance that results from increased ME intake (Pettigrew, 1998; Aherne et al., 1999.). Increased ME intake results in increased circulating insulin levels, and that appears to stimulate improved reproduction. However, insulin levels are more responsive to carbohydrate intake than to fat intake. Therefore, substituting fat for cereals (carbohydrates) could theoretically be detrimental to subsequent reproduction, because it might reduce insulin levels. It now appears (Kemp et al., 1995; Lorschy et al., 1997; van den Brand et al., 2000) that if there is a detrimental effect of dietary fat on reproduction, it is very small.

Overall, then, we recommend the use of supplemental fat in lactation diets for heat-stressed sows. We believe the effect on reproductive performance will be neutral or beneficial, and there will be an increase in litter weight at weaning.

Table 4. Effect of room temperature and dietary amino acid concentration on sow and litter performance*

Traits Environment	Thermoneutral		Hot		Significance, *P*	
Protein level:	Adequate	Low	Adequate	Low	Environment	Protein
Sow Lactation Feed intake, Kg	6.44	6.31	4.13	4.25	>.01	ns
Lactation weight gain/lost, Kg	2.1	-1.2	-15.6	-19.5	>.01	ns
Respiration rate, breath/min	37.2	34.8	64.7	66.0	>.01	ns
Litter weaning weight, Kg	74.1	69.7	60.5	62.1	>.01	.05**

**Room temperature (diet interaction.
*from Johnston et al., 1999

Table 5. Effect of dietary energy source and environmental temperature on intake and performance of lactating sows*,**

Criterion	Room Temp.	Source of Energy: Fiber	Starch	Fat	Effect	*P*
					Temperature	<.05
Lactation weight loss, kg	20°C	6.6	2.6	2.0		
	32°C	13.2	15.9	16.3		
					Temperature × Energy density	<.05
Feed intake, kg/day	20°C	5.94	5.90	5.31		
	32°C	4.49	3.36	3.54		
					Temperature × Energy density	<.05
ME intake, Mcal/day	20°C	16.7	19.4	20.0	Linear effect of energy density at 20°C	<.05
	32°C	12.6	10.9	13.0		
					Linear effect of energy density at 32°C	<.08
Milk yield, kg/day	20°C	8.43	8.34	8.03		
	32°C	7.33	7.47	7.62		
Milk energy yield, Mcal/day	20°C	8.54	7.96	9.16	Temperature effect	<.12
	32°C	7.05	7.73	8.58	Linear effect of energy density at 32°C	<.08
Milk fat, %	22°C	5.57	4.98	6.90	Temperature effect (P<.15)	<.15
	32°C	5.18	5.75	6.80	Linear effect of energy density at 32°C	<.05

*Each value is the mean of 10 sows per treatment group over a 22-d lactation.
**from Schoenherr et al., 1989.

Although fiber may be used as a source of energy in sow diets, it should not be used in lactation diets, especially in hot environments. Fiber dilutes the energy content of the diet, and reduces the bulk density of the diet. Because of this, the sow is typically unable to consume a quantity of feed needed to maintain a constant level of ME intake as the fiber content of the diet increases. In addition, fiber has a high heat increment, causing an increased metabolic heat load, thereby exacerbating the effects of heat stress on feed intake.

Sow body condition at farrowing

It has been well documented that sows with excessive body condition have reduced feed intake during lactation (Mullan and Williams, 1989; Revell et al., 1998; Sinclair et al., 2001), which is presumed to be attributed to increased fat reserves (Sinclair et al.., 2001). However, when feed intake is low, the sow must rely on body reserves to support lactation. In this regard, adequate body reserves are needed to buffer against nutrient inadequacy during periods of low feed intake, for sows with limited body reserves are more likely to have impaired subsequent reproductive performance as a consequence of low feed intake in lactation (Mullan and Williams, 1989; Clowes et al., 2003a,b). Clowes et al. (2003b) demonstrated that increasing sow body protein mass prior to lactation had a protective effect against protein restriction in lactation on subsequent reproduction. In addition, Sinclair et al. (2001) showed that feed intake of sows in lactation was not affected by gestation feeding strategies that promoted deposition of both fat and lean tissue. Therefore, careful attention should be given to gestation feeding programs to ensure appropriate body condition of sows at farrowing.

Summary

Sows in early pregnancy, and lactation are most affected by seasonal infertility. Suggested management strategies to alleviate seasonal effects on fertility should include an increased feeding level for group-housed sows in early pregnancy, and a systems approach to increase feed intake in lactation.

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