The influence of nutrient intake on biological measures of breeding herd productivity

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Summary: *This review examines the influence of lactational feed and nutrient intake on common measures of breeding herd productivity: weaning-to-first-service interval, total pigs born per litter, the occurrence of reproductive failure, and percent preweaning mortality. Evidence suggests that inadequate intake of feed, protein, and energy are associated with prolonged weaning-to-first-service intervals. There is conflicting evidence regarding their influence on rates of returns to service after mating and total-born litter size. Adding fat to the diets of lactating sows is cited as having an inconsistent effect on weaning-to-first-service interval and a positive influence on preweaning mortality in those herds with persistently high mortality rates. Adding various forms of sugar such as molasses to lactation diets was found in some studies to result in larger subsequent litter sizes and more rapid returns to service after weaning. While being used prophylactically to alleviate constipation, fiber appears to have no beneficial effect on either subsequent litter size, weaning-to-first-service intervals, or preweaning mortality when added to lactation diets. There is evidence that adding fiber to gestation diets may improve sow longevity, body weight loss during lactation, and the prevalence of stereotypical behavior. Calcium and phosphorus may influence the prevalence of reproductive failure by affecting sows' longevity. Insufficient salt is associated with reduced litter sizes. The vitamins biotin, folic acid, vitamin A/ß carotene, and vitamin E/selenium have been found in some studies to influence total-born and/or born-alive litter size by affecting ovulation, implantation, and/or embryonic survival rates. Rates of occurrence of reproductive failure, intervals from weaning to service, and preweaning mortality may be influenced by biotin and/or riboflavin. In sum, there is a great deal of research indicating that nutrient intake during lactation has substantial and multiple effects on the reproductive performance of sows after weaning. The diagnostician is not only faced with the problem of ruling out lactation nutrition as one of the several potential causes of reproductive failure but is also faced with the problem of determining which of several nutrients is the cause of suboptimal performance.*

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The intake of several nutrients during the various phases of the reproductive cycle have been found to significantly influence reproductive and/or lactational performance. To optimize breeding herd performance and to efficiently and effectively troubleshoot reproductive problems, the diagnostician must understand the effects of nutrients on breeding female performance. This review critically examines the effects of nutrient intake during various phases of the reproductive cycle on sow lactational and reproductive performance; specifically, number of pigs weaned, litters per sow per year, and litter weaning weights and the parameters that comprise them. It is intended to bridge the gap between what is published in the scientific literature and situations commonly encountered by diagnosticians working with commercial breeding herds.

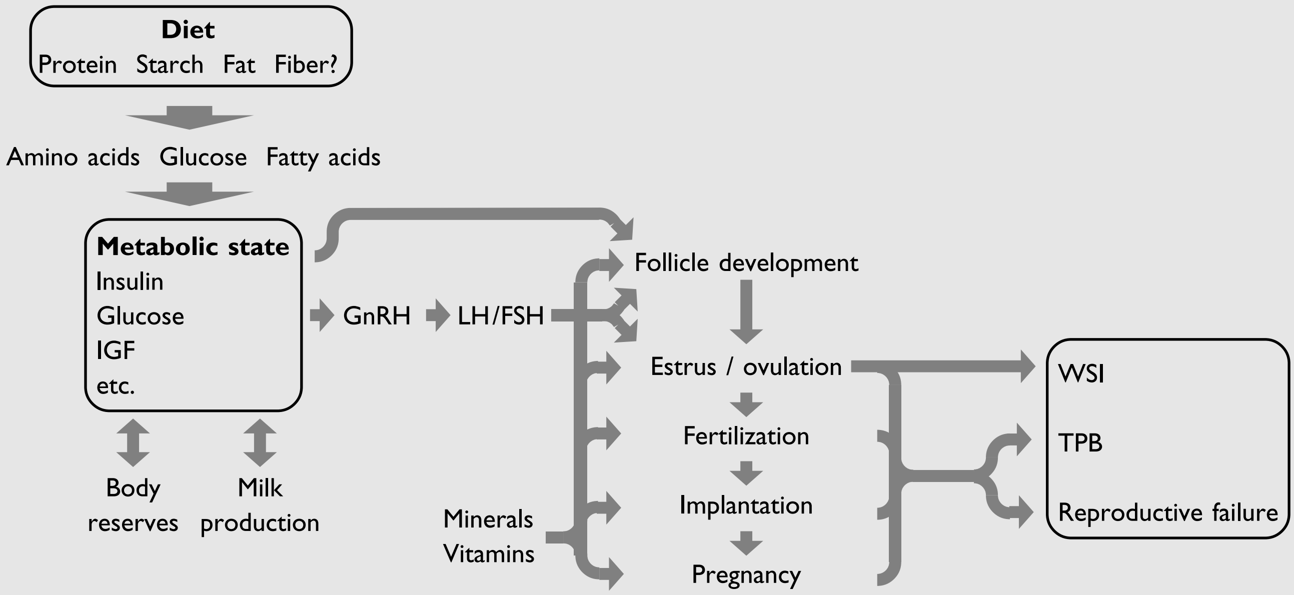
Feed, energy, and protein

Nutrient intake (i.e., feed, energy, protein) may affect reproduction indirectly through metabolic processes that include changes in metabolites (e.g., glucose, nonesterified fatty acids, triglycerides) and metabolic hormones (e.g., insulin, insulin-like growth factor [IGF], glucagon) (Figure 1).[1] Through their metabolites, protein, starch, and fat influence the metabolic state of the sow. It is not clear whether fiber, minerals, and vitamins affect the metabolic state. Consequent changes in metabolic hormones and metabolites have a direct influence on follicular development as well as indirect effects through the release of gonadotropins. Minerals and vitamins affect the ovario-uterine system, influencing follicular development, rates of ovulation and conception, and the capacity of females to maintain pregnancy. Nutrient intake affects litter size, the occurrence of reproductive failure, and the rapidity of returns to service after weaning through their effects on follicular development as well as rates of fertilization, implantation, and pregnancy. The following discussion details the biological relationships between the intake of nutrients and four measures of reproductive performance.

Weaning-to-first-service interval

Reduced feed intake during lactation influences litters per female per year through prolonged weaning-to-first-service intervals and the increased occurrence of reproductive failure. Regression analysis has been used to determine the relationship between either average daily feed intake (ADFI) or feed intake during lactation and weaning-to-first-service interval of parity-one sows.[2,3] Weaning-to-estrus interval was increased by 6.26 days for each 1-kg decrease in ADFI[2] and 0.12 days for each 1-kg decrease in total feed intake during lactation.[3] Yang, et al., failed to find a relationship in multiparous sows.[3] This

Figure 1



Proposed model for how nutrients influence reproductive performance of sows. GnRH: gonadotropin-releasing hormone; LH: luteinizing hormone; FSH: follicle-stimulating hormone; WSI: weaning-to-first service interval and TPB: Total pigs born.

may suggest that the weaning-to-first-service intervals of low-parity sows may be more sensitive to changes in lactation feed intake than those of high-parity sows.

The influence of energy[4–7] and protein[8–11] intake during lactation on weaning-to-estrus interval has also been investigated. Low energy (i.e., 6 Mcal ME;[12] 8 Mcal ME;[4,5,13] or 10 Mcal ME[6] per day per sow) resulted in prolonged weaning-to-estrus interval or weaning-to-first-service interval in parity-one and parity-two sows. Some researchers have suggested that energy intake beyond either 11.5 Mcal ME[14] or 10.5 Mcal ME[15] per day per sow during lactation produced little improvement of weaning-to-first-service interval; however, a negative linear association between feed intake and weaning-to-first-service interval was confirmed at energy intakes above these levels in other studies.[2,3,16]

Low protein intakes, such as 380 g[9,10] and 404 g per day per sow[11] also prolong weaning-to-first-service interval. The proportion of sows exhibiting estrus within 7–8 days postweaning increased as protein intake increased from 220 g to 700 g crude protein per day, either alone or with increases in energy.[15] Pettigrew and Tokach have concluded that restriction of either energy or protein during lactation increases weaning-to-first-service interval.[1] King suggested that the effect of protein intake was independent of energy intake.[15] It has been hypothesized that nutrition does not directly affect reproduction, but that nutrient intake, changes in body reserves, and milk production all affect the metabolic state of the sow.[17] The sow's metabolic state, in turn, affects postweaning reproductive parameters such as weaning-to-first-service interval through the reproductive hormones, gonadotropin-releasing hormone (GnRH), and luteinizing hormone (LH). Nutritional effects on reproduction appear to be indirect, and therefore are difficult to predict without considering other influencing factors.

Returns to reservice and removal

Although nutrition has been shown to influence the occurrence of reproductive failure, the relatively low rates of failure observed in commercial herds (i.e., farrowing rates = 75%–90%) have not allowed us to conclude that there is a significant relationship between nutrient intake and reproductive failure in most of the experiments.[2,4,8,9] Baidoo, et al., reported that 32% of 44 sows in a low-feed-intake treatment returned to estrus within 25 days after weaning compared with 89% for sows provided a high feed intake.[13] We have reported previously that sows with low feed intakes during lactation have a higher occurrence of returns to service after mating and increased rates of removal from the herd for reproductive failure.[18]

Total pigs born and weaning litter weight

Reports on the effects of feed intake during lactation on litter size at subsequent farrowing are conflicting. In some studies, lower feed intake during lactation caused an extension of weaning-to-first-service interval while having little effect on ovulation rates, conception rates, or subsequent litter size.[8,19] However in other investigations, a positive association has been observed between lactation feed intake and subsequent litter size.[16,20] The observation that insufficient energy intake during lactation may not increase ovulation rate, but may increase embryonic mortality rate,[21] provides further confusion.

Protein consists of 22 amino acids, of which 10 are indispensable for pigs. While the amino acid requirements for lactating sows have not yet been well defined, significant progress has been made in recent years. It has been suggested that the lysine requirement for high-pro-

Table 1

Influence of select nutrients and dietary ingredients on reproductive parameters with references[a,b]

Item	WSI (days)	TPB (pigs)	RF (%)	PWM (%)
Feed (kg)	–6.3[2]	+0.01[16]	N[12]	N[2]
	–4.9[12]	N[4,14]	–[18]	
	–0.1[16]			
Protein (100g)	–2.6[8]	?[8]	?[8,19]	?[8,9]
	–[9]	N[19]		
	–2.4[11]			
Energy (Mcal)	-4,-7.7[7d]	?[8]	–10[4]	N[6,8,9]
	–8[8]	N[19]	?[8,9]	
	N[6,9]			
Fat	?[1]	?[28,32]	?[9]	–6[27,29]
Sugar (%)	–1.3[43g]	+0.9[42]	N[43]	?[41]
	N[36,39,41]	N[43,44]		N[43]
	N[44,45]			
Fiber (10%)	+0.26[46]	+0.26[46]	–15[46]	N[52,53]
	N?[51,52,54]	N[51,52,54]	N[49]	
Water	N[101j]	?	?[102]	?

a: +, –, N, and ? indicate affect positively, affect negatively, not changed, and not well defined, respectively.
b: Reproductive parameters are WSI: weaning-to-first service interval; TPB: total pigs born; RF: reproductive failure and farrowing rate; and PWM: preweaning mortality.
c: 88% or 60% of sows fed a high (760 g/d) or low (380 g/d) protein diet, respectively, exhibited estrus by d7 postweaning.
d: 94% or 50% of sows fed a high (12 Mcal/d) or low (8 Mcal/d) energy diet, respectively, exhibited estrus by d7 postweaning.
e: Logistic coefficients (–0.12 to –0.19) have been reported.
f: Supplemental fat (>1kg) before farrowing was provided to the sow.
g: A diet containing 2.5% feed-grade sugar was used.
h: Cane molasses (50%) was used during the postweaning period. The effect is nonsignificant.
i: Alfalfa haylage-based (30%) diet was used during gestation.
j: Water deprivation prior to weaning was used.

ducing sows is much greater than NRC guidelines. NRC guidelines call for 31.8 g per day,[22] whereas swine research suggests lactating sows need >45 g per day.[23,24] Valine may be a limiting amino acid for milk production, when diets are formulated to >0.9% lysine.[25] Richert, et al., proposed that high-producing sows have a higher valine requirement of >117% of the lysine levels required during lactation than a guideline (100% of lysine) in NRC.[25] Pettigrew[26] has proposed a framework that uses factorial approaches for estimating the amino acid requirements for sows at different levels of milk production.[28] In his estimate, young sows (160 kg body weight after farrowing) producing a litter gain of 2 kg per day need 51.3 g lysine per day,[26] which is much higher than the 31.8 g per day recommended by the NRC.[22]

Fat

Weaning-to-first-service interval, total pigs born, and weaning litter weights

Increasing the energy density of the diet by supplementing the ration with fat decreases feed intake, but increases total energy intake.[27] The low heat increment of fat is useful to increase energy intake when sows are subjected to heat stress. Feed intake is reduced less by heat stress when sows are provided fat-supplemented diets than when fed diets without added fat.

Weaning litter weights increased with added fat, and responses were greatest when 10%–14% fat was added to the lactating sow diet.[28] The influence of supplemental fat on weaning-to-first-service interval, subsequent litter size, and reproductive failure in lactating sows is not clear.[29,30] While fat supplementation of the lactation diet affects ovarian follicular development in cattle,[31] that response has not been confirmed in lactating sows.[32] In primiparous sows with high lactation weight losses, feeding supplemental fat after weaning increased the proportion returning to estrus within 7 days postweaning.[33]

Preweaning mortality

Supplementing late-gestation diets with fat may improve preweaning mortality by increasing the glycogen stores of fetal piglets during this phase of gestation.[27] Supplementing the ration with fat during gestation increases sow milk yield and milk fat content. Pettigrew[27] concluded that supplemental fat intake (>1 kg before farrowing) improves preweaning mortality, when preweaning mortality is >20%. Presumably, this response is the consequence of increased mammary transfer of energy to piglets. Low viability is the second-most frequent (29.7%) cause of preweaning mortality after trauma (33.8%).[34] Assuming some of the low-viability piglets can be saved by increasing their glycogen stores at birth, nutritional supplementation of gestation diets with fat may reduce preweaning mortality by up to 30%. Because producer-reported data often misclassifies the cause of preweaning mortality,[34] it is possible that other causes of mortality, besides low viability, may be improved by supplementing gestation diets with fat. However, the effects of nutrition on preweaning mortality are likely to be small.

Fasting sows starting 1 week prior to farrowing was thought to be an alternative method to improve preweaning mortality. Prefarrowing fasting was thought to mobilize maternal energy stores, thereby increasing fetal energy stores. In a study conducted to test this theory, circulating fatty acids were increased in fasting sows but did not improve the nutritional status of their fetuses.[35] Apparently sows store their energy as fat, whereas piglets store energy in the form of glycogen, not fat.[29] Technologies for increasing fetal glycogen stores remain

Table 2

Influence of minerals and vitamins on reproductive parameters with references[a,b,c]

Item	WSI (days)	TPB (pigs)	RF (%)	PWM (%)
Ca/P	?	?N[59]	–30[59d]?	??
Na/Cl	?	?	?	?
Mg, K, I, Mn, Fe	?	?	?	N[61]
Chromium	?	+2.2[66]	?	?
Copper	?	?	?[105]	?
Zinc	?	N[106]	?	?[106]
A/ß-carotene	N[91]	+1.6[91f] +1.3[92g] N[93]	?	N[91]
D, K, B_6, B_{12}	?	?	?	?
E/Se	?	?[99]	?[99]	–14[99h]
Biotin	–4.3[74] N[76]	+0.9[74j] N[76]	–28[75k] N[75,76]	–7[75 l]
Choline	?	+0.6[77m]	?	?
Folic acid	?[81]	N[78] +0.9[81n]	?N[81]	N[78]
Riboflavin	N[88]	+1.1? [82o]	–17[88p]	N[88]

a: +, –, N, and ? indicate affect positively, affect negatively, not changed, and not well defined, respectively.

b: Reproductive parameters are WSI: weaning-to-first service interval; TPB: total pigs born; RF: reproductive failure and farrowing rate; and PWM: preweaning mortality.

c: Nutrients are calcium: Ca; phosphorus: P; sodium: Na; chloride: Cl; magnesium: Mg; potassium: K; iodine: I; iron: Fe; manganese: Mn; selenium: Se; zinc: Zn; Vitamins A, B, D and E: A, B, D and E respectively.

d: High (0.975%–0.75%) and low (0.65%–0.50%) Ca-P treatments during gestation were compared.

e: Chromium picolinate (200 ppb) was supplemented during the growing, finishing, and reproductive phases.

f: Vitamin A (12,300 IU) and ß-carotene (32.6 mg) were injected once weekly during gestation.

g: ß-carotene (200 mb/kg) was injected to multiparous sows at weaning.

h: Se (0.3 ppm) and 66 IU of DL-α-tocopherol acetate/kg were supplemented over a three-parity period.

i,j: Supplemental biotin treatments (440µg/kg versus 0) during the breeding, gestation, and lactation periods were compared.

j: The effect was seen in parity ≥2 sows.

k: Diets were supplemented with 250 µg/kg biotin in gestation and 150 µg in lactation.

l: Biotin (330 µg) was supplemented during gestation and lactation.

m: Supplemental choline (770 mg/kg) was used during gestation and lactation.

n: Folic acid (1 ppm) was supplemented during gestation and lactation.

o: Riboflavin (100 mg/kg) was supplemented during the postbreeding period.

p: Dietary riboflavin 60 mg/d and 10 mg/d were compared during gestation.

to be discovered.

Sugar

Weaning-to-first-service interval and total pigs born

Circulating levels of insulin and glucose are not only interrelated but they also appear to mediate between lactational nutrient intake and postweaning reproduction. As illustrated in Figure 1, insulin and glucose not only influence the sow's metabolic state but they also appear to be determinants of LH secretion.[36,37] There are several lines of evidence that support this model. The intramuscular administration of insulin (0.4 IU per kg per day) during the postweaning period improved total piglets born at the second parity.[38] This response suggests that dietary sugar, through effects on serum insulin concentrations, might similarly be used to improve litter size, perhaps by stimulating release of LH, a reproductive hormone necessary for follicle growth, ovulation, and the resumption of estrus following weaning. It follows that supplementing diets with sugars might be used to improve reproductive performance. In fact, the infusion of either glucose or phlorizin (a compound which blocks glucose absorption) altered LH secretion in gilts.[36,39,40] Campbell, et al.,[41] observed 91% of primiparous and 98% of multiparous sows fed a diet containing either 20% fructose (high-fructose corn syrup) or 20% glucose (dextrose) exhibited estrus by day 8 after weaning. While these rates were much higher than normally observed on commercial farms, the study did not include sows fed a diet without sugars (control group). In another study, gilts fed diets containing 50% cane molasses during a breeding cycle had more corpora lutea than control gilts.[42] Sows fed 50% cane molasses during the postweaning period produced numerically larger litters at the subsequent farrowing than sows not fed cane molasses (11.4 versus 10.5 pigs per litter). The weaning-to-estrus interval of sows fed a lactation diet containing 2.5% sugar was 1.3 days shorter than that of the sows fed a control diet.[43] While there is growing evidence that dietary sugar positively influences reproductive performance, not all studies observed such a response. Neither feeding sows a diet containing 40% cane molasses during a 3-week lactation[44] nor administering a 3-day infusion of glucose at 1 kg per day during midlactation[45] shortened weaning-to-first-service interval or altered LH secretion.

Fiber

Lactational and reproductive failure and total pigs born.

High dietary levels of fiber dilute nutrient and energy densities, even though feed intake increases.[46] Thus, the addition of fibrous ingredients to lactation diets are typically not recommended. Nonetheless, adding alfalfa meal, wheat bran, beet pulp, and other bulky ingredients to the sow's diet before and for a few days postfarrowing is a common practice in North America to prevent constipation and reduce the incidence of mastitis.[47] It remains to be established whether the potential beneficial effects of fiber compensate for its energy-diluting effects.

While controversial in lactation diets, bulky ingredients may also prove beneficial in gestation diets. Sow longevity and bodyweight loss during lactation were improved when sows were fed diets containing alfalfa.[48,49] Sows fed diets containing alfalfa also appeared to be more docile and easier to manage than those fed diets without alfalfa. Bulky diets containing either wheat bran or oat hulls reduced stereotyped or abnormal behaviors.[50] Hagen suggested that these behavioral responses are related to the stress-reducing effects of bulky diets.[46]

Several sources of dietary fiber (i.e., alfalfa meal,[51,52] wheat bran,[53] and beet pulp[54]) have not been found to influence subsequent litter size, weaning-to-first-service interval, and preweaning mortality. Recently, Matte, et al., reported that the use of bulky diets during gestation increased lactational feed intake of parity-one and -two sows.[55] Because greater feed intake during lactation improved reproductive performance,[15] the potential remains that adding fiber to gestation diets may affect weaning-to-first-service interval and litter size by increasing feed intake during lactation.

Minerals

The NRC[56] lists 14 minerals as essential nutrients for swine. Minimum requirements are given for all except cobalt and sulfur. The general functions and signs of deficiency for each mineral have been well documented.[56,57] Because they are needed in relatively large quantities by swine, calcium, chlorine, sodium, phosphorus, magnesium, potassium, and sulfur are considered macrominerals. The last three are usually not added to swine diets, being present in sufficient quantities in the feedstuffs used in swine diets to satisfy requirements. The microminerals supplemented to swine diets include cobalt, copper, iodine, iron, manganese, selenium, and zinc.

Reproductive failure

The dietary needs of the breeding female for calcium, phosphorus, sodium, chlorine, magnesium, potassium, iodine, and manganese are not as well defined as they are for growing pigs. Estimates of the mineral requirements for breeding females have been derived from studies of growing pigs.[56] No reports have been made, to date, on the effects of minerals on the reproductive performance of breeding females.

Sows fed low phosphorous levels (0.31%) during gestation had an increased occurrence of posterior paralysis.[58] Nimmo, et al., reported that 30% of sows fed diets low in both calcium (0.65%) and phosphorus (0.50%) during growth and gestation were subsequently removed for locomotive problems, compared to 0% of sows fed control diets (0.975% calcium, 0.75% phosphorous).[59] Feeding gilts adequate levels of dietary calcium and phosphorus during their early growth stages improves their reproductive longevity.[59] Higher-producing sows (litter weight > 60 kg at day 21 of lactation) have reduced skeletal mineral content, especially calcium, than lower-producing sows after three parities.[60] This suggests that sows mobilize their skeletal minerals to produce milk during lactation and that calcium requirements may vary with levels of milk production.

Too much calcium depresses feed intake in lactating sows.[47] More than 1.25% calcium should be avoided.[47] In addition, the suggested ratios of calcium and phosphorous ratios between 1:1 and 1.5:1 (NRC)[56] and between 1.2:1 and 1.5:149 have been suggested.

Preweaning mortality

Feeding sows diets containing high levels of iron during late gestation did not increase fetal iron.[61] Thus, supplemental iron may not alleviate anemia and its associated effects on preweaning mortality. Manganese deficiency in breeding sows resulted in small and weak pigs at birth[62] and, thus may increase preweaning mortality.

Total pigs born

The recent attention of swine nutritionists has been directed toward dietary chromium (Cr) because of its apparent effects on carcass leanness and immune response.[63] Chromium is not on the list of minerals required by the NRC. It has been investigated as an immune promotor for weaned pigs[64] and a metabolic regulator for growing pigs.[63] Supplementation of 200 ppb chromium picolinate decreased percent fat and increased percent muscle in the carcass.[65] Supplementing growing, finishing, and all sow diets with 200 ppb increased total pigs born in parity-one and -two sows.[66] We do not yet know the mechanism by which Cr increases litter size. Insulin and IGF-1 appear to have some association with postweaning reproduction.[17] Perhaps Cr enhances insulin-mediated gonadotropin release. However, this requires experimental verification. Chromium is thought to enhance insulin action. Fat sows have impaired insulin sensitivity.[67] Administering a complex of insulin and Cr is more effective than insulin alone.[63] Thus, Cr supplements may improve feed intake during lactation by normalizing insulin action.

Adding less than 0.30% of salt appeared to be insufficient for breeding animals and may reduce total pigs born.[68,69] Australian researchers have recommended 0.38 salt per kg for gestation diets and 0.51% salt per kg diet for lactation diets.[70] When groundwater contains excessive levels of sodium, salt can be removed from the diet and the limestone replaced with calcium chloride.[44]

Because it is postulated in dairy cattle, attention might also be directed to cation-anion imbalance in sows. If cattle diets include an excess of anions, calcium is mobilized from bone to neutralize the anions.[71] Crenshaw, et al., failed to create a cation-anion imbalance in sows using ammonium chloride (NH_4Cl).[72] The reproductive outcome of cation-anion imbalance in lactating sows remains unknown.

Vitamins

The NRC[56] has published the quantitative requirements for 13 vitamins. Signs of deficiency for each vitamin have been reviewed previously.[56,57] The fat-soluble vitamins essential to swine diets are A, D, E, and K. The essential water-soluble vitamins are B_6, B_{12}, biotin, choline, folacin, niacin, pantothenic acid, riboflavin, and thiamin. Choline, biotin, vitamin A / ß-carotene, riboflavin, and vitamin E/selenium have been found recently to influence reproductive performance.[1]

Biotin

Weaning-to-first-service interval and total pigs born

Biotin supplementation of sow diets reduces hoof lesions and may improve sow longevity.[47,73] Biotin supplements of 100–550 mg per kg diet have been found to increase total pigs born,[74] increase the number of pigs weaned,[74,75] and reduce weaning-to-estrus interval.[74] In other studies, weaning-to-first-service interval,[75,76] litter size, and the prevalence of reproductive failure[76] was not improved when 440 mg per kg biotin was added to sow diets. Pettigrew and Tokach have recommended biotin supplements of 200 mg per kg for lactation and gestation diets, although they admit results are conflicting.[1]

Choline

Total pigs born

Supplementing soybean meal-based gestation diets with 770 mg choline per kg improved total pigs born and pigs born alive,[77] even though soybean meal is a rich source of choline. It has been recommended that all sow diets include total choline at a concentration of 1200 mg per kg.[16]

Folic acid

Total pigs born

The NRC[56] recommendations call for 0.3 mg folic acid per kg diet for lactating sows. The 10 intramuscular injections of 15 mg of folic acid to sows from weaning until day 60 of pregnancy increased total pigs born.[78] When folic acid was provided during lactation only, litter size and growth performance were not affected.[79] In one study, total pigs born and weaned pigs were not increased in sows receiving 15 mg per kg of dietary folic acid during gestation and lactation relative to control sows.[80] Lindemann and Kornegay concluded that the supplementation of corn-soybean gestation and lactation diets with 1 mg per kg of folic acid positively influenced total pigs born.[81]

Riboflavin

Total pigs born

The daily oral administration of 100 mg per kg of riboflavin on days 4–10 of pregnancy increased total pigs born, pigs born alive, embryonic survival, conception rate, and preweaning mortality.[82] However, these observations have not been confirmed by other researchers.[83,84]

Reproductive failure

Riboflavin deficiency resulted in an increased occurrence of anestrus[85] and reproductive failure in gilts.[85,86] Frank and coworkers[87] observed that four out of six gilts fed diets deficient in riboflavin (0.77 kg per kg) farrowed prematurely, two had stillborn litters, and two failed to farrow by day 121 of gestation. A high level of dietary riboflavin (>60 mg per day) during the first 21 days of gestation improved farrowing rate.[88] Because reports are limited, further research is needed in both multiparous and primiparous sows.

Vitamin A and ß-carotene

Total pigs born

Vitamin A is important for reproduction as well as vision, growth, and maintaining differentiated epithelial mucus secretions.[89] The symptoms of vitamin A deficiency in sows are increased numbers of pigs born weak, increased stillbirths, and reduced pigs born alive.[90] ß-carotene is the most biologically active of the provitamin As and is converted to vitamin A primarily in the intestinal mucosa.[89]

The effects of vitamin A and ß-carotene injections on total pigs born are conflicting. Gilts injected weekly with 228 mg of ß-carotene beginning the day of breeding and continuing until day 21 postfarrowing decreased embryonic mortality, increased total pigs born and improved litter weights at both birth and weaning compared to untreated gilts.[91] Coffey and Britt[92] observed that litter size at birth improved with increasing dosage (0–200 mg) of ß-carotene in multiparous sows, but not in primiparous sows. Mooney, et al., did not find significant effects of either vitamin A or ß-carotene on total pigs born.[93]

The mechanism and sites of the effects of vitamin A and ß-carotene on litter size are not well defined. Vitamin A and ß-carotene are thought to work at several critical sites to enhance embryonic development and survival.[94] Vitamin A increased embryo survival during the first 2 weeks after mating.[95] Vitamin A also alleviated the detrimental effects of high energy diets on embryonic mortality when given before and after breeding.[96] Plasma, granulosa cells, follicular fluid, and corpora lutea concentrations of vitamin A derivatives and ß-carotene were elevated in ß-carotene-injected gilts in one study.[97] In another investigation, treatment had no influence on plasma and uterine fluid levels of vitamin A and ß-carotene or on the number of corpora lutea in gilts.[98]

Vitamin E and selenium

Total pigs born and reproductive failure

Vitamin E and selenium (Se) have a complex interrelationship.[47] Vitamin E and Se deficiencies reduce total pigs born through embryonic loss rather than through reductions in either ovulation or implantation.[99] Retained placentas have not been reported as a sign of vitamin E-Se deficiency in swine, as they have been in cattle.[100] However, extended parturition time has been observed. Mahan recommends 41 IU per kg of vitamin E in sow diets.[100]

Other vitamins

There is a paucity of information regarding the influence of vitamins D, K, B_6, B_{12}, and thiamine on breeding females and research findings are inconclusive.[56]

Water

Reproductive failure

Depriving sows of water prior to weaning does not shorten weaning-to-first-service interval as has been commonly thought by producers.[101] Madec suggests that low water intake causes an increased incidence of urinary disorders in sows.[102] Of 426 dead sows, 7.5% were diagnosed for urinary disorders.[103] Thus, low water intake may influence the occurrence of sow culling and deaths.

Water allowances of 20–35 L per day per sow and 4–5 L per kg feed for lactating sows have been recommended.[70] While a 2 L per min flow rate from nipple drinkers for lactating sows is often recommended, Patience[104] warns that nipples with high flow rates increase water wastage.

Implications

- Sufficient nutrient intakes during lactation and gestation are critical to optimize breeding herd productivity.
- Careful attention should be given to intake of carbohydrate, protein (amino acids), fat, macro- and microminerals, water-soluble vitamins, and water.
- Base levels of vitamins and minerals in corn-soy diets will vary.

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