Boar Nutrition for Optimum Sperm Production

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■ Introduction

Natural service boars and boars who's semen is collected for artificial insemination make up a relatively small portion of the pig population. This may partially explain the limited amount of data on the nutritional requirements and feeding practices of adult boars. Several research and literature reviews have been done, Kemp and den Hartog (1989), Colenbrander and Kemp (1990), Close and Roberts (1993), Brown (1994), Patience *et al*., (1995), Close and Cole (2000), Wilson (2000) and Kemp and Soede (2001).

Boars received little attention in a review by NRC (1998) where it was estimated that a boar requires a 2 kg feed intake per day of a 13% CP diet (lysine 0.6% and total sulfur amino acids 0.42%) containing 13.66 MJ DE/kg. Many commercial boar studs in the US and Canada feed diets formulated above these requirements. Because the cost of feed is considered low in relation to other production costs and the potential exists for improvements in semen quantity and/or quality with higher nutritional levels, most boar diets are likely to be over fortified. Determining the specific dietary needs of the boar may not be as critical as determining potential positive and negative effects of specific dietary factors on sperm production.

When evaluating nutritional effects on boars, one should consider the following categories: libido, quality and quantity of sperm, fertility of the spermatozoa, welfare, and environmental impacts. In addition, formulation and ease of implementation of the boar diet should be considered.

Factors, which can impact research results, are age of the boar, genetics, environment, and collection frequency. All these factors must be considered when evaluating results from research trials.

▪ Effect of Energy

Overfeeding and excess body weight contributes to the increased incidence of feet and leg problems as well as the reduction of libido in boars. In the past, excess body weight was found to be the major reason for culling boars (Penny and Guise, 1989). Recent summaries of reasons for culling boars from a large Midwest (U.S.A.) commercial boar stud (Gall, 1999), revealed that age and semen quality (each 28% of the culls) were the most important reasons for culling boars. Soundness and libido were the next most common reason for culling (both 10% of the culls). Today, boars used for semen collection are not typically maintained in the commercial studs for as long as they have in the past. Selection pressure for continued genetic improvement requires frequent replacement of boars with higher indexing animals.

Evaluation of 166 boars (12,717 ejaculates) showed that maximum semen volume, sperm concentration and doses of semen were obtained from boars 24-29 months old, while boars under 9 months of age demonstrated lower production (Kennedy and Wilkins, 1984). In addition, a significant increase in sperm production was found in boars older than 12 months compared to boars 8-12 months of age (Cameron, 1987). Levis (1997) reported sperm output is rather constant in boars from 12-35 months of age. Today, the average boar remains in a stud from 7 to 18 months of age. Therefore, the boar stud manager is faced with the dilemma of maximizing dose output from the stud to reduce the fixed and variable costs per dose of semen, while continually culling boars in response to genetic progress.

Feeding three different levels of energy to Yorkshire boars (ad libitum; NRC (moderate); and restrict-fed) had no impact on motility or fertility of freshly ejaculated spermatozoa (Stevermer et al., 1961). In another study on the effects of total feeding levels on sperm production in the boar, Kemp (1989) fed three groups of 14 Yorkshire boars either (a) ad libitum (74 MJ ME/d, 5.89 kg of diet), (b) at a moderate level (47 MJ ME/d, 3.74 kg of diet), or (c) at a restricted low level intake (25 MJ ME/d, 1.99 kg diet) during a 12-week trial. Because spermatogenesis and maturation of sperm takes six to seven weeks, nutritional effects were not expected to be evident prior to 6 weeks (Swiestra, 1968). No changes in sperm numbers were observed during the first six weeks. However, significant differences were recorded at 8 through 12 weeks of semen collection. Sperm production decreased as feed intake levels changed from high to medium and medium to low. In a more recent trial with two different genetic lines of boars, Boyd *et al*., (1996) reported that higher feed intake increased sperm production and libido in one genetic line while the other line failed to show any improvement.

In commercial studs, maternal line boars are often kept in the stud longer than terminal line sires. Retention of both lines until the need to cull for reasons of genetic progress is problematic. The balance between regulation of body weight gain to prevent lameness problems and the need to maximize sperm production requires deliberate decisions on energy levels.

Dutch researchers (Kemp and den Hartog, 1989) suggest a moderate weight gain of 400 g/d for the 150-250 kg body weight boar and a slower weight-gain of 200 g/d for the mature boar (250-400 kg). Currently, diets are formulated to meet the more moderate weight gains (Aherne, 1995), which may maximize sperm production but compromise longevity. Field experience indicates that by reducing the energy density and allowing boars to be fed larger amounts of feed, more consistent, but lower weekly semen production can be maintained. If longevity is improved, the lifetime semen production may be increased. Therefore, maximum semen production may not be the best indicator of efficiency for the boar studs. Until further data are established, a body condition score of 3 is a good target (Levis, 1997). As a rule, it is best to avoid over conditioning; however, sperm output is optimized if the boars continue to gain weight.

Energy requirements for the boar can be broken into several categories: maintenance, weight gain, mating activity and sperm production. Kemp (1991) summarized several trials to develop an equation that expresses the energy maintenance requirement of adult boars. The maintenance requirement was calculated as 415 kJ ME/kg live weight$^{0.75}$/d for young boars. Further calculations (Close and Roberts, 1993) were extrapolated to predict the maintenance needs of adult boars (763 kJ ME/kg live weight$^{0.665}$). The difference between these equations predicts an increase in the energy maintenance requirements of adult boars by about 3-4 MJ ME/d or 0.25 to 0.32 kg/d of a diet with 12.56 MJ ME/kg. Principles of nutrient partitioning and a few assumptions were used to create equations that would estimate energy requirements for growth, mating activity and sperm production (Kemp, 1991) and calculate a total energy requirement for boars (**Table 1**, Kemp and Soede, 2001)

Since the energy requirements for mating activity and sperm production are small, they are often ignored when figuring the energy needs of the working boar. Thermoneutral temperature of a boar is 20ºC (Kemp *et al*., 1989); therefore, it is important to adjust rations 0.08 kg/day for every 1ºC below 20ºC to compensate for increased heat production (Tokach *et al*., 1996).

Table 1. Thermoneutral feeding level for boars based on a factorial approach[a]

Live weight, kg	150	200	250	300	350	400
Weight gain, g/d	500	400	300	200	100	50
ME Maintenance, MJ/d[b]	17.79	22.07	26.09	29.91	33.58	37.12
ME weight gain, MJ/d[c]	16.40	13.11	9.83	6.55	3.28	1.64
ME total, MJ/d	34.19	35.18	35.92	36.46	36.86	38.76
kg of diet, 12.56 MJ ME/kg	2.7	2.8	2.9	2.9	2.9	3.1

[a] Data of Kemp (1991)

[b] Maintenance = 415 kJ/kg live weight0.75/d. ME = metabolizable energy

[c] Efficiency for growth from ME is 0.72, energy in growth = 23.6 kJ/g

▪ Proteins and Amino Acids

Severe protein restriction in the diet (6 g lysine/d vs. control, 17 g lysine/d) reduced semen volume and libido after 7 weeks (Louis *et al*., 1994 a, b). The decreased libido was measured as reduced duration of ejaculation and increased time to initiate ejaculation. In contrast, dramatic increases in lysine intake do not improve libido. No differences were detected in libido (measured as refusal to mount) of 100 boars at various studs fed diets (12.56 MJ ME/kg) with either 6.8 or 12 g lysine/kg diet (lysine intake averaged 18 and 31g/d) (Kemp, 1989). Also, in this study, there were no effects on sperm number or quality produced by boars consuming 18 g vs. 31 g lysine/d.

The literature reports of feeding protein and amino acids to boars have ranged from consumption of 6.8 to as high as 57 grams of lysine per day. In the field dietary recommendations with extremely high lysine and methionine levels are still found. These recommendations likely stem from past research (Poppe *et al*., 1974) where elevated synthetic lysine and methionine were reported to show large increases in sperm numbers, (7% and 28% respectively, when a high collection frequency was used). At low collection frequency there was no difference between treatment groups. When Dutch researchers ran a trial with lysine and methionine levels elevated above that of a basal diet, no differences in sperm output were detected in boars with a high collection frequency (Kemp *et al*., 1988). In a field trial a positive response was observed in boars fed increased energy and lysine (14 vs 20 g/d). With an increase in both energy and lysine these boars showed an improvement ($P < 0.05$) in sperm dose production (4 doses at 4×10^9 sperm/dose) (Wilson, 2000). This may indicate that there is a fairly sensitive minimum threshold on daily lysine consumption for active collection boars.

An amino acid that probably deserves greater attention at this time is threonine. A recent paper by Allee (2001) showed that as pigs age, the optimum threonine to lysine ratio increases. Further work needs to be done in the boar because the role for more elevated levels of threonine seems quite plausible from current data in late finishing for both barrows and gilts. The opportunity to create more environmentally friendly diets will increase and the cost for synthetic threonine becomes competitive. The use of synthetic amino acids allow diet formulations to reduce nitrogenous waste from the pig. Excessive feeding levels of crude protein and extremely high lysine diets only increase ammonia problems within the boar stud and for neighbours. Kemp reported that the lowest level that did not affect boar performance were formulations with 12.5 MJ ME/kg, 14.5% CP, 0.68% total lysine and 0.44% total sulfur-containing amino acids. Most studs feed levels slightly higher than this, particularly lysine.

▪ Effect of Minerals and Vitamins

Calcium and phosphorus are the two most important minerals to consider when formulating boar diets. Optimizing bone mineralization is generally thought to require more calcium and phosphorus than amounts needed for optimum growth (Kornegay and Thomas, 1981; Kornegay *et al.,* 1981 and Nimmo *et al*., 1980). The amounts of calcium and phosphorus fed during development may be more important than the levels fed to boars once they are in the stud. Levels of calcium and phosphorus fed in the field average around 0.85 to 0.9% and 0.7 to 0.8% of the diet, respectively. Fortification of diets with calcium and phosphorus above these levels is not supported. Based on concerns in developing gilts related to over-supplementation (Crenshaw, 2003), use of excessive calcium and phosphorus levels to force bone mineralization may increase potential for lameness problems associated with cartilage damage.

In order to avoid environmental concerns and to prevent excess excretion of phosphorus in the manure, nutritionists are pressured to formulate diets with phosphorus levels close to the minimum amounts required by the boar. An alternate approach for the nutritionist is the use of phytase to optimize phosphorus utilization. To our knowledge, no reports have been published on the efficacy of phytase in diets for boars.

Zinc and biotin may be important in helping reduce foot problems. Zinc is also involved in testicular function (Hesketh, 1982). A zinc deficiency may result in underdevelopment of the Leydig cells, reduced sensitivity to LH and impaired steriodogenesis. Dietary zinc concentrations commonly used in the field range from 70-150 ppm. A trial conducted using elevated levels above current recommendations with an organic form of zinc showed no increase in semen quantity or quality as determined by motility scores, number of doses rejected, and morphological exam score (Althouse *et al*., 2000). However, elevating these organic forms of zinc can be a helpful control for foot problems in the case of migrating bacterial infections from cracked hoofs and injured dewclaws. Additionally, biotin levels are generally increased in the diet if foot problems exist in the stud. Levels of feeding biotin range from 200 to 1000 μg/kg of diet.

Vitamin E and selenium have long been thought to be important in reproduction. Boars fed diets with 0.5 ppm added Se improved sperm concentrations, motility and fertilization rates over boars fed 220 IU of supplemental vitamin E and the controls (0 ppm supplemental Se and 0 supplemental IU vitamin E) (Marin-Guzman et al., 1997). Many of the experimental treatments with selenium fed to boars are at levels above that which feed manufactures are allowed to put into the feed (0.3 ppm). Therefore, in countries where it is allowed, partial substitution with organic sources of selenium may improve nutrient uptake of selenium and the subsequent effectiveness of its antioxidant properties. The antioxidant properties of both vitamin E and selenium seem to have effects on sperm maturation and semen quality. In Asia and several other warm climatic regions, levels of vitamin E are being used at more than 2x NRC in boar stud diets. The antioxidants are thought to help reduce stress and membrane damage. There is little evidence for improved reproductive performance related to the vitamin E levels being fed to the boar. However, in studs where elevated levels are fed, managers feel that they have more viable sperm cells and fewer problems with rejected ejaculates, particularly in the hot summer months. Controlled studies to document these advantages have not been reported.

A controlled study feeding chromium tripicolinate was designed to provide 200 ppb intake/day to the treated animals (Wilson *et al*., 2002). A 90-day adjustment period was followed by a 90-day study of the effects of added chromium. There was no response on total sperm production or improved quality of sperm cells in response to increased chromium in the diet. Although this study showed no effect on sperm quality or quantity, we have not tested chromium in boars subjected to stressors. Under high stress conditions, sow performance improves with chromium tripicolinate treatment compared to untreated controls. Chromium tripicolinte may provide inexpensive insurance in the boar stud during to periods of high stress.

Vitamin C has been used to reduce heat stress in birds. It has been suggested that vitamin C may help improve semen quality in boars during summer heat stress. Increased sperm concentrations ($P < 0.05$) and a decrease in abnormal sperm ($P < 0.05$) were reported in one of two test locations during hot weather (Lin *et al.,* 1985). Field data in the US has been equivocal when similar feeding levels were used (350 mg/head/d) (Wilson *et al*., 2001). Manufactures recommend feeding vitamin C prior to the beginning of hot weather to maximize the effect.

▪ Fatty Acids

The lipid components of the sperm cell are unique for different species and involve a high degree of polyunsaturation. Alteration of these fatty acid ratios on the plasma membrane by nutritional supplementation improved fecundity in females. The supplementation of a specific fatty acid treatment decreased levels of DPA (C22:5 n-6) and increased levels of DHA (C22:6 n-3) (Penny *et al*., 2001). A similar response to alteration of phospholipid fatty acids was demonstrated by feeding tuna oil (Rooke *et al*., 2001). Equivocal data from the field would suggest that positive responses are more likely under stress conditions and when fatty acids are fed to boars with sub-fertile sperm cells (poor morphology and motility). Further research needs to be conducted to delineate the exact role of fatty acids in the boar diet.

▪ Physical Factors of the Diet

Hunger, frustration, abnormal behavior, and poor welfare may occur in boars that are fed a restricted diet. Dietary fiber content offers the potential to improve satiety and may have a significant role in altering microbial populations in the hindgut of the boar. Further evidence for positive health aspects of fiber relate to the potential for reductions in incidence of esophageal lesions in cereal fed animals.

Fiber may also play an additional role in hormone regulation. A mechanism has been described for the absorption and recycling of steroid hormones from the intestine via the enterohepatic circulation in which the steroids are re-circulated through either bile or the peripheral circulation (Ruoff and Dzuik 1994a,b). These hormones can influence reproduction. The recovery of estrogens after passing normal bile into the stomach of a pig demonstrated a rise in endogenous estrogens (Ruoff and Dzuik, 1994 a,b). The same mechanism may affect steroidogenisis of the boar. Control or alteration of the ability of this pathway to function has shown that antibiotics can reduce the enterohepatic recirculation of steroids and even make oral contraceptives ineffective in women (Adelercreutz, 1977). A similar disruption of this pathway occurs with altered dietary fiber (Goldin *et al*., 1981) and decreased levels of fat intake (Rose et al., 1987). Unpublished data by Dziuk imply that activated charcoal and high amino acid levels (methionine) create a similar response. This leads to some speculation that the physical properties of a boar diet may contribute to issues such as libido and the amount of androgen release. A very interesting phenomenon was observed in several trials looking at fiber levels. When appropriate soluble and non-soluble fiber types were fed verses a corn-soy based control diet (4.5% CF vs. 2.9% CF) a difference in sperm output was observed within three weeks and thought to result from some spermatogenesis hormonal response to the properties of the feed. Brown (1994) suggested that there is considerable evidence that the influence of nutrition on reproductive processes is mediated via effects of dietary constituents on the hypothalamic-pituitary axis.

▪ Mycotoxins

When feeding boars, it is necessary to store and handle feed ingredients properly to minimize the presence of molds and mycotoxins. An experiment was conducted with three levels of zearalenone fed for 8 weeks. Semen characteristics or libido of the boar were not affected (Ruhr *et al.*, 1983); however, total sperm ejaculated decreased linearly with increasing amounts of zearalenone. Aflatoxin B_1 has a detrimental effect on semen characteristics and fertility (Levis, 1997). The boar is one of the most sensitive animals to vomitoxin (Louis, 1996). Several field investigations have shown marked improvement in semen quality when sources of mycotoxins were blended down or eliminated. Addition of mold inhibitors and binding agents into boar feeds is recommended to help protect against possible sources of contamination. Practical management tips that may help you avoid this problem include: maintaining fresh feed, cleaning bins several times during the summer, and grinding smaller batches more frequently. Suspicious grain or fiber sources should be checked for mycotoxins prior to feeding to boars.

▪ Summary

Severe under nutrition of either proteins or energy affects sperm production. Optimum sperm production occurs when boars are gaining weight, yet excessive weight gain may compromise longevity. The feed intake level and desired rate of gain in the boar will be dependent on the turnover rate for genetic progress within a stud. Most diets are over formulated and boars are over-fed. The average cost of nutrition per dose of semen is $0.13-0.16 in the US. The range for the cost of nutrition in a dose of semen is from $0.07-0.36. Cost per dose depends on several factors, such as how many inactive or untrained boars are standing in the stud, how many rejected collections occur each week, cost of the diet, disease, and environmental factors. All of these factors can impact the number of doses per week, which ultimately changes the cost of nutrition.

Take care of the basics when formulating diets for boars. There is little evidence to support an over-supply of nutrients beyond maintenance and moderate growth to achieve an improvement on sperm production or quality. Evaluate other feed additive effects on either changes in output or changes in fertility to ensure a financial payback. New research will increase our understanding of the impacts that physical factors have on the diet and the implications on reproductive performance. Predicting the true dietary requirements for boars will become more specific and accurate, as new techniques are developed to assess semen which have a greater correlation to fertility.

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