Sow feed additives on the market: Are they worth it?

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Introduction

As new feed additive or ingredients are developed or researched that can potentially improve sow reproductive performance or longevity, producers, nutritionists and consulting veterinarians must be diligent in evaluation before implementation. Typical concerns in evaluating new products may include: 1) Retrospective trials evaluating groups over time rather then side by side analysis; 2) Proprietary composition of feed additive or ingredient that make it difficult to understand the mode of action; 3) Lack of all research data being reported, both negative and positive; 4) Comparing feeding durations and levels between research studies; and 5) Finding significant differences due to the large numbers of sows per treatment needed for statistical reproductive differences. However, decisions based on sound scientific data from both research and commercial environments can build confidence in practical uses for these products.

Reproductive female diets for swine require additional feed additives or specific ingredients compared to typical corn-soy diets for nursery or grow-finish pigs for optimal performance. Such additives typically include supplemental biotin, choline, and folic acid and therefore will not be specifically discussed in this paper. Also, we recognize the importance of energy density in lactation diets through supplemental fat inclusion and the use of soy hulls or wheat middlings during gestation for increased fiber and energy dilution. Furthermore, many operations utilize in-feed antimicrobials in reproductive rations either continuously or by pulsing for disease control but have not been included in this review.

Proper nutrition and feeding, genetics, facilities, husbandry and reproductive management decisions of the female herd should not go unrecognized as the primary drivers of overall reproductive performance and longevity. Feed additives should not be used as a means to cover up deficiencies in any one area but rather to improve reproductive performance above those areas for individual operations. In this paper, we will briefly review selected feed additives that have been introduced in the US market for use in sow diets in the last 10 years.

Economics for each product are presented as included on a ton basis or cost per farrowing. Additionally, we calculated the cost of including each product on a value per weaned pig basis. For this calculation, we used the assumptions of 10 pigs per litter or 20 pigs per sow per year. Also, we used a feed consumption of 25 lb of lactation feed and 80 lb of gestation feed per weaned pig.

Diet acidification

Altering the dietary electrolyte balance (**dEB**; calculated as mEq/kg of (Na% * 434.98) + (K% * 255.74) – (Cl% * 282.06) of dairy cattle is a common practice among dairy nutritionists to improve health and performance. Goff and Horst (1998) reported a 53% reduction in the incidence of milk fever among dairy cows fed diets with a low **dEB**. Also, dEB is frequently increased during lactation to help buffer the rumen and prevent digestive problems in high intake cows.

Recently an increase in interest in altering the diet acidity or dEB of sow diets to improve sow performance has been evaluated. Two main areas have been researched; 1) methods to reduce urine pH to improve urinary tract health; and 2) increasing blood Ca levels to decrease stillbirths.

Feeding methods to reduce sow urine pH for improvement in the health of the urinary tract have been evaluated by two different means: 1) addition of organic sources (organic acids with do not alter the dEB of the diet); and 2) addition of inorganic sources (mineral sources). Dee et al. (1994) suggested manipulation of diets using citric acid could lower urine pH and, thereby, decrease the likelihood of urinary track infections in sows. However, DeRouchey et al. (1998) were not successful in reducing urine pH using citric acid alone or a combination product of fumaric, lactic, propionic, formic and citric acids (Acid Lac®, Kemin Industries) included in the diet. However, urine pH was reduced with the addition of an inorganic phosphoric acid based additive (Kem-Gest®, Kemin Industries).

Tilley (1997) reported from South Africa the first data in which sows fed lactation rations with a lowered dEB had greater survivability of piglets and litter weight gains. DeRouchey et al. (2003) reported improved piglet survivability, reduced blood and urine pH and decreased total urinary bacteria as the dEB of the diet was reduced from 500 to 0 mEq/kg (typical corn-soy lactation ration dEB = 185 to 220 mEq/kg). DeRouchey et al. (2003) utilized Calcium chloride and hydrochloric acid as a diet acidification sources and sodium bicarbonate to increase dEB. Both Tilley (1997) and DeRouchey et al. (2003) reported sows had increased blood Ca concentrations as dEB was lowered. This can be explained (Seldin and Giebisch, 1989) as the result of more bone mobilization to buffer the extracellular fluid with the increase in H^+ concentration in the blood as dEB was decreased. Also, Ca absorption is increased with a decrease in blood pH. While bicarbonate feed additives can be used to increase performance in high intake dairy cows, those advantages have not been proven in lactating sows. Dove and Haydon (1994) and DeRouchey et al. (2003) reported no improvement in sow performance as dEB of the lactation diets was increased.

Since blood Ca concentrations have been shown to increase in sows fed a decreased dEB diet, it has been theorized that this may decrease the number of stillbirths due to more Ca available for muscle contractions during the birthing process. WEANMOR+® (Soda Feed Ingredients, LLC) is a microencapsulated dry calcium chloride product and was shown to reduce stillbirths and increase milk yield in field trials (unpublished data). DeRouchey et al. (2005) reported in their own field experiment (control diet = 218 mEq/kg and WEANMOR+® diet = 150 mEq/kg) that this product tended to lower urine pH and there was a tendency for a parity group by stillborn interaction ($P < 0.10$) where feeding WEANMOR+® reduced the number of stillborn pigs in the parity 2 to 5 sows (by 0.46 pigs per litter) with numeric increase in stillborns when WEANMOR+® was fed to parity 6 and over sows.

Practical recommendations for dEB manipulation can be achieved by replacing limestone with calcium chloride in the lactation diet. To achieve a 150 mEq/kg from a typical 220 mEq/kg lactation ration, replace 7 lbs of limestone and 3 lbs of corn with 10 lbs of calcium chloride. Currently, calcium chloride is priced at approximately $$0.19/lb, which would add $1.66 per ton of complete feed.

Flowabilty and handling of calcium chloride in feed mills due to clumping and poor flow ability can limit use of calcium chloride and has led to increased interest and use of encapsulated product (WEANMOR+®). Currently, WEANMOR+® is priced at $5.00 per lb. This product is recommended as a top dress for 4 days prior to farrowing at 25 grams per day, which equates to a cost of $.27 per day feeding. If used in this manner for reduction in stillbirths, the total cost per sow per farrowing would be $1.10. If WEANMOR+® is used for the entire lactation period, simply multiply the days of lactation by $0.27 to determine the cost per lactation period for benefits of urinary tract health and potential improved milk production.

Practically the dEB of the diet can be altered by replacing limestone with calcium chloride in the lactation diet. Replacing 7 lbs of limestone and 3 lbs of corn with 10 lbs of calcium chloride will provide a dEB of 150 mEq/kg. This is reduced from a typical 220 mEq/kg dEB for a corn-soybean meal based lactation diet. Currently, calcium costs approximately $0.19/lb, which would add $1.66 per ton of complete lactation feed or about $0.02 per weaned pig.

Due to its hygroscopic nature, calcium chloride can cause flow ability and handling problems in feed mills which may limit its use. An encapsulated product (WEANMOR+®) is currently available with less of these problems. Encapsulated calcium chloride currently costs $5.00 per lb. This product is recommended as a top dress for 4 days prior to farrowing at 25 grams per day, which equates to a cost of $.27 per day feeding. If used in this manner for reduction in stillbirths, the total cost per sow per farrowing would be $1.10. If WEANMOR+® is used for the entire lactation period, simply multiply the days of lactation by $0.27 to determine the cost per lactation period for benefits of urinary tract health and potential improved milk production. Thus, the cost per weaned pig would be about $0.055 for topdressing the four days prior to farrowing and an additional $0.26 per weaned pig if feed for the entire lactation period.

L-carnitine and CarniChrome

Carnitine is a vitamin like, water soluble compound that functions to transport fatty acids across the mitochondria membrane where they are processed to produce energy. Most research that has been conducted with supplemental L-carnitine (Carniking; Lonza Inc, Fair Lawn, NJ) has been fed at a rate of 50 ppm of complete diet.

Previous research has indicted that that L-carnitine can elicit improvements in the number of pigs born and weaned (Fremaut, 1993; Musser et al., 1999). New research suggests that L-carnitine will improve sow and litter performance in many other ways including improved fetal growth and development and increased milk production in sows. A number of studies have reported that when L-carnitine is included in gestation diets that piglet birth weights in the subsequent litter will be increased (Musser et al., 1999; Eder et al., 2001; Ramanau et al., 2002; Eder et al., 2003; Table 1). Even when the number of piglets born alive is increased, the piglet birth weight is maintained or greater when L-carnitine is included in the diets (Ramanau et al., 2004), a relationship which is normally inversely related. These findings would suggest that L-carnitine will elicit beneficial effects on fetal growth and development. This is supported by other observations showing that L-carnitine will reduce the number of non-viable piglets born (less than 1.76 lbs) (Eder et al., 2001; Ramanau et al., 2002; Eder et al., 2003; Table 1) and reduce the number of stillborns (Eder et al., 2001; Ramanau et al., 2002; Table 1). Other research has reported that L-carnitine fed in gestation diets will elicit increased muscle development of the offspring. Musser et al. (2001) reported that in two studies piglets obtained from sows fed diets containing L-carnitine during gestation had 27.8% and 6.5% more muscle fibers compared to piglets obtained from sows fed diets without L-carnitine. In a third study, Musser et al. (2000) confirmed that L-carnitine enhanced muscle fiber development of the offspring and observed that the benefit was maintained at slaughter as piglets from sows fed diets with L-carnitine had greater ($P < 0.05$) loin depth (59.4 vs 57.0 mm) and lean percent (55.1 vs 54.5%).

The exact mode of action for L-carnitine's ability to improve fetal growth and development is unknown; however, it is most likely related to its ability to influence energy metabolism (Owen et al., 2001), increase maternal IGF-1 concentrations (Musser et al., 1999), and influence maternal leptin concentrations (Woodworth et al., 2003). Waylan et al. (2005) reported that maternal supplementation of L-carnitine affected the gene expression of key growth factor and transcription factor genes, which ultimately will regulate the proliferation and differentiation status of these important myogenic precursor cells. This process could give rise to increased fiber numbers at birth due to increased number of embryonic myoblasts. These results suggest that L-carnitine fed during gestation will elicit a beneficial impact on fetal growth and development that can be observed in increased birth weights, reduced stillborns, and increased muscle development.

Past research has shown that when sows are supplemented with L-carnitine during lactation, the piglets grew faster compared to the piglets of control sows (Eder et al., 2001; Ramanau et al., 2002). Recent research (Ramanau et al., 2004) confirms these observations and suggests that the improved growth performance is a reflection of increased milk production.

The exact mode of action for the ability of L-carnitine to elicit improvements in sow and litter performance is not completely understood. The fact that L-carnitine has been shown to influence a number of different response criteria in sows might suggest that it works in many direct and indirect ways. It is widely accepted that L-carnitine plays an integral role in fatty acid metabolism. In addition to fatty acids, Owen et al. (2001) observed that L-carnitine also influences carbohydrate and protein metabolism. In another study, Woodworth et al. (2003) observed that when gestating sows were fed diets containing L-carnitine, glucose utilization after feeding was enhanced and fatty acid utilization during fasting was improved. These studies suggest that L-carnitine may play an important role in maintaining or enhancing sow energy status. This hypothesis would be supported by Woodworth et al. (2003) who also reported that sows fed diets containing L-carnitine had greater circulating leptin concentrations at day 28 of gestation. It is important to remember that sows at day 28 of gestation are in a mode of energy accretion as sows are replacing the energy reserves lost during the previous lactation. The greater leptin concentrations would be associated with greater energy reserves, suggesting that L-carnitine increased energy status of the sows. It is also important to realize that the leptin concentrations reported with these sows were at least 10x lower than values reported for finishing pigs and thus, the higher leptin concentration would not be associated with reduced feed intake as it is commonly in obese animals. Leptin has been shown to influence reproductive performance in other species (Barash et al., 1996), and therefore the effect L-carnitine elicited on circulating leptin could partially be responsible for the improvements in reproductive performance in sows that are observed.

L-carnitine can also be supplied in the diet through the commercial product Carnichrome (Lonza Inc, Fair Lawn, NJ), which provided 50 ppm L-carnitine and 200 ppb chromium from chromium picolinate. Effects of chromium supplementation to sow diets will be discussed in the next section of this paper. Real et al. (2003) reported that when sows were fed Carnichrome, there were additive effects of improved reproductive performance compared to sows only fed L-carnitine or chromium picolinate.

L-carnitine can be added directly to the diet or more typically is included in the vitamin premix. The cost of Carniking which is the trade name for L-carnitine for 50 ppm per ton of complete feed is $4.15. The cost of Carnichrome which provided 50 ppm L-carnitine and 200 ppb of chromium picolinate per ton of complete feed is $4.45. This equates to about $0.22 per weaned pig for carnitine supplementation and an additional $0.015 per weaned pig to use the carnitine and chromium combination product.

Table 1. Effects of maternal L-carnitine supplementation on sow and litter performance.

	Carnitine supplementation[a]		
Item	No	Yes	P <
Number of pigs born alive/litter			
Musser et al., 1999	10.3	10.4	0.75
Eder et al., 2001	10.0	9.9	0.88
Ramanau et al., 2002	10.6	11.1	0.16
Ramanau et al., 2003	10.0	12.8	0.01
Number of Stillborn pigs/litter			
Musser et al., 1999	0.8	0.5	0.02
Eder et al., 2001	2.4	2.1	0.36
Ramanau et al., 2002	0.9	0.8	0.50
Number of Non-viable pigs/litter[b]			
Eder et al., 2001	0.9	0.4	0.03
Ramanau et al., 2002	0.4	0.3	0.08
Number of pigs weaned/litter			
Musser et al., 1999	8.9	9.0	0.76
Eder et al., 2001	8.1	8.5	0.19
Ramanau et al., 2002	8.4	9.1	0.06
Piglet birth weight, kg			
Musser et al., 1999	1.49	1.53	0.01
Eder et al., 2001	1.37	1.47	0.05
Ramanau et al., 2002	1.38	1.48	0.02
Ramanau et al., 2003	1.62	1.46	0.05
Piglet wean weight, kg			
Musser et al., 1999	4.7	5.0	0.01
Eder et al., 2001	8.2	8.7	0.02
Ramanau et al., 2002	7.6	8.0	0.23
Ramanau et al., 2003	9.2	9.8	0.05

[a] Diets were supplemented or top dressed to provide approximately 50 ppm of L-carnitine.

[b] Non-viable pigs were defined as those with birth weights less than 1.76 lbs.

Chromium

Chromium is a trace mineral that is actively involved in the metabolism of carbohydrates, lipids, protein and nucleic acids in the body. Chromium influences insulin action by increasing the cellular uptake of glucose and intracellular carbohydrate and cellular metabolism.

Most research involving chromium supplementation in sow diets has been done by the use of chromium picolinate (Chromax®, Prince Agri Products, Inc., Quincy, IL). However, other products such as chromium L-methionine (MiCroPlex® (Zinpro Corp, Eden Prairie, MN) and chromium propionate (KemTRACE®, Kemin Industries, Inc., Des Moines Iowa) are approved for use in swine.

While a specific chromium requirement for swine has not been determined, the level frequently researched and thus used as a guideline for practical use in diets is chromium supplementation at 200 ppb. Three research trials have shown to statistically increase live born when sows were supplemented with chromium picolinate at 200 ppb (Lindemann et al., 1995a, 11.25 vs 8.93; Hagen et al., 2000, 10.42 vs 10.05; and Lindemann et al., 2000, 11.45 vs 10.77). Also, a trial using chromium methionine showed statistical improvements when fed at 200 ppb (Perez-Mendoza et al., 2003, 11.0 vs 9.6). Five other research trials did not report statistical differences, but all had numerical advantages to chromium supplementation compared to control sows (Lindemann et al., 1995b, 10.50 vs 9.60; Campbell, 1998; Trial 1, 10.01 vs 9.94; Campbell, 1998; Trial 2, 10.54 vs 10.41; Charraga and Cuaron, 1998, 10.6 vs 9.55; and Lindemann et al., 2004, 9.82 vs 9.49).

In a limited number of published studies, higher levels of chromium have been evaluated on sow reproductive performance. Lindemann et al. (2004) reported statistical improvements in live born when sows were supplemented at 600 ppb (10.94) compared to control sows (9.49) and females fed 200 ppb (9.82). Also, Perez-Mendoza et al., 2003 reported that females supplemented with 400 ppb chromium from chromium methionine had statistically improved live born (10.90) compared to control sows (9.6), but was not different then sows supplemented at the 200 ppb per ton (11.0).

It is important to note that the research trials conducted with chromium differ in length of supplementation and involve both research and commercial settings. However, with positive data reported in each experiment, it is important to recognize the potential for improved reproductive performance from supplemental chromium in sow diets. The average response for an increase in live born was 0.80 per litter.

The cost of chromium picolinate (Chromax®) at 200 ppb inclusion per ton of complete feed is about $1.35 or $.30 per ton if fed in combination with carnitine. This equates to about $0.07 per weaned pig to feed the separate chromium picolinate (Chromax®) product.

The cost of chromium methionine (MiCroPlex®) at 200 ppb inclusion per ton of feed is about $1.05. This equates to about $0.05 per weaned pig. However, producers are able to feed up to 400 ppb in swine diets of this chromium product.

The cost of chromium propionate (KemTRACE®) at 200 ppb inclusion per ton of feed is about $1.40. This equates to about $0.053 per weaned pig.

Fatty acid supplementation

Omega 3-fatty acids have received increasing amounts of attention partly due to human research implicating potential health benefits. Omega-3 fatty acids are long chains of carbon atoms (18 to 22), with three to six double bonds (unsaturation sites. The term "omega" refers to the last carbon on the fatty acid's carbon chain. This carbon is usually designated as the "n" carbon. Omega-3 fatty acids (n-3) contain their first double bond at the third carbon, while omega-6 fatty acids (n-6) have their first double bond at the sixth carbon.

The fatty acids of particular interest by researchers for improving performance are eicosapentaenoic (EPA, C20:5) and docosahexaenoic (DHA, C22:6). These fatty acids are believed to assist in the development of brain function, which may lead to a more viable pig at birth. While many different marine oil sources (tuna, salmon, menhaden, etc.) are the best sources of these fatty acids, most are not available or practical for use in female swine diets.

One potential source of omega-3 fatty acids is through the inclusion of flax into diets. The omega-3 fatty acid contained in flax seed and thus fractionated flax oil can be included in the diet, and thereby be concentrated either in meat products such as pork (Romans et al. 1995) or in eggs (Ahn et al. 1995). Lawrence et al. (2004) added 5 percent flaxseed to basal sow diets and reported that flax addition decreased weaning-to-estrus interval (8.0 vs 7.4 d) and pre-weaning mortality (13.7 percent vs. 10.0 percent), along with increasing pigs weaned per mated sow (20.8 vs 20.3, annual production). However, other researchers believe that the conversion of fatty acids in flaxseed is not efficient and sufficient to meet the animal's requirements (Neutkens, 2004). Therefore, the response flaxseed in sow diets may be attributed to other factors other then fatty acid supplementation.

Fertilium™ (United Feeds, Sheridan, IN) is a dried, processed blend of omega-3 fatty acids, protein, vitamins and minerals. The source of its marine-derived oil is proprietary as well as the product undergoes an encapsulation process to stabilize the fatty acids.

In early research with Fertilium™, Webel et al. (2003) reported that sows fed Fertilium™ for 35 days prior to breeding had increased subsequent total born (11.6 vs 11.0) and subsequent live born (10.8 vs 10.3) compared to non-supplemented sows. In a review of company research, Kitt and Moser (2005) reported in 12 experiments (total females = 2,050) ranging in supplementation days from 24 to 35 prior to breeding, the average increase in both total born and live born was 0.6 pigs per litter for Fertilium™ supplemented sows. Statistically, 3 trails were significant at $P < 0.03$, 3 experiments reported a trend at $P < 0.11$, and no statistical differences were detected ($P > 0.20$) in the other 6 experiments. Furthermore, in a separate summary of 6 experiments (total females = 1,141) ranging in supplementation days from 10 to 23 prior to breeding, no improvements were detected for Fertilium™ supplemented sows.

However, due to practical limitations of top dressing for a target of 28 days prior to breeding, Fertilium™ 365 has been introduced to be fed continuously in female diets. Research is more limiting with Fertilium™ 365, although Kitt and Moser (2005) have reported similar responses in females to that of the original product. Fertilium™ 365 is recommended to be fed at a rate of 15 lb per ton during gestation, 20 lbs per ton during lactation and for 45 days prior to breeding developing gilts.

Levis (2005) summized the need for additonal research with omega-3 fatty acid supplemetation to clarify: 1) the optimium amount of omega-3 fatty acids to add to sow diets; 2) which aspects of the sow reproductive cycle should omega-3 fatty acids be provided to enhance reproductive performance; and 3) the perferred sources of omega-3 fatty acids.

Fertilium™ 365 is currently priced at $0.70 per lb. Thus, dietary inclusion would cost $10.50/ton in gestation and $14.00/ton in lactation or about $0.60 per weaned pig.

Organic Selenium

While almost all sow diets in the U.S. already contain the legal limit of 0.3 ppm of added selenium, inorganic selenium is the normal source in trace mineral premixes. The recent availability of organic selenium sources has increased interest in their use to replace the inorganic selenium in the diet. The organic products are thought to have higher bioavailability.Two organic products are available for use in swine diets: 1) SEL-PLEX (Alltech, Nicholasville, KY; and 2) SelenoSource AF™ (Diamond V Yeast, Cedar Rapids, Iowa).

Research has reported increases in sow serum levels (Mahan, 2000; Steidinger and Yoon, 2004) in sows fed Se from an organic vs inorganic source. Also, numerous experiments have reported that sows fed Se from an organic source had increased Se levels in colostrum (Mahan, 2000; Mahan and Peters, 2004) and increased milk Se levels (Mahan and Kim, 1996; Mahan, 2000; Mahan and Peters, 2004; Diamond V, 2004; Lampe et al., 2005) compared to sows fed inorganic Se. Also, increased tissue levels of Se in 0-day old pigs (Mahan and Peters, 2004) and testes from nursing pigs (Diamond V, 2004) have been reported when sows were fed organic verses inorganic Se.

While body concentrations of Se have been increased in sows and offspring fed organic versus inorganic sources, the impact on reproductive performance has been inconsistent. Research has reported no differences in reproductive performance between organic and inorganic Se fed to sows (Mahan and Peters, 2004; Steidinger and Yoon, 2004) or to gilts (Mahan and Kim, 1996). An additional study by Lampe et al. (2005) reported no differences in born live, stillborns, and wean to service interval, a trend (P

<0.07) for higher birth weights, and improved number weaned and litter weaning weight ($P < 0.05$) for sows fed organic Se compared to sows fed inorganic Se.

Currently, organic Se can be used as a replacement for inorganic Se (typically sodium selenite) at a cost of approximately $1.12 per ton of complete feed at an inclusion level of 0.3 ppm. (Sodium selenite = $0.02 per ton; Organic Se = $1.14 per ton.) Thus, the organic source costs about $0.07 per weaned pig more than the inorganic source.

Pyridoxine

Pyridoxine (B_6) supplementation in reproductive sow diets may or may not be needed for sows. Ritchie et al. (1960) reported no advantages in reproductive performance in gilts and sows when fed either diets with a total of 1.0 or 10.0 ppm pyridoxine from the 2 month of gestation through 35 days of lactation. Easter et al. (1983) reported an increase in litter size at birth and at weaning when 1.0 ppm pyridoxine was add to a corn-soybean meal diet fed to gilts during gestation. More recently, Knights et al. (1998) reported a tendency for decreased wean to estrus interval ($P < 0.11$) when sows were supplemented with 16 ppm compared to 1 ppm pyridoxine in a barley based diet with no other significant reproductive differences between supplemental levels. With limited data available, recommendations can vary widely for this nutrient in female reproductive diets.

Currently, pyridoxine HCl costs approximately $8.23 per lb. If included at 5 ppm of complete feed, the total cost per ton would increase by be $0.10. Thus, including supplemental pyridoxine at 5 ppm would cost about $0.005 per weaned pig.

Beta Glucans

Beta glucans are a family of polysaccharides found in yeast cell walls and many plants including oats and barley. There are many types of beta glucans, depending on how the glucose units are linked together. Each source of beta glucan has a different purity and chemical arrangement and thus potentially different biological activity.

There is only a limited amount of data to quantify the response in reproductive females to these products. Hurnik (2005) reported a trend for increased live born ($P < 0.07$) and pigs weaned ($P < 0.08$) when sows were fed yeast beta glucan (**YBG**; Progressive BioActives Inc., Cornwall, Prince Edward Island, Canada) for one month prior to farrowing.. However, this area of feed additives needs more extensive research to quantify the effects of beta glucagons in reproductive diets for swine.

Current recommendations for feeding YBG included both during the gestation and lactation periods. The price for inclusion of YBG at manufacturers recommended levels is $5.25 per sow per farrowing or about $0.52 per weaned pig.

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