EFFECT OF PHYTOGENIC EXTRACTS AND ORGANIC ACIDS ON GROWTH PERFORMANCE OF NURSERY AND FINISHING PIGS

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EFFECT OF PHYTOGENIC EXTRACTS AND

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Abstract: Five studies were conducted to observe the effects of phytogenic extracts and organic acids on nursery, growing, and finishing pig growth performance. Two studies were performed to test the effect of Yucca extract on nursery pig growth performance when fed diets with elevated levels of soybean meal. Micro-Aid, a product made from yucca extract, was observed to improve pig ADG and G:F during the first 14-21 days of the nursery phase. There was a tendency for pigs fed Micro-Aid to have increased d 14 or 21 BW. Pigs that were fed elevated levels of soybean meal experienced a decrease in growth performance, as well as final BW. Additionally, another two nursery studies were conducted to evaluate the effect of Outpace, a phytogenic and organic acid blend, on nursery pig growth performance when antibiotics were not added to the diet. There were no effects observed on pig performance with the exception of G:F from d 0-42. From d 0-42, pigs fed the diet with the addition of Outpace had improved G:F compared to pigs fed a control diet. Lastly, a study to test the effects of Outpace on growth performance during the late nursery and early finishing phases was conducted. The effects of Ambitine, a blend of functional extracts and acidifiers, on finishing pig growth performance and carcass characteristics when fed a diet void of ractopamine HCl were also investigated during this study. When fed at this stage of production, Outpace did not have any effect on growth performance. However, the addition of Ambitine to a finishing diet resulted in pigs achieving higher G:F, as well as a tendency to have increased ADG. Pigs fed Ambitine also had a tendency to have more back fat than pigs fed a control diet. There was a decrease in kcals required/ kg of gain when Ambitine was added to the diet. Therefore, it was observed that soybean meal has a negative effect on the growth performance of nursery pigs. Additionally, phytogenic extracts and organic acids have the ability to improve ADG and feed efficiency during the nursery and late finishing stages of pig production.

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CHAPTER I

REVIEW OF LITERATURE

Weaning Challenges

Early weaning of young pigs results in a “growth check,” also commonly known as post-weaning lag (Pluske et al., 1997). Lalles et al. (2007) defined “early weaning” as taking place between 21 and 35 days of age. In commercial settings, piglets are weaned between 19 and 23 days of age, placed on a truck and transported to a nursery or wean–to–finish facility, where they are subjected to multiple stressors that can impact performance. Pluske et al. (1997) reported change in diet, new pens mates, and a new environment to all be contributors to the stress newly weaned pigs experience. The transition from a highly digestible liquid diet to a solid diet that is more complex is an additional challenge that these pigs face (Lalles et al., 2007). Intestinal disturbances are common during the days following weaning. Boudry et al. (2004) found that piglets experienced these disturbances following weaning regardless of the diet they consumed.

It is recognized that both psychological stress that occurs at weaning and both voluntary and involuntary food deprivation contribute to changes in intestinal physiology (Goldstein et al., 1985). Pluske and Williams (1996) postulated that these psychological stressors, such as separation from the sow and mixing of pen mates, are also confounded with the piglets maintaining low levels of feed intake for the first several days post weaning. Subsequently, pre-weaning metabolisable energy (ME) intake levels are not achieved until the end of the second week post-weaning (Le Dividich and Herpin, 1994).

It has been demonstrated that pigs that consume more feed have higher and thus more favorable, villi measurements (Beers-Schreurs et al., 1995). When pigs were weaned at 21 days of age, Hampson (1986) found that villous height was reduced by 25% when compared to pre-weaning villous height. Additionally, these researchers reported that this decrease continued until d 5 post-weaning, with villous height being reduced by 50% overall. These reductions in villous height are often associated with reduction in brush border enzymes (Pluske et al., 1995). Reduction in these enzymes results in decreased digestion and absorption which can result in reduced growth performance (Nabuurs et al., 1994). Although, Miller et al. (1986) concluded that reduced growth following weaning could be more fully attributed to decreased enzyme production alone and not impacted by absorptive capabilities. Pluske et al. (1997) suggested that maintaining steady feed intake immediately following weaning will promote mucosal growth and integrity of the small intestine, which will lead to higher digestive and absorptive capabilities and ultimately better growth performance.

Boudry et al. (2004) hypothesized that the acute and long lasting effects on the intestines that are induced by weaning could be reduced with increasing voluntary feed intake of newly-weaned pigs. There is an interest to achieve this increased feed intake without the addition of antibiotics or more expensive feed ingredients, such as milk and animal protein products (de Lange et al., 2010). However, there is still work to be done to evaluate the best options to replace these products. Pluske et al. (1997) postulated that feed intake, hypersensitivity, and health challenges all interact to play a role in intestinal development following weaning.

Post-weaning diarrhea is another factor that contributes to post-weaning lag. The effect of bacteria such as *Escherichia coli* (*E. coli*) on the prevalence of diarrhea, 3-10 d post-weaning, has been well documented and is a main contributor to economic loss during the nursery phase of production (Pluske et al., 1997). Prior to weaning, piglets are provided with secretory immunoglobulins in sows milk, after weaning when these immunoglobulins are no longer available, piglets are more vulnerable to pathogenic infections (Kelly et al., 1994).

Dreau and Lalles (1999) suggested that weaning weight, feed intake, diet type, and the condition of the environment that the pigs are housed in should all be taken into consideration when diagnosing the cause of post-weaning diarrhea and post-weaning lag.

Protein Sources in Nursery Diets

As discussed in the previous section, voluntary feed intake can have a profound impact on growth performance of weaned pigs. Spray-dried plasma has a high palatability which can aid in voluntary feed intake (Pierce et al., 2005). When spray dried plasma was added to nursery diets, an increase in growth performance was observed, mainly attributed to an increase in feed intake (van Dijk et al., 2001). Plasma may down regulate inflammation in healthy pigs which could result in nutrients being used for other productive functions (Touchette et al., 2002).

Soybean meal (SBM) is a cheaper protein source to include in nursery pig diets. However, there are many negative impacts that can be observed when feeding SBM early in the nursery phases. Dunshea et al. (2002) found that although there was no impact of diet on performance from d 0-4 post-weaning, when comparing pigs fed a SBM-based diet to a diet that included animal plasma, there was an impact on performance after d 4, with the pigs fed the SBM diet experiencing lower ADG and ADFI. Pigs fed a diet that contained 50% SBM had reduced ADG and ADFI from d 0-21 and d 0-35 post-weaning when compared to pigs fed a diet that contained 25% SBM and inclusion of spray-dried porcine plasma (Chae et al., 1999). Myers et al.

(2014) observed reduced ADG and G:F for pigs fed a SBM-based diet without spray-dried plasma or fishmeal, when compared to pigs that were fed a diet that did contain these specialty products. One particular reason for reduced feed intake when pigs are fed SBM-based diets appears to be the reduced palatability (Sohn et al., 1994). In opposition to most literature, Moran et al. (2017) observed an increase in growth performance with increasing levels of soybean meal in weaned pig diets; however, it should be noted that all the dietary treatments still included the same levels of spray-dried plasma regardless of soybean meal inclusion, which is not consistent with most other high-SBM diets.

There is also evidence that suggests that soybean meal induces an immune response, thought to be caused by glycinin and B-conglycinin, immunologically active proteins, that are found in SBM (Li et al., 1991). Miller et al. (1984) suggested that the antigenicity of the diet that includes high levels of SBM fed to weaned pigs is a concern and may lead to malabsorption of nutrients for nursery pigs. When SBM was added to weaned pig diets in place of whey, Li et al. (1991) found a negative effect on growth performance for pigs fed the SBM diets in comparison to pigs fed the control diet. In the same study, it was observed that pigs fed SBM had shorter villus height and greater crypt depth than these of pigs fed a diet that contained milk-protein products.

Friesen et al. (1993) found that pig growth performance is reduced when increased levels of SBM were added to the diet regardless, whether the increased was at d 0 post-weaning or d 14 post-weaning, after pigs had consumed a highly digestible diet for 14 days. However, several other researchers have reported that pigs fed high levels of SBM immediately post-weaning do not see any long term effects on performance compared to those fed a control diet with low levels of SBM (Wilson et al., 1989). Lenehan et al. (2007) also did not observe any growth performance difference between pigs fed a diet that contained animal protein products and pigs fed a diet that contained no animal protein and elevated levels of SBM. Friesen et al. (1993) postulated that

SBM could be added to weaned pig diets at a rate of 22.5% without causing a reduction in ADG or G:F. Mckracken and Kelly (1984) suggested that the changes in intestinal atrophy following weaning may be more closely related to feed deprivation, than to the antigens present in the diet, or the low levels of digestive enzymes following weaning.

Antibiotics

Preventing disease and enhancing growth and feed efficiency are important goals for modern pig production (Mroz, 2005). The addition of antibiotics to weaned pig diets has been shown to increase ADG by 3-8% and improve feed efficiency by 3% (Doyle, 2001). Until recently, antibiotics have been added to diets at sub-therapeutic levels to achieve those goals (Mroz, 2005). Partanen and Mroz (1999) explained that use of antibiotics in swine feeds is common at the beginning of the nursery phase, following weaning, as well as at the time that pigs are moved from a nursery to a finishing facility. The use of antibiotics is often used to reduce the incidence of diarrhea caused by gastrointestinal infections when pigs are mixed and subjected to potentially new pathogens or a diet change is made (Verstegen and Williams, 2002). When pigs experience diarrhea often other consequences occur, such as reduced growth and increased morbidity and mortality. In recent years, there has been concern about antibiotic use in livestock feeds and how they affect the development of pathogen strains that are resistant to antibiotics (Heuer et al., 2006). However, the removal of antibiotics from swine feeds may result in decreased performance. Che et al. (2012) reported that pigs fed a diet void of antibiotics had decreased ADG and ADFI when compared to diets that had antibiotic inclusion. These pigs also experienced an *E. coli* health challenge during this experiment. When antibiotics were not included in the diet, pig mortality increased and pigs experienced decreased ADG, ADFI, as well as a negative effect on feed efficiency when compared to that of pigs fed a diet with antibiotic inclusion (Tsiloyiannis et al., 2001). Similarly, Bhandari et al. (2008) reported that pigs fed a diet void of antibiotics experienced a higher mortality rate than that of pigs that were fed a diet with antibiotics; however, there was no difference in growth performance detected between the 2 dietary treatments. In a study where there were four different sub-therapeutic feed antibiotic treatments compared to an antibiotic free diet, all pigs fed the antibiotic treatments experienced increased ADG and improved feed efficiency when compared to the pigs fed the control diet (Longlois et al., 1978).

In 2017, the Veterinary Feed Directive (VFD), enacted by the Food and Drug Administration (FDA), went in to effect. This VFD states "Veterinarians play an important role in animal and human health and their oversight, as an integral part of the VFD process, will help ensure that medically important antimicrobial drugs will be used in feed according to label directions and only when appropriate to meet specific animal health needs" (FDA, 2017). With this new regulation in place, antibiotic alternatives have risen in interest. Some alternatives to antibiotics that have been considered are: spray-dried plasma, milk-protein products, enzymes, essential oils, and acids (Pettigrew, 2006).

Phytogenics

Phytogenic feed additives, sometimes referred to as plant extracts are products that are derived from plants and can be an addition to livestock feed to improve performance (Windisch et al., 2008). Phytogenics have recently gained interest due to the new regulations regarding sub-therapeutic antibiotic use. There is speculation that performance is improved in animals when using phytogenics in the diet because of the elevated feed intake attributed to increased palatability of the diet although there is no concrete evidence that this is the case (Windisch et al., 2008). In addition to a possible palatability benefit, many phytogenics are also considered to have anti-oxidative, antimicrobial, and anti-inflammatory properties (Lee et al., 2004).

There have been studies that indicate that plant extracts can improve performance of pigs under an immune challenge (Liu et al., 2013b). In pigs that were infected with the porcine respiratory and reproductive syndrome virus (PRRS), pigs fed diets that included plant extracts had improved feed efficiency when under an immune challenge compared to pigs fed a diet that did not include plant extracts; however, there was no difference in performance observed between diet type when pigs were not under a disease challenge. In a similar study by Liu et al. (2013a), an increase in ADG from d 0-5 post-weaning was observed for pigs fed diets that contained plant extracts when compared to a control diet; however, there was no additional difference observed in growth performance throughout the remainder of the study that could be attributed to dietary treatment. Plant extracts have also been shown to decrease rate of diarrhea when pigs were health challenged with *E. coli* (Liu et al., 2013a). Gutierrez (2007) reported that plant extracts may help with reducing diarrhea by increasing water absorption in the small intestine. There may be other potential mechanisms to improve gut health. This includes aiding in strengthening the gut barrier and decreasing “leaky gut” (Karmouty-Quintan et al., 2007). One specific plant extract of interest is Yucca *schidigera*, or yucca extract.

Yucca *schidigera* is a desert plant that is native to the southwest region of the United States and the Northern area of Mexico. It is an herbaceous plant that is part of the lily family (Cheeke et al., 2006). Yucca extract has been designated as safe by the FDA and is approved for human and animal consumption (Sen et al., 1998). Yucca schidigera includes saponins. Saponins play an active role in the mode of action for Yucca (Wallace et al., 1994; Killeen et al., 1998). Francis et al. (2002) stated that yucca is the most common source for steroid saponins used commercially.

Gee et al. (1997) observed that saponins from plant sources can increase permeability at the brush border of the small intestine allowing nutrients to be more readily absorbed. Saponins also play a role in immune response, but the mechanisms are not fully understood. Francis et al. (2002) postulated that this increase in immune response may be due to effects of yucca on membrane permeability, and the increased uptake of antigen it allows. Yucca saponins have shown to have antiprotozoal activities that could have an impact on pathogen proliferation and response time to specific pathogens in the body (Cheeke, 1999).

Yeo and Kim (1997) reported that chicks fed a diet with the addition of Yucca had similar growth performance as chicks fed a diet that contained antibiotics. Cromwell et al. (1985) observed increased growth performance when pigs were fed yucca extract. However, there was no improvement in pig growth performance seen by Gipp et al. (1988) when yucca extract was added to the diet. Feed intake was higher for pigs fed a diet with the addition of yucca compared to a diet that did not contain yucca or antibiotics; however, there was no difference in ADG or feed efficiency observed between the two dietary treatments (Yen and Pond, 1993). In an additional study, Yen and Pond (1993) reported that ADG was similar during the last four weeks of a study when comparing pigs fed a diet that included yucca extract and pigs fed a diet that included antibiotics, furthermore, there was no difference in feed efficiency between the two dietary treatments throughout the entire study.

In rabbits fed diets that included yucca extract, ADG, feed efficiency, and final body weight was increased when compared to that of rabbits fed a control diet. These increases in performance were assumed to be because of an improved health status (Amber et al., 2004). Amber et al. (2004) also found that in analyzed diets that were fed to the rabbits and fecal samples taken from the rabbits, the diet containing yucca extract had significantly increased digestibility of dry matter, crude protein, ether extract, and gross energy when compared to the control diet that did not contain yucca. This could be attributed to the cells of the small intestine being able to absorb more nutrients because of the increased gut integrity the rabbits had when fed the yucca diet (Johnson et al., 1982). Amber et al. (2004) also reported a numerical increase of net revenue when rabbits were fed yucca extract. This is important to note because most studies do not contain any cost or revenue analysis when using these products.

In addition to growth performance benefits, it was observed by Wallace et al. (1994) that the addition of yucca extract helped to inhibit the growth of detrimental gut microbes in ruminant animals. In poultry production, yucca has been used to control coccidiosis, due to yucca *schidigera's* ability to inhibit protozoa growth attributed to its large inclusion of saponins (Alfaro et al., 2007). The addition of Yucca extract to poultry diets resulted in a higher crypt depth to villus height ratio because of the positive effect on cell turnover in the intestine in the broiler (Alfaro et al., 2007). Cabuk et al. (2004) did not detect any difference in ADFI, feed efficiency, or body weight when comparing broilers fed a diet that contained yucca extract to broilers fed a control diet. However, Ayasan et al. (2005) observed a positive effect on poultry feed efficiency when yucca was added to the diet. Similarly, when yucca was added to a diet that also contained caprylic acid, ADG, ADFI, feed efficiency, and mortality rate were all improved when compared to that of broilers fed a diet that was void of antibiotics. In the same study, when comparing growth performance of broilers fed the yucca extract, to that of the broilers fed a diet that included antibiotics, there was no difference in performance detected between the two treatments (Begum et al., 2015). Conversely, there was an effect on mortality rate between the treatments with the broilers fed the yucca extract in the diet having a significantly lower mortality rate than that of the birds fed antibiotics.

Yucca extract has been widely researched as an alternative for antibiotics. Yucca can result in similar growth performance to that of pigs fed antibiotics (Yeo and Kim, 1997). However, the benefits of yucca because of its anti-inflammatory properties may be prominent in pigs fed less digestible diets, although more research is needed in this area.

Organic Acids

Organic acids have been widely studied in recent years. Organic acids may be more commonly recognized as antimicrobials and effective preservatives when added to livestock feeds instead of a feed technology that can benefit animal growth and performance. They can naturally be formed through fermentation of carbohydrates by microbes in the large intestine of pigs (Partanen and Mroz, 1999). There are multiple factors that could lead to the positive impacts observed on pig performance, such as, antimicrobial activity, lowering of pH in the stomach and small intestine, slowing of gastric emptying rate, stimulating enzyme production, and providing nutrients preferred by the luminal tissue (de Lange et al., 2010). Slowing gastric emptying rate allows for protein molecules to be better hydrolyzed, which results in more opportunity for amino acids and proteins to be absorbed (Gabert and Sauer, 1994). Blank et al. (1999) and Mroz et al. (2006) stated that the effectiveness of organic acid addition to pig diets will vary depending on the combination of acids used, diet type, as well as, the physiological state of the animal.

When added to weaned pig diets, fumaric, citric, and formic acids are commonly used (Partanen and Mroz, 1999). Bouldan et al. (1988a,b) most closely related the increase in piglet ADG to increase in ADFI due to addition of organic acids making the diet more palatable. It has also been observed that there is a greater potential for growth promoting effects when added to diets that are predominately formulated with plant-based proteins in contrast to those diets that have a high inclusion of animal proteins and milk based products (Burnell et al., 1988; Giesting et al., 1991). Grecco et al. (2018) reported that there was no benefit in growth performance when an acidifier blend was added to weaned pig diet; however, it was mentioned that the lack of response could be attributed to the high weaning weight, the high health status of the pigs, or the addition of zinc and copper at high levels to the diets. Another recent study that used a highly digestible nursery diet did not observe any benefit on growth performance when 2 different organic acid blends and a combination of the blends were fed (Li et al., 2018). In a similar study, an increase in ADG and feed efficiency was observed for pigs fed a diet with organic acid blends, when compared to a diet with no organic acid added (Li et al., 2018). These diets did not include high levels of zinc oxide and were considered to be less digestible than the diets in the previous study.

Pigs fed diets containing predominantly plant protein that included organic acids had improved mortality rate and growth performance when compared to pigs fed a diet that did not contain organic acids and was also void of antibiotics when under a health challenge (Tsiloyiannis et al., 2001). In this particular study, pigs fed a diet supplemented with lactic acid experienced similar growth performance to those fed the control diet that did contain antibiotics. Conversely, pigs that were fed citric acid had improved ADG and feed efficiency in comparison to pigs that were fed a diet void of antibiotic supplementation (Ahmed et al., 2014). In the same study, pigs fed an acidifier blend had poorer growth performance than pigs fed a diet with no antibiotics, a diet with antibiotics, and the diet that included citric acid. Pigs fed the antibiotic diet had the best growth performance from d 0 – 14 post-weaning among all dietary treatments. In another recent study, Long et al. (2018) observed that pigs fed a diet with a blend of organic acids pigs had an increased ADG compared to that of pigs fed either a diet that included a sub-therapeutic dose of antibiotics or a control diet. It was also observed that both the pigs fed the organic acid blend and the pigs fed antibiotics were more feed efficient than control pigs.

Pigs fed formic and lactic acid had increased ADG when compared to pigs fed a diet without the added organic acids, as well as the pigs being fed the diet with addition of formic acid being more feed efficient than control pigs (Jongbloed et al., 2000). Mroz (2005) listed some of the common benefits of organic acids as: 1) reducing gastric pH, 2) providing energy for mucosal development that can result in greater absorption of nutrients, and 3) greater activation of pepsinogen than inhibition of bacterial growth in the small intestine. There have been differing reports on the effects of organic acids on microbial counts in the digestive tract. Gedek et al. (1992) observed that when formic acid was added to nursery diets, there was a reduction of Lactobacillus. Lactobacillus commonly decreases the prevalence of *E. coli* in the digestive tract of the chicken by inhibiting *E. coli* from binding (Fuller, 1977). Recently, a study conducted by Kairie et al. (2018) indicated that pigs fed benzoic acid had similar ADG when compared to pigs fed a diet that included antibiotics and had increased ADG when compared to that of pigs fed a diet with no antibiotic.

With these widely varying results, there is still a need for investigation of when is the most effective time to utilize organic acid in swine diets for an increase in performance while also maintaining a cost benefit.

Finishing Performance

Ractopamine hydrochloride has been utilized to increase protein deposition while decreasing fat deposition (Anderson et al., 1987). The addition of ractopamine to finishing diets improve ADG and feed efficiency when compared to that of pigs not fed ractopamine (Watkins et al., 1990). Additionally, in this study, pigs fed ractopamine had increased dressing percentage, increased longissimus muscle area, and decreased back fat when compared to that of pigs not fed ractopamine. Gu et al. (1991) reported that pigs fed ractopamine had increased dressing percentage, and a tendency to have less back fat and more favorable feed conversion ratio when compared to the performance and carcass characteristics of pigs fed a diet that did not include ractopamine. In a more current study, it was observed that the addition of ractopamine to finishing diets increased ADG by 18.8%, and G:F by 23.7% while reducing ADFI by 3.3% when compared to a control diet with no ractopamine (Rickard et al., 2017).

The current challenge with ractopamine in the swine industry is the different perception and acceptance level of the use of the product internationally. Ractopamine is banned or restricted in China, Russia and 158 other countries. However, the United States, Canada, Japan, and 24 other countries have deemed the use of ractopamine acceptable and the meat from the animals fed ractopamine safe for human consumption (Pacelle, 2014).

With international commerce in mind, there is a need to identify products that can be used as a replacement for ractomaine that yields the same growth performance and carcass benefits.

Summary

Post-weaning lag is a challenge that is not new to the swine industry. Post-weaning lag can be difficult to mitigate due to the many factors that contribute to the reduced growth performance that occurs immediately following weaning. Due to these factors varying immensely from system to system in modern production, there may be varying solutions to the problem depending on health status, diet composition, and management style.

Feed costs are the largest input cost when raising growing pigs. Minimizing diet cost while still maintaining optimal growth performance and pig health is important to producers. Addition of elevated levels of SBM to nursery diets, while decreasing animal based protein products is a potential way to reduce diet cost. However, accurate analysis of pigs' growth performance response to being fed this increased level of SBM is hard to achieve. Throughout the literature, diet formulation varies exponentially, actual levels of SBM used in conjunction with the other ingredients added in the diet provide a challenge in identifying what is actually the optimal level of SBM in the diet for weaned pigs.

Increased regulation on how meat animals are raised opens the door for more feed technologies to be developed and evaluated. Previously, sub-therapeutic use of antibiotics was a common practice for maintaining herd health and increasing growth performance. Regulation of sub-therapeutic antibiotic use has posed a new challenge to keep these high levels of performance and health in the swine industry today, using more "natural" products. The ability to export products is also important to the swine industry. The stringent regulation of the use of ractopamine and the export of meat from animals fed this product has led researchers to begin to look for alternatives to ractopamine that also have the ability to enhance late finishing performance as well as yield a lean carcass.

Phytogenics and organic acids continue to be feed technologies of interest when looking to increase performance throughout all stages of swine production while using “natural” feed additives. Though there are decades of research on phytogenics and organic acids, there is still need for further investigation when evaluating these additives and their potential to enhance growth performance. There is a wide array of results reported in the literature when considering these types of additives and diet type, health status, management style, and stage of production are all factors that can impact how they affect growth performance. With there being many different blends or phytogenics and acids being added to swine diets there is a continuous need for these additives to be evaluated to determine their contribution and appropriate use in modern swine production.

CHAPTER II

EFFECTS OF LEVEL OF SOYBEAN MEAL AND YUCCA *SCHIDIGERA* ON NURSERY PIG GROWTH PERFORMANCE

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Abstract

Two experiments were conducted to evaluate the effects of level of soybean meal (SBM) and the addition of Micro-Aid (DPI Global, Porterville, CA) to nursery diets on pig growth performance. A total of 180 crossbred pigs for Experiment 1 and 280 crossbred pigs for Experiment 2 (average BW = 6.1 kg) were used to determine the effects of addition of Micro-Aid (Yucca *schidigera*) to a soybean meal-based diet on growth performance of nursery pigs in 43-d and 40-d experiments, respectively. Pigs were weaned at 20 d of age for both studies. During Experiment 1, pigs were allotted to 1 of 3 treatments in a randomized complete block design (6 pens/trt). The three dietary treatments consisted of: 1) control diet (CNT) containing animal protein sources (plasma, fish meal), 2) a high soybean meal-based diet without animal protein sources (HSBM), and 3) the SBM-based diet plus 125 ppm of Micro-Aid (SMA). During Experiment 2, the same dietary treatments were used and a fourth treatment 4) control diet with

the addition of 125 ppm of Micro-Aid (CMA) was added to the design. During Experiment 2, pigs were allotted to 1 of 4 treatments (7 pens/trt). Pigs were fed in four dietary phases during both experiments. Soybean meal was included at 30% in phases 1 (d 0 – 7), 2 (d 7-14), and 3 (d 14 -21) for the HSBM and SMA diets. Soy protein concentrate, soybean oil, L-lysine HCl, DL-methionine, L-threonine, dicalcium phosphate, and limestone were added to the HSBM and SMA diets to equalize ME, amino acid, Ca, and P concentrations. During phase 4 (d 21-43), due to decreasing use of animal protein sources, the concentration of SBM was similar across all dietary treatments. Feed disappearance and BW were recorded to calculate ADG, ADFI, and G:F for d 0-14, 0-21, and 0-40 or 43. For Experiment 1, from d 0-14, pigs fed CNT had greater ($P < 0.02$) ADG (222 vs 186 g/d), ADFI (281 vs 254 g/d), and G:F (0.79 vs 0.73) compared with pigs fed the SBM diet. There was no difference ($P > 0.10$) in growth performance between pigs fed CNT and SMA diets during d 0-14. Pigs fed SMA tended to have greater ($P < 0.10$) ADG (209 vs 186 g/d) and greater ($P < 0.04$) G:F (0.78 vs 0.73) compared with pigs fed the HSBM diet during d 0-14. However, from d 0-21 and 0-43, there were no differences ($P > 0.10$) among treatments. For Experiment 2, from d 0-21, pigs fed the diets with increased levels of SBM had reduced ($P < 0.01$) ADG (288 vs 336 g/d), ADFI (380 vs 394 g/d), and GF (0.76 vs 0.85) when compared to pigs fed diets with low SBM. Pigs fed the diets with the inclusion of MA had improved ($P = 0.04$) ADG (323 vs 300 g/d) and GF (0.83 vs 0.78) when compared to the pigs fed diets that did not include MA. There was no effect ($P > 0.10$) on ADFI from d 0-21 with the inclusion of MA in the diet. From d 0-40, pigs fed the high SBM diets experienced a decrease ($P < 0.01$) in ADG (459 vs 484 g/d) and ADFI (671 vs 697 g/d) and a tendency ($P = 0.06$) to have decreased G:F (0.68 vs 0.69) ratio in comparison to the diets that contained the lower levels of SBM. The addition of MA to diets did not have an effect ($P > 0.10$) on ADG or ADFI, but there was an improvement ($P = 0.02$) in G:F (0.687 vs 0.683) when compared to the diets that did not contain MA. Experiment 1 results suggest pigs fed the HSBM diet from d 0-14 have decreased performance, but recover in the following phases, such that no differences in performance were noted at the end of the nursery phase. Addition of Micro-Aid tended to partially alleviate the negative effects of high SBM on growth performance during d 0-14 in the nursery. Similarly, in Experiment 2 pigs fed high levels of SBM had decreased growth performance during the first 21 days, as well as, for the overall phase. Micro-Aid was able to improve performance during the early part of the nursery phase, as well as the feed efficiency for the overall experimental period.

Introduction

Newly-weaned pigs face several challenges. Dietary changes, social stress, and immunological challenges to name a few (Pluske et al., 1997). When pigs are weaned, they are transitioned from the liquid diet they are used to receiving from the sow to a solid, nutrient dense diet that is formulated to meet their digestive capabilities (Lalles et al., 2007). This type of diet includes a combination of animal protein products, as well as, milk products such as whey and lactose. Protein products are included in newly-weaned pig diets to help stimulate feed intake, as well as to improve gut integrity (Bergstrom et al., 1997). Although these diets are easily digested by the young pig, they can prove to be very expensive, in comparison to diets that do not include these types of products or even just a smaller inclusion of them.

Soybean meal is an available and less expensive protein source. However, these more economical diets that include plant proteins, such as soybean meal (SBM), are not as easily digested and can decrease performance compared to a diet with animal protein products such as spray dried plasma (Chae et al., 1999; Myers et al., 2014). This decreased performance may be due in part to glycinin and β-conglycinin that are antinutrional factors that cause hypersensitivity to SBM (Li et al., 1991). This hypersensitivity may lead to malabsorption of nutrients in the small intestine of young pigs that can result in decreased growth performance (Miller et al., 1984). Additionally, another digestive challenge of weaned pigs is lack of sufficient amounts of HCL and pancreatic enzymes being secreted in the stomach and small intestine in the first weeks following weaning (Aumaitre et al., 1995). This lack of enzyme secretion can pose an additional contributor to intestinal disturbances such as inflammation, maldigestion, and malabsorption, which can result in decreased growth performance when pigs are fed elevated levels of SBM (Lalles, 1993).

There continues to be an interest in products that can mitigate the negative effects that soybean meal elicits on the gut and ultimately growth performance of weanling pigs. Phytogenic additives are one area of interest. Specifically, Yucca schidigera is a potential phytogenic that could be beneficial in nursery pig diets. Yucca has anti-inflammatory and anti-microbial properties (Cheeke et al., 2006) that could potentially be beneficial to the gut of young pigs when high levels of soybean meal are being fed to try to reduce the negative effects that occur in the small intestine. Yucca contains saponins that have been observed to increase permeability of the brush border in the small intestine, which can allow for nutrients to be absorbed more readily (Gee et al., 1996). Yucca extract's potential to act in the small intestine to combat, inflammation and increase permeability for increased nutrient absorption, could provide an opportunity to add additional SBM to weaned pig diets, without the negative effects that are usually observed for growth performance that are associated with SBM in the early nursery phases.

Therefore, the objective of these studies was to evaluate the effect that the addition of Yucca schidigera (MicroAid) has on growth performance of nursery pigs when fed in combination with a diet that has a high inclusion rate of soybean meal.

Materials and Methods

Experiment 1

One hundred eighty crossbred pigs were weaned at 20 days of age and transported to Oklahoma State University Swine Research and Education Center. Upon arrival pigs were allotted to 1 of 18 pens (10 pigs/pen) and pens were allotted to 1 of 3 dietary treatments.

Treatments included: 1) Control (CNT) – a standard nursery diet that contained plasma and fish meal and low levels of soybean meal, 2) High Soybean Meal (HSBM) – diet containing high level of soybean meal (30%) and no plasma or fish meal, and 3) Micro-Aid (SMA) – the HSBM diet with the inclusion of Yucca extract at 125 mg/kg of diet. There were 4 dietary phases, Phase 1 (d 0-7), Phase 2 (d 7-14), Phase 3 (d 14-21) and Phase 4 (d 21- 43). During Phase 4, due to the decreasing use of animal protein products in the CNT diet, the level of soybean meal was similar across all treatments. Pens and feeders were weighed weekly to calculate ADG, ADFI, and GF.

Experiment 2

Two hundred eighty crossbred pigs were weaned at 20 days of age and transported to Oklahoma State University Swine Research and Education Center. Upon arrival pigs were allotted to 1 of 28 pens (10 pigs/pen) and blocked randomly by body weight. Pens were then allotted to 1 of 4 dietary treatments. Those treatments included 1) Control (CNT) – a standard nursery diet that contained plasma and fish meal and low levels of soybean meal, 2) Soybean Meal (HSBM) – diet containing high level of soybean meal (30%) and no plasma or fish meal, 3) Control + Micro-Aid (CMA) – the CNT diet with the inclusion of Yucca extract at 125 mg/kg of diet and 4) Soybean Meal + Micro-Aid (SMA) – the HSBM diet with the inclusion of Yucca extract at 125 mg/kg of diet. There were 4 dietary phases, Phase 1 (d 0-7), Phase 2 (d 7-14), Phase 3 (d 14-21) and Phase 4 (d 21- 43). During Phase 4, due to the decreasing use of animal protein products in the CNT and CMA diets, the level of soybean meal was similar across all treatments. Pens and feeders were weighed weekly to calculate ADG, ADFI, and GF.

Statistical Analysis

Experiment 1

Data were analyzed as a randomized complete block design using the General Linear Model (GLM) procedure in SAS. The model included the effects of treatment, rep., and the interaction of rep and treatment. Pen served as experimental unit and there were 6 reps/treatment. Means were reported as least square means and significance level was declared at $P < 0.05$, with values between 0.05 and 0.10 being considered a trend.

Experiment 2

Data were analyzed as a randomized complete block design using the General Linear Model (GLM) procedure in SAS. The model included the effects of treatment, rep., and the interaction of rep and treatment. Pen served as experimental unit and there were 7 reps/treatment. The effects of SBM, MA, and their interaction were tested. Means were reported as least square means and significance level was declared at $P < 0.05$, with values between 0.05 and 0.10 being considered a trend.

Results

Experiment 1

Performance results for Experiment 1 are presented in Table II.3. Performance results were measured from d 0-14, d 0-21, and d 0-43. From d 0-14, pigs fed the HSBM diet had decreased ADG ($P = 0.02$) and GF ($P = 0.03$) when compared to the pigs fed the CNT diet. There was a tendency ($P = 0.09$) for pigs fed the CNT diet to have increased ADFI when compared to pigs fed the SBM treatment, as well as a tendency ($P = 0.06$) for pigs fed the SMA diet to have a higher G:F than pigs fed the SBM diet. On d 14, pigs fed the SBM diet had the lowest BW ($P = 0.05$) of all the dietary treatments, the pigs fed the CNT diet had the highest BW with the SMA pigs having an intermediate BW. From d 0-21, there was no difference in performance ($P > 0.10$) among the 3 dietary treatments. Overall (d 0-43) ADG was not affected by dietary treatment. However, there was a tendency ($P = 0.08$) for the pigs fed the CNT diet to have a higher ADFI than the pigs fed the HSBM diet, as well as a tendency ($P = 0.07$) for pigs fed the SMA diet to have a lower GF ratio than that of the pigs fed the HSBM treatment. There was no effect ($P >$ 0.10) of dietary treatment on d 21 or d 43 BW.

Experiment 2

In Experiment 2, performance results are reported from d 0-21 and d 21-40 (Table II.4.). From d 0-21, pigs fed the dietary treatments with elevated levels of soybean meal had decreased ($P < 0.01$) ADG compared to the pigs fed the diets that included animal protein products and low SBM. The addition of Micro-Aid to diets had a positive effect ($P = 0.04$) on ADG from d 0-21 compared to the pigs fed the diets void of MA. There was a greater magnitude of response (SBM X MA: $P = 0.02$) for ADG when MA was added to the HSBM diet compared to MA added to the CNT diet. Pigs fed the high soybean meal diets had a decreased ($P < 0.01$) ADFI from d 0-21 compared to those fed the low levels of soybean meal. There was no effect of the addition of MA on ADFI during this period. Pigs fed the low soybean meal diets had improved ($P < 0.01$) feed efficiency, compared to those fed the high soybean meal diets. Inclusion of MA to diets improved ($P = 0.04$) pig G:F when compared to pigs fed diets that did not include MA. There was a greater response ($P = 0.03$) to the addition of MA on G:F seen when added to the HSBM diet compared to when MA was added to the CNT diet. On d 21, pigs fed the high soybean meal diets had a lower ($P < 0.01$) BW than those fed the low soybean meal diets. The addition of MA helped to increase ($P = 0.03$) BW for the pigs fed the diets with MA inclusion when compared to pigs fed the diets void of MA. Pigs fed the high levels of soybean meal had a greater ($P = 0.03$) increase in BW on d 21 with the addition of MA when compared to the increase in BW observed when MA was added to the CNT diet.

Overall, pigs fed the high levels of soybean meal had decreased ($P < 0.01$) ADG when compared to the pigs fed diets that had low levels of soybean meal. There was no effect ($P >$ 0.10) of MA inclusion in the diet on ADG, however there was a greater improvement ($P < 0.01$)

in ADG when MA was added to the CNT diet when compared to the improvement of ADG when MA was added to the HSBM diet. Pigs fed the HSBM and SMA diets had decreased ($P < 0.01$) ADFI compared to pigs fed the CNT and CMA diets. There was no effect ($P > 0.10$) of the addition of MA to ADFI in respect to overall performance. There was a tendency for a greater ($P = 0.07$) magnitude of improvement on ADFI when MA was added to the HSBM diet than when MA was added to the CNT diet. Pigs fed the high soybean meal diets tended ($P = 0.06$) to have decreased GF when compared to the pigs fed the low level soybean meal diets. GF was improved ($P = 0.01$) for pigs fed diets with the addition of MA when compared to GF of pigs fed diets that were void of MA. On d 40, pigs fed the high soybean meal diets had a lower ($P < 0.01$) BW than those fed the low level soybean meal diets. There was a tendency ($P = 0.09$) for there to be a greater improvement in d 40 BW when MA was added to the CNT diet compared to when MA was added to the HSBM diet.

Discussion

A difference in performance was observed during the early nursery stages for pigs fed the high-SBM diets. These elevated levels of SBM induce an inflammatory response in the small intestine, due to glycinin and β-conglycinin causing hypersensitivity (Li et al., 1991). Dreau and Lalles (1999) hypothesized that intestinal damages could be due to an immune response at the time of weaning to dietary antigens as previously stated. It has also been hypothesized that reduction of voluntary FI post weaning is another main cause of inflammation in the SI (McCracken et al., 1999). In this study, a reduction in FI with the addition of high levels of SBM was observed, which could contribute to the reduced ADG. Sohn et al. (1994) hypothesized that a reduction in feed intake for pigs fed diets with elevated levels of SBM could be due to decreased diet palatability. Although reduced FI could be a contributor to reduced ADG, there was still a reduction of feed efficiency that is not affected by FI. In a study conducted by Chae et al. (1998), pigs fed up to 50% of SBM immediately following weaning did not experience any adverse effects on G:F from d 0-21 post weaning, although reduced ADG and ADFI were observed in the high-SBM diet compared to a diet that contained animal plasma. Conversely, Myers et al. (2014) did observed decreased G:F for pigs fed a SBM based diet compared to that of pigs fed a diets that contained spray dried animal plasma or fishmeal.

It was observed that during the first 14-21 days, the addition of MA to diets had the ability to improve ADG, as well as feed efficiency. Cromwell et al. (1985) reported an increase in growth performance in pigs fed yucca extract, as well. Unlike the lack of response in this particular study, Yen and Pond (1993) observed an increase in ADFI from d 0-28 of the nursery period for pigs fed a diet with the inclusion of 125 ppm of MA, when compared to that of pigs fed a similar diet that did not include MA.

During this study, health status of the pigs was stable and there were no immunological challenges present to put additional strains on performance. This would be an area to explore to evaluate if the same performance results would be observed with an additional stress of an immune challenge present. Evaluation of scour scores, as well as, responses to an immune challenge are other areas of interest to be used when evaluating the value of the addition of Yucca extract to high SBM diets fed in the early nursery stages.

Conclusion

Micro-Aid helps to mitigate the negative effects that high levels of soybean meal have on performance during the nursery phase. The addition of Micro-Aid to diets that contained high levels of SBM resulted in a 9% increase of ADG and a 6% increase of G:F.

Table II.1. Composition of nursery pig diets[1]

	Phase 1 (d 0-7)		Phase 2 (d 7-14)		Phase 3 (d 14-21)		Phase 4 (d 21-43)	
Ingredient %	CNT[a]	HSBM[b]	CNT[a]	HSBM[b]	CNT[a]	HSBM[b]	CNT[a]	HSBM[b]
Corn	31.30	20.66	37.29	30.16	52.82	50.10	58.71	58.71
Soybean meal, 47.5% CP	15.00	30.00	20.00	30.00	26.32	30.00	34.30	34.30
Soybean Oil	0.00	0.00	0.00	0.00	0.00	0.00	3.00	3.00
Whey, dried	25.00	25.00	25.00	25.00	10.00	10.00	0.00	0.00
Lactose	7.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00
Blood cell, spray-dried	0.00	0.00	1.25	0.00	1.25	0.00	0.00	0.00
Plasma, spray-dried	6.00	0.00	2.50	0.00	0.00	0.00	0.00	0.00
Fish meal, menhaden	6.00	0.00	4.00	0.00	2.00	0.00	0.00	0.00
Soy protein concentrate	2.21	6.99	2.12	5.18	0.00	1.50	0.00	0.00
Granulated fat	4.00	5.45	4.00	4.95	3.00	3.40	0.00	0.00
L-Lysine HCl	0.17	0.26	0.21	0.29	0.27	0.32	0.25	0.25
DL-Methionine	0.18	0.25	0.21	0.23	0.17	0.16	0.11	0.11
L-Threonine	0.07	0.11	0.10	0.11	0.12	0.11	0.09	0.09
Dicalcium Phosphate	0.67	1.85	0.93	1.63	1.39	1.67	1.58	1.58
Limestone	0.45	0.47	0.44	0.50	0.72	0.79	0.74	0.74
Salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Zinc Oxide	0.29	0.29	0.29	0.29	0.29	0.29	0.05	0.05
Vitamin Premix	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06
Trace Mineral Premix	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05
Selplex	0.05	0.05	0.05	0.05	0.05	0.05	0.50	0.50
Mecadox 2.5	1.00	1.00	1.00	1.00	1.00	1.00	0.05	0.05
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[1]All diets met or exceeded NRC requirements for nursery pigs
[a]CMA-CNT diet with addition of Micro-Aid at 0.0125% at the expense of corn and was only utilized for Experiment 2
[b]SMA-HSBM diet with addition of Micro-Aid at 0.0125% at the expense of corn

Table II.2. Chemical Composition of Diets[1]

	Phase 1 (d 0-7)		Phase 2 (d 7-14)		Phase 3 (d 14-21)		Phase 4 (d 21-43)	
	CNT	HSBM	CNT	HSBM	CNT	HSBM	CNT	HSBM
ME, kcal/kg	3497	3498	3478	3477	3420	3419	3608	3608
Crude Protein, %	22.93	23.96	22.97	23.58	20.94	21.06	21.5	21.5
SID Lysine %	1.54	1.54	1.51	1.51	1.31	1.31	1.25	1.25
Calcium %	0.89	0.89	0.85	0.85	0.85	0.85	0.75	0.75
Available Phosphorus %	0.59	0.59	0.55	0.55	0.45	0.45	0.37	0.37

[1]All diets were analyzed by Servitech Labs, Dodge City, KS

Table II.3. Effects of level of SBM and Micro-Aid on growth performance of nursery pigs[1]

	CNT	HSBM	SMA	SE	P-Value
BW[2], kg					
d 0	6.1	6.2	6.1	0.00	0.999
d 14	9.3[a]	8.8[b]	9.0[ab]	0.15	0.057
d 21	13.0	12.6	12.9	0.24	0.433
d 43	27.4	26.3	26.7	0.45	0.292
ADG[3], g/d					
d 0-14	222[a]	186[b]	209[ab]	10.40	0.063
d 0-21	328	308	326	11.40	0.417
d 21-43	647	622	627	13.60	0.421
d 0-43	491	468	472	11.80	0.363
ADFI[4], g/d					
d 0-14	281[a]	254[b]	267[ab]	10.90	0.090
d 0-21	418	395	408	13.20	0.464
d 21-43	1026[a]	976[b]	1021[ab]	18.60	0.070
d 0-43	729[a]	693[b]	718[ab]	14.10	0.080
G:F[5]					
d 0-14	0.79[a]	0.73[b]	0.78[a]	0.04	0.066
d 0-21	0.78	0.78	0.80	0.02	0.627
d 21-43	0.63	0.64	0.61	0.02	0.225
d 0-43	0.67[ab]	0.68[b]	0.66[a]	0.02	0.070

[1]Least squares means for 6 pens/trt

[a,b]Means that have no common superscript are significantly different

[2] Body Weight

[3] Average Daily Gain

[4] Average Daily Feed Intake

[5] Gain to Feed Ratio

Table II.4. Effects of level of SBM and Micro-Aid on growth performance of nursery pigs[1]

	Treatment[2]					P-Value		
	CNT	**CMA**	**HSBM**	**SMA**	**SE**	**SBM[3]**	**MA[4]**	**Int.[5]**
BW[a], kg								
d 0	6.1	6.1	6.1	6.1	0.03	0.9999	0.9999	0.9999
d 21	13.1	13.1	11.7	12.6	0.18	<0.0001	0.0338	0.0181
d 40	24.9	25.9	23.9	24.2	0.36	0.0013	0.3337	0.0861
ADG[b], g/d								
d 0-21	334	337	267	309	9.00	< 0.0001	0.0409	0.0236
d 21-40	623	661	643	613	13.50	0.3289	0.0199	0.7896
d 0-40	471	496	446	453	9.10	0.0015	0.3443	0.0859
ADFI[c], g/d								
d 0-21	393	395	374	386	4.50	0.0042	0.2759	0.1331
d 21-40	1049	1088	977	1028	20.00	0.0041	0.7736	0.0371
d 0-40	693	701	650	680	10.00	0.0051	0.2982	0.0724
G:F[d]								
d 0-21	0.85	0.85	0.72	0.80	0.02	0.0001	0.0365	0.0285
d 21-40	0.59	0.60	0.66	0.60	0.01	0.0049	0.0002	0.0087
d 0-40	0.68	0.71	0.69	0.67	0.01	0.0621	0.0159	0.6209

[1]Least squares means for 7 pens/trt

[2]CNT:Control; CMA:Control + Micro-Aid; HSBM: High SBM; SMA: High SBM + Micro-Aid

[3]Effect of level of SBM

[4]Effect of addition of Micro-Aid

[5]Interaction of level of SBM and addition of Micro –Aid

[a] Body Weight

[b] Average Daily Gain

[c] Average Daily Feed Intake

[d] Gain to Feed Ratio

CHAPTER III

THE EFFECT OF OUTPACE ON NURSERY PIG PERFORMANCE

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Abstract

Two experiments were performed to determine the effects of Outpace feed additive (PMI Nutritional Additives, Shoreview, MN) on growth performance of nursery pigs. Each experiment utilized 280 (14 reps/trt) crossbred pigs (PIC 337), with an initial BW of 6.11 kg. Pigs were weaned at 20 days of age and were allotted 5 barrows and 5 gilts per pen and assigned to 1 of 2 dietary treatments in a completely randomized fashion. The 2 treatments consisted of the following: 1) Control (CNT) and 2) Control + Outpace (OP). Diets were fed in 5 phases, with the first diet being a common diet for all pigs. Outpace was included at 0.50% of diet in 2nd and 3rd phases and at 0.25% of the diet in the 4th and 5th phases at the expense of corn. Diets were comparable to a standard 5 phase nursery program and were formulated on an ME and SID Lysine basis. No antibiotics were added to the diets throughout either experiment. Feed disappearance and BW were recorded to calculate ADG, ADFI, and G:F. Data were analyzed

using the MIXED procedure in SAS with pen being the experimental unit. Effects tested included, experiment, treatment, and the interaction of experiment and treatment. There were no experiment by treatment interactions ($P > 0.10$), so data from the 2 experiments were pooled. From day 0-21, there was no difference ($P > 0.10$) in ADG (249 vs. 248 g), ADFI (309 vs. 303 g), or G:F (0.81 vs 0.82) between treatments. From day 21-42, there was a tendency ($P = 0.09$) for ADG (517 vs 530 g) to be greater for pigs fed the Outpace diet than those fed the control diet, but there were no differences ($P = 0.50$) in ADFI (784 vs 792 g) or G:F (0.66 vs 0.67) between treatments. For the overall period (d 0-42), there was no treatment effect ($P > 0.10$) on ADG (381 vs 390 g) or ADFI (537 vs 536 g) of the pigs. However, there was an improvement ($P = 0.01$) in G:F (0.71 vs 0.73) for pigs fed the Outpace treatment in comparison to those fed the control treatment. There was no treatment effect ($P > 0.10$) on morbidity or mortality. The results suggest that Outpace fed during the nursery phase had no effect on ADFI, but increased ADG (d 21-42) and improved feed efficiency from day 0-42.

Introduction

Nursery pigs face many challenges immediately following weaning. Change in diet, social stress, diseases challenges, and fasting during transit from sow farms to nursery/grower facilities can all have an impact on nursery pig growth performance (Pluske et al.,1997). Boudry et al. (2004) postulated that there are both acute and long lasting effects on intestinal morphology seen when voluntary feed intake declines. Encouraging feed consumption is important post weaning as these declines in feed intake cause there to be decreased villus height in the small intestines of weaned pigs (Beers-Schreurs et al., 1995). Decreased villus height often results in decreased digestive and absorptive capabilities that ultimately results in poor growth performance (Pluske et al., 1997).

Until 2017, sub-therapeutic levels of antibiotics could be added to nursery diets to mitigate some of the negative effects that weaning has on growth performance (Mroz, 2005). Doyle (2001) reported that the addition of antibiotics in nursery diets can increase ADG up to 8% and G:F by 3%. Although this is a strategy used to increase growth performance in nursery pigs, there has been concern about the use of antibiotics in the livestock industry and antibiotic resistance (Heuer et al., 2006). Antibiotic resistance concerns led to the Food and Drug Administration to mandate the Veterinary Feed Directive (VFD) in 2017. This VFD limits the use of antibiotics in feeds to have to be prescribed by veterinarians and only to be used for treatment of disease, and not for disease prevention or performance enhancement.

Feed additives such as Outpace (PMI Nutritional Additives, Shoreview, MN), that are comprised of organic acids and phytogenic extracts have recently become an area of growing interest in response to the VFD. Although it becomes difficult to declare the mode of action of a proprietary blend, the literature mentions the use of organic acids and plant extracts both individually and in blends are beneficial on performance when included in pig diets. Organic acids have been shown to be a possible alternative for in feed antibiotics that can elicit the same growth promoting benefits that antibiotics have (Partanen, 1999). Organic acids also have the ability to lower pH in the stomach and small intestine and slow down gastric emptying rate, which have been observed to allow for better protein and amino acid digestion and absorption (de Lange et al., 2010; Gabert and Sauer, 1994).

Plant extracts have risen in popularity, as they have been shown to have some ability to fight pathogens, and improve gut integrity, thus leading to increased pig performance (Sad and Bilkei, 2003; Manzanilla et al., 2004; Michiels et al., 2010). Lee et al. (2004) found that plant extracts have antioxidant, antibacterial, and immunoregulatory effects which can result in improved immune response. Antibacterial properties of plant extracts can help to keep the intestinal microflora in balance to alleviate post weaning diarrhea that is often a problem for young pigs (Liu et al., 2013a).

Therefore, the objective of these studies was to evaluate the effect of Outpace, a blend of key extracts and functional acids, on pig growth performance during the nursery phase.

Materials and Methods

Two experiments of 280 pigs each were used to evaluate the effect of Outpace Feed Additive on nursery pig performance. Pigs were weaned at 20 days of age and transported to Oklahoma State University Swine Research and Education Center where they were housed in an environmental controlled building. On d 0, pigs were randomly allotted to 1 of 28 pens (10 pigs/pen), and pens were randomly allotted to 1 of 2 dietary treatments 1) Control diet (CNT) which consisted of a standard nursery diet that consisted of corn and soybean meal, and a commercial nursery premix or 2) Outpace diet (OP) which was the CNT diet with the addition of Outpace. Outpace was added at the rate of 0.50% during phases 2-3 and 0.25% during phases 4-5 at the expense of corn. A common pelleted diet was fed for phase 1, which lasted 4 days post arrival. All diets were void of any antibiotics. Pigs and feeders were weighed on d 0, 7, 14, 21, 28, 35, and 42 to calculate ADG, ADFI, and FG. Each pen was equipped with a stainless steel 4-hole dry feeder and 1 cup waterer. Feed and water were offered *ad libitum* throughout the 42 d test period.

Statistical Analysis

Data were analyzed using the MIXED procedure in SAS as a randomized complete block design. The effect of treatment, experiment, and treatment by experiment interaction were tested. There were no experiment by treatment interactions ($P > 0.10$) therefore, the data from the 2 experiments were pooled. There were 28 reps /treatment and pen served as the experimental unit.

Means were reported as Least Square Means (LS Means). Significance was declared at $P < 0.05$, and values that fell between 0.05 and 0.10 were declared a trend.

Results

Performance results are presented in Table III.3. Dietary treatment did not have an effect on ADG, ADFI, or GF from d 0-21. There was no effect on d 21 BW between the 2 treatments. From d 21-42 there was a tendency ($P = 0.09$) for pigs fed the OP treatment to have increased ADG when compared to pigs fed the CNT treatment. However, dietary treatment had no effect on ADFI, GF, or final body weight during this time. When evaluating overall performance (d 0-42), there was no treatment effect on ADG or ADFI. There was an improvement ($P = 0.01$) in GF for the pigs fed the OP treatment in comparison to the pigs fed the CNT treatment. Though, there was no statistical difference in body weight on d 42, pigs fed the OP treatment did have a slightly numerically higher end weight than those fed the CNT diet. When looking at the cost analysis of these 2 dietary treatments, there was no difference in feed cost/kg of gain from d 0-21, 21-42, or overall during the test period. There was no effect of dietary treatment on caloric efficiency from d 0-21 or d 21-42, however, there was an effect ($P < 0.01$) for the overall period when comparing the 2 treatments, with the pigs that were fed the OP treatment requiring less kcal/kg of gain.

Discussion

Addition of Outpace increased diet cost, however, increased feed efficiency for pigs fed the OP treatment led to a similar cost/kg of gain between the 2 dietary treatments. In a previous study, Partanen and Mroz (1999) stated that increase in growth is well explained by feed intake increase. Similarly, Bolduan et al. (1988) observed improved growth in young pigs when acids were added to the diet and this was highly correlated to increased FI which was assumed to be a result of increased palatability of the diet. In this trial, however, feed intake for pigs fed the OP diet did not differ from those fed the CNT diet. There was a tendency for increased ADG during the last 21 days of the study for pigs fed the OP treatment, though this slight increase did not affect end BW between the two treatments. Similarly, in previous studies there was no increase in growth performance when organic acids were added to diets with or without antibiotics (Che, et al., 2012). Liu et al. (2013a) found that when plant extracts were added to nursery pig diets, pigs had a greater ADG immediately following weaning than pigs fed a diet without plant extracts, however after d 5 the pigs fed the plant extract had a slower growth rate than that of the CNT diet.

Addition of acids to growing pig diets may provide opportunity for more nutrient absorption in the small intestine by lowering gastric pH, which slows down the passage rate of stomach and intestinal contents (Mroz, 2003; Kim et al., 2005). Diet type has been shown to influence the magnitude of the benefit of the addition of acids to nursery diets. Partanen and Mroz (1999) stated that diets that did not contain milk products, but contained a majority of plant protein sources left a greater opportunity to the acidification of diets and had a more profound effect on growth performance than those diets that did include milk products. This is an area that could be explored more with this specific product, as these diets utilized a commercial nursery premix that contained milk and animal products and only low levels of SBM were included during the early nursery phases. Due to the additive being a proprietary blend, only speculation can be made about the mode of action of this particular product. Mroz (2005) stated that several factors could affect the efficacy of acids added to the diet, the amount of fermentable carbohydrate sources in the basal diet, weaning age, cleanliness of facility, stocking density, and previous level of performance, to name a few.

Conclusion

The goal during the nursery period is to produce the heaviest pig with the least cost to the producer. There are still questions to be answered about the best time to add Outpace to a nursery diet and at what rate it should be added to achieve optimal growth and feed efficiency. The duration of time that Outpace should be fed to be most cost effective should also be explored. The answers to these questions will likely vary from producer to producer, depending on factors such as time of year, diet type, and the health status of that particular herd. However, without knowledge of those factors that vary so largely from farm to farm, Outpace does have the potential to increase GF in pigs that are in a low stress environment, void of a disease challenge, as observed in these studies.

Table III.1. Nutrient Composition of Nursery Diet[a]

Ingredient, %	Phase 2	Phase 3	Phase 4	Phase 5
Corn	44.72	51.88	54.56	54.49
Soybean Meal	28.1	29.94	29.46	24.89
Premix	25	7.5	0	0
Dried Distiller Grain w/ Solubles	0	7.5	11.25	15
Soybean Oil	0	0	1.4	2.36
Limestone, ground	0.541	0.743	0.873	0.928
Dicalcium Phosphate	0.410	0.647	0.774	0.671
Salt	0.391	0.495	0.517	0.480
L-Lysine HCl	0.292	0.437	0.500	0.534
Mineral Premix	0.093	0.168	0.200	0.200
DL-Methionine	0.083	0.140	0.158	0.136
L-Threonine	0.080	0.115	0.128	0.126
Zinc Oxide	0.155	0.265	0.000	0.000
Vitamin Premix	0.024	0.042	0.050	0.050
Copper Chloride	0.017	0.031	0.037	0.037
Optiphos 1000	0.100	0.100	0.100	0.100
L-Tryptophan	0.000	0.000	0.003	0.012
TOTAL	100	100	100	100

[a]Outpace was added at 0.50% and 0.25% during phases 2-3 and 4-5, respectively to the control diet at the expensive of corn

Table III.2. Chemical Composition of Diet[1]

	Phase 2	Phase 3	Phase 4	Phase 5
ME, kcal/kg	3254	3203	3263	3307
Crude Protein, %	21.5	22.4	22.4	21.4
Crude Fat, %	3.1	3.1	4.4	5.6
Ca, %	0.85	0.72	0.68	0.66
P, %	0.67	0.6	0.57	0.55
Na, %	0.4	0.3	0.25	0.25
Zn, ppm	2800	2500	127	127
Cu, ppm	208	216	216	215

[1]All diets were analyzed by Servitech Labs, Dodge City, KS

Table III.3 Effects of Outpace on Growth Performance of Nursery Pigs[a]

	CNT	OP	SE	P value
BW[1], kg				
d 0	6.11	6.11	0.025	0.963
d 21	11.47	11.44	0.120	0.879
d 42	22.11	22.50	0.188	0.148
ADG[2], g/d				
d 0-21	249	248	5.398	0.899
d 21-42	517	530	5.734	0.097
d 0-42	381	390	4.392	0.141
ADFI[3] kg/d				
d 0-21	309	303	5.457	0.453
d 21-42	784	792	8.776	0.545
d 0-42	537	536	6.746	0.918
G:F[4]				
d 0-21	0.805	0.817	0.014	0.334
d 21-42	0.659	0.670	0.011	0.107
d 0-42	0.709[b]	0.728[c]	0.014	0.011

[a] Least Square Means (28 pens/trt)
[b, c] Means with different superscripts in the same row differ ($P < 0.05$)
[1] Body Weight
[2] Average Daily Gain
[3] Average Daily Feed Intake
[4] Gain to Feed Ratio

CHAPTER IV

The Effects of Outpace and Ambitine Feed Additives on Performance of Wean-to-Finish Pigs

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Abstract

Five hundred twenty-eight crossbred pigs (PIC 337) were used to determine the effects of Outpace and Ambitine feed additives (PMI Nutritional Additives, Shoreview, MN) on growth performance of pigs. Pigs were randomly allotted to pens (11 pigs/pen) on day 0 and fed a common diet for 21 days. All diets consisted of corn and soybean meal with the addition of DDGS and were formulated on an ME and SID Lysine basis, with no medications added. Weight gain and feed disappearance were measured to calculate ADG, ADFI, and G:F. On day 21, pigs (10.8 kg) were randomly allotted to 1 of 2 dietary treatments (24 pens/trt). The 2 dietary treatments consisted of 1) Control diet (CNT), and 2) Control diet + Outpace (OP). Outpace was included of 0.25% of the diet at the expense of corn. Data were analyzed using the MIXED procedure of SAS. Pigs were fed the CNT and OP diets for 39 days (10.8-36.7 kg BW) and were weighed on days 21, 34, 48, and 60. There were no differences ($P > 0.10$) in ADG, ADFI, or G:F between pigs fed the 2 dietary treatments. Following this phase, from day 61-135, all pens were

again fed a common diet. On day 136, pens were randomly allotted to 1 of 2 dietary treatments: 1) Control diet (CNT) or 2) Control diet + Ambitine (AMB). Ambitine was added to the finishing diet at 0.10% at the expense of corn. The CNT and AMB diets were fed for 38 days (101.4-130.6 kg BW). Weights were taken on days 136, 159, and 174 and carcass measurements collected at slaughter. There was a tendency ($P = 0.07$) for ADG (0.769 vs 0.797 kg) to be higher for pigs fed the AMB treatment compared to the CNT treatment. Pigs fed the AMB treatment had improved ($P = 0.036$) G:F (0.29 vs 0.31) compared to those fed the CNT treatment. Dietary treatment had no effect (P > 0.10) on final BW (130 vs 131 kg). There was a tendency ($P = 0.07$) for pigs fed the AMB diet to have a greater amount of back fat (1.40 vs 1.47 cm); however, there was no treatment effect ($P > 0.10$) on loin depth (7.0 vs 7.0 cm) or % lean (56.5 vs 56.4). The results of this study suggest that feeding Outpace for a portion of the growing period had no impact on performance, but feeding Ambitine at the end of the finishing period improves feed efficiency and had a tendency to increase ADG.

Introduction

Similarly, to the interest in natural products to add to diets during the early nursery stages, there is also growing interest in natural products to be used at the end of the grow/finish stage during pig production. Demand for pork that is raised in systems that do not use ractopamine hydrochloride is becoming increasingly popular in the international market (Pacelle, 2014). Traditionally, ractopamine is fed to pigs to increase muscle deposition while decreasing fat deposition. Feeding ractopamine also results in a pig that has greater feed efficiency (Gu et al., 1991). Additionally, Burnett et al. (2016) found that pigs fed ractopamine had an increase in longissimus muscle area by 12.6% when compared to their counterparts that were fed a control diet. Pigs fed ractomapine were observed to have an increase in BW, ADG, G:F, HCW, and yield, in addition to a decrease in ADFI when compared to pigs fed a diet void of ractopamine (Mendoza et al., 2017).

Finding products that can help increase performance similarly to the magnitude that ractopamine does is of interest throughout the industry today. There has been a wide variety of results observed when evaluating phytogenic and organic acids products. The content of the blend of acids can widely effect the results achieved. Different acids elicit different physiological responses and when fed in a blend, responses can be hard to tease out. Acids can decrease gut and digesta pH and can lead to increased nutrient digestion and absorption potential (Mroz, 2003). The way these acids act on a particular animal can depend on many factors: age, diet composition, health status and other physiological stress that the animal may be under (Mroz et al., 2006; Blank et al., 1999). Diet composition, simple or more complex diets, as well as the intestinal physiology when the diets are fed can also have a large effect on how the acids act when effecting digestion (Mroz, 2005). It has been assumed that there is less of a response to feeding organic acids as the gut becomes more developed and gastric secretions increase (Kirchgessner and Roth, 1982; Easter, 1988).

Thus, the objective of this project was to evaluate the effect of Outpace Feed Additive (PMI Nutritional Additives, Shoreview, MN) on late nursery and early finishing growth performance and the effect of Ambitine Feed Additive (PMI Nutritional Additives, Shoreview, MN) on late finishing performance and carcass characteristics.

Materials and Methods

Five hundred twenty-eight crossbred pigs (PIC 337), were weaned at 20 days of age and transported to Oklahoma State University Swine Research and Education Center where they were housed in an environmentally controlled building until they reached market weight and were shipped to a commercial slaughter facility. Upon arrival, pigs were randomly allotted to 1 of 48 pens (11 pigs/pen). Each pen contained 1 feeder and 1 cup waterer where feed and water were offered ad libitum. Pens were then fed a common diet for 21 days. On d 21, pens were weighed and randomly allotted to 1 of 2 dietary treatments: 1) Control (CNT) which was a standard late nursery /early finishing diet consisting of corn and soybean meal with the addition of dried distillers grains with solubles (DDGS) or 2) Outpace (OP) the CNT diet with the addition of Outpace at the rate of 0.25% of the diet at the expense of corn. There were no antibiotics included in either of the diets. The average starting weight of pigs during this experimental period was 10.8 kg. Pens were fed their respective treatments for 39 days and were offered feed and water ad libitum. Pigs and feeders were weighed on d 21, 34, 48, and 60 to calculate ADG, ADFI, and GF.

At the conclusion of the first experimental period, all pens were placed back on a common diet for 74 days before being allotted to 1 of 2 dietary treatments on d 136 post arrival at the facility, with an average weight of 101.4 kg. Dietary treatments were: 1) Control Diet (CNT), which consisted of corn, soybean meal, and DDGs or 2) Ambitine Diet (AMB), which was the CNT diet with the addition of the Ambitine Feed Additive. Ambitine was added at 0.10% of the diet at the expense of corn. There was no ractopamine hydrochloride included in either of these diets. When allotting pens to dietary treatment during this phase of the study, previous dietary treatment was taken into consideration and evenly distributed between the 2 new dietary treatments. Diets were fed from d 136- 174. Pens and feeders were weighed on d 136, 159, and 174 to calculate ADG, ADFI, and FG. On d 174, pigs were shipped to a commercial slaughter facility where carcass measurements were taken during the time of processing. Carcass measurements included, hot carcass weight, back fat, loin depth, and percent lean.

Statistical Analysis

Data were analyzed using the MIXED procedure in SAS. Pen served as the experimental unit and there were 24 replicates/trt. Means were reported as Least Square Means (LS Means). Significance was declared at $P < 0.05$, and values that fell between 0.05 and 0.10 were declared a trend.

Results

When Outpace was fed during the late nursery and early finishing phases, there were no effects observed on performance (Table IV.3). There were no effects ($P > 0.10$) on ADG, ADFI, GF, nor final BW for pigs fed the OP diet compared to the pigs fed the CNT diet. However, the addition of Outpace during late nursery and early finishing did result in a slightly numerically higher end BW for those pigs fed the OP treatment. Cost per kg of gain was increased ($P < 0.01$) for pigs fed the OP diet, due to the increase of diet cost with the addition of Outpace and no improvement in growth performance observed for pigs fed this diet.

Ambitine performance results are presented in Table IV.4. The addition of Ambitine to late finishing diets had no effect on ADFI ($P > 0.10$). There was a tendency ($P = 0.08$) for ADG to be increased for pigs fed the AMB treatment. Pigs fed the AMB treatment had improved ($P = 0.04$) feed efficiency when compared to the pigs fed the CNT diet. There was no effect of dietary treatment on end body weight ($P > 0.10$). However, there was a slight numerical increase in ending body weight for the pigs fed the AMB treatment when compared to the pigs fed the CNT treatment.

Carcass traits are presented in Table IV.5. There was no effect ($P > 0.10$) of dietary treatment on % lean or loin depth. There was a tendency ($P = 0.07$) for pigs fed the AMB treatment to have a higher back fat than those fed the CNT diet. There was an improvement ($P = 0.04$) in caloric efficiency, measured as ME (kcal/kg of gain) for the pigs fed the AMB treatment compared to pigs fed the CNT treatment. Although there was no a statistical difference ($P = 0.12$) for cost per kg of gain between the 2 treatments, there was a numerical improvement for pigs fed the AMB treatment when compared to the CNT treatment, with that improvement being 0.026 cents difference between the 2 treatments.

Discussion

No improvement in growth performance was observed with the addition of Outpace during the later nursery and early finishing phases. Similarly, Che et al. (2012) observed no growth performance benefits when comparing pigs fed a diet that contained an addition of organic acids to pigs that were fed a control diet. It should be noted that during this study, antibiotics were included in both dietary treatments. However, in a previous study with growing pigs (avg wt: 22 kg), there was an improvement in ADG seen when formic or lactic acid was added to growing pig diets, as well as an improvement of GF with the addition of formic acid (Jongbloed et al., 2000). Likewise, Mroz et al. (1997) found that when organic acids were fed to finishing pigs, the digestibility of protein and amino acids were increased. In previous studies conducted by our lab, there was a benefit of the addition of Outpace during the early nursery phases. There is a difference in potential hurdles that newly weaned nursery pigs have and those that have already been at a facility for 3-4 weeks. During this trial, pigs were not subjected to any particular stress during the experimental period when Outpace was added to the diet. Pen hierarchy was already established, pigs had already been comingled and subjected to any diseases brought in from other groups of piglets. The crucial time when piglets are adapting to a new diet would be coming to an end by the time Outpace was added to the diet in this particular trial. There are some commercial systems where pigs would be transported from a nursery facility to a finishing facility around the time that Outpace was fed during this trial. This move could induce more stress and immunological challenges. Pigs faced with these challenges could see a potential benefit in performance similar to that seen when pigs were fed Outpace for the entirety of the nursery phase. Studies where this management style is used would be an important next step when evaluating how and when Outpace is best used.

Though complete modes of action are not known, in this study, Ambitine did improve feed efficiency and had a tendency to increase ADG. Crowder, et al. (2016) observed increased feed efficiency for pigs fed Ambitine during the late finishing stages. When Ambitine was fed in addition to ractopamine, ADG, feed efficiency and hot carcass weight were all improved in comparison to pigs fed a diet that still contained ractopamine but did not contain Ambitine (Crowder et al., 2017). Mzor et al. (1997) found that there was improvement in protein and amino acid digestion when organic acids were added to fattening pig diets. Similar to the results observed in this study, Jongbloed et al. (2000) observed an increase in gain and improvement in feed conversion when lactic and formic acids were added to the diet, as well as, Partanen et al. (2001) reporting an improvement in weight gain, as well as feed efficiency when formic, proprionic, or fumaric acid were added to growing pig diets.

Similar to the Outpace product, cost analysis has to be done to calculate when is the best time to use the product, what rate to include it at, and the duration of time for which it should be fed to see the most return.

Conclusion

There should be further research done to determine the best time and rate to add Outpace to nursery and early finishing diets. Management systems and health status of pigs may have an effect on the optimal use of Outpace.

Ambitine can be used as an effective tool to improve feed efficiency during the late finishing stage of swine production. Ambitine is a useful alternative to the use of ractopamine hydrochloride in finishing diets with the standards that are in place today with consumer and trade demand.

Table IV.1. Nutrient composition of growing[a] and finishing diets[b]

Ingredient, %	N4	N5	F1	F5	F6
Corn	54.56	54.49	59.77	73.69	74.18
Soybean Meal	11.25	24.89	25.14	7.81	7.52
Dried Distiller Grain, w/Solubles	29.46	15.00	10.00	10.00	10.00
Soybean Oil	1.40	2.36	2.52	6.17	6.08
Limestone, ground	0.87	0.93	0.68	0.81	0.81
Dicalcium Phosphate	0.77	0.67	0.43	0.29	0.17
Salt	0.52	0.48	0.45	0.50	0.50
L-Lysine HCl	0.50	0.53	0.48	0.38	0.38
Mineral Premix	0.20	0.20	0.20	0.20	0.20
DL-Methionine	0.16	0.14	0.12	0.00	0.00
L-Threonine	0.13	0.13	0.13	0.11	0.11
Vitamin Premix	0.05	0.05	0.00	0.00	0.00
Copper Chloride	0.04	0.04	0.03	0.03	0.03
Optiphos 1000	0.10	0.10	0.05	0.01	0.02
L-Tryptophan	0.003	0.01	0.01	0.02	0.02
Total	100	100	100	100	100

[a]Outpace added at 0.25% in N4-F1 diets at the expense of corn

[b]Ambitine added at 0.10% in F5-F6 diets at the expense of corn

Table IV.2. Chemical Composition of Diets[1]

	N4	N5	F1	F5	F6
ME, kcal/kg	3414	3436	3436	3568	3568
Crude Protein, %	21.1	21.6	21.5	11.9	12.7
Crude Fat, %	4.4	3.1	4.4	10.0	6.3
Ca, %	0.86	1.36	1.10	0.58	0.58
P, %	0.59	0.69	0.50	0.35	0.32
Na, %	0.27	0.33	0.25	0.24	0.26
Zn, ppm	128	195	133	151	183
Cu, ppm	259	27	202	182	238

[1]All diets were analyzed by Servitech Labs, Dodge City, KS

Table IV.3. Effects of Outpace on performance of growing pigs[a]

	CNT	OP	SE	P value
BW[1], kg				
d 0	10.83	10.81	0.106	0.867
d 39	36.64	36.78	0.289	0.724
ADG[2], kg/d				
d 0-39	0.66	0.67	0.050	0.569
ADFI[3] kg/d				
d 0-39	1.14	1.16	0.014	0.227
G:F[4]				
d 0-39	0.582	0.574	0.007	0.232

[a] Least Square Means (24 pens/trt)

[b, c] Means with different superscripts in the same row differ ($P < 0.05$)
[1] Body Weight
[2] Average Daily Gain
[3] Average Daily Feed Intake
[4] Gain to Feed Ratio

Table IV.4. Effects of Ambitine on performance of finishing pigs[a]

	CNT	AMB	SE	P value
BW[1], kg				
d 0	104.37	104.48	0.823	0.920
d 38	130.16	130.99	0.883	0.509
ADG[2], kg/d				
0-38	0.769	0.797	0.017	0.079
ADFI[3] kg/d				
0-38	2.62	2.58	0.043	0.538
G:F[4]				
0-38	0.294[b]	0.309[c]	0.056	0.036

[a] Least Square Means (24 pens/trt)
[b, c] Means with different superscripts in the same row differ ($P < 0.05$)
[1] Body Weight
[2] Average Daily Gain
[3] Average Daily Feed Intake
[4] Gain to Feed Ratio

Table IV.5. Effects of Ambitine on carcass characteristics[a]

	CNT	AMB	SE	P value
Live Wt, kg	130.11	131.00	0.883	0.47
Carcass Wt, kg	96.92	97.81	0.717	0.37
BF[b,] cm	1.4[d]	1.47[e]	0.004	0.08
LD[c], cm	7.01	7.02	0.010	0.90
% Lean	56.56	56.41	0.105	0.26
Kcal/kg gain	12184[d]	11610[e]	198.23	0.04
Cost/kg gain	0.721	0.695	0.011	0.12

[a] Least Square Means (24 pens/trt)

[b]Backfat

[c]Loin Depth

[d, e] Means with different superscripts in the same row differ ($P < 0.05$)

CHAPTER V

Summary

Commercial swine producers are constantly looking for ways to produce pork in a safe and cost-effective way. There are challenges to overcome due to increased regulation and feed ingredient cost and availability. However, researchers are continuing to review the best feed options and feed technologies, both new and old to provide the information about the best use of these products to producers. With that being the objective of these studies, it was observed that there are natural alternatives to sub-therapeutic use of antibiotics during nursery phases, as well as, similar alternatives to use of ractopamine during the late finishing stages of swine production.

These studies also helped to conclude that Yucca *schidigera,* a plant extract, are a viable addition to nursery diets for producers who use elevated levels of soybean meal in feed. Addition of Yucca extract has the potential to result in increased pig growth performance during the first 14 -21 days post weaning. Yucca extract could also be utilized to enhance performance of nursery pigs throughout the entirety of the nursery phase when pigs are fed a traditional nursery diet with the inclusion of products that are considered more digestible.

Outpace, a blend of plant extracts and acidifiers can be added to weaned pig diets to improve feed efficiency of nursery pigs throughout the nursery phase. This is an important area of swine production today, due to the regulations put on antibiotic use, such antibiotics have been commonly used in the past to enhance weaned pig performance. Outpace is a viable product to add to nursey diets in place of antibiotics to increase performance possibly through means of increased digestion an absorption. There is also potential to measure the immune benefits of additions of phytogenics and organic acids like Outpace to weaned pig diets. In opposition, there was no benefit observed when Outpace was added to growing pig diets at the end of the nursery and early finishing stages. Outpace is likely more effective during times that the pig is under high stress or has the potential to be immunocompromised.

Ambitine, a blend of plant extracts and functional acids, is an option for producers that are raising pigs with ractopamine-free diets. Ambitine increased feed efficiency when fed during the late finishing stages. This product, being of a similar blend as Outpace, likely enhances performance through reduced gastric pH, and increased digestion and absorption, while promoting gut integrity.

Micro-Aid, Outpace, and Ambitine all are natural products that can be included in swine diets during different stages of production to increase growth performance to various degrees.

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APPENDICES

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Appendix 1

Experiment 1

Appendix 1. Table 1. Pen means for body weight and average daily gain

			BW, kg				ADG, g			
Block	Pen	TRT	d 0	d 14	d 21	d 43	d 0-14	d 0-21	d 21-43	d 0-43
1	15	SMA	6.7	10.1	14.2	28.4	240	357	644	504
1	17	CNT	6.6	9.4	13.2	27.0	201	313	609	465
1	18	HSBM	6.4	9.4	13.6	27.7	211	344	640	495
2	1	SMA	6.0	8.8	12.7	26.3	198	320	617	472
2	8	HSBM	6.5	8.4	11.8	24.1	139	253	559	410
2	16	CNT	6.4	9.4	12.9	27.2	211	311	648	484
3	2	SMA	5.8	8.4	12.2	25.8	182	305	617	465
3	9	HSBM	6.4	8.9	12.7	25.7	172	298	592	449
3	10	CNT	5.5	9.4	13.2	26.6	272	363	613	491
4	3	SMA	6.4	9.6	13.5	26.7	224	273	601	433
4	4	HSBM	5.8	8.3	12.1	25.7	182	301	617	462
4	11	CNT	6.1	9.0	12.2	26.9	208	292	669	485
5	5	HSBM	6.3	9.2	13.3	27.7	208	333	656	498
5	12	SMA	5.7	8.6	12.4	26.7	204	318	652	489
5	13	CNT	6.2	9.2	13.2	27.4	211	333	646	493
6	6	CNT	6.1	9.5	13.6	29.0	246	357	700	532
6	7	HSBM	5.9	8.7	12.7	27.2	195	320	662	495
6	14	SMA	6.0	8.9	12.7	26.6	204	318	629	477

Appendix 1. Table 2. Pen means for average daily feed intake and gain to feed ratio

			ADFI, g				G:F			
Block	Pen	TRT	d 0-14	d 0-21	d 21-43	d 0-43	d 0-14	d 0-21	d 21-43	d 0-43
1	15	SMA	318	472	1051	768	0.754	0.756	0.613	0.656
1	17	CNT	284	414	1021	724	0.708	0.757	0.596	0.641
1	18	HSBM	286	425	1001	720	0.737	0.809	0.639	0.688
2	1	SMA	239	389	1010	707	0.829	0.823	0.611	0.668
2	8	HSBM	213	335	909	629	0.655	0.756	0.615	0.652
2	16	CNT	286	420	1062	748	0.736	0.741	0.610	0.646
3	2	SMA	252	390	1030	717	0.721	0.782	0.599	0.647
3	9	HSBM	239	380	1001	698	0.719	0.784	0.592	0.643
3	10	CNT	308	438	978	714	0.885	0.830	0.627	0.687
4	3	SMA	261	415	963	683	0.856	0.657	0.624	0.634
4	4	HSBM	244	393	898	651	0.745	0.765	0.687	0.710
4	11	CNT	277	401	1013	714	0.750	0.728	0.660	0.679
5	5	HSBM	296	444	1010	734	0.702	0.750	0.650	0.679
5	12	SMA	262	404	1031	725	0.779	0.787	0.632	0.674
5	13	CNT	252	397	1001	706	0.835	0.838	0.645	0.698
6	6	CNT	284	440	1083	769	0.869	0.812	0.646	0.692
6	7	HSBM	253	398	1046	729	0.770	0.805	0.633	0.679
6	14	SMA	257	378	1027	710	0.796	0.842	0.613	0.672

Experiment 2

Appendix 1. Table 3. Pen means for body weight and average daily gain

			BW, kg			ADG, g		
Block	Pen	Trt	d 0	d 21	d 40	d 0-21	d 21-40	d 0-40
1	1	HSBM	5.6	10.9	22.4	253	605	420
1	13	CNT	5.7	11.7	22.1	287	549	411
1	15	CMA	5.6	13.0	24.7	353	615	478
1	17	SMA	5.6	12.3	23.3	318	581	443
2	5	SMA	5.8	12.2	24.0	309	618	456
2	6	CNT	5.8	13.4	24.9	362	607	478
2	7	CMA	5.8	12.2	25.9	307	689	501
2	20	HSBM	5.7	10.8	23.0	244	642	433
3	11	SMA	5.9	12.5	24.8	317	650	475
3	14	HSBM	5.9	11.3	23.4	255	639	437
3	18	CMA	5.9	13.5	25.5	362	634	491
3	19	CNT	5.9	13.2	26.1	346	679	504
4	4	CNT	5.9	12.5	25.4	312	679	486
4	9	CMA	5.9	13.4	25.6	354	644	492
4	10	SMA	5.9	12.4	24.3	310	623	459
4	22	HSBM	5.9	12.1	24.4	295	647	462
5	8	HSBM	6.1	11.8	23.9	275	634	445
5	21	SMA	6.0	12.6	23.2	313	557	429
5	24	CNT	6.0	13.4	26.0	349	663	498
5	28	CMA	6.0	13.6	28.4	361	719	559
6	2	CMA	6.5	13.0	25.4	308	655	473
6	16	CNT	6.3	13.8	25.2	359	598	473
6	23	SMA	6.5	12.3	23.7	277	597	429
6	27	HSBM	6.6	12.3	25.0	275	666	460
7	3	CNT	6.8	13.6	24.7	324	583	447
7	12	SMA	6.7	13.5	26.1	321	663	483
7	25	HSBM	6.6	12.3	25.1	275	671	463
7	26	CMA	6.7	13.3	26.0	311	668	481

Appendix 2. Table 4. Pen means for average daily feed intake and gain to feed ratio

			ADFI, g			G:F		
Block	Pen	Trt	d 0-21	d 21-40	d 0-40	d 0-21	d 21-40	d 0-40
1	1	HSBM	358	927	619	0.706	0.652	0.679
1	13	CNT	344	922	609	0.833	0.595	0.675
1	15	CMA	399	1087	714	0.886	0.566	0.669
1	17	SMA	385	999	667	0.825	0.581	0.664
2	5	SMA	377	1028	675	0.820	0.601	0.675
2	6	CNT	395	1116	726	0.915	0.544	0.659
2	7	CMA	379	1079	680	0.808	0.639	0.737
2	20	HSBM	372	940	632	0.656	0.683	0.685
3	11	SMA	385	1082	705	0.822	0.600	0.674
3	14	HSBM	368	963	641	0.691	0.664	0.682
3	18	CMA	399	1059	702	0.908	0.598	0.700
3	19	CNT	403	1080	713	0.857	0.629	0.706
4	4	CNT	410	1109	730	0.762	0.612	0.666
4	9	CMA	405	1046	687	0.874	0.616	0.717
4	10	SMA	388	1079	705	0.798	0.578	0.651
4	22	HSBM	385	1004	669	0.767	0.644	0.691
5	8	HSBM	367	978	647	0.748	0.648	0.688
5	21	SMA	384	937	638	0.814	0.594	0.672
5	24	CNT	394	1072	705	0.885	0.619	0.707
5	28	CMA	387	1185	711	0.931	0.607	0.786
6	2	CMA	407	1045	695	0.757	0.627	0.681
6	16	CNT	403	996	671	0.891	0.601	0.705
6	23	SMA	384	962	649	0.721	0.620	0.660
6	27	HSBM	386	983	660	0.711	0.677	0.698
7	3	CNT	403	1045	697	0.805	0.558	0.641
7	12	SMA	396	1107	722	0.812	0.599	0.670
7	25	HSBM	379	1042	683	0.725	0.644	0.678
7	26	CMA	390	1114	721	0.800	0.600	0.667

Appendix 2

Experiment 3

Appendix 2. Table 1. Pen means for body weight, average daily gain, average daily feed intake, and gain to feed ratio

		BW, kg			ADG, g			ADFI, g			G:F		
Pen	Diet	d 0	d 21	d 42	d 0-21	d 21-42	d 0-42	d 0-21	d 21-42	d 0-42	d 0-21	d 21-42	d 0-42
1	CNT	6.08	12.08	22.80	272	536	398	338	863	578	0.806	0.621	0.689
2	OP	6.04	12.49	24.15	293	583	431	357	905	618	0.820	0.645	0.698
3	CNT	6.31	12.26	23.06	270	540	399	338	820	568	0.800	0.659	0.703
4	OP	6.08	11.99	22.93	268	547	401	331	839	573	0.810	0.652	0.700
5	CNT	6.04	12.08	22.61	274	527	395	355	842	587	0.774	0.626	0.673
6	OP	5.90	10.44	21.96	206	511	382	240	818	486	0.861	0.625	0.786
7	CNT	6.13	11.94	21.97	264	502	377	342	867	592	0.772	0.579	0.637
8	OP	6.17	12.26	23.88	277	581	422	351	903	614	0.787	0.644	0.687
9	CNT	6.04	11.99	22.56	270	529	393	342	839	578	0.791	0.631	0.680
10	OP	6.17	12.03	22.47	266	522	388	342	788	555	0.779	0.662	0.700
11	CNT	6.17	10.94	21.16	217	511	357	297	800	536	0.730	0.638	0.665
12	OP	5.90	11.21	22.80	241	517	402	326	838	557	0.740	0.617	0.723
13	CNT	6.22	11.25	22.19	229	547	380	300	835	537	0.762	0.655	0.708
14	OP	6.17	11.55	22.60	244	552	391	307	848	551	0.797	0.651	0.710
15	OP	6.27	11.99	23.29	260	565	405	341	877	596	0.762	0.645	0.680
16	CNT	5.90	12.26	23.05	289	540	408	325	836	558	0.888	0.646	0.732
17	OP	5.90	10.81	21.84	223	552	379	286	819	540	0.780	0.674	0.703
18	CNT	6.08	11.00	22.76	223	519	397	286	879	539	0.782	0.591	0.737
19	OP	6.08	10.76	22.60	213	532	393	297	859	550	0.716	0.619	0.715
20	CNT	6.40	12.26	24.47	266	611	430	329	912	607	0.809	0.670	0.709
21	OP	6.36	12.30	24.11	270	590	423	349	886	605	0.774	0.666	0.699
22	CNT	6.08	11.21	21.47	233	513	366	297	782	528	0.784	0.656	0.694
23	OP	6.31	12.03	22.79	260	538	392	326	858	580	0.797	0.627	0.677
24	CNT	5.99	10.09	19.07	186	449	311	272	659	448	0.684	0.681	0.694
25	OP	6.17	12.12	23.70	270	579	417	356	875	603	0.760	0.661	0.692
26	CNT	6.17	11.70	23.15	251	573	404	295	861	553	0.853	0.665	0.731
27	OP	6.22	12.67	23.88	293	561	420	334	848	578	0.878	0.661	0.727
28	CNT	6.13	11.76	21.88	256	506	375	319	811	553	0.802	0.624	0.678

Experiment 4

Appendix 2. Table 2. Pen means for body weight, average daily gain, average daily feed intake, and gain to feed ratio

		BW, kg			ADG, g			ADFI, g			G:F		
Pen	Trt	d 0	d 21	d 42	d 0-21	d 21-42	d 0-42	d 0-21	d 21-42	d 0-42	d 0-21	d 21-42	d 0-42
1	OP	6.17	10.71	21.57	216	517	366	274	737	506	0.788	0.701	0.725
2	OP	6.04	11.21	21.52	246	491	369	296	700	498	0.832	0.701	0.740
3	CNT	5.99	10.40	20.78	210	495	352	268	672	463	0.783	0.736	0.761
4	CNT	6.27	10.99	20.70	225	463	344	271	728	499	0.831	0.636	0.688
5	CNT	6.04	10.49	21.54	212	526	369	248	738	484	0.855	0.713	0.762
6	OP	6.08	12.11	23.15	287	526	406	303	766	526	0.946	0.687	0.772
7	OP	6.08	11.00	22.20	234	533	384	253	750	493	0.924	0.711	0.778
8	CNT	5.95	11.44	23.56	262	577	419	324	838	581	0.807	0.689	0.722
9	CNT	5.99	11.17	21.25	246	480	363	314	695	504	0.785	0.691	0.720
10	OP	6.17	10.08	20.93	186	517	351	249	704	469	0.748	0.734	0.750
11	OP	5.95	11.08	21.07	244	476	360	295	690	493	0.828	0.689	0.731
12	OP	6.27	11.17	22.15	233	521	378	296	742	507	0.789	0.702	0.745
13	CNT	6.04	11.67	22.70	268	525	397	318	799	559	0.843	0.657	0.710
14	CNT	6.40	11.03	21.16	221	482	351	277	680	478	0.796	0.709	0.734
15	CNT	6.08	11.94	23.15	279	534	406	342	797	570	0.814	0.670	0.714
16	CNT	5.95	11.80	22.93	279	530	404	332	778	555	0.841	0.681	0.729
17	CNT	6.31	12.08	23.47	275	543	409	343	832	587	0.800	0.652	0.695
18	OP	6.08	11.96	23.61	280	555	417	299	733	508	0.934	0.757	0.821
19	OP	5.90	10.99	21.79	242	515	378	291	745	518	0.832	0.690	0.730
20	CNT	6.13	11.67	21.88	264	486	375	336	736	536	0.784	0.661	0.699
21	CNT	6.17	11.75	22.30	266	502	384	302	703	490	0.881	0.715	0.784
22	OP	6.27	11.89	22.38	268	499	384	301	714	508	0.890	0.699	0.756
23	OP	6.04	10.44	21.62	210	492	371	241	739	466	0.871	0.665	0.796
24	OP	6.17	11.21	21.20	240	476	358	290	706	498	0.827	0.673	0.718
25	CNT	6.08	10.31	19.98	201	460	331	246	674	460	0.817	0.683	0.719
26	CNT	6.08	11.58	21.57	262	476	369	309	706	508	0.846	0.674	0.726
27	OP	6.17	10.35	21.49	199	497	365	256	726	479	0.776	0.685	0.761
28	OP	6.04	11.55	22.45	263	519	391	306	778	538	0.857	0.667	0.727

Appendix 3

Experiment 3

Appendix 3. Table 1. Pen means for body weight, average daily gain, average daily feed intake, gain to feed ratio, and cost per Kilogram of gain

Pen	Trt	d 0, kg	d 39, kg	ADG, kg	ADFI, kg	G:F	Cost/Kg of gain
1	OP	10.44	36.57	0.67	1.21	0.55	0.45
2	CNT	10.62	36.23	0.66	1.15	0.57	0.43
3	OP	10.03	34.88	0.64	1.08	0.59	0.42
4	CNT	11.03	37.46	0.68	1.15	0.59	0.41
5	CNT	11.02	34.71	0.61	0.98	0.62	0.40
6	CNT	10.94	38.67	0.71	1.21	0.59	0.41
7	CNT	10.81	37.05	0.67	1.16	0.58	0.42
8	OP	10.85	36.41	0.66	1.10	0.59	0.42
9	CNT	11.00	36.93	0.66	1.13	0.59	0.42
10	OP	11.10	37.23	0.67	1.23	0.54	0.46
11	OP	10.69	35.62	0.64	1.07	0.60	0.42
12	OP	11.23	36.98	0.66	1.18	0.56	0.44
13	CNT	10.40	34.83	0.63	1.07	0.59	0.42
14	CNT	11.52	39.50	0.72	1.20	0.60	0.41
15	CNT	10.67	36.05	0.65	1.11	0.59	0.42
16	CNT	10.65	34.96	0.62	1.07	0.58	0.42
17	CNT	10.52	35.41	0.64	1.08	0.59	0.42
18	CNT	11.76	39.13	0.70	1.23	0.57	0.42
19	OP	9.94	36.52	0.68	1.12	0.61	0.41
20	OP	11.64	39.18	0.71	1.21	0.58	0.43
21	OP	9.35	33.10	0.61	1.06	0.57	0.44
22	OP	10.73	35.95	0.65	1.10	0.59	0.43
23	OP	10.94	36.11	0.65	1.11	0.58	0.43
24	OP	11.76	38.95	0.70	1.29	0.54	0.46
25	OP	11.56	37.06	0.65	1.13	0.58	0.43
26	CNT	9.99	34.64	0.63	1.07	0.59	0.41
27	OP	9.86	34.79	0.64	1.13	0.57	0.44
28	CNT	10.57	36.49	0.66	1.13	0.59	0.42
29	CNT	11.18	36.86	0.66	1.10	0.60	0.41
30	OP	10.81	37.15	0.68	1.25	0.54	0.46
31	OP	10.94	36.49	0.66	1.12	0.59	0.43
32	CNT	11.10	37.64	0.68	1.12	0.61	0.40
33	OP	11.45	38.82	0.70	1.13	0.62	0.40
34	CNT	10.44	35.41	0.64	1.10	0.58	0.42
35	OP	11.27	38.09	0.69	1.22	0.56	0.44
36	CNT	11.68	38.34	0.68	1.22	0.56	0.43
37	OP	9.62	34.96	0.65	1.15	0.56	0.44
38	CNT	10.32	35.58	0.65	1.13	0.57	0.43

39	CNT	10.40	36.82	0.68	1.14	0.59	0.41
40	OP	11.06	37.56	0.68	1.18	0.57	0.43
41	OP	11.06	37.10	0.67	1.13	0.59	0.42
42	CNT	10.65	35.91	0.65	1.12	0.58	0.42
43	CNT	10.65	35.58	0.64	1.16	0.55	0.44
44	OP	10.52	36.24	0.66	1.15	0.57	0.44
45	CNT	10.85	36.93	0.67	1.31	0.51	0.48
46	OP	11.14	37.35	0.67	1.23	0.55	0.45
47	OP	11.35	39.73	0.73	1.26	0.58	0.43
48	CNT	11.18	38.26	0.69	1.14	0.61	0.40

Appendix 3. Table 2. Pen means for body weight, average daily gain, average daily feed intake, gain to feed ratio, cost per Kilogram of gain, and metabolizable energy per kilogram of gain

Pen	Trt	d 0, kg	d 38, kg	ADG, kg	ADFI, kg	G:F	Cost/Kg of gain	ME/Kg gain
1	AMB	103.56	131.41	0.86	2.63	0.33	0.65	10911
2	CNT	98.52	123.54	0.77	2.39	0.32	0.65	11028
3	AMB	102.23	130.93	0.88	2.40	0.36	0.59	9788
4	CNT	110.19	137.65	0.84	2.74	0.31	0.69	11690
5	CNT	104.17	131.37	0.82	2.74	0.30	0.70	11913
6	AMB	110.32	137.03	0.80	2.87	0.28	0.76	12734
7	AMB	104.87	130.30	0.79	2.34	0.34	0.64	10633
8	CNT	114.54	138.47	0.73	2.84	0.26	0.82	13905
9	CNT	101.75	133.53	0.98	3.18	0.31	0.68	11532
10	AMB	107.23	136.20	0.88	2.82	0.31	0.68	11398
11	AMB	102.23	130.22	0.84	2.71	0.31	0.69	11477
12	CNT	107.72	132.77	0.76	2.89	0.26	0.80	13643
13	CNT	95.30	121.84	0.80	2.47	0.32	0.65	11028
14	AMB	112.19	141.70	0.93	2.97	0.31	0.68	11407
15	CNT	103.42	131.34	0.85	2.63	0.32	0.65	11014
16	AMB	98.02	126.71	0.86	2.58	0.33	0.64	10664
17	CNT	105.91	130.01	0.73	2.67	0.27	0.77	13117
18	AMB	106.94	133.19	0.79	2.70	0.29	0.73	12161
19	AMB	100.18	127.22	0.84	2.67	0.31	0.68	11411
20	CNT	106.46	134.38	0.85	2.79	0.31	0.69	11682
21	AMB	100.59	126.87	0.81	2.81	0.29	0.74	12344
22	CNT	102.19	130.59	0.86	2.75	0.31	0.68	11478
23	AMB	105.46	131.02	0.78	2.43	0.32	0.66	11104
24	CNT	108.32	133.02	0.75	2.63	0.29	0.74	12463
25	CNT	99.76	123.94	0.71	2.30	0.31	0.68	11574
26	CNT	101.92	129.75	0.82	2.58	0.32	0.66	11175
27	AMB	97.93	121.90	0.71	2.38	0.30	0.72	11998
28	AMB	102.47	130.21	0.82	2.66	0.31	0.69	11580
29	CNT	103.64	132.49	0.84	2.71	0.31	0.68	11446
30	CNT	101.98	127.57	0.75	2.94	0.25	0.83	14004
31	AMB	100.58	131.12	0.90	2.54	0.36	0.60	10040
32	AMB	108.96	132.20	0.68	2.50	0.27	0.78	13102
33	CNT	106.29	130.92	0.75	2.45	0.31	0.69	11643
34	AMB	100.79	127.35	0.79	2.60	0.30	0.71	11807
35	AMB	110.86	136.61	0.75	2.63	0.29	0.74	12433
36	CNT	106.69	129.31	0.66	2.51	0.26	0.80	13542
37	CNT	101.70	123.74	0.59	2.12	0.28	0.76	12908
38	CNT	98.68	117.38	0.55	2.25	0.24	0.87	14688
39	AMB	101.32	122.17	0.61	2.14	0.28	0.75	12549
40	AMB	104.50	129.60	0.73	2.30	0.32	0.67	11160
41	CNT	107.46	133.48	0.78	2.50	0.31	0.67	11412
42	AMB	106.51	132.34	0.76	2.56	0.30	0.71	11937
43	CNT	101.65	130.07	0.76	2.53	0.30	0.70	11929

44	AMB	104.28	129.14	0.75	2.43	0.31	0.70	11620
45	CNT	107.65	132.42	0.74	2.49	0.30	0.71	11957
46	CNT	108.86	134.28	0.76	2.49	0.31	0.69	11642
47	AMB	107.46	135.75	0.84	2.77	0.30	0.71	11811
48	AMB	108.10	132.70	0.73	2.57	0.28	0.75	12576

Appendix 3. Table 3. Pen means for average live weight, carcass weight, percent lean, backfat and loin depth.

Pen	Trt	Live Wt, kg	Carc Wt, kg	% Lean	BF[a], cm	LD[b], cm
1	AMB	131.41	96.30	57.08	1.38	7.28
2	CNT	123.54	93.07	56.67	1.34	6.98
3	AMB	130.93	97.11	55.39	1.66	6.73
4	CNT	137.65	103.06	57.16	1.54	7.59
5	CNT	131.37	98.11	56.73	1.42	7.14
6	AMB	137.14	104.28	57.26	1.41	7.43
7	AMB	130.30	97.16	55.83	1.47	6.69
8	CNT	138.47	103.51	55.82	1.70	6.99
9	CNT	133.53	97.96	56.11	1.46	6.82
10	AMB	136.20	101.33	56.88	1.47	7.31
11	AMB	130.22	96.58	56.53	1.42	7.02
12	CNT	131.12	97.02	56.14	1.69	7.22
13	CNT	121.84	89.93	56.90	1.13	6.81
14	AMB	141.82	106.16	56.40	1.66	7.32
15	CNT	131.34	97.52	57.03	1.47	7.40
16	AMB	126.71	94.23	56.29	1.45	6.91
17	CNT	130.47	97.70	56.28	1.44	6.91
18	AMB	133.19	99.88	56.42	1.54	7.12
19	AMB	127.22	93.83	56.19	1.51	6.93
20	CNT	134.38	100.74	57.01	1.32	7.13
21	AMB	126.87	95.29	56.53	1.62	7.33
22	CNT	130.59	95.88	56.35	1.41	6.91
23	AMB	131.02	98.74	56.39	1.39	6.88
24	CNT	133.02	99.34	56.34	1.24	6.64
25	CNT	123.94	93.32	57.43	1.20	7.22
26	CNT	129.75	97.07	57.43	1.48	7.64
27	AMB	121.90	91.66	56.86	1.32	7.07
28	AMB	130.21	96.34	57.02	1.20	6.96
29	CNT	132.49	98.27	56.56	1.32	6.89
30	CNT	127.57	93.98	56.62	1.28	6.86
31	AMB	131.12	97.36	55.91	1.68	7.05
32	AMB	132.20	98.23	56.68	1.35	7.02
33	CNT	130.92	97.67	55.55	1.57	6.67
34	AMB	127.35	94.84	56.75	1.36	7.06
35	AMB	136.61	102.48	56.21	1.53	7.01
36	CNT	129.31	97.40	56.32	1.37	6.81
37	CNT	123.74	92.92	56.84	1.24	6.93
38	CNT	117.38	87.46	55.64	1.18	6.12
39	AMB	122.17	92.12	56.18	1.36	6.72
40	AMB	129.60	99.05	56.66	1.34	6.96
41	CNT	133.48	99.63	56.87	1.48	7.32
42	AMB	132.34	98.61	56.10	1.53	6.91
43	CNT	130.07	96.61	56.84	1.38	7.13
44	AMB	129.14	96.95	56.04	1.62	7.02

45	CNT	132.42	98.11	56.61	1.43	7.07
46	CNT	134.28	99.88	56.17	1.59	7.08
47	AMB	135.75	101.15	56.33	1.54	7.08
48	AMB	132.70	97.75	55.86	1.50	6.74

[a]Backfat

[b]Loin Depth

VITA

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Candidate for the Degree of

Master of Science

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