EFFECT OF A WATER-SOLUBLE PLANT EXTRACT

ON NURSERY PIG PERFORMANCE

By

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Abstract: The objective of this study was to investigate the efficacy of a water-soluble phytogenic product on growth performance and immune response of nursery pigs. 280 pigs were utilized in this 42-day study. Pigs were allocated to pens (10 pigs/pen; 7 pens/treatment) and pens were randomly assigned to 1 of 4 treatments on d 0. Four water treatments consisted of 4 different levels (0, 16, 94, and 188 ml/L) of Quillaja Saponaria in a stock solution water medicator and set to a 1:128 ratio for drinking water. Control (CON) consisted of 0 mL/L QS; Q2 consisted of 16 mL/L QS and administered all 42 d of the study; Q12 consisted of 94 mL/L QS and administered on d 1-5 and d 18-28 of the study; Q24 consisted of 188 mL/L of QS and administered on d 1-5 and d 18-28 of the study. On d 23 of the study, pigs were injected intramuscularly with LPS (10 ug/kg BW). Pigs and feeders were weighed weekly to determine ADG, ADFI, and G:F. Blood samples, BW, and rectal temperature (RT) were taken before the LPS injection on d23 and on H3, H6, H12 and H24. Data were analyzed using the MIXED procedure in SAS with pen as the experimental unit. Relative to CON, Q2 had increased ADG, ADFI and G:F. The Q24 treatment had increased recordings of diarrhea. There was no significant difference in TNF-α or CRP values ($p > 0.10$).

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INTRODUCTION

Due to antibiotic resistance, environmental and sustainability concerns, there is a need for finding alternatives to routine in-feed antibiotics and pharmacological levels of zinc and copper in nursery pigs. The European Union banned the use of in-feed antibiotics in 2006 and is banning pharmacological levels of zinc in June 2022. U.S pork production currently uses pharmacological levels of zinc oxide and copper sulfate for their growth-promoting effects. More research is needed to determine the best alternative for growth-promoting antibiotics, zinc oxide, and copper sulfate. Phytogenic additives, also known as plant extracts, have shown improved disease prevention, immune response, and growth performance (Windisch et al., 2008). One specific plant extract of interest is Quillaja Saponaria, commonly known as the "soap bark" plant. Quillaja Saponaria is a natural saponin that has foaming properties that are commonly used as detergents, food additives, cosmetics, cough relievers, and anti-inflammatory aids. Therefore, the objective of this study was to evaluate the effect of Quillaja Saponaria on growth performance and immune response in nursery pigs.

To be able to maintain cost-effectiveness, pork producers must be able to optimize production and minimize costs of production. One way to optimize production is to understand the estimated performance for nursery ADFI, ADG, and ending weight. This value could be utilized by knowing the starting nursery weight and creating a prediction value to determine pigs expected average performance in the nursery and the finisher. It has been stated that there is a positive linear relationship between nursery ADG and finishing weight (Zeng et al., 2019). However, there is little research on prediction models for growth performance based on starting nursery weights. The objective of this study was to predict nursery and finishing performance based on starting nursery weight. This was study was completed to determine the changes in nursery and finishing performance compared to previous prediction models.

CHAPTER II

REVIEW OF LITERATURE

Weaning issues

Pigs face several challenges during weaning, which is why it is considered to be the most stressful stage of their life (Campbell et al., 2013). There are social hierarchy changes, climate changes, transportation stress, immune stressors, and physiological changes in their digestive tract due to changes in diet. The stress from weaning results in post-weaning lag which consists of reduced growth performance, a reduction in feed intake, post-weaning diarrhea, and increased mortality (Pluske et al., 1997; Ravindran et al., 1993). Since the immune system in a nursery pig isn't fully developed at this stage of life, it faces several immune challenges during this time as well (Kick et al., 2012; de Lange et al., 2010). Post-weaning lag is an animal welfare and economical concern, it can take up to two weeks to recover from this reduction in growth performance (Sève, 2000). It is an industry focus to reduce post-weaning lag by studying various nutritional strategies to provide the best transition from weaning into the nursery.

Prediction of nursery performance

The transition from weaning into the nursery is the most influential stage of a pig's life and undergoes a variety of stressors as previously mentioned. With decreased performance from post-weaning lag, there is also a decrease in efficient production. One way to optimize production is to understand the estimated performance for nursery ADFI, ADG, and ending weight. This number could be utilized by knowing the starting nursery weight and creating a prediction value to determine that pigs expected average performance in the nursery and the finisher. There is contradicting evidence in the scientific literature regarding performance indicators in pigs. Some researchers state that lightweight pigs at weaning have poor growth performance compared to heavier pigs (He et al., 2016; Douglas et al., 2013). Other literature shows light weaning weight pigs can catch up to heavier pigs (Huting et al., 2018; Zeng et al., 2019). It has been stated that there is a positive linear relationship between nursery ADG and finishing weight (Zeng et al., 2019). However, there is little research on prediction models for growth performance based on starting nursery weights. One article has a prediction value using a weaning weight at d28 (**W**) to predict the number of days it takes to grow to 20 kg (**T**); **T** = 52.1 (± 1.69) – 3.39 (± 0.224) **W** (R2 =0.85, P<0.001) (Campbell et al., 1990). This equation proposes that 1 kg at weaning will result in 3 fewer days for that pig to make it to 20 kg (Pluske et al., 2003). Other studies agree with this, stating heavier weight pigs at weaning maintain a heavier weight throughout their lifetime (Mahan and Lepine, 1991; Le Dividich et al., 2003). Cole and Close (2001) propose that days to market can be reduced by 10 days for a pig 1 kg heavier at weaning. Dietary requirements and research for nursery pig performance have advanced and an updated model for predicting nursery performance similar to previous models is needed.

Antibiotic use in nursery pigs

Antibiotics have been used in livestock production to aid in growth performance or to prevent, control, or treat health issues (Dunlop et al., 1994; Straw et al., 1994). To treat specific diseases, antibiotics will be administered 2-6 weeks or in a pulse dose. When administering antibiotics to enhance growth performance, it is commonly administered in the entire stage of production. Consumer concerns about antimicrobial resistance led to the ban on the use of antibiotics in pork production in the European Union (EU). With trade concerns and restrictions on the use of antibiotics, this pushed the US towards a restriction on the use of antibiotics like the European Union. Antibiotics can be fed in the United States, but now require a Veterinary Feed Directive (VFD) effective on January 1st, 2017. A VFD is provided to producers after a veterinarian oversees the swine herd and shows signs of health issues requiring prevention or treatment (AVMA, accessed 2022). With the restrictions on antibiotics being implemented in the US, there has been extensive research to find alternatives to improve growth performance in nursery pigs. Zinc and copper have been heavily researched and have shown performance parameters similar to the administration of antibiotics.

Pharmacological levels of zinc

Zinc plays a key role in immune cells and antioxidant function. Zinc is an essential trace mineral since it has an impact on cellular signaling, digestion, cellular respiration, and nucleic acid metabolism (Hill et al., 2019; Sloup et al., 2017). McDonald et al. (2011) reported that a deficiency of zinc in piglets is related to growth restriction, reduced appetite, lower feed conversion ratio, and skin complications. The NRC recommends daily requirements of zinc in growing pigs of 26.6 mg/kg (5-7 kg BW), 46.8

mg/kg (7-11 kg BW), and 72.4 mg (11-25 kg BW) (NRC, 2012). It has been reported that higher levels of zinc in the diet result in an improvement in nursery pig performance (Van Heugten et al., 2003). Following studies have also reported an improvement in post-weaning diarrhea (PWD), immune response, growth performance, and reduced mortality with levels of zinc exceeding NRC recommendations (Van Heugten et al., 2003; Hu et al., 2013; Martin et al., 2013; Johansen et al., 2007; Poulsen, 1995; Poulsen, 1998). Hill et al. (2001) state that optimum levels of zinc in nursery diets are above 1000 ppm, with the best performance noticed at 2,500 ppm.

Zinc oxide (ZnO) has been the common form of zinc in swine diets to aid in reducing PWD. Starting June 2022 there will be a restriction on the use of pharmacological levels of ZnO in the European Union. Similar to feed-grade antibiotics, the trade concerns and consumer interest will have a similar impact on US pork production. Therefore, an alternative for the use of pharmacological levels of zinc is needed to improve nursery performance.

Pharmacological levels of copper

The inclusion of copper leads to an increase in ADG and feed efficiency and has been used in nursery pig diets for decades. Poulsen (1995) states that Cu causes a growth-limiting effect on the intestinal microflora which aids in reducing PWD and allowing for more nutrients to be available for absorption. Excessive levels of Zn and Cu in swine diets have an environmental concern including metal build-up in soil from manure application and toxicity of fields with this manure that is high in copper can become toxic to sheep due to high levels of copper (Poulsen et al., 1998). The European Union has implemented restrictions based on the amounts of Cu spread per hectare of land, where the Cu contribution is coming from the manure of pigs fed excess levels. Therefore, there is a growing concern to find an alternative to antibiotics and pharmacological levels of Zn and Cu due to antimicrobial and environmental concerns.

Alternatives to improve nursery performance

The laws in the European Union and the United States that have banned the use of antibiotics have led to a need for alternatives to aid in the reduction of post-weaning lag. This gave rise to the implementation of pharmacological levels of zinc and copper, which have been used to promote gut health, immune response, and growth performance in nursery pigs. In June 2022, the European Union is also banning the use of pharmacological levels of zinc due to concerns with antimicrobial resistance and accumulation of excess metals in the environment from the manure. Alternatives to improve nursery performance that has been studied include organic acids, probiotics, prebiotics, minerals, oligosaccharides, and phytogenic compounds (Hashemi et al., 2011; Valenzuela-Grijalva et al., 2017).

Phytogenic compounds have been considered a growth-promoting alternative, but their impact on performance has been conflicting (Upadhayay et al., 2014). With consumer concerns, there has been a push to investigate natural alternatives to antibiotics and supplements like Zn and Cu (Dhama et al., 2014, Golestan et al., 2010). Although some studies show inconsistent results, these phytogenic compounds have been proposed to replace antibiotics and aid in muscle synthesis (Herrera et al., 2015; González-Ríos et al., 2016; Devi et al., 2015). Some phytogenic additives enhance the palatability of feed, having a positive effect on growth performance (Al-Kassie et al., 2009; Bartoš et al., 2016; Janz et al., 2007; Jiang et al., 2007). Jugl-Chizzola et al. (2006) and Yan et al. (2011) reported that high inclusion levels of phytogenic additives (>1500 mg/kg) showed a decrease in feed intake.

Phytogenic compounds

A phytogenic compound is defined as a group of natural growth promoters that are used as a feed additive with a plant or herb origin. There are varying impacts on performance due to the variety of structures and active components in different plants and herbs. There has been a rise of interest in phytogenic compounds for the potential positive impacts on growth performance, antimicrobial, antioxidant, and immune system (Golestan et al., 2010; Bahadoran et al., 2013; Krause et al., 2005). The mode of action in phytogenic additives is uncertain but proposes that physiological changes in animals fed phytogenic supplements are part of these principal mechanisms: improved feed intake levels, improved nutrient digestion and absorption; and a source of anabolic activity on target tissues (Valenzuela-Grijalva et al., 2017; Surai et al., 2014; Golestan et al., 2010; Kroon et al., 1999; Bahadoran et al., 2013; Krause et al., 2005).

Dhama et al. (2014) reported that phytogenic additives have a variety of biological activities that are related to the gastrointestinal tract, including digestive secretions and nutrient absorption. There have been reports of a reduction of bacterial and pathogenic levels in the intestinal lumen with supplementation of phytogenic compounds (Ahmed et al., 2013). Multiple sources state that phytogenic supplementation developed anti-inflammatory properties in the lumen, leading to an enhanced gut morphology

(Muanda et al., 2011; Khalaji et al., 2011; Diao et al., 2015). Varel et al. (2001) also report that supplementation has led to a reduction in the fermentation of nitrogen compound waste. Valenzuela-Grijalva et al. (2017) reports that actions of phytogenic compounds that seem to improve gastrointestinal health has complex functions and may include the use of multiple mechanisms. Many reports suggest phytogenic compounds may improve gut function, but the number of studies on swine is limited.

Some phytogenic compounds have shown potential as growth promoters in the early stages of livestock by aiding in muscle synthesis (Herrea et al., 2011; Devi et al., 2015). Devi et al. (2015) and Liu et al. (2008) report the anabolic effect can be produced from phytogenic compounds, specifically plant extracts. It has been reported in poultry studies that phytogenic compound supplements may aid in the immune response by increasing the activity of lymphocytes, immunoglobulins, monocytes, and macrophages (Alipour et al., 2015; Khalaji et al., 2011). Phytogenic compounds have been suggested as an alternative to antibiotic growth promoters, but few studies have been completed on swine.

Quillaja saponin extract

Quillaja saponin is the extract from the soap bark tree, Quillaja Saponaria, and contains a non-steroid saponin called triterpenoids (Francis et al., 2002). A saponin is defined as a triterpene glycoside, sourced from plants that have a foaming property when agitated with water. Yucca Schidigera extract has been shown to improve growth performance in nursery pigs with an inclusion rate of 100mg/kg (Cromwell et al., 1985). Saponins from the Yucca extract are structurally different and have a steroid rather than a triterpenoid nucleus that is found in Quillaja Saponaria (Ilsley et al., 2005). This difference in structure could be the reasoning behind a difference in growth performance parameters.

Quillaja saponins have been stated as a performance enhancer (Windisch et al., 2008; Hu et al., 2006; Wang et al., 2017), with supporting evidence of increased ADG, ADFI, and F:G (Bartos et al., 2016; Vaclavkova and Beckova, 2008). There are contradicting studies stating dietary QS had little influence on growth performance or immune response (Turner et al., 2000; Ilsley et al., 2005). Saponins have also been proposed to decrease the production of ammonia, but the underlying mechanisms are still unknown (Francis et al., 2002; Colina et al., 2001).

Gee et al. (1996) states high levels of saponins can have adverse effects on the intestinal villi, which can compromise weaned pigs' ability to absorb required nutrients. Saponins are known for their bitter taste and increased levels in the diet can reduce palatability leading to reduced feed intake. Hu et al (2006) and Wang et al (2017) stated a reduction in growth performance at high doses of saponin supplementation. Ilsley et al. (2005) also stated a negative impact on growth performance with QS levels at 1300 mg/kg.

There is evidence of increased nutrient and CP digestibility in sows with 250 mg/kg supplementation (Ilsley et al., 2003). There was no reported change in growth performance in finishing pigs with an inclusion level of 400 mg/kg, but there was a reduction in NH_3 emissions compared to the control group (Dang and Kim, 2020). Turner et al. (2000) reported that 0, 125, 187.5, and 250 mg/kg in the diet had no effect on growth performance but had an increased rectal temperature post-immune challenge in

QS supplemented pigs. Inclusion of 0, 125, 250, and 500 mg/kg of crude saponin extract in the diet showed no significant changes in growth performance or immune response to a Salmonella typhimurium challenge in nursery pigs (Turner et al., 2002). Supplementation of 300 and 750 mg/kg of QS in diet also had no significant effect on growth performance, besides increased feed intake and higher C-reactive proteins on d 20 in nursery pigs on d 20 (Ilsely et al., 2005). Vaclavkova and Beckova (2008) noted that weaned pigs fed a diet supplemented with 125 mg/kg Quillaja saponin had higher feed consumption and feed conversion efficiency. The Turner et al. (2002) study used a crude extract that was around 10% saponin. Ilsey et al. (2005) suggests that a follow-up study similar to Turner 2002 is needed with a controlled pathogen challenge with a purified saponin.

Lipopolysaccharide challenge in pigs

The interactions between animal and the external environment mostly occur in the gastrointestinal tract. There is a critical role the mucosal barrier plays in digestion, absorption, and metabolism but also regulates the passage of pro-inflammatory molecules, microorganisms, and toxins (Farré et al., 2020). Inflammation can cause a reduction in barrier function and cause a shift in nutrient utilization towards immune support (Klasing and Johnstone, 1991). Lipopolysaccharide (LPS) is a component of the outer membranes of gram-negative bacteria including E. coli and Salmonella sp. that stimulates the innate immunity in pigs. Small levels of LPS can initiate an inflammatory response that can imitate a gram-negative infection. Lipopolysaccharide challenges are a common practice in immune response studies in swine (Wright et al., 2000). An LPS challenge will induce disease-like symptoms including diarrhea, vomiting, fever, and reduced ADFI (Webel et al., 2000).

Tumor necrosis factor-alpha

Cytokines are synthesized in response to an immune challenge, stressors, or infections. The production of cytokines is used for immune regulators to address the immune challenge, stressors, or infections to bring the body back to its homeostatic levels as soon as possible. The most common cytokines produced in responses to a bacterial infection or LPS challenge are interleukin-1, tumor necrosis factor-alpha (TNF-α), and interleukin-6. There has been extensive research looking at the role of TNF-α in response to immune challenges including TNF-α reducing collagen deposition (Pischon et al., 2004), TNF-α aids in muscle catabolism (Fischer and Hasselgren, 1991), TNF-α blocks lipid deposition and alters adipose tissue deposition (Ramsay et al., 2013), and TNF-α has negative effects on the gut barrier integrity (Liu et al., 2008). Tumor necrosis factor-alpha binds to two types of receptors: TNF-R1, which is found on all cell types and TNF-R2, which is found on immune and endothelial cells (Sethi et al., 2008). Tumor necrosis factor-alpha can activate nuclear factor kappa-light-chain-enhancer (NF-κB), which is a key factor in pro-inflammatory cytokine synthesis by playing a role in cell proliferation, cell adhesion, and immune response (Jarosz et al., 2017). In summary, TNF-α can be used as an indicator of inflammation.

C-reactive proteins

C-reactive protein is an acute phase serum protein and can serve as a mediator of immune response in pigs (Chomdej et al., 2004). C-reactive protein (CRP) in pig saliva is a minimally invasive assay that is useful in pig health monitoring while minimizing stress at the time of collection (Guzik et al., 2006, Eckersall, 2004). There is an additional benefit of collecting saliva and using it for analysis instead of blood since it does not clot (Wong, 2006). Wong (2006) also states that the downside to collecting saliva for CRP analysis is that the concentration levels are much smaller. Following an infection, the liver focuses on mediating acute phase protein (APP) synthesis based on proinflammatory cytokine stimuli. There are two classifications of APPs: positive APP and negative APP. Positive APPs are increased in the animal serum post-infection and examples of these are CRP, haptoglobin, serum amyloid A, and fibrinogen. Negative APPs have a reduction in synthesis following an infection and some examples of these include cortisol binding globulin, transthyretin, and retinol-binding protein. C-reactive proteins are considered to be the first line of positive APP, with an increase in CRP levels within hours of infection (Ng et al., 2004; Peterson et al., 2004). C-reactive proteins are acute phase proteins that can provide an anti-inflammatory effect (Xia and Samols, 1997). There was an increase in CRP, but no difference in major-acute phase protein concentrations in pigs challenged with 15 μg/kg BW of LPS injection (Yin et al., 2017). This concludes that CRP is considered the first acting APP and can be used to look at inflammation levels in pigs.

Summary

There is little research on prediction models for growth performance based on starting nursery weights. The first study was conducted to predict nursery and finishing performance based on starting nursery weight. This study was completed to determine the changes in nursery and finishing performance compared to previous prediction models.

Weaned pigs require additional support in the nursery to support immune response and growth performance. With restrictions on antibiotics, Zn, and Cu, there is a need to find another alternative to meet these needs. Previous research has shown phytogenic compounds aiding in growth performance, but further research is necessary to determine effective supplementation rates at different production phases. Previous studies have not shown a significant improvement in growth performance or inflammatory response at varying levels of QS. Contradicting studies have noticed a difference with the supplementation of QS at 125 mg/kg for improved intake and feed efficiency (Vaclavkova and Beckova, 2008).

Therefore, more research is needed to determine the effect of this water-soluble plant extract on nursery pig performance and what level of supplementation is needed. Ilsey et al. (2005) suggested a follow-up study with a controlled pathogen challenge with a purified saponin. The second study was conducted to evaluate the effects of water-soluble QS on nursery pig performance and immune response in nursery pigs challenged with an LPS immune challenge. The present study utilized a 99% concentration of extract, diluted in stock solution for concentration levels of 0, 15.63, 93.75, and 187.52 mL/L. A timeframe around the LPS challenge and weekly saliva collections were included to evaluate inflammatory markers and determine a response pattern of pigs challenged with LPS.

CHAPTER III

PREDICTION OF NURSERY AND FINISHING PERFORMANCE BASED ON STARTING NUSERY WEIGHTS

Abstract

A total of 5 experiments were used to determine the relationship between nursery start weight and nursery/finishing performance traits. In each experiment, 48 pens containing 11 pigs/pen (0.65 m^2/pig) were utilized. Age entering the nursery was 18-21 d and average BW was 5.9 kg. Pigs were blocked by BW and allotted to pens upon arrival and fed diets meeting or exceeding NRC (2012) recommendations. The nursery phase lasted between 42-45 d and pigs were marketed at a target weight of 136 kg. Pigs remained in the same pens from weaning to market. Data were analyzed using PROC REG/PROC CORR procedure in SAS. Pen served as experimental unit with a total of 240 observations. Nursery BW upon entry had positive ($P < 0.01$) correlations (r) with nursery end BW (0.57), ADG (0.23), and ADFI (0.30). There was a linear relationship between nursery starting BW and ending nursery BW [Ending BW = 2.41(nursery start BW, kg) + 8.99, $R^2 = 0.32$, $P < 0.001$]. Starting nursery BW also was positively ($P < 0.01$) correlated with finishing end BW (0.58), ADG (0.21), ADFI (0.30), and negatively correlated with G:F (-0.25). A linear relationship was noted between starting nursery BW and market BW [Market wt = 8.66(nursery start BW, kg) + 85.66, $R^2 = 0.34$, $P < 0.001$]. Linear relationships ($P < 0.01$) also were noted for nursery starting BW on

finishing ADG, ADFI, and G:F. Finishing starting BW was positively correlated ($P < 0.01$) with market BW (0.52), ADG (0.32), and ADFI (0.37) and negatively correlated with G:F (-0.23). Starting finishing BW had a linear relationship with market BW [Market BW = 1.82(finishing start BW, kg) + 94.54, $R^2 = 0.27$, $P < 0.001$]. Nursery starting BW has positive effects on growth performance in nursery and finishing phases as well as market weight.

Introduction

Pork is the most consumed animal protein in the world. Pork is known as a high-quality source of protein and a more cost-effective option compared to beef or fish. To be able to maintain cost-effectiveness, pork producers must be able to optimize production and minimize costs of production. The transition from weaning into the nursery is one of the most altering stages of a pigs life and can impact their performance in the nursery. There is a large focus in the industry to make this transition as smooth as possible, so that the post-weaning lag is reduced. Reduced performance in the nursery leads to less efficient production, making the producer not as cost-effective as they could be. Post-weaning lag is defined as reduced growth performance, a reduction in feed intake, post-weaning diarrhea, and increased mortality (Pluske et al., 1997; Ravindran et al., 1993).

There are consumer concerns about livestock production being sustainable and safe. There are producer concerns about livestock production being cost-effective and efficient. Being able to produce high-quality pork while reducing days to market meets these demands of reducing days on feed, less water used, and less waste produced. One way to optimize production is to understand the estimated performance for nursery ADFI, ADG, and ending weight. This value could be utilized by knowing the starting nursery weight and creating a prediction value to determine that pigs expected average performance in the nursery and the finisher. There is contradicting evidence in the scientific literature regarding performance indicators in pigs. Some researchers state that lightweight pigs at weaning have poor growth performance compared to heavier pigs (He et al., 2016; Douglas et al., 2013). Other literature shows light weaning weight pigs can catch up to heavier pigs (Huting et al., 2018; Zeng et al., 2019). It has been stated that there is a positive linear relationship between nursery ADG and finishing weight (Zeng et al., 2019). However, there is little research on prediction models for growth performance based on starting nursery weights. One article has a prediction value using a weaning weight at d 28 (**W**) to predict the number of days it takes to grow to 20 kg (**T**); **T** = 52.1 (± 1.69) – 3.39 (± 0.224) **W** (R^2 =0.85, P<0.001) (Campbell et al., 1990). This equation proposes that 1 kg at weaning will result in 3 fewer days for that pig to make it to 20 kg (Pluske et al., 2003). Other studies agree with this, stating heavier weight pigs at weaning maintain a heavier weight throughout their lifetime (Mahan and Lepine, 1991; Le Dividich et al., 2003). One paper even proposes that days to market can be reduced by 10 days for a pig 1 kg heavier at weaning (Cole and Close, 2001). Dietary requirements and research for nursery pig performance have advanced and an updated model for predicting nursery performance similar to previous models is needed. The objective of this study was to predict nursery and finishing performance based on starting nursery weight. This study was completed to determine the changes in nursery and finishing performance compared to previous prediction models.

Materials and Methods

Experimental Design

A total of 5 experiments were used to determine the relationship between nursery start weight and nursery and/or finishing performance traits. In each experiment, 48 pens containing 11 pigs per pen (0.65 m^2/pig) were utilized. A total of 2,640 weaned pigs with an initial age entering the nursery of 18-21 d and an average BW of 5.9 kg. Pigs were blocked by BW and allotted to pens upon arrival and fed diets meeting or exceeding NRC (2012) recommendations. Pens contained one stainless steel feeder and one cup waterer (Suevia Model 929TM). Barn temperature upon arrival was 31.1°C and decreased by 1°C each week. Nursery pigs were fed a standard 4- or 5-phase feeding program based on the study. Feed intake and body weights were collected weekly during the nursery phase (d 7, d 14, d 21, d 28, d 35, d 41) to determine the average daily gain, average daily feed intake, and gain to feed ratios. Pigs were vaccinated with CICUMVENT® (Merck Animal Health, Madison, NJ) on d 3-5 and d 24-26. The nursery phase lasted between 42-45 d and pigs were marketed at a target weight of 136 kg. Pigs remained in the same pens from weaning to market. All studies within this analysis were approved by the Oklahoma State University International Animal Care and Use Committee (IACUC).

Statistical Analysis

Data were analyzed using PROC REG and PROC CORR procedure in SAS 9.4. Pen served as experimental unit with a total of 240 observations. Average ending nursery weight, average ending finishing weight, ADG, ADFI, and G:F served as the dependent variables. Average starting nursery weight and average starting finishing weight served as the independent variables. Water intake and ADFI were corrected to daily water and feed intake, by dividing water disappearance and feed intake per pen by pig days. The significance level was set to $P < 0.05$. The strength of the correlation and fit of the variables were measured with R^2 and r.

Results

Nursery BW upon entry had positive ($P < 0.01$) correlations (r) with nursery end BW (0.57), ADG (0.23), and ADFI (0.30). There was a linear relationship between nursery starting BW and ending nursery BW [Ending BW = 2.41(nursery start BW, kg) + 8.99, $R^2 = 0.32$, $P < 0.001$] (Figure 1). Starting nursery BW also was positively ($P < 0.01$) correlated with finishing end BW (0.58), ADG (0.21), ADFI (0.30), and negatively correlated with G:F (-0.25) (Table 1). A linear relationship was noted between starting nursery BW and market BW [Market wt = 8.66(nursery start BW, kg) + 85.66, $R^2 = 0.34$, $P < 0.001$] (Figure 2). Linear relationships ($P < 0.01$) also were noted for nursery starting BW on finishing ADG, ADFI, and G:F. Finishing starting BW was positively correlated ($P < 0.01$) with market BW (0.52), ADG (0.32), and ADFI (0.37) and negatively correlated with G:F (-0.23) (Table 1). Starting finishing BW had a linear relationship with market BW [Market BW = 1.82(finishing start BW, kg) + 94.54, $R^2 = 0.27$, $P < 0.001$] (Figure 3).

Discussion and conclusion

This study aimed to create a prediction model for nursery and finishing performance based on starting nursery performance. In this analysis, we were able to find a correlation between starting nursery weight on average ending nursery weight, average ending finishing weight, ADG, ADFI, and finishing G:F. As previously stated by Pluske et al. (2003), pigs that are 1 kg heavier at weaning will reach 20 kg, 3 days quicker. This general relationship is confirmed by other studies with similar models that heavier pigs at weaning will maintain a heavier weight to market (Dritz et al., 1996; Miller et al., 1999; Mahan and Lepine, 1991; Le Dividich et al., 2003). Campbell et al. (2013) proposes a prediction formula for days to get to 20 kg (T) based on starting nursery weight (W); $T = 52.1 (\pm 1.69) – 3.39 (\pm 0.224) W$. The current study agrees with previous literature showing a positive correlation between heavier starting BW on ending nursery weight and market weight (Mahan and Lepine, 1991; Le Dividich et al., 2003). Similar to the observation from Pluske et al. (2003), pigs that are 1 kg heavier at weaning will weigh 2.4 kg heavier at the end of the nursery phase with the current prediction value. The current study also implies that 1 kg at starting nursery weight will be equivalent to 8.66 kg at market weight. One kg at starting finishing weight will be equivalent to 1.82 kg at market weight in the present study. To the author's knowledge, this is the first and only prediction value equation for nursery pig performance (Average ending weight, ADG, ADFI, and G:F) based on starting nursery weight. There is a correlation between starting nursery weight and ending nursery weight, showing that ending weight could be predicted.

Continued research on predicting nursery and finishing performance is needed as research on nutrition, genetics, etc. also progresses. Predicting nursery performance can aid in improving production practices and lead to an increase in productivity and flow of production. If pigs fall behind these prediction values, there can be an underlying cause including health-related challenges or other complications on the farm. Nursery starting BW has a linear correlation between nursery growth performance (ADG, ADFI, and ending nursery weight) and finishing growth performance (ADG, ADFI, G:F, and ending finishing weight). In conclusion, heavier pigs entering the nursery will have a heavier finishing weight or reach market weight sooner than lighter weight pigs entering the nursery.

The application of this study can be used in a research or commercial setting for an improved understanding of production flow and predicted market weights. If nursery and finishing performance falls below the prediction values, there could be an underlying issue relating to health, management, or the facility. With these performance prediction indicators, production can be optimized by understanding estimated performance in the nursery and finisher.

Table 1. Prediction equations of nursery performance and finishing performance based on starting nursery and finishing weight.

Predicting[1]:	Linear Equation				r	r p-value	R^2	R^2 p-value
NEwt=	8.99	+	2.41	(NSTwt[2])	0.57	< .0001	0.32	< .0001
NADG=	0.30	+	0.02	(NSTwt[2])	0.23	0.0003	0.06	0.0003
NADFI=	0.39	+	0.03	(NSTwt[2])	0.30	< .0001	0.09	< .0001
FEwt=	85.66	+	8.66	(NSTwt[2])	0.58	< .0001	0.34	< .0001
FADG=	0.73	+	0.02	(NSTwt[2])	0.21	0.001	0.05	0.001
FADFI=	0.59	+	0.12	(NSTwt[2])	0.30	< .0001	0.09	<.0001
FGF=	0.43	-	0.01	(NSTwt[2])	-0.25	0.0002	0.07	< .0001
FEwt=	94.54	+	1.82	(FSTwt[3])	0.52	< .0001	0.27	< .0001
FADG=	0.67	+	0.01	(FSTwt[3])	0.32	< .0001	0.10	< .0001
FADFI=	1.49	+	0.03	(FSTwt[3])	0.37	< .0001	0.14	< .0001
FGF=	0.43	-	0.00	(FSTwt[3])	-0.23	0.0004	0.07	< .0001

[1] NEwt: average ending nursery weight, NADG: nursery average daily gain, NADFI: nursery average daily gain, FEwt: average ending nursery weight, FADG: finishing average daily gain, FADFI: finishing average daily feed intake, FGF: finishing gain to feed ratio

[2]NSTwt: average starting nursery weight

[3]FSTwt: average starting finishing weight

Figure 1. Relationship between starting nursery weight and ending nursery weight.

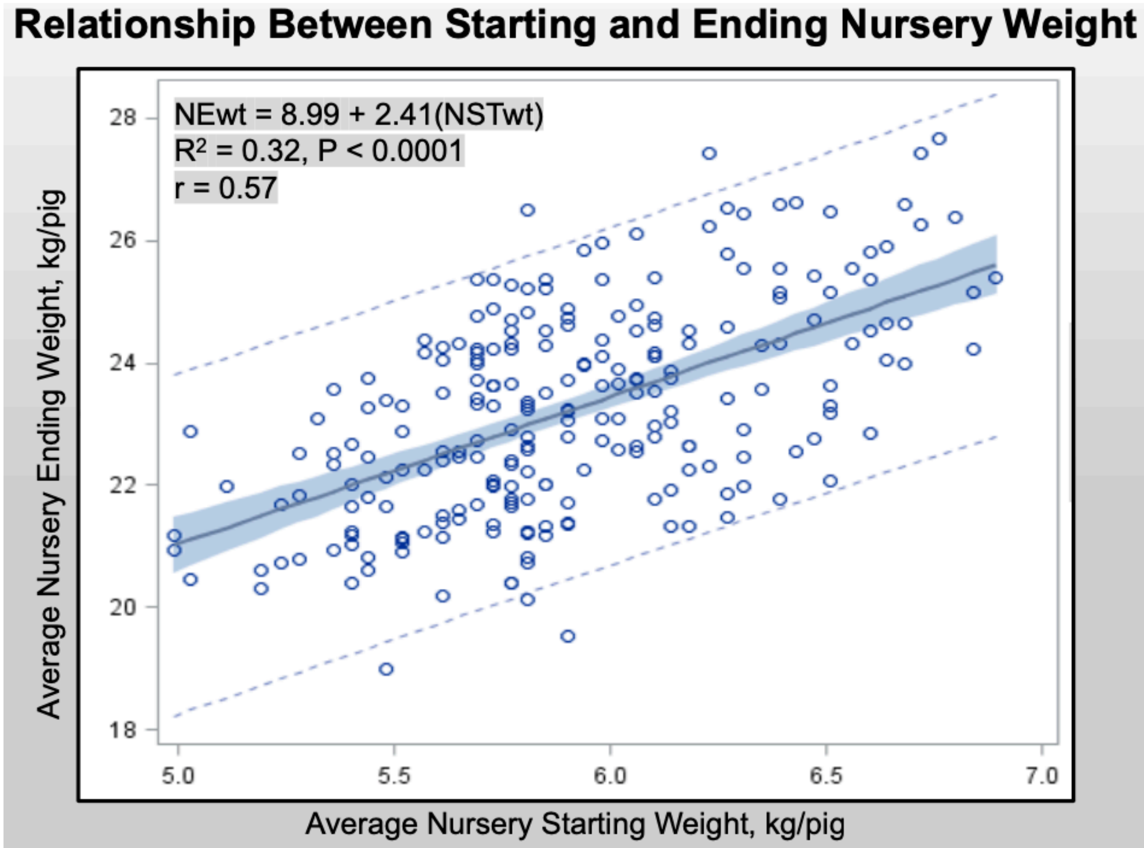


Figure 2. Relationship between starting nursery weight and ending finishing weight.

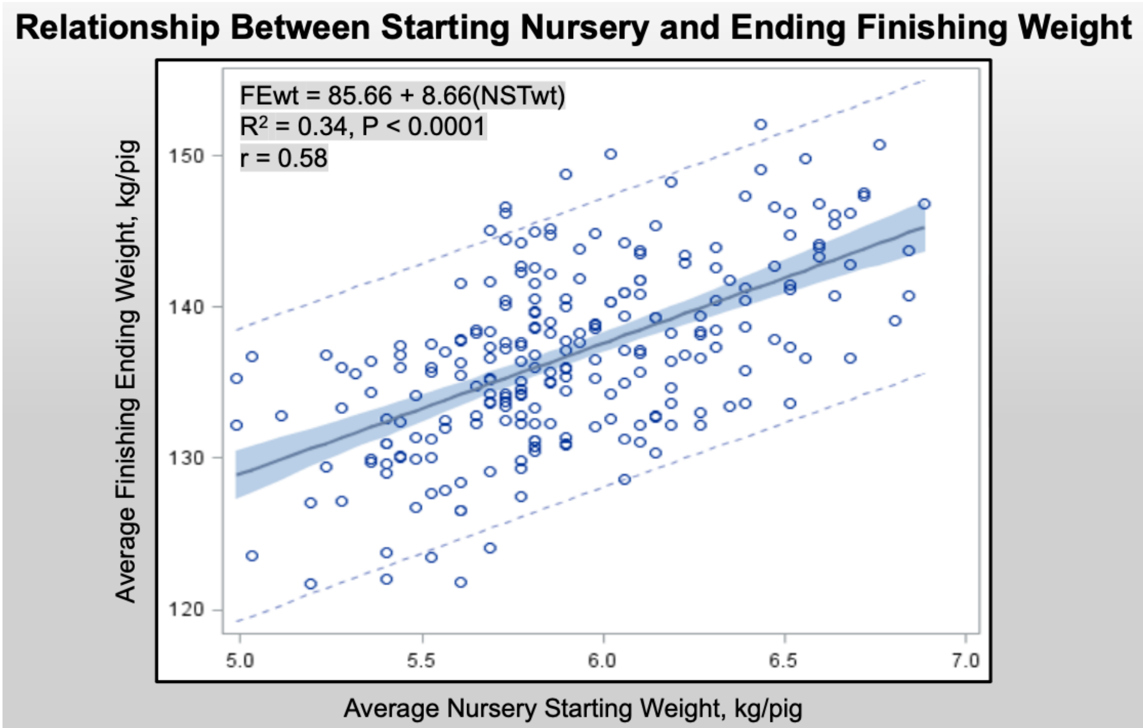
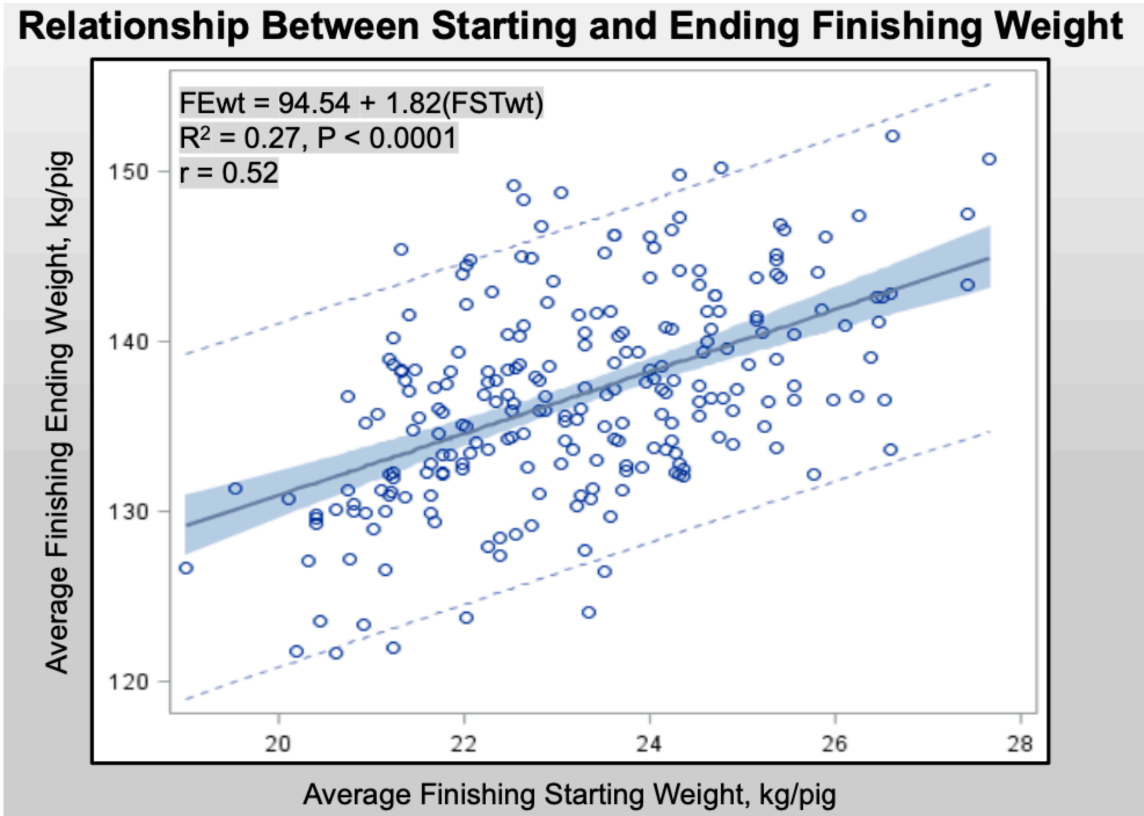


Figure 3. Relationship between starting finishing weight and ending finishing weight.



CHAPTER IV

EFFECT OF A WATER-SOLUBLE PLANT EXTRANT ON NURSERY PIG PERFORMANCE

Abstract

The objective of this study was to investigate the efficacy of a water-soluble phytogenic product on growth performance and immune response of nursery pigs. Two-hundred and eighty pigs were utilized in this 42-day study. Pigs were allocated to pens (10 pigs/pen; 7 pens/treatment) and pens were randomly assigned to 1 of 4 treatments on d 0. Four water treatments consisted of 4 different levels (0, 16, 94, and 188 ml/L) of Quillaja Saponaria (QS) in a stock solution water medicator and set to a 1:128 ratio for drinking water. Control (CON) consisted of 0 mL/L QS; Q2 consisted of 16 mL/L QS and administered all 42 d of the study; Q12 consisted of 94 mL/L QS and administered on d 1-5 and d 18-28 of the study; Q24 consisted of 188 mL/L of QS and administered on d 1-5 and d 18-28 of the study. On d 23 of the study, pigs were injected intramuscularly with LPS (10 ug/kg BW). Pigs and feeders were weighed weekly to determine ADG, ADFI, and G:F. Blood samples, BW, and rectal temperature (RT) were taken before the LPS injection on d 23 and on h 3, h 6, h 12 and h 24. Data were analyzed using the MIXED procedure in SAS with pen as the experimental unit. Relative to CON, Q2 had increased ADG ($P < 0.05$), ADFI ($P < 0.05$) and G:F ($P < 0.05$). There was no significant difference between treatments for TNF-α ($P > 0.10$). There was a reduction in

CRP in Q12 supplemented pigs compared to the control ($P < 0.05$) and an increase in CRP in Q2 supplemented pigs compared to the other three treatments on d 22 ($P < 0.05$).

Introduction

Pork is the leading animal protein source consumed in the world. To be able to meet consumer's demands, the pork industry must be able to produce pork as efficiently as possible. Nutrition plays a key role in efficiency and cost-effectiveness in pork production, with feed costs making up 60% of overall production costs (Lammers et al., 2008).

The weaning transition is the most stressful stage of a pig's life, due to changes in diet, environment, and social encounters. The gastrointestinal tract of weaned pigs is being altered as they transition from a milk-based diet to a meal-based diet which leads to post-weaning diarrhea. These stressors and exposure to pathogens during transit lead to depressed growth performance and immune function (Lallès et al., 2004; Moeser et al., 2007; Campbell et al., 2013). This reduction in performance is also known as post-weaning lag. At this stage of life, the immune system is still developing and is more susceptible to immune challenges (Kick et al., 2012; de Lange et al., 2010). Addressing the challenges related to weaning has been a peak interest in the pork industry to be able to reduce post-weaning lag.

The use of antibiotic growth promoters (AGP) in nursery diets helped reduce post-weaning lag. The European Union banned the use of these AGPs in 2006, the ban also was implemented in the United States. Researchers are still looking into alternatives for AGPs, and more research is needed to determine the best alternatives. U.S. pork production currently uses pharmacological levels of zinc oxide and copper sulfate for their growth-promoting effects. The European Union is banning the pharmacological levels of zinc oxide in livestock diets starting June 2022 due to environmental and antimicrobial resistance concerns.

There has been increased interest in phytogenic additives in nursery diets as an alternative to feed-grade antibiotics, zinc oxide, and copper sulfate. Phytogenic additives, also known as plant extracts, have shown improved disease prevention, immune response, and growth performance (Windisch et al., 2008). One specific plant extract of interest is Quillaja Saponaria, commonly known as the "soap bark" plant.

Quillaja Saponaria is an evergreen tree native to central Chile and saponins are extracted from the bark of the tree. Quillaja Saponaria is a natural saponin that has foaming properties that are commonly used as detergents, food additives, cosmetics, cough relievers, and anti-inflammatory aids. Therefore, the objective of this study was to evaluate the effect of Quillaja Saponaria on growth performance and immune response in nursery pigs.

Materials and methods

Animal care, housing, and experimental design

All experimental procedures were performed in accordance with the Oklahoma State University Institutional Animal Care and Use Protocol and were approved by this committee. The live animal research was completed at the Oklahoma State University Swine Research and Education Center (Stillwater, OK). Two hundred and eighty weanling pigs (5.71 kg; 20 d of age) were used to determine the effects of a nutritional/plant-based water supplement containing Quillaja Saponaria extract on growth performance and immune response of nursery pigs. Upon arrival, pigs were randomly allotted by BW to one of 28 pens consisting of 7 replicate pens per treatment with ten pigs per pen.

Four water treatments consisted of 4 different levels (0, 16, 94, and 188 ml/L) of Quillaja Saponaria in a stock solution water medicator and set to a 1:128 ratio for drinking water. Control (CON) consisted of 0 mL/L QS; Q2 consisted of 16 mL/L QS and administered all 42 d of the study; Q12 consisted of 94 mL/L QS and was administered on d 1-5 and d 18-28 of the study; Q24 consisted of 188 mL/L of QS and was administered on d 1-5 and d 18-28 of the study.

Feed intake, water intake, and growth performance:

Pigs were housed in a temperature-controlled room and allowed ad libitum access to feed and water throughout the experiment. Pigs were fed standard, corn-soybean meal diets in four dietary phases (Phase 1: d 0-7, Phase 2: d 7-14, Phase 3: d 14-21, Phase 4: d 21- 42), all meeting or exceeding NRC recommendations (Table 2). No antibiotics or pharmacological levels of zinc or copper were used in these diets. Pigs and feeders were weighed weekly to determine ADG, ADFI, and G:F. Water meters were used to determine water disappearance and were recorded daily at the same time. Pigs were weaned from the sow on d 20 of age, blocked by weight, then randomly assigned to 1 of 28 pens in the nursery (Figure 4). Within the nursery, pens were randomly assigned to 1 of 4 water treatments. Water treatments were employed using a Dosatron water medicator set to a 1:128 ratio. A stock solution for each treatment was prepared daily to supply the concentrations of QS. Water samples were collected for further analysis and feed was sampled after each mixing to determine proximate analysis.

Feed, water, and saliva samples collection

Approximately 500 g of feed were collected upon completion of mixing each diet, samples were collected from each feed bag and stored at 20°C until proximate analysis. Approximately 180 mL of water from each water treatment was collected weekly, samples were stored at 4°C until water composition analysis. Saliva samples were collected weekly during the trial. Ropes were hung in each pen on d 7, 14, 21, and 28 to collect saliva at the same time each week. Saliva samples were stored at -18°C until further analysis.

Diet and water analysis

Diets were formulated as basal diets to meet NRC (2012) recommendations (Table 2). Diet samples were analyzed by ServiTech (Dodge City, KS, USA) for chemical composition (Table 3). Water samples were analyzed by Oklahoma State University Soil, Water and Forage Analytical Laboratory (Stillwater, OK, USA) for chemical composition (Table 4).

Fecal score collection

Fecal scoring was performed on d 7 14, 21, 23, 24, 25, 26, 27, 28, 35, and 42 at the same time of day by the same personnel to maintain scoring consistency. The fecal scoring system was based on a 3-point scale: 1 = normal feces, 2 = mild diarrhea with looseness but still some form, and 3 = water diarrhea (Figure 5). Scores were determined based on the worst consistency found within the pen.

Immune challenge

On d 23 of the study, an acute LPS challenge was administered intramuscularly with lipopolysaccharide (LPS) from Escherichia coli serotype O55:B5 (lyophilized powder purified by phenol extraction; Sigma-Aldrich, St. Louis, MO). Pigs were weighed and then all pigs in each pen received an LPS dose of 10 ug LPS/kg body weight based on average pen weight. Within each pen, two pigs closest to the average weight of the pen were ear-tagged, weighed, rectal temperature recorded, and blood collected prior to the LPS administration at h 0. At h 3, 6, 12, and 24 post-injections, the ear-tagged pigs were weighed, rectal temperature recorded, and blood collected.

Rectal temperatures were collected using a digital thermometer. The thermometer was left inside the rectum for 5 seconds until a stable reading was recorded. Temperatures were collected twice per pig at h 0 3, 6, 12, and 24 and the average between readings was used.

Blood was taken from the jugular vein in the supine position using a 20-gauge 3.8 cm vacutainer needle with a 10 mL sterile serum tube (BD, Franklin Lakes, NJ). The h 0 samples collected were used as the baseline values. Blood samples were stored on ice until processed in the lab to collect serum. Blood was centrifuged for 20 minutes at 1000 x g to collect serum and stored at -20°C until further analysis.

Saliva was collected weekly using 100% cotton, three-stranded ropes. The ropes were zip tied to the top of each pen gate, allowing for the rope to be at shoulder height of the pigs. Pigs were allowed to chew on the ropes for 20 minutes before saliva collection. Ropes were then cut, placing the salivated ends in Ziploc bags. Each bag was squeezed and the fluid from the roped was placed in a test tube. Samples were centrifuged at 2500 x g, 4°C for 15 min to allow dirt and feed particles to be separated. The clear liquid was transferred into 1.5 mL microtubes and stored at 20°C until salivary C-reactive protein (CRP) analysis.

Serum was collected and analyzed for TNF-α using commercial porcine ELISA kits (R&D Systems Inc. Minneapolis, MN). Absolute values for the blood parameters are reported for h 0, 3, 6, 12, and 24. The change between each hour was calculated to determine the effect of treatment on immune system response. The TNF-α samples were tested in duplicate. Samples from h 0 and 24 did not have a dilution rate. Samples from h 3 were diluted in a 1:7 ratio, h 6 were diluted in a 1:2 ratio, and h 12 were diluted in a 1:1 ratio.

Saliva was analyzed for C-reactive protein (CRP) to determine the effect of treatment on this measure of inflammation. A commercial ELISA kit was used (Life Diagnostics Co. Ltd. West Chester, PA). Absolute values for the saliva parameters are reported for d 7, 14, 21, 28, 35, and 42. The change between each hour was calculated to determine the effect of treatment on immune system response. The CRP samples were tested in duplicate.

Statistical analysis

Data were analyzed as a randomized complete block design using analysis of variance procedures. Proc GLM, LS means and pdiff were used to determine the effects of QS supplementation through the water by treatment. Pen served as the experimental unit. Variability of data is expressed as standard error (SE) and the statistical significance was noted at $P \leq 0.05$. The average inter-assay CV for TNF-α was 8.21% and the average intra-assay CV for TNF-α was 8.63%, respectively. The average inter-assay CV for CRP was 7.65% and the average intra-assay CV for CRP was 8.05%, respectively.

Results

Growth performance

The growth performance measures are presented in Table 5. Growth performance was collected for periods d 0-22, d 22-42, and overall d 0-42. The initial body weight was not different across treatments ($P > 0.10$), with an average of 5.71 kg on d 0. From d 0-22, there was an increase in ADFI for pigs on Q2 treatment compared to Q24 ($P < 0.05$). The Q2 treatment had an improved G:F ratio compared to the control ($P < 0.05$). Q2 also had a higher ADG compared to control ($P < 0.05$). When comparing body weights, Q2 had a higher ending weight on d 22 than Q24 ($P > 0.05$). Overall, there were no significant differences in ADWI, W:F, fecal scores, or mortality rates ($P > 0.10$). There was a decrease in ADWI from d 1-5 with the Q24 treatment compared to the control ($P < 0.05$). During the second pulse dose, there was a decrease in ADWI with Q12 and Q24 compared to the control ($P < 0.05$). There was no difference in ADWI between the control and Q2 during either pulse dose period ($\underline{P} > 0.10$) (Table 8).

From d 22-42, Q2 had higher ADFI compared to control and Q24 ($P < 0.05$). Q2 had higher ADG compared to Q12 and Q24 ($P < 0.05$), but no difference from control, therefore no difference was noticed from the control treatment across treatments ($P >$

0.10). Q2 G:F was improved compared to the control treatment ($P < 0.05$). Q24 had a higher mortality rate than Q2 from d 22-42 ($P < 0.05$). There was no difference in ADWI or W:F ($P > 0.10$). There was a difference by treatment in the d 22-42 period for ADFI ($P < 0.05$).

There was a difference in treatments for d 0-42 ADFI and ADG ($P < 0.05$). ADFI and ADG were higher in Q2 compared to the control, Q12, and Q24 ($P < 0.05$). There were no significant differences in G:F, W:F, or mortality rates ($P > 0.10$).

LPS Challenge

The immune response measures are presented in Table 6. Immune response was collected for periods h 0-3, h 0-6, h 0-12, and h 0-24 for BW, RT, and TNF-α and weekly for CRP, respectively. The baseline for collections was set at h 0 and there were no differences among treatments for BW, RT, or TNF-α at h 0, 3, 6, 12, and 24 ($P > 0.10$). There was an increase in TNF-α and CRP values following the LPS challenge across all treatments, but values returned to pre-challenge levels by d 42. There was a time effect across all treatments ($P < 0.05$). However, there were no treatment or time x treatment effects ($P > 0.10$) (Table 7). Overall, there were few differences in the immune response to LPS challenge across treatments. With few exceptions, there was no difference in BW, BW change, RT, RT change, or TNF-α concentrations.

Discussion and conclusion

Quillaja saponins have been suggested as a performance enhancer (Windisch et al., 2008; Hu et al., 2006; Wang et al., 2017), with supporting evidence of increased ADG, ADFI, and F:G (Bartos et al., 2016; Vaclavkova and Beckova, 2008). Results from the present study agree with previous studies showing an increase in ADG and ADFI with a low dose supplementation of QS. There was an overall enhancement in performance with the low dose supplementation, Q2. There are contradicting studies stating dietary QS had little influence on growth performance or immune response (Turner et al., 2000; Ilsley et al., 2005). Results are also in agreement with previous studies stating that there was little influence on growth performance with the higher levels of QS. There were no differences noticed between the control, Q12, and Q24 for performance characteristics. These results are similar to previous studies considering that the inclusion level of QS from Q12 and Q24 treatments are similar to Turner et al. (2000).

Some phytogenic additives enhance the palatability of feed, having a positive effect on growth performance (Al-Kassie et al., 2009; Bartoš et al., 2016; Janz et al., 2007; Jiang et al., 2007). Jugl-Chizzola et al. (2006) and Yan et al. (2011) reported that high inclusion levels of phytogenic additives (>1500 mg/kg) showed a decrease in feed intake. Saponins are known for their bitter taste and increased levels in the diet can reduce palatability leading to reduced feed intake. The reduction of ADWI can be caused by palatability issues due to strong taste and smell with high levels of QS. The water composition analysis shows a lower pH, and increased levels of potassium and magnesium levels in the Q24 sample (Table 4). The Q12 and Q24 treatments also have increased levels of iron, zinc, chlorine, and calcium. Consequently, the increased levels of QS in the Q12 and Q24 treatments could have a negative impact on palatability. Overall, there was no effect on ADWI, but on d 1-5 and d18-28 there was a decrease in intake during the pulse dose of Q12 and Q24 and intake was similar to the control on days not receiving the pulse dose. This concludes that decreased water intake could be due to a negative effect on palatability.

Previous results agree with the present study, having a reduction in BW and ADFI in increased levels of QS in Q12 and Q24. Further research is needed to investigate the impact of concentration levels of QS on growth performance. Hu et al (2006) and Wang et al (2017) observed a reduction in GP at high doses of saponin supplementation. Ilsley et al. (2005) also observed a negative impact on growth performance with QS levels at 1300 mg/kg.

Pigs administered LPS intramuscularly regardless of water supplement showed signs of increased body temperature and reduction in body weight. Previous studies state no difference in immune response with supplementation of QS in nursery pigs (Turner et al., 2000; Turner et al., 2002). There was a reported increase in RT post-immune challenge in QS supplemented pigs (Turner et al., 2000). Ilsely et al. (2005) stated little influence of QS on immune response but did show an increase in CRP on d 20 in nursery pigs. The present study showed that the Q2 treatment did not have a large reduction in BW during the immune challenge and was lower than Q12 from h 0-6. During the 24 h period of the immune challenge, the control and Q2 treatments gained weight while the Q12 and Q24 returned to the h 0 BW by h 24. During h 0-12, there was a higher change in RT with the Q2 supplemented pigs compared to Q12. Like previous studies, there were no other differences in immune response with supplementation of QS at varying levels. There was an increase in mortalities and removals with the Q24 treatment compared to the lack of mortalities and removals with Q2 following the LPS challenge.

There was no impact on the immune response for TNF-α in this model, but there was a reduction of CRP in Q12 supplemented pigs on d 14 and an increase of CRP in Q2 supplemented pigs on d 22. Ilsely et al. (2005) reported an increase of CRP in all QS supplemented pigs, but the present study only shows an increase with the low dose of QS.

Therefore, there is another underlying mechanism that led to improved growth performance with the Q2 treatment besides inflammatory response. The reasoning behind improved performance could be due to improved feed intake levels, improved nutrient digestion and absorption, or a source of anabolic activity on target tissues (Valenzuela-Grijalva et al., 2017; Surai et al., 2014; Golestan et al., 2010; Kroon et al., 1999; Bahadoran et al., 2013; Krause et al., 2005). An improvement in the performance of Q2 could be due to a less negative impact on palatability. With this treatment, the improvement of growth performance was observed with heavier BW prior to the immune challenge compared to Q24. This could be related to the lack of mortality and removals of Q2 and the increase of mortalities and removals from Q24. Water and feed intake are positively correlated, which supports the improved feed intake results of this study and the lack of depression in water intake with the Q2 treatment.

Nutrient digestion and absorption could have been improved with pigs on the Q2 treatment from an increase in digestive secretions as proposed by (Valenzuela-Grijalva et al., 2017). With previous studies using phytogenic compound supplementation, there has been an increase in the secretion of pancreatic and intestinal enzymes that speed up the digestion process and promote an improvement in digestibility and availability of nutrients. Improved performance could be due to a reduction of bacteria and pathogens in the lumen proposed by Ahmed et al. (2013). An improvement in gut morphology due to increased anti-inflammatory properties in the lumen could also be the reasoning behind improved performance with Q2 supplementation (Muanda et al., 2011; Khalaji et al., 2011; Diao et al., 2015). There is an ongoing discussion on phytogenic compounds and their impact on gut morphology. Phytogenic compounds are hydrophobic, and this allows the component to interact with the cell membrane. A previous study showed antimicrobial activity with a decrease in fecal *Salmonella* and E. coli counts (Ahmed et al., 2013). The Q2 treatment also showed a decrease in *E. coli* scores from a fecal swab done on d 36 of this study (data not shown). Leading to the conclusion that the microbiome was altered with the supplement of Q2 treatment. There was a physiological change in performance with pigs supplemented with Q2, but the mode of action that led to this outcome is still uncertain and further research is needed.

From the previous chapter, there is a linear relationship between nursery starting BW and ending nursery BW [Ending BW = 2.41(nursery start BW, kg) + 8.99, $R^2 = 0.32$, $P < 0.001$]. The starting nursery weight in the Quillaja Saponaria study was 5.71 kg, with a predicted ending nursery weight of 22.75 kg. A linear relationship was also noted between starting nursery BW and market BW [Market wt = 8.66(nursery start BW, kg) + 85.66, $R^2 = 0.34$, $P < 0.001$]. The predicted market weight for pigs in the Quillaja Saponaria study is 135.13 kg, based on the average starting weight of 5.71 kg. Starting finishing BW has a linear relationship with market BW [Market BW = 1.82(finishing start BW, kg) + 94.54, $R^2 = 0.27$, $P < 0.001$]. With varying ending nursery weights by treatment, the predicted market weights by treatment are 129.48, 131.39, 129.17, and 128.64 kg for CON, Q2, Q12, and Q24, respectively). This data would suggest that the

Q2 treatment is predicted to have a heavier market weight compared to the other three treatments.

Overall, there was an increase in performance with Q2 supplementation without the use of antibiotics, Zn, or Cu. Supplementation of QS at 16 mL/L resulted in improvements in ADFI, ADG, and G:F during d 0-22 compared to the control. During d 22-42 there was also an improvement in ADFI and G:F in Q2 compared to the control. Therefore, there was an improvement in ADFI and ADG during d 0-42 with Q2 supplementation compared to the control. There remains a growing concern to find an alternative to antibiotics and pharmacological levels of Zn and Cu due to antimicrobial and environmental concerns. Further research is needed for dosage levels with a continuous dose.

Table 2. Formulated diet composition (as-fed basis).

	Diets[1]			
Ingredients %	N1	N2	N3	N4
Corn, yellow dent	32.55	38.54	54.07	59.26
Soybean meal, 47.5% CP	15.00	20.00	26.32	34.30
Whey, dried	25.00	25.00	10.00	-
Lactose	7.00	-	-	-
Plasma spray-dried	6.00	2.50	-	-
Blood cell, spray-dried	-	1.25	1.25	-
Fish Meal	6.00	4.00	2.00	-
Soy Protein Concentrate	2.21	2.12	-	-
Soybean Oil	4.00	4.00	3.00	3.00
L-Lysine HCl	0.17	0.21	0.27	0.25
DL-Methionine	0.18	0.21	0.17	0.11
L-Threonine	0.07	0.10	0.12	0.09
Dicalcium Phosphate	0.67	0.93	1.39	1.58
Limestone	0.45	0.44	0.72	0.74
Salt	0.50	0.50	0.50	0.50
Nursery Vit. Premix[2]	0.05	0.05	0.05	0.05
Trace Mineral Premix[3]	0.06	0.06	0.06	0.06
SelPlex	0.05	0.05	0.05	0.05
Choline Cl	0.03	0.03	0.03	-
Total	100.00	100.00	100.00	100.00

[1]N1: nursery phase 1, fed for one week of study (from d1-7); N2: nursery phase 2 fed from d 8 to 14; N3: nursery phase 3, fed from d 15 to 21; N4: nursery phase 4, fed from d 22 to 42.

[2]Vitamin premix was ordered from Ralco (Neosho, MO, USA). Vitamin premix was provided per kg of diet and consists of: vitamin A, 5506.61 IU/kg; vitamin D, 825.99 IU/kg; vitamin E, 37.79 IU/kg; vitamin B12, 20.37 mcg/kg; vitamin B6, 0.69 mg/kg; vitamin K, 2.86 mg/kg; biotin, 110.13 mcg/kg; folic acid, 0.61 mg/kg; niacin, 24.78 mg/kg; D-pantothenic acid, 22.58 mg/kg; riboflavin, 4.96 mg/kg; thiamine, 1.10 mg/kg.

[3]Trace mineral mix was ordered from Ralco (Neosho, MO, USA). Trace mineral mix was provided per kg of diet and consists of copper 9.6 mg/kg; iron 90.67 mg/kg; iodine 0.36 mg/kg; manganese 31.8 mg/kg; zinc 99 mg/kg ppm.

Table 3. Analyzed diet chemical composition.

	Diets[1]			
Analyzed Chemical Composition[2]	N1	N2	N3	N4
Dry matter, %	91.1	89.5	88.2	87.4
Crude protein, %	22.2	21.6	18.9	20.9
Crude fiber, %	1.4	1.8	2.3	2.3
Crude fat, %	6.4	6.1	5.5	5.4
Calcium, %	0.84	0.85	0.84	0.8
Phosphorous, %	0.74	0.76	0.68	0.72
Magnesium, %	0.12	0.14	0.15	0.16
Potassium, %	1.11	1.18	0.97	0.99
Sulfur, %	0.29	0.26	0.23	0.23
Sodium, %	0.51	0.38	0.27	0.19
Zinc, mg/kg	105	87	105	124
Iron, mg/kg	227	224	272	245
Manganese, mg/kg	46	45	53	67
Copper, mg/kg	12	11	12	13
Total Fumonisins, ppm	0.27	0.54	0.53	0.96

[1]N1: nursery phase 1, fed for one week of study (from d1-7); N2: nursery phase 2 fed from d 8 to 14; N3: nursery phase 3, fed from d 15 to 21; N4: nursery phase 4, fed from d 22 to 42.
[2]Diets were analyzed by ServiTech (Dodge City, KS, USA).
[3]Crude protein = %N x 6.25.

Table 4. Analyzed water composition.

	Chemical Water Composition[2]										
Treatment[1]	pH	Na, ppm	K, ppm	Ca, ppm	Mg, ppm	Cl, ppm	TDS, ppm	Zn, ppm	Cu, ppm	Mn, ppm	Fe, ppm
Control	7.48	48.28	10.50	39.43	20.58	42.65	415.07	0.03	0.02	0.04	0.03
Q2	7.55	48.70	12.00	39.95	21.13	42.75	421.32	0.04	0.01	0.05	0.05
Q12	7.55	49.10	18.00	43.00	21.95	45.50	440.05	0.28	0.01	0.06	0.10
Q24	7.10	45.60	27.50	48.85	23.45	48.55	468.51	0.21	0.02	0.07	0.13

[1]Control (CON), consisted of 0 ml/L QS; Q2, consisted of 15.63 ml/L QS and administered all 42 d of the study; Q12, consisted of 93.76 ml/lL QS and administered on d 1-5 and d 18-28 of the study; Q24, consisted of 187.52 ml/L of QS and administered on d 1-5 and d 18-28 of the study

[2]Na: sodium, K: potassium, Ca: calcium, Mg: magnesium, Cl: chlorine, TDS: total dissolved solids, Zn: zinc, Cu: copper; Mn: manganese, Fe: iron

Table 5. Effect of Quillaja saponin extract concentration on growth performance of nursery pigs.

	Dietary Treatment[1]				
d 0-22	Control	Q2	Q12	Q24	SE
d 0 BW, kg[2]	5.78	5.65	5.65	5.74	0.058
ADG, kg[2]	0.18[a]	0.24[b]	0.19[ab]	0.18[a]	0.015
ADFI, kg[2]	0.25[ab]	0.28[a]	0.25[ab]	0.23[b]	0.013
G:F, kg[2]	0.73[a]	0.84[b]	0.78[ab]	0.76[ab]	0.029
ADWI, L[2]	1.08	1.07	1.04	0.92	0.066
W:F, L/kg[2]	4.48	3.79	4.25	3.97	0.336
Fecal Score	1.66	1.86	1.66	1.94	0.153
Mortality, %	4.30	1.40	1.40	0.00	0.180
d 22-42					
d 22 BW, kg[2]	10.23[ab]	10.96[a]	9.96[ab]	9.70[b]	0.360
ADG, kg[2]	0.43[ab]	0.463[a]	0.41[b]	0.41[b]	0.016
ADFI, kg[2]	0.66[a]	0.75[b]	0.68[ab]	0.65[a]	0.024
G:F, kg[2]	0.66	0.62	0.61	0.63	0.025
ADWI, L[2]	2.43	2.56	2.34	2.13	0.192
W:F, L/kg[2]	3.65	3.43	3.46	3.23	0.222
Fecal Score	1.77	2.00	1.99	1.96	0.084
Mortality, %	1.40[ab]	0.00[a]	2.90[ab]	7.10[b]	0.199
d 0-42					
d 42 BW, kg	19.18	20.23	19.01	18.72	0.603
ADG, kg[2]	0.30[a]	0.35[b]	0.30[a]	0.28[a]	0.014
ADFI, kg[2]	0.44[a]	0.50[b]	0.45[a]	0.43[a]	0.017
G:F, kg[2]	0.68	0.69	0.66	0.67	0.020
ADWI, L[2]	1.71	1.78	1.65	1.47	0.111
W:F, L/kg[2]	3.89	3.53	3.71	3.44	0.207
Fecal Score	1.71	1.93	1.81	1.96	0.083
Mortality, %	5.70	1.40	4.30	7.10	0.289

[1]Control (CON), consisted of 0 ml/L QS; Q2, consisted of 15.63 ml/L QS and administered all 42 d of the study; Q12, consisted of 93.76 ml/lL QS and administered on d 1-5 and d 18-28 of the study; Q24, consisted of 187.52 ml/L of QS and administered on d 1-5 and d 18-28 of the study

[2]ADG: average daily gain, ADFI: average daily feed intake, G:F: gain to feed ratio, ADWI: average daily water intake, W:F: water to feed ratio

[a, b] Values within row with unlike supersctipts differ ($P \leq 0.05$)

Table 6. Effect of Quillaja saponin extract on body weight, rectal temperature, and TNF-α following an LPS challenge.

	Dietary Treatment[1]				
Body Weight, kg	Control	Q2	Q12	Q24	SE
H0	11.26	10.99	11.14	10.92	0.387
H3	10.99	10.85	10.74	10.6	0.388
H6	10.98	10.89	10.72	10.59	0.388
H12	11.14	11.01	10.88	10.65	0.391
H24	11.72	11.28	11.13	10.93	0.489
H0-3	-0.27	-0.14	-0.40	-0.33	0.107
H0-6	-0.28^{ab}	-0.10^{a}	-0.43^{b}	-0.34^{ab}	0.100
H0-12	-0.12	0.02	-0.27	-0.28	0.125
H0-24	0.46	0.29	-0.01	0.01	0.203
Rectal Temp, °C					
H0	39.92	39.8	39.98	39.94	0.097
H3	41.43	41.26	41.45	41.31	0.130
H6	40.44	40.43	40.45	40.35	0.183
H12	39.99	40.33	39.93	40.11	0.178
H24	39.73	39.78	39.95	39.85	0.098
H0-3	1.52	1.47	1.47	1.38	0.119
H0-6	0.52	0.64	0.47	0.41	0.174
H0-12	0.07^{ab}	0.53^{a}	-0.05^{b}	0.17^{ab}	0.166
H0-24	-0.19	-0.02	-0.02	-0.09	0.101
Serum TNF-Alpha Concentration, pg/mL					
H0	223	225	241	269	35
H3	5618	5536	5682	6273	718
H6	2177	2027	2113	2433	274
H12	732	652	743	940	127
H24	244	222	259	209	25
H0-3	5395	5311	5440	6004	720
H0-6	1955	1802	1871	2164	263
H0-12	509	427	502	671	106
H0-24	21	-2	18	-60	34

[1]Control (CON), consisted of 0 ml/L QS; Q2, consisted of 15.63 ml/L QS and administered all 42 d of the study; Q12, consisted of 93.76 ml/lL QS and

administered on d 1-5 and d 18-28 of the study; Q24, consisted of 187.52 ml/L of QS and administered on d 1-5 and d 18-28 of the study

[a, b] Values within row with unlike subscripts differ ($P \leq 0.05$)

Table 7. Effect of Quillaja saponin extract on body weight, rectal temperature, TNF-α, and CRP looking at time effect.

		P-value			
	Estimate	Time	Trt	Time x Trt	LS Means SE
BW	10.97	<0.0001	0.88	0.58	0.4
RT	40.32	<0.0001	0.98	0.52	0.12
TNF-α	1840.96	<0.0001	0.72	0.99	312.17
CRP	58.16	<0.0001	0.37	0.16	8.77

Table 8. Average daily water intake during pulse dose administration.

	Dietary Treatment[1]				
	Control	Q2	Q12	Q24	SE
d 1-5	0.88[a]	0.78	0.71	0.65[b]	0.06
d 18-28	1.98[a]	2.11[a]	1.52[b]	1.45[b]	0.13

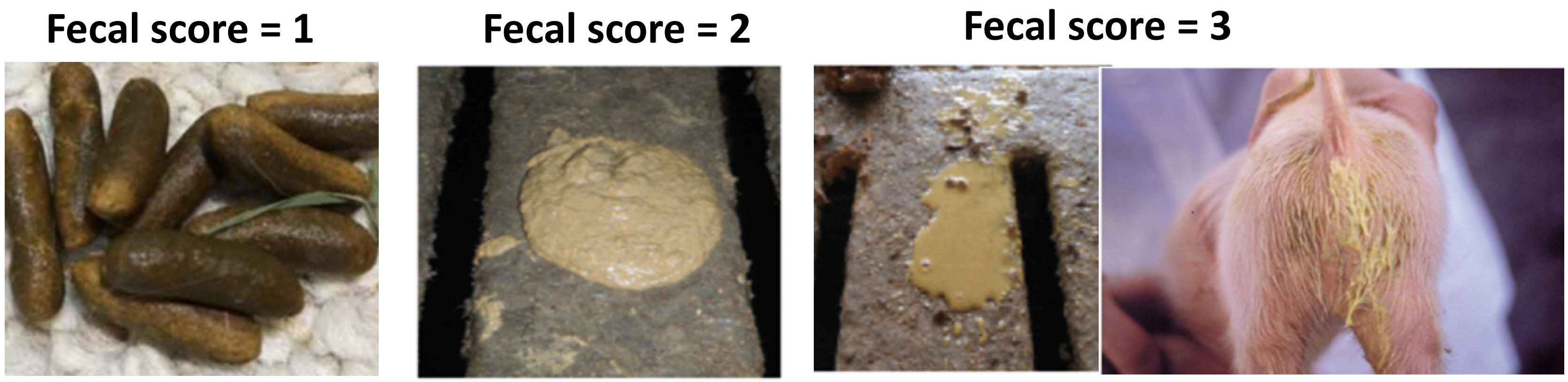
[1]Control (CON), consisted of 0 ml/L QS; Q2, consisted of 15.63 ml/L QS and administered all 42 d of the study; Q12, consisted of 93.76 ml/lL QS and administered on d 1-5 and d 18-28 of the study; Q24, consisted of 187.52 ml/L of QS and administered on d 1-5 and d 18-28 of the study

[a, b] Values within row with unlike subscripts differ ($P \leq 0.05$)

Figure 4. Pen allotment by block

East Barn								West Barn							
	Block 1		Block 2		Block 3		Block 4		Block 5		Block 6		Block 7		
Exit	Pen 8 Q24	Pen 9 CON	Pen 10 Q12	Pen 11 Q2	Pen 12 Q24	Pen 13 CON	Pen 14 CON	Pen 22 Q24	Pen 23 CON	Pen 24 Q12	Pen 25 Q24	Pen 26 Q12	Pen 27 Q24	Pen 28 Q2	Exit
	Pen 1 Q2	Pen 2 Q12	Pen 3 CON	Pen 4 Q24	Pen 5 Q2	Pen 6 Q12	Pen 7 Q12	Pen 15 Q2	Pen 16 Q2	Pen 17 Q24	Pen 18 CON	Pen 19 Q2	Pen 20 CON	Pen 21 Q12	

Figure 5. Fecal score collection scale.



CHAPTER V

SUMMARY

There has been an increase in research looking at alternatives to growth promoting antibiotics, zinc oxide, and copper sulfate. In swine nutrition, there has been few studies looking at Quillaja saponin extract supplementation and there is potential for more research with this focus. The present research demonstrated that nutritional water supplementations of Quillaja saponins have potential for improving nursery performance, although further research is needed to determine adequate inclusion levels. Moreover, this research suggests that lower levels of Quillaja saponaria extract supplemented to nursery pigs can improve nursery performance with the absence of growth promoting antibiotics, zinc oxide, and copper sulfate. More studies in this area are essential to find alternatives, improve nursery growth performance and to understand underlying mechanisms of phytogenic compounds.

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APPENDICES

Appendix Table 1. Pen mean for nursery growth performance

Exp	Pen	N days	NavgSTwt	NavgEwt	NADG	NADFI	NGF
2	1	42	13.27	54.60	0.98	1.36	0.72
2	2	42	13.36	55.00	0.99	1.41	0.70
2	3	42	12.91	51.82	0.93	1.31	0.71
2	4	42	13.36	54.09	0.97	1.38	0.70
2	5	42	12.55	49.55	0.88	1.23	0.71
2	6	42	13.36	49.73	0.87	1.24	0.70
2	7	42	12.55	54.64	1.00	1.46	0.68
2	8	42	12.91	53.55	0.97	1.41	0.69
2	9	42	13.00	51.27	0.91	1.32	0.69
2	10	42	12.27	53.73	0.99	1.36	0.73
2	11	42	12.55	51.64	0.93	1.38	0.67
2	12	42	12.55	53.27	0.97	1.34	0.73
2	13	42	12.73	54.09	0.98	1.40	0.70
2	14	42	12.82	50.27	0.89	1.32	0.68
2	15	42	12.55	55.91	1.03	1.39	0.74
2	16	42	12.64	55.91	1.03	1.37	0.75
2	17	42	12.64	48.64	0.86	1.26	0.68
2	18	42	12.36	53.50	0.98	1.40	0.70
2	19	42	12.82	58.45	1.09	1.48	0.73
2	20	42	12.82	55.60	1.02	1.31	0.78
2	21	42	12.73	49.27	0.87	1.24	0.70
2	22	42	13.00	51.18	0.91	1.33	0.68
2	23	42	13.00	54.90	1.00	1.30	0.77
2	24	42	13.18	53.73	0.97	1.39	0.69
2	25	42	12.64	54.91	1.01	1.38	0.73
2	26	42	12.55	51.45	0.93	1.33	0.70
2	27	42	12.64	52.09	0.94	1.38	0.68
2	28	42	12.55	53.00	0.96	1.36	0.71
2	29	42	13.36	57.55	1.05	1.47	0.72
2	30	42	12.73	52.18	0.94	1.29	0.73
2	31	42	12.91	54.09	0.98	1.36	0.72
2	32	42	12.27	49.09	0.88	1.29	0.68
2	33	42	12.73	55.73	1.02	1.42	0.72
2	34	42	12.82	54.73	1.00	1.41	0.71
2	35	42	13.27	52.73	0.94	1.32	0.71
2	36	42	12.73	54.45	0.99	1.46	0.68
2	38	42	12.36	51.82	0.94	1.39	0.68
2	39	42	12.18	50.45	0.91	1.31	0.69

2	40	42	12.18	51.36	0.93	1.34	0.70
2	41	42	12.55	53.45	0.97	1.37	0.71
2	42	42	12.91	55.64	1.02	1.39	0.73
2	43	42	12.09	51.55	0.94	1.30	0.72
2	44	42	12.27	53.30	0.98	1.35	0.72
2	45	42	12.45	53.64	0.98	1.43	0.69
2	46	42	12.55	47.82	0.84	1.22	0.69
2	47	42	12.64	51.36	0.92	1.27	0.73
2	48	42	12.00	52.36	0.96	1.41	0.68
3	2	42	14.09	58.64	1.06	1.54	0.69
3	3	42	14.09	55.27	0.98	1.42	0.69
3	4	42	14.55	56.91	1.01	1.41	0.71
3	5	42	14.82	57.91	1.03	1.50	0.68
3	6	42	13.09	57.00	1.05	1.42	0.74
3	7	42	14.36	55.45	0.98	1.44	0.68
3	8	42	12.73	53.64	0.97	1.43	0.68
3	9	42	13.18	57.27	1.05	1.48	0.71
3	10	42	13.00	52.27	0.94	1.36	0.69
3	11	42	14.27	56.09	1.00	1.47	0.68
3	12	42	13.73	60.45	1.11	1.56	0.71
3	13	42	13.82	56.82	1.02	1.49	0.69
3	14	42	14.73	52.91	0.91	1.29	0.71
3	15	42	15.18	56.00	0.97	1.42	0.69
3	16	42	13.64	53.64	0.95	1.41	0.68
3	17	42	12.64	52.09	0.94	1.34	0.70
3	18	42	14.73	58.64	1.05	1.49	0.70
3	19	42	14.45	56.36	1.00	1.41	0.71
3	20	42	12.55	52.27	0.95	1.36	0.69
3	21	42	12.55	52.91	0.96	1.36	0.71
3	22	42	14.45	53.64	0.93	1.32	0.71
3	23	42	13.73	57.82	1.05	1.48	0.71
3	24	42	14.64	57.09	1.01	1.42	0.71
3	25	42	14.09	56.36	1.01	1.39	0.72
3	26	42	13.45	53.18	0.95	1.32	0.72
3	27	42	14.09	55.45	0.98	1.42	0.69
3	28	42	13.91	56.36	1.01	1.47	0.69
3	29	42	14.36	58.36	1.05	1.50	0.70
3	30	42	14.55	55.91	0.98	1.52	0.65
3	31	42	13.00	54.55	0.99	1.40	0.71
3	32	42	12.82	51.36	0.92	1.29	0.71

3	33	42	13.82	58.50	1.06	1.48	0.72
3	34	42	14.82	60.45	1.09	1.59	0.68
3	35	42	14.91	61.00	1.10	1.54	0.71
3	36	42	12.91	55.91	1.02	1.51	0.68
3	37	42	14.27	54.45	0.96	1.35	0.71
3	38	42	14.00	53.55	0.94	1.29	0.73
3	39	42	15.09	55.45	0.96	1.33	0.72
3	40	42	13.18	50.91	0.90	1.34	0.67
3	41	42	14.64	54.36	0.95	1.37	0.69
3	42	42	13.18	53.18	0.95	1.34	0.71
3	43	42	13.45	54.55	0.98	1.43	0.68
3	44	42	15.00	58.18	1.03	1.49	0.69
3	45	42	13.18	55.91	1.02	1.41	0.72
3	46	42	14.09	53.64	0.94	1.34	0.70
3	47	42	14.18	58.70	1.06	1.47	0.72
3	48	42	13.00	54.27	0.98	1.39	0.71
4	1	41	12.18	46.56	0.84	1.17	0.72
4	2	41	12.18	46.10	0.83	1.20	0.69
4	3	41	12.82	44.36	0.77	1.21	0.64
4	4	41	12.00	48.10	0.88	1.25	0.71
4	5	41	12.82	45.73	0.80	1.20	0.67
4	6	41	12.82	49.00	0.88	1.36	0.65
4	7	41	12.00	45.45	0.82	1.41	0.58
4	8	41	12.91	47.00	0.83	1.20	0.69
4	9	41	12.82	48.00	0.86	1.20	0.71
4	10	41	13.00	47.90	0.85	1.24	0.69
4	11	41	12.00	45.91	0.83	1.23	0.67
4	12	41	11.91	47.73	0.87	1.34	0.65
4	13	41	11.45	45.45	0.83	1.22	0.68
4	14	41	12.82	51.25	0.94	1.20	0.78
4	15	41	12.82	46.80	0.83	1.23	0.67
4	16	41	12.36	46.64	0.84	1.26	0.67
4	17	41	12.73	45.00	0.79	1.20	0.65
4	18	41	13.82	51.64	0.92	1.37	0.67
4	19	41	11.45	44.80	0.81	1.24	0.66
4	20	41	13.27	50.90	0.92	1.39	0.66
4	21	41	12.09	41.90	0.73	1.13	0.65
4	22	41	12.82	45.91	0.81	1.23	0.66
4	23	41	13.00	47.09	0.83	1.26	0.66
4	24	41	13.55	50.80	0.91	1.35	0.67

4	25	41	11.91	48.55	0.89	1.30	0.69
4	26	41	11.91	45.00	0.81	1.28	0.63
4	27	41	12.36	44.55	0.78	1.26	0.62
4	28	41	12.18	46.64	0.84	1.30	0.65
4	29	41	12.45	47.64	0.86	1.25	0.69
4	30	41	12.73	49.36	0.89	1.36	0.66
4	31	41	11.91	46.73	0.85	1.25	0.68
4	32	41	12.27	46.82	0.84	1.31	0.64
4	33	41	12.82	51.50	0.94	1.16	0.81
4	34	41	11.64	45.82	0.83	1.22	0.68
4	35	41	11.82	49.27	0.91	1.34	0.68
4	36	41	12.55	50.09	0.92	1.37	0.67
4	37	41	11.09	45.10	0.83	1.19	0.69
4	39	41	11.91	46.82	0.85	1.32	0.65
4	40	41	11.55	47.82	0.88	1.28	0.69
4	41	41	11.64	48.18	0.89	1.31	0.68
4	42	41	11.00	46.73	0.87	1.31	0.67
4	43	41	11.82	46.18	0.84	1.24	0.68
4	44	41	11.91	46.36	0.84	1.28	0.66
4	45	41	12.73	48.00	0.86	1.22	0.71
4	46	41	12.09	48.82	0.90	1.29	0.69
4	47	41	11.73	50.90	0.96	1.36	0.70
4	48	41	12.64	48.45	0.87	1.27	0.69
5	1	42	12.91	48.55	0.85	1.25	0.68
5	2	42	13.45	51.91	0.92	1.35	0.68
5	3	42	13.36	51.82	0.92	1.31	0.70
5	4	42	13.09	52.90	0.95	1.36	0.70
5	5	42	12.91	48.55	0.85	1.19	0.71
5	6	42	11.82	49.64	0.90	1.28	0.70
5	7	42	13.91	58.30	1.06	1.46	0.72
5	8	42	12.73	45.00	0.77	1.11	0.69
5	9	42	12.82	46.82	0.81	1.21	0.67
5	10	42	12.64	47.09	0.82	1.17	0.70
5	11	42	13.55	52.64	0.93	1.36	0.69
5	12	42	12.64	53.45	0.97	1.40	0.69
5	13	42	13.36	52.27	0.93	1.34	0.69
5	14	42	11.55	45.73	0.81	1.17	0.70
5	15	42	12.64	52.09	0.94	1.34	0.70
5	16	42	13.64	49.09	0.84	1.23	0.69
5	17	42	13.09	49.09	0.86	1.26	0.68

5	18	42	12.73	47.91	0.84	1.23	0.68
5	19	42	12.45	49.73	0.89	1.27	0.70
5	20	42	13.55	48.36	0.83	1.26	0.66
5	21	42	14.64	53.00	0.91	1.22	0.75
5	22	42	13.73	49.18	0.84	1.21	0.70
5	23	42	12.82	46.82	0.81	1.13	0.72
5	24	42	11.64	49.64	0.90	1.31	0.69
5	25	42	13.09	52.82	0.95	1.31	0.72
5	26	42	12.00	49.55	0.89	1.25	0.72
5	27	42	11.91	50.00	0.91	1.23	0.73
5	28	42	13.45	53.18	0.95	1.37	0.69
5	29	42	12.73	48.45	0.85	1.19	0.71
5	30	42	14.36	51.36	0.88	1.24	0.71
5	31	42	14.27	50.18	0.85	1.20	0.72
5	32	42	13.36	52.36	0.93	1.32	0.70
5	33	42	13.64	54.09	0.96	1.38	0.70
5	34	42	13.00	50.27	0.89	1.20	0.74
5	35	42	12.73	50.50	0.90	1.25	0.72
5	36	42	12.73	53.45	0.97	1.39	0.70
5	37	42	12.45	49.55	0.88	1.26	0.70
5	38	42	11.09	50.45	0.94	1.28	0.73
5	39	42	11.82	52.00	0.96	1.30	0.73
5	40	42	12.36	49.70	0.89	1.23	0.72
5	41	42	12.82	49.82	0.88	1.30	0.68
5	42	42	12.36	53.00	0.97	1.36	0.71
5	43	42	12.18	49.09	0.88	1.25	0.70
5	44	42	12.09	47.73	0.85	1.24	0.69
5	45	42	12.73	47.73	0.83	1.24	0.67
5	46	42	12.00	51.30	0.94	1.29	0.72
5	47	42	11.00	46.18	0.84	1.26	0.66
5	48	42	11.27	48.45	0.89	1.23	0.72
6	1	45	13.00	43.09	0.67	1.05	0.64
6	2	45	13.00	47.18	0.76	1.24	0.61
6	3	45	13.00	50.82	0.84	1.26	0.67
6	4	45	13.27	49.82	0.81	1.31	0.62
6	5	45	12.36	47.18	0.77	1.18	0.65
6	6	45	13.82	54.20	0.90	1.24	0.72
6	7	45	13.45	50.27	0.82	1.32	0.62
6	8	45	13.36	49.90	0.81	1.27	0.64
6	9	45	12.36	47.45	0.78	1.25	0.62

6	10	45	13.64	49.91	0.81	1.28	0.63
6	11	45	12.18	46.45	0.76	1.16	0.65
6	12	45	13.45	50.64	0.83	1.23	0.67
6	13	45	12.36	49.36	0.82	1.27	0.65
6	14	45	12.82	49.89	0.82	1.16	0.71
6	15	45	13.55	51.18	0.84	1.29	0.65
6	16	45	14.73	54.36	0.88	1.32	0.67
6	17	45	13.55	52.36	0.86	1.30	0.67
6	18	45	13.45	54.27	0.91	1.39	0.65
6	19	45	12.45	47.27	0.77	1.24	0.62
6	20	45	12.64	46.82	0.76	1.14	0.67
6	21	45	12.91	46.73	0.75	1.12	0.67
6	22	45	14.55	50.36	0.80	1.23	0.65
6	23	45	13.45	56.00	0.95	1.35	0.70
6	24	45	13.27	52.18	0.86	1.34	0.64
6	25	45	13.64	47.00	0.74	1.13	0.65
6	26	45	13.45	48.00	0.77	1.20	0.64
6	27	45	13.91	48.45	0.77	1.19	0.65
6	28	45	13.82	47.36	0.75	1.17	0.64
6	29	45	13.64	49.90	0.81	1.15	0.70
6	30	45	13.55	47.00	0.74	1.18	0.63
6	31	45	13.91	50.55	0.81	1.22	0.66
6	32	45	14.36	48.64	0.76	1.22	0.62
6	33	45	13.91	49.55	0.79	1.19	0.67
6	34	45	13.45	53.27	0.88	1.35	0.66
6	35	45	15.09	53.45	0.85	1.30	0.65
6	36	45	14.55	54.09	0.88	1.32	0.66
6	37	45	14.36	51.09	0.82	1.31	0.63
6	38	45	14.09	48.00	0.75	1.19	0.63
6	39	45	13.82	48.20	0.76	1.19	0.64
6	42	45	13.18	50.09	0.82	1.25	0.66
6	44	45	14.36	52.09	0.84	1.27	0.66
6	45	45	14.18	49.70	0.79	1.12	0.70
6	46	45	14.00	52.00	0.84	1.27	0.66
6	47	45	12.64	48.55	0.80	1.17	0.68
6	48	45	13.18	52.09	0.86	1.34	0.65

Appendix Table 2. Pen mean for finishing growth performance

Exp	Pen	Fdays	FavgSTwt	FavgEwt	FADG	FADFI	FGF
2	1	113	54.60	331.11	2.19	5.59	0.39
2	2	111	55.00	302.44	1.96	4.77	0.41
2	3	107	51.82	320.22	2.13	5.47	0.39
2	4	111	54.09	318.00	2.09	5.67	0.37
2	5	122	49.55	296.09	1.96	5.24	0.37
2	6	122	49.73	283.64	1.86	4.87	0.38
2	7	112	54.64	301.30	1.96	5.28	0.37
2	8	122	53.55	291.82	1.89	4.78	0.40
2	9	122	51.27	288.73	1.88	4.96	0.38
2	10	122	53.73	292.27	1.89	4.63	0.41
2	11	122	51.64	312.45	2.07	5.23	0.40
2	12	122	53.27	294.64	1.92	4.77	0.40
2	13	112	54.09	303.00	1.98	4.79	0.41
2	14	111	50.27	299.90	1.98	5.48	0.36
2	15	111	55.91	320.00	2.10	5.53	0.38
2	16	122	55.91	295.00	1.90	4.58	0.41
2	17	107	48.64	294.22	1.95	5.13	0.38
2	18	122	53.50	303.70	1.99	5.49	0.36
2	19	122	58.45	314.36	2.03	5.54	0.37
2	20	117	55.60	310.00	2.02	4.94	0.41
2	21	101	49.27	303.63	2.02	5.18	0.39
2	22	122	51.18	298.64	1.96	5.31	0.37
2	23	122	54.90	299.80	1.94	5.19	0.37
2	24	122	53.73	291.36	1.89	5.32	0.35
2	25	122	54.91	295.55	1.91	5.03	0.38
2	26	122	51.45	273.64	1.76	4.55	0.39
2	27	111	52.09	296.10	1.94	5.27	0.37
2	28	122	53.00	295.00	1.92	4.76	0.40
2	29	122	57.55	310.73	2.01	5.24	0.38
2	30	122	52.18	295.91	1.93	5.19	0.37
2	31	122	54.09	299.18	1.95	4.57	0.43
2	32	122	49.09	282.09	1.85	4.96	0.37
2	33	122	55.73	300.91	1.95	5.01	0.39
2	34	122	54.73	307.82	2.01	5.35	0.38
2	35	122	52.73	292.40	1.90	5.05	0.38
2	36	108	54.45	314.67	2.07	5.15	0.40
2	38	122	51.82	279.00	1.80	4.40	0.41

2	39	122	50.45	299.91	1.98	4.98	0.40
2	40	122	51.36	281.64	1.83	4.78	0.38
2	41	122	53.45	298.27	1.94	5.31	0.37
2	42	122	55.64	297.64	1.92	4.99	0.38
2	43	122	51.55	289.73	1.89	4.80	0.39
2	44	122	53.30	302.20	1.98	5.46	0.36
2	45	122	53.64	292.82	1.90	4.77	0.40
2	46	103	47.82	302.78	2.02	5.51	0.37
2	47	114	51.36	309.80	2.05	4.95	0.41
2	48	119	52.36	291.90	1.90	5.12	0.37
3	2	128	58.64	294.73	1.78	4.64	0.38
3	3	128	55.27	305.73	1.88	5.29	0.36
3	4	118	56.91	317.80	1.96	5.20	0.38
3	5	128	57.91	325.00	2.01	5.65	0.36
3	6	128	57.00	312.90	1.92	5.51	0.35
3	7	127	55.45	312.00	1.93	5.02	0.38
3	8	122	53.64	318.00	1.99	5.13	0.39
3	9	128	57.27	301.09	1.83	4.81	0.38
3	10	124	52.27	310.00	1.94	5.06	0.38
3	11	128	56.09	323.27	2.01	5.35	0.38
3	12	128	60.45	316.18	1.92	5.05	0.38
3	13	128	56.82	291.64	1.77	4.35	0.41
3	14	128	52.91	322.36	2.03	5.27	0.38
3	15	120	56.00	323.80	2.01	5.34	0.38
3	16	128	53.64	291.55	1.79	4.69	0.38
3	17	124	52.09	322.50	2.03	5.27	0.39
3	18	128	58.64	314.91	1.93	5.38	0.36
3	19	128	56.36	301.18	1.84	4.99	0.37
3	20	128	52.27	298.18	1.85	4.95	0.37
3	21	128	52.91	305.18	1.90	5.08	0.37
3	22	118	53.64	330.40	2.08	5.56	0.37
3	23	128	57.82	301.73	1.83	4.89	0.37
3	24	128	57.09	322.18	1.99	5.60	0.36
3	25	116	56.36	309.67	1.90	4.93	0.39
3	26	128	53.18	299.36	1.85	4.88	0.38
3	27	128	55.45	311.45	1.92	5.23	0.37
3	28	127	56.36	302.90	1.85	4.65	0.40
3	29	128	58.36	311.18	1.90	5.07	0.37
3	30	128	55.91	317.45	1.97	5.50	0.36
3	31	128	54.55	296.45	1.82	4.78	0.38

3	32	128	51.36	308.18	1.93	5.20	0.37
3	33	128	58.50	301.20	1.82	4.78	0.38
3	34	128	60.45	325.36	1.99	5.70	0.35
3	35	128	61.00	332.40	2.04	5.78	0.35
3	36	122	55.91	319.30	1.98	5.23	0.38
3	37	118	54.45	314.80	1.96	5.28	0.37
3	38	128	53.55	294.27	1.81	4.67	0.39
3	39	124	55.45	316.90	1.97	5.10	0.39
3	40	128	50.91	298.45	1.86	4.99	0.37
3	41	128	54.36	310.27	1.92	5.22	0.37
3	42	128	53.18	305.64	1.90	4.85	0.39
3	43	128	54.55	312.73	1.94	5.25	0.37
3	44	128	58.18	306.64	1.87	5.13	0.36
3	45	128	55.91	306.36	1.88	4.91	0.38
3	46	128	53.64	324.91	2.04	5.56	0.37
3	47	128	58.70	335.30	2.08	5.92	0.35
3	48	128	54.27	308.73	1.91	5.18	0.37
4	1	128	46.56	289.44	1.83	4.78	0.38
4	2	127	46.10	272.11	1.70	4.45	0.38
4	3	128	44.36	288.40	1.83	4.44	0.41
4	4	129	48.10	303.20	1.92	4.98	0.38
4	5	129	45.73	289.36	1.83	4.87	0.38
4	6	129	49.00	301.82	1.90	4.95	0.38
4	7	116	45.45	287.00	1.82	4.61	0.39
4	8	129	47.00	305.00	1.94	5.07	0.38
4	9	128	48.00	294.11	1.85	5.13	0.36
4	10	129	47.90	300.00	1.90	4.98	0.38
4	11	129	45.91	286.82	1.81	4.78	0.38
4	12	129	47.73	288.82	1.81	4.97	0.36
4	13	129	45.45	268.36	1.68	4.24	0.40
4	14	128	51.25	312.13	1.96	5.33	0.37
4	15	129	46.80	289.30	1.82	4.67	0.39
4	16	129	46.64	279.09	1.75	4.50	0.39
4	17	129	45.00	286.36	1.81	4.89	0.37
4	18	129	51.64	293.36	1.82	4.86	0.37
4	19	116	44.80	280.22	1.77	4.69	0.38
4	20	129	50.90	296.00	1.84	4.91	0.38
4	21	117	41.90	279.44	1.79	4.75	0.38
4	22	129	45.91	287.64	1.82	4.78	0.38
4	23	126	47.09	288.60	1.82	4.54	0.40

4	24	129	50.80	293.00	1.82	4.85	0.38
4	25	129	48.55	273.00	1.69	4.29	0.39
4	26	119	45.00	285.80	1.81	4.59	0.39
4	27	125	44.55	268.50	1.68	4.40	0.38
4	28	121	46.64	286.80	1.81	4.61	0.39
4	29	129	47.64	291.82	1.84	4.77	0.39
4	30	129	49.36	281.00	1.74	5.15	0.34
4	31	128	46.73	288.80	1.82	4.68	0.39
4	32	129	46.82	291.18	1.84	4.77	0.39
4	33	128	51.50	288.38	1.78	4.79	0.37
4	34	126	45.82	280.50	1.76	4.67	0.38
4	35	129	49.27	300.91	1.89	4.96	0.38
4	36	129	50.09	284.82	1.76	4.71	0.37
4	37	127	45.10	272.56	1.71	4.44	0.39
4	39	129	46.82	269.09	1.67	4.41	0.38
4	40	129	47.82	285.45	1.79	4.52	0.40
4	41	123	48.18	294.00	1.85	4.73	0.39
4	42	121	46.73	291.50	1.84	4.66	0.40
4	43	128	46.18	286.50	1.81	4.51	0.40
4	44	123	46.36	284.44	1.79	4.64	0.39
4	45	128	48.00	291.67	1.83	5.03	0.36
4	46	120	48.82	295.78	1.86	4.69	0.40
4	47	129	50.90	299.00	1.87	4.93	0.38
4	48	125	48.45	292.30	1.83	4.70	0.39
5	1	117	48.55	313.67	2.10	5.37	0.39
5	2	123	51.91	301.91	1.98	5.26	0.38
5	3	123	51.82	297.70	1.95	5.02	0.39
5	4	123	52.90	317.10	2.10	5.75	0.36
5	5	123	48.55	297.82	1.98	5.32	0.37
5	6	123	49.64	296.36	1.96	5.10	0.38
5	7	123	58.30	314.50	2.03	5.92	0.34
5	8	122	45.00	285.20	1.91	5.09	0.37
5	9	123	46.82	291.82	1.94	5.21	0.37
5	10	123	47.09	303.64	2.04	5.69	0.36
5	11	123	52.64	307.27	2.02	5.55	0.36
5	12	114	53.45	323.22	2.14	5.71	0.37
5	13	122	52.27	289.40	1.88	5.20	0.36
5	14	123	45.73	301.73	2.03	5.06	0.40
5	15	123	52.09	302.64	1.99	5.22	0.38
5	16	123	49.09	294.82	1.95	5.13	0.38

5	17	113	49.09	304.89	2.03	5.48	0.37
5	18	123	47.91	296.73	1.97	5.29	0.37
5	19	122	49.73	305.30	2.03	5.36	0.38
5	20	112	48.36	307.30	2.06	5.80	0.35
5	21	123	53.00	320.80	2.13	5.87	0.36
5	22	117	49.18	315.11	2.11	5.57	0.38
5	23	123	46.82	305.73	2.05	5.25	0.39
5	24	122	49.64	299.90	1.99	5.17	0.38
5	25	116	52.82	303.50	1.99	5.39	0.37
5	26	120	49.55	301.80	2.00	5.11	0.39
5	27	123	50.00	292.36	1.92	4.76	0.40
5	28	123	53.18	302.45	1.98	5.16	0.38
5	29	120	48.45	297.90	1.98	5.02	0.39
5	30	123	51.36	302.82	2.00	5.23	0.38
5	31	123	50.18	304.09	2.02	5.58	0.36
5	32	115	52.36	307.40	2.02	5.54	0.37
5	33	123	54.09	300.91	1.96	5.44	0.36
5	34	123	50.27	303.73	2.01	5.19	0.39
5	35	119	50.50	313.78	2.09	5.59	0.37
5	36	123	53.45	296.00	1.92	5.66	0.34
5	37	120	49.55	305.00	2.03	5.19	0.39
5	38	123	50.45	301.55	1.99	5.18	0.38
5	39	122	52.00	286.00	1.86	5.11	0.36
5	40	123	49.70	300.60	1.99	5.40	0.37
5	41	112	49.82	305.70	2.03	5.82	0.35
5	42	123	53.00	304.00	1.99	5.44	0.37
5	43	106	49.09	303.38	2.02	5.20	0.39
5	44	123	47.73	286.55	1.90	5.13	0.37
5	45	123	47.73	292.82	1.95	5.40	0.36
5	46	117	51.30	300.00	1.97	5.44	0.36
5	47	123	46.18	298.27	2.00	5.51	0.36
5	48	123	48.45	292.82	1.94	5.05	0.38
6	1	138	43.09	289.64	1.79	4.59	0.39
6	2	138	47.18	302.36	1.85	4.73	0.39
6	3	125	50.82	328.11	2.03	5.22	0.39
6	4	136	49.82	309.45	1.89	4.95	0.38
6	5	138	47.18	312.27	1.92	5.08	0.38
6	6	152	54.20	307.45	1.84	4.92	0.37
6	7	136	50.27	289.00	1.74	4.44	0.39
6	8	152	49.90	310.91	1.90	5.05	0.37

6	9	138	47.45	298.82	1.83	4.75	0.38
6	10	134	49.91	296.89	1.81	4.61	0.39
6	11	138	46.45	299.36	1.84	4.89	0.38
6	12	138	50.64	316.55	1.93	5.07	0.38
6	13	135	49.36	283.20	1.71	4.42	0.39
6	14	152	49.89	319.80	1.97	5.12	0.38
6	15	136	51.18	287.50	1.72	4.28	0.40
6	16	136	54.36	301.40	1.80	4.80	0.38
6	17	136	52.36	292.70	1.75	4.66	0.38
6	18	138	54.27	312.55	1.88	4.88	0.38
6	19	136	47.27	297.30	1.82	4.67	0.39
6	20	138	46.82	309.09	1.90	4.91	0.39
6	21	138	46.73	306.45	1.89	4.89	0.39
6	22	113	50.36	323.75	2.02	5.16	0.39
6	23	152	56.00	316.91	1.89	5.10	0.37
6	24	138	52.18	309.36	1.87	5.00	0.37
6	25	138	47.00	304.82	1.87	4.73	0.40
6	26	138	48.00	291.64	1.77	4.63	0.38
6	27	138	48.45	317.36	1.95	4.85	0.40
6	28	138	47.36	305.18	1.87	4.93	0.38
6	29	143	49.90	327.00	2.02	5.10	0.40
6	30	121	47.00	320.67	2.01	5.25	0.38
6	31	138	50.55	305.45	1.85	4.90	0.38
6	32	138	48.64	319.27	1.97	5.11	0.38
6	33	138	49.55	309.64	1.89	5.12	0.37
6	34	138	53.27	310.64	1.87	4.94	0.38
6	35	138	53.45	310.45	1.87	4.88	0.38
6	36	138	54.09	316.09	1.90	5.06	0.38
6	37	138	51.09	294.73	1.77	4.83	0.37
6	38	138	48.00	299.45	1.83	4.69	0.39
6	39	152	48.20	304.80	1.87	4.63	0.40
6	42	138	50.09	319.55	1.96	5.21	0.38
6	44	138	52.09	322.45	1.96	5.22	0.38
6	45	132	49.70	328.89	2.05	5.16	0.40
6	46	137	52.00	312.60	1.90	5.06	0.38
6	47	138	48.55	318.55	1.96	5.14	0.38
6	48	136	52.09	306.00	1.85	4.94	0.38

Appendix Table 3. Pen mean for water to feed intake in relation to treatment represented by d 0-22, 22-42, and 0-42.

Pen	Trt	Block	D 0-22	D 22-42	D0-42
1	Q2	1	2.98	2.71	2.79
2	Q12	1	4.20	3.32	3.58
3	Control	2	5.78	3.58	4.25
4	Q24	2	3.38	3.07	3.17
5	Q2	3	2.49	2.78	2.69
6	Q12	3	3.61	2.86	3.08
7	Q12	4	2.73	2.36	2.48
8	Q24	1	3.49	3.49	3.49
9	Control	1	3.23	2.90	3.01
10	Q12	2	5.39	3.00	3.77
11	Q2	2	3.79	3.55	3.62
12	Q24	3	4.72	3.02	3.48
13	Control	3	5.54	3.54	4.10
14	Control	4	3.72	2.70	2.99
15	Q2	4	3.92	3.31	3.49
16	Q2	5	3.59	2.94	3.11
17	Q24	5	2.55	3.09	2.93
18	Control	6	4.84	3.62	3.97
19	Q2	6	4.56	4.19	4.29
20	Control	7	4.17	5.50	5.09
21	Q12	7	4.36	4.01	4.12
22	Q24	4	5.08	2.84	3.49
23	Control	5	4.08	3.69	3.79
24	Q12	5	4.41	3.15	3.49
25	Q24	6	4.72	3.98	4.18
26	Q12	6	5.08	5.55	5.42
27	Q24	7	3.87	3.17	3.36
28	Q2	7	5.22	4.50	4.71

Appendix Table 4. Pen mean for growth performance represented by d 0-22

Pen	Trt	Block	ADFI	ADWI	ADG	G:F	Fecal Score	Mortality & Removals	BW d 0	BW d 22
1	Q2	1	0.31	0.91	0.25	0.81	2.00	0	5.535	11.03
2	Q12	1	0.26	1.08	0.19	0.73	2.33	0	5.985	10.08
3	Control	2	0.21	1.20	0.14	0.69	1.33	0	5.625	8.78
4	Q24	2	0.28	0.93	0.22	0.79	2.33	0	5.715	10.49
5	Q2	3	0.31	0.77	0.27	0.86	1.33	0	5.94	11.79
6	Q12	3	0.28	1.01	0.23	0.81	2.00	0	5.625	10.62
7	Q12	4	0.25	0.69	0.19	0.74	1.33	1	5.445	10.25
8	Q24	1	0.31	1.07	0.25	0.82	2.33	0	5.85	11.39
9	Control	1	0.33	1.07	0.27	0.81	1.33	0	5.76	11.70
10	Q12	2	0.23	1.24	0.16	0.70	2.00	0	5.445	9.00
11	Q2	2	0.30	1.16	0.23	0.76	2.00	0	5.67	10.80
12	Q24	3	0.19	0.90	0.12	0.63	2.00	0	5.715	8.37
13	Control	3	0.20	1.11	0.13	0.64	1.67	0	5.58	8.42
14	Control	4	0.26	0.97	0.21	0.79	2.00	0	5.805	10.35
15	Q2	4	0.26	1.03	0.23	0.86	1.67	0	5.535	10.49
16	Q2	5	0.24	0.86	0.20	0.85	1.67	0	5.445	9.90
17	Q24	5	0.23	0.60	0.20	0.87	2.00	0	5.535	10.04
18	Control	6	0.24	1.17	0.19	0.80	1.33	0	5.985	10.26
19	Q2	6	0.26	1.20	0.24	0.90	2.33	0	5.625	10.80
20	Control	7	0.30	1.25	0.24	0.81	2.00	1	5.985	12.15

21	Q12	7	0.26	1.12	0.20	0.78	1.67	0	5.85	10.22
22	Q24	4	0.22	1.14	0.14	0.64	2.00	0	5.805	8.96
23	Control	5	0.19	0.79	0.11	0.57	2.00	2	5.67	9.96
24	Q12	5	0.21	0.91	0.17	0.83	1.00	0	5.67	9.41
25	Q24	6	0.22	1.04	0.18	0.83	1.33	0	5.715	9.72
26	Q12	6	0.24	1.24	0.21	0.85	1.33	0	5.535	10.13
27	Q24	7	0.19	0.74	0.14	0.74	1.67	0	5.805	8.91
28	Q2	7	0.29	1.54	0.24	0.82	2.00	1	5.76	11.90

Appendix Table 5. Pen mean for growth performance represented by d 22-42

Pen	Trt	Block	ADFI	ADWI	ADG	G:F	Fecal Score	Mortality & Removals	BW d 22	BW d 42
1	Q2	1	0.77	2.09	0.46	0.59	2.33	0	11.03	20.16
2	Q12	1	0.69	2.30	0.43	0.63	2.33	0	10.08	18.72
3	Control	2	0.53	1.91	0.43	0.80	1.67	0	8.78	17.33
4	Q24	2	0.68	2.09	0.48	0.71	2.33	0	10.49	20.07
5	Q2	3	0.77	2.14	0.46	0.60	1.67	0	11.79	20.97
6	Q12	3	0.76	2.16	0.46	0.61	2.00	0	10.62	21.40
7	Q12	4	0.68	1.61	0.37	0.54	2.33	1	10.25	18.90
8	Q24	1	0.65	2.28	0.49	0.75	2.00	0	11.39	21.11
9	Control	1	0.71	2.07	0.43	0.60	2.00	1	11.70	22.20
10	Q12	2	0.59	1.75	0.35	0.59	1.67	1	9.00	17.00
11	Q2	2	0.74	2.62	0.47	0.64	2.00	0	10.80	20.25
12	Q24	3	0.71	2.15	0.38	0.53	2.00	2	8.37	18.00
13	Control	3	0.57	2.04	0.43	0.76	2.00	0	8.42	17.10
14	Control	4	0.72	1.95	0.44	0.61	2.00	0	10.35	19.13
15	Q2	4	0.69	2.28	0.44	0.64	2.00	0	10.49	19.31
16	Q2	5	0.69	2.04	0.41	0.60	2.33	0	9.90	18.18
17	Q24	5	0.64	1.96	0.35	0.56	1.67	1	10.04	18.40
18	Control	6	0.66	2.41	0.40	0.61	2.00	0	10.26	18.32
19	Q2	6	0.74	3.09	0.47	0.64	2.00	0	10.80	20.30
20	Control	7	0.76	4.18	0.46	0.60	1.00	0	12.15	21.30
21	Q12	7	0.70	2.80	0.41	0.59	1.33	0	10.22	19.90
22	Q24	4	0.64	1.82	0.36	0.56	2.00	1	8.96	17.50

23	Control	5	0.67	2.46	0.45	0.67	1.67	0	9.96	18.90
24	Q12	5	0.63	1.97	0.44	0.70	2.00	0	9.41	18.14
25	Q24	6	0.71	2.83	0.44	0.62	2.00	1	9.72	19.60
26	Q12	6	0.69	3.82	0.44	0.64	2.33	0	10.13	18.99
27	Q24	7	0.55	1.75	0.37	0.67	1.67	0	8.91	16.34
28	Q2	7	0.82	3.68	0.53	0.65	1.67	0	11.90	22.45

Appendix Table 6. Pen mean for growth performance represented by d 0-42

Pen	Trt	Block	ADFI	ADWI	ADG	G:F	Fecal Score	Mortality & Removals	BW d 0	BW d 42
1	Q2	1	0.53	1.48	0.35	0.66	2.17	0	5.54	20.16
2	Q12	1	0.46	1.66	0.30	0.65	2.33	0	5.99	18.72
3	Control	2	0.36	1.54	0.28	0.77	1.50	0	5.63	17.33
4	Q24	2	0.47	1.48	0.34	0.73	2.33	0	5.72	20.07
5	Q2	3	0.53	1.42	0.36	0.68	1.50	0	5.94	20.97
6	Q12	3	0.50	1.54	0.34	0.67	2.00	0	5.63	21.40
7	Q12	4	0.44	1.09	0.27	0.60	1.83	2	5.45	18.90
8	Q24	1	0.47	1.65	0.36	0.77	2.17	0	5.85	21.11
9	Control	1	0.51	1.54	0.34	0.67	1.67	1	5.76	22.20
10	Q12	2	0.39	1.47	0.25	0.63	1.83	1	5.45	17.00
11	Q2	2	0.51	1.85	0.35	0.68	2.00	0	5.67	20.25
12	Q24	3	0.41	1.43	0.23	0.56	2.00	2	5.72	18.00
13	Control	3	0.38	1.55	0.27	0.72	1.83	0	5.58	17.10
14	Control	4	0.48	1.44	0.32	0.66	2.00	0	5.81	19.13
15	Q2	4	0.47	1.62	0.33	0.71	1.83	0	5.54	19.31
16	Q2	5	0.46	1.42	0.30	0.67	2.00	0	5.45	18.18
17	Q24	5	0.42	1.22	0.27	0.65	1.83	1	5.54	18.40
18	Control	6	0.44	1.76	0.29	0.66	1.67	0	5.99	18.32
19	Q2	6	0.49	2.10	0.35	0.72	2.17	0	5.63	20.30
20	Control	7	0.52	2.62	0.34	0.67	1.50	1	5.99	21.30
21	Q12	7	0.46	1.89	0.30	0.65	1.50	0	5.85	19.90

22	Q24	4	0.42	1.45	0.24	0.58	2.00	1	5.81	17.50
23	Control	5	0.40	1.52	0.26	0.64	1.83	2	5.67	18.90
24	Q12	5	0.41	1.42	0.30	0.73	1.50	0	5.67	18.14
25	Q24	6	0.44	1.85	0.30	0.68	1.67	1	5.72	19.60
26	Q12	6	0.46	2.47	0.32	0.70	1.83	0	5.54	18.99
27	Q24	7	0.36	1.22	0.25	0.69	1.67	0	5.81	16.34
28	Q2	7	0.54	2.54	0.38	0.70	1.83	1	5.76	22.45

Appendix Table 7. Pig mean for daily water intake during pulse dose.

Pen	Trt	Block	D 1-5	D 18-28
1	Q2	1	0.73	1.75
2	Q12	1	0.60	1.61
3	Control	2	0.77	1.88
4	Q24	2	0.81	1.69
5	Q2	3	0.45	1.89
6	Q12	3	0.77	1.57
7	Q12	4	0.36	1.12
8	Q24	1	0.73	1.87
9	Control	1	0.87	1.79
10	Q12	2	0.80	1.76
11	Q2	2	0.72	2.20
12	Q24	3	0.52	0.84
13	Control	3	0.63	2.10
14	Control	4	0.94	1.73
15	Q2	4	0.76	1.98
16	Q2	5	0.74	1.57
17	Q24	5	0.44	1.36
18	Control	6	1.03	1.93
19	Q2	6	0.90	2.32
20	Control	7	1.22	2.64
21	Q12	7	0.81	1.29
22	Q24	4	0.76	1.48
23	Control	5	0.68	1.82
24	Q12	5	0.75	1.38
25	Q24	6	0.69	1.69
26	Q12	6	0.88	1.91
27	Q24	7	0.60	1.20
28	Q2	7	1.14	3.09

Appendix Table 8. Pen mean for immune response of nursery pigs (2 pigs per pen) represented by h 0

Pen	Trt	Block	BW	RT	TNF-α
1	Q2	1	10.08	39.42	273.10
2	Q12	1	10.49	39.61	234.96
3	Control	2	10.53	39.76	245.92
4	Q24	2	11.03	39.78	142.29
5	Q2	3	12.20	39.97	203.71
6	Q12	3	11.61	40.17	152.85
7	Q12	4	10.89	39.82	415.08
8	Q24	1	11.34	40.24	196.43
9	Control	1	12.92	40.13	265.46
10	Q12	2	11.34	40.01	259.29
11	Q2	2	11.57	39.68	201.77
12	Q24	3	9.59	39.74	207.58
13	Control	3	10.67	39.63	144.72
14	Control	4	11.52	40.24	252.65
15	Q2	4	11.12	39.69	187.41
16	Q2	5	10.04	39.96	154.32
17	Q24	5	11.61	40.00	169.65
18	Control	6	9.86	40.06	257.88
19	Q2	6	10.49	40.10	308.10
20	Control	7	11.39	40.04	230.46
21	Q12	7	10.17	40.03	174.95
22	Q24	4	9.99	39.65	666.42
23	Control	5	11.93	39.56	160.92
24	Q12	5	10.80	40.04	221.51
25	Q24	6	12.24	39.83	218.15
26	Q12	6	12.69	40.15	231.81
27	Q24	7	10.67	40.35	283.51
28	Q2	7	11.43	39.75	245.56

Appendix Table 9. Pen mean for immune response of nursery pigs (2 pigs per pen) represented by h 3

Pen	Trt	Block	BW	RT	TNF-α
1	Q2	1	9.99	40.82	3166.36
2	Q12	1	10.44	41.15	2383.66
3	Control	2	10.13	41.08	4334.75
4	Q24	2	10.58	41.69	6883.99
5	Q2	3	11.97	41.44	4670.59
6	Q12	3	11.48	41.64	5703.19
7	Q12	4	10.44	41.30	5797.50
8	Q24	1	11.16	41.58	6181.90
9	Control	1	12.87	41.38	2590.53
10	Q12	2	10.62	41.64	5844.64
11	Q2	2	12.29	41.44	5040.54
12	Q24	3	9.63	40.53	2284.80
13	Control	3	10.62	40.89	7332.29
14	Control	4	11.48	41.74	6352.54
15	Q2	4	10.67	41.10	3565.98
16	Q2	5	9.63	41.63	7158.16
17	Q24	5	11.21	41.29	7636.15
18	Control	6	9.50	41.56	10201.88
19	Q2	6	10.04	40.53	6261.22
20	Control	7	11.16	41.92	5976.88
21	Q12	7	9.95	41.74	4695.30
22	Q24	4	9.77	41.04	6308.84
23	Control	5	11.16	41.47	2537.42
24	Q12	5	10.40	41.53	5274.04
25	Q24	6	11.66	41.34	8143.84
26	Q12	6	11.88	41.14	10075.09
27	Q24	7	10.17	41.72	6472.18
28	Q2	7	11.39	41.88	8888.04

Appendix Table 10. Pen mean for immune response of nursery pigs (2 pigs per pen) represented by h 6

Pen	Trt	Block	BW	RT	TNF-α
1	Q2	1	9.90	40.65	1100.05

2	Q12	1	10.40	40.07	1272.29
3	Control	2	10.31	39.91	1729.74
4	Q24	2	10.49	41.06	2513.52
5	Q2	3	12.15	41.01	1865.28
6	Q12	3	11.21	41.19	1589.04
7	Q12	4	10.49	40.01	1377.71
8	Q24	1	10.80	40.35	2026.10
9	Control	1	12.83	40.36	2124.31
10	Q12	2	10.80	40.47	2854.53
11	Q2	2	12.24	40.22	2788.88
12	Q24	3	9.72	40.06	1235.66
13	Control	3	10.40	39.99	2941.73
14	Control	4	11.34	41.24	2028.91
15	Q2	4	10.85	39.76	1029.15
16	Q2	5	9.63	40.56	2114.53
17	Q24	5	11.16	40.08	1761.16
18	Control	6	9.63	40.36	2830.46
19	Q2	6	10.08	40.44	2202.64
20	Control	7	11.25	40.06	2838.41
21	Q12	7	9.86	39.97	1822.51
22	Q24	4	9.77	39.94	3272.95
23	Control	5	11.12	41.17	748.88
24	Q12	5	10.31	40.79	2387.76
25	Q24	6	11.93	40.44	2683.22
26	Q12	6	11.97	40.65	3484.57
27	Q24	7	10.26	40.49	3541.59
28	Q2	7	11.39	40.40	3089.22

Appendix Table 11. Pen mean for immune response of nursery pigs (2 pigs per pen) represented by h 12

Pen	Trt	Block	BW	RT	TNF-α
1	Q2	1	9.99	40.33	480.12
2	Q12	1	10.49	39.96	495.48
3	Control	2	10.44	40.13	815.47
4	Q24	2	10.80	41.03	601.92
5	Q2	3	12.11	40.92	620.80
6	Q12	3	11.79	40.51	283.43

7	Q12	4	10.49	40.11	926.51
8	Q24	1	10.53	40.92	515.20
9	Control	1	12.96	39.76	716.91
10	Q12	2	10.85	39.79	698.83
11	Q2	2	12.60	39.92	516.66
12	Q24	3	9.86	39.54	447.33
13	Control	3	10.71	39.75	729.43
14	Control	4	11.39	40.54	838.29
15	Q2	4	10.94	40.57	369.54
16	Q2	5	9.81	39.74	875.32
17	Q24	5	11.25	39.76	819.72
18	Control	6	9.86	40.28	870.46
19	Q2	6	10.13	40.29	715.21
20	Control	7	11.16	39.76	898.34
21	Q12	7	9.86	39.57	421.46
22	Q24	4	9.77	39.35	1847.90
23	Control	5	11.43	39.71	254.51
24	Q12	5	10.67	39.79	962.56
25	Q24	6	12.02	40.07	1029.98
26	Q12	6	12.02	39.78	1415.47
27	Q24	7	10.31	40.08	1317.76
28	Q2	7	11.48	40.53	985.24

Appendix Table 12. Pen mean for immune response of nursery pigs (2 pigs per pen) represented by h 24

Pen	Trt	Block	BW	RT	TNF-α
1	Q2	1	10.17	40.01	257.33
2	Q12	1	10.76	39.99	240.46
3	Control	2	10.40	39.58	224.36
4	Q24	2	10.98	40.14	167.06
5	Q2	3	12.20	40.01	218.42
6	Q12	3	11.93	40.26	211.28
7	Q12	4	10.62	39.75	442.48
8	Q24	1	11.03	40.39	138.29
9	Control	1	15.26	39.86	265.33
10	Q12	2	11.21	40.38	217.91

11	Q2	2	12.83	39.97	210.14
12	Q24	3	9.95	39.74	220.57
13	Control	3	10.89	40.06	182.41
14	Control	4	11.66	40.10	265.57
15	Q2	4	11.21	39.81	117.19
16	Q2	5	10.17	39.49	174.91
17	Q24	5	11.88	39.65	210.20
18	Control	6	9.99	39.50	298.60
19	Q2	6	10.49	39.68	256.31
20	Control	7	11.84	39.19	313.97
21	Q12	7	10.17	39.46	189.89
22	Q24	4	10.04	39.44	208.54
23	Control	5	11.97	39.81	158.02
24	Q12	5	10.98	40.14	235.67
25	Q24	6	12.06	39.67	219.19
26	Q12	6	12.24	39.69	276.11
27	Q24	7	10.58	39.94	298.05
28	Q2	7	11.88	39.46	322.39

Appendix Table 13. Pen mean for CRP of nursery pigs represented by d7, 14, 22, 28, 35, and 42

Pen	Trt	Block	D 7	D 14	D 22	D 28	D 35	D 42
1	Q2	1	79.79	19.52	104.79	63.96	70.46	49.73
2	Q12	1	107.03	16.66	29.84	78.06	41.41	114.39
3	Control	2	70.86	34.93	19.94	70.35	26.40	62.08
4	Q24	2	44.66	59.20	27.07	61.66	17.57	61.62
5	Q2	3	66.05	57.54	55.48	118.56	64.69	33.53
6	Q12	3	16.19	37.87	39.55	125.94	85.82	93.89
7	Q12	4	56.78	22.11	28.54	73.91	57.81	36.34
8	Q24	1	30.39	48.00	43.94	101.61	76.67	23.09
9	Control	1	77.38	76.10	76.60	57.60	25.00	104.52
10	Q12	2	62.12	39.41	17.41	72.36	45.26	51.65
11	Q2	2	57.98	77.68	120.82	73.44	62.96	95.22
12	Q24	3	73.80	16.86	26.92	63.03	33.35	22.60
13	Control	3	64.21	48.33	7.33	90.65	46.05	33.24
14	Control	4	97.04	132.56	30.39	70.58	37.60	37.17

15	Q2	4	94.78	54.24	51.42	43.61	73.71	16.89
16	Q2	5	39.78	84.70	40.24	92.68	43.44	25.68
17	Q24	5	48.02	128.55	82.67	87.44	29.74	62.48
18	Control	6	-	81.08	30.28	84.28	46.21	45.04
19	Q2	6	47.68	59.55	94.07	135.10	38.90	28.57
20	Control	7	40.57	96.72	87.35	93.80	61.23	16.76
21	Q12	7	-	53.05	99.93	-	33.48	23.39
22	Q24	4	66.48	16.35	30.68	58.39	29.74	133.45
23	Control	5	61.87	72.95	38.88	142.12	65.46	20.08
24	Q12	5	89.81	56.36	31.40	73.75	51.61	30.48
25	Q24	6	62.72	47.64	18.45	108.93	39.52	23.24
26	Q12	6	42.38	28.09	26.76	90.32	54.30	41.47
27	Q24	7	28.62	62.00	28.34	81.65	80.79	37.28
28	Q2	7	25.27	53.64	89.82	117.41	24.82	19.60

Appendix Table 14. Pen mean for BW change represented by h 0-3, 0-6, 0-12, and 0-24.

Pen	Trt	Block	H 0-3	H 0-6	H 0-12	H 0-24
1	Q2	1	-0.09	-0.18	-0.09	0.09
2	Q12	1	-0.05	-0.09	0.00	0.27
3	Control	2	-0.40	-0.23	-0.09	-0.14
4	Q24	2	-0.45	-0.54	-0.23	-0.05
5	Q2	3	-0.23	-0.05	-0.09	0.00
6	Q12	3	-0.14	-0.41	0.18	0.32
7	Q12	4	-0.45	-0.41	-0.40	-0.27
8	Q24	1	-0.18	-0.54	-0.81	-0.32
9	Control	1	-0.04	-0.09	0.04	2.34
10	Q12	2	-0.72	-0.54	-0.50	-0.13
11	Q2	2	0.72	0.68	1.04	1.26
12	Q24	3	0.04	0.13	0.27	0.36
13	Control	3	-0.04	-0.27	0.05	0.23
14	Control	4	-0.04	-0.18	-0.14	0.14
15	Q2	4	-0.45	-0.27	-0.18	0.09
16	Q2	5	-0.41	-0.41	-0.23	0.14
17	Q24	5	-0.41	-0.45	-0.36	0.27
18	Control	6	-0.36	-0.23	0.00	0.14

19	Q2	6	-0.45	-0.41	-0.36	0.00
20	Control	7	-0.23	-0.14	-0.23	0.45
21	Q12	7	-0.23	-0.32	-0.32	0.00
22	Q24	4	-0.22	-0.22	-0.22	0.05
23	Control	5	-0.77	-0.81	-0.49	0.05
24	Q12	5	-0.40	-0.49	-0.14	0.18
25	Q24	6	-0.59	-0.32	-0.23	-0.18
26	Q12	6	-0.81	-0.72	-0.68	-0.45
27	Q24	7	-0.50	-0.41	-0.36	-0.09
28	Q2	7	-0.04	-0.04	0.04	0.45

Appendix Table 15. Pen mean for RT change represented by h 0-3, 0-6, 0-12, and 0-24.

Pen	Trt	Block	H 0-3	H 0-6	H 0-12	H 0-24
1	Q2	1	1.40	1.23	0.92	0.60
2	Q12	1	1.54	0.46	0.35	0.38
3	Control	2	1.32	0.14	0.36	-0.19
4	Q24	2	1.92	1.28	1.25	0.36
5	Q2	3	1.47	1.04	0.94	0.04
6	Q12	3	1.47	1.02	0.35	0.10
7	Q12	4	1.48	0.19	0.29	-0.07
8	Q24	1	1.35	0.12	0.68	0.15
9	Control	1	1.25	0.23	-0.36	-0.26
10	Q12	2	1.63	0.46	-0.22	0.36
11	Q2	2	1.76	0.54	0.24	0.29
12	Q24	3	0.79	0.33	-0.19	0.00
13	Control	3	1.27	0.36	0.12	0.43
14	Control	4	1.50	1.00	0.31	-0.14
15	Q2	4	1.40	0.07	0.88	0.11
16	Q2	5	1.67	0.60	-0.22	-0.47
17	Q24	5	1.29	0.08	-0.24	-0.35
18	Control	6	1.50	0.31	0.22	-0.56
19	Q2	6	0.43	0.35	0.19	-0.42
20	Control	7	1.88	0.01	-0.28	-0.85
21	Q12	7	1.71	-0.06	-0.46	-0.57
22	Q24	4	1.39	0.29	-0.31	-0.21
23	Control	5	1.92	1.61	0.15	0.25

24	Q12	5	1.49	0.75	-0.25	0.10
25	Q24	6	1.51	0.61	0.24	-0.17
26	Q12	6	0.99	0.50	-0.38	-0.46
27	Q24	7	1.38	0.14	-0.26	-0.41
28	Q2	7	2.13	0.65	0.78	-0.29

Appendix Table 16. Pen mean for TNF-α change represented by h 0-3, 0-6, 0-12, and 0-24.

Pen	Trt	Block	H 0-3	H 0-6	H 0-12	H 0-24
1	Q2	1	2893.27	826.95	207.03	-15.76
2	Q12	1	2148.70	1037.33	260.51	5.49
3	Control	2	4088.83	1483.82	569.55	-21.56
4	Q24	2	6741.70	2371.24	459.63	24.78
5	Q2	3	4466.89	1661.58	417.10	14.72
6	Q12	3	5550.33	1436.19	130.57	58.43
7	Q12	4	5382.42	962.63	511.42	27.40
8	Q24	1	5985.47	1829.67	318.78	-58.13
9	Control	1	2325.07	1858.85	451.45	-0.13
10	Q12	2	5585.35	2595.24	439.54	-41.38
11	Q2	2	4838.77	2587.11	314.89	8.37
12	Q24	3	2077.22	1028.08	239.75	12.99
13	Control	3	7187.56	2797.00	584.71	37.68
14	Control	4	6099.89	1776.26	585.64	12.92
15	Q2	4	3378.56	841.74	182.12	-70.22
16	Q2	5	7003.84	1960.21	721.01	20.60
17	Q24	5	7466.50	1591.51	650.07	40.56
18	Control	6	9944.01	2572.58	612.58	40.72
19	Q2	6	5953.12	1894.53	407.11	-51.79
20	Control	7	5746.42	2607.95	667.88	83.51
21	Q12	7	4520.35	1647.56	246.50	14.94
22	Q24	4	5642.42	2606.53	1181.48	-457.88
23	Control	5	2376.51	587.97	93.60	-2.90
24	Q12	5	5052.52	2166.25	741.05	14.16
25	Q24	6	7925.69	2465.07	811.83	1.04
26	Q12	6	9843.28	3252.76	1183.66	44.30
27	Q24	7	6188.67	3258.09	1034.25	14.54

28	Q2	7	8642.49	2843.67	739.68	76.83

Appendix Table 17. Pen mean for CRP change represented by d 7-14, 7-22, 7-28, 7-35, and 7-42.

Pen	Trt	Block	D 7-14	D 7-22	D 7-28	D 7-35	D7-42
1	Q2	1	-60.27	25.01	-15.83	-9.32	-30.06
2	Q12	1	-90.37	-77.19	-28.97	-65.62	7.36
3	Control	2	-35.93	-50.93	-0.52	-44.46	-8.79
4	Q24	2	14.53	-17.59	16.99	-27.10	16.96
5	Q2	3	-8.51	-10.57	52.51	-1.36	-32.52
6	Q12	3	21.68	23.36	109.75	69.63	77.70
7	Q12	4	-34.67	-28.24	17.13	1.03	-20.44
8	Q24	1	17.61	13.55	71.23	46.29	-7.30
9	Control	1	-1.28	-0.78	-19.78	-52.38	27.14
10	Q12	2	-22.71	-44.71	10.24	-16.86	-10.48
11	Q2	2	19.70	62.84	15.46	4.98	37.25
12	Q24	3	-56.95	-46.88	-10.77	-40.46	-51.20
13	Control	3	-15.88	-56.87	26.44	-18.16	-30.96
14	Control	4	35.52	-66.65	-26.47	-59.45	-59.87
15	Q2	4	-40.53	-43.36	-51.17	-21.07	-77.89
16	Q2	5	44.92	0.46	52.90	3.66	-14.10
17	Q24	5	80.52	34.65	39.41	-18.28	14.46
18	Control	6	-	-	-	-	-
19	Q2	6	11.87	46.40	87.42	-8.77	-19.11
20	Control	7	56.14	46.77	53.23	20.65	-23.82
21	Q12	7	-	-	-	-	-
22	Q24	4	-50.14	-35.80	-8.10	-36.74	66.97
23	Control	5	11.08	-22.99	80.25	3.59	-41.79
24	Q12	5	-33.46	-58.41	-16.06	-38.20	-59.34
25	Q24	6	-15.08	-44.27	46.22	-23.20	-39.48
26	Q12	6	-14.30	-15.63	47.94	11.91	-0.91
27	Q24	7	33.38	-0.28	53.03	52.17	8.66
28	Q2	7	28.37	64.55	92.14	-0.45	-5.68

VITA

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