The Effects of Nursery Pig Diet Complexity on Growth Performance and Carcass Quality in Various Commercial Swine Settings

by

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ABSTRACT

THE EFFECTS OF NURSERY DIET COMPLEXITY ON GROWTH PERFORMANCE AND CARCASS QUALITY IN VARIOUS COMMERCIAL SWINE SETTINGS

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Early nursery pig diets contain costly, highly digestible protein ingredients that improve growth and the transition at weaning. A large-scale study was conducted on multiple commercial swine farms in Southern Ontario to assess the influence of nursery diet complexity on growth performance from weaning to a targeted market weight, carcass traits at time of processing and a serum health biomarker (i.e. haptoglobin). Two dietary treatments were applied during the nursery period, one treatment was high complexity (HC) nursery diets and the second treatment was low complexity (LC) nursery diets. Overall, feeding LC nursery diets did not influence pig growth performance, or serum haptoglobin concentrations. Carcass quality traits and carcass value was also not influenced by nursery diet complexity. Reducing nursery diet complexity may be a feasible alternative to help reduce the cost of pork production.

DEDICATION

This thesis is dedicated to my family, my father, sister, brother and sister in-law who continuously support me and push me to follow my dreams. I would also like to dedicate this to all the farmers and people involved in agriculture; it is an incredible industry that I am very proud to be a part of. Lastly, to Charlotte my niece who has shown me the little joys in life and whom I will encourage every day to reach for the stars.

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LIST OF ABBREVIATIONS

AB	Antibiotics
AB-	In-feed antibiotics not used
AB+	In-feed antibiotics used
ADFI	Average daily feed intake
ADFO	Average daily feed offered
ADG	Average daily gain
APP	Acute phase protein
Bio-markers	Biological markers
BF	Back fat
BW	Body Weight
°C	Degrees Celsius
CHO	Carbohydrates
CP	Crude protein
DM	Dry matter
DOA	Days of age
GH	Growth hormone
GIT	Gastrointestinal tract
HDW	Hot Dress Weight
HC	High complexity
Hp	Haptaglobin
IGF-1	Insulin-like growth factor
INF-λ	Interferon gamma
IgG1	Immunoglobulin G 1

IL	Interleukin
Kg	Kilogram
LC	Low complexity
N	Nitrogen
P	Probability
PRRS	Porcine Respiratory and Reproductive Syndrome
SAS	Statistical analysis system
SBM	Soybean meal
SOP	Standard Operating Practises
T3	Triiodothyonine
T4	Thyroxine
TNF-α	Tumour necrosis factor alpha
Wean-to-finish	Period of time from weaning to 17 weeks post weaning

1.0. LITERATURE REVIEW

1.1. Introduction

There has been extensive research on the nutrient requirements and effects of different diets on nursery pigs. This research is critical because the pig's digestive system is still developing at 21 days of age (DOA) and is more adapted to digesting milk as compared to plant-based diets. After weaning, digestive enzymes such as amylase and other pancreatic enzymes begin to increase in concentration and this results in the ability to process plant-based nutrients. Currently, the swine industry utilizes highly complex and digestible nursery diets in order to provide optimal concentrations of highly bio-available nutrients without ingredients that may result in inflammation in the gastrointestinal tract (GIT). Highly digestible ingredients such as milk whey, blood plasma and fishmeal are commonly used in early nursery diets in order to promote a healthy start and to reduce the post-weaning growth lag. However, these ingredients are expensive and increase the cost of pork production. Due to certain selective pressures, such as increasing costs of production, bio-security concerns with the use of animal by-product ingredients and consumer pressures to provide a 'vegan' fed or organically-raised pig means blood plasma, fish meal and in some cases, whey, are no longer desirable ingredients. As such, the industry may need to re-evaluate the complex nursery diet and find cost effective alternatives that do not compromise the overall efficiency and welfare of the pig.

A recent large-scale production study found that feeding a lower complexity diet post-weaning reduces average daily gain during the first part of the nursery phase, however, by the middle of the grower phase those pigs fed the low complexity diet experienced compensatory growth and had equal bodyweight (BW) to pigs fed the control highly complex diet (Skinner et al., 2014). In addition, nursery diet complexity did not influence carcass composition or quality

at the time of slaughter (Skinner et al., 2014). However, it is important to understand not only how diet, specifically protein quality and source affects the performance of weanling pigs, but also how it impacts their immune function.

1.1.2. Nursery Pig Diet Complexity

Newly weaned pigs undergo an immense amount of stress at the time of weaning; this is a result of many factors including change of environment, social pressures and dietary changes. These stressors greatly influence the early weaning period that is characterized by a post-weaning growth lag where pigs experience a reduction or negative ADG. The length and severity of the growth lag is greatly influenced by weaning weight, age, stress, health status, early feed intake and nursery diet complexity (Leibbrandt et al., 1975 and Mahan et al., 1991). A temporary decrease in the production of pancreatic enzymes at the time of weaning has been characterized in previous studies, however, the mechanism is not well understood and is thought to be related to the depression of feed intake during early weaning (Owsley et al., 1986a). The young pig's digestive system is still developing in order to transition from digesting milk to plant based ingredients. The development of digestive enzymes such a trypsin and chymotrypsin greatly increase between 21-56 days of age (DOA) (Owsley et al., 1986a and Mahan et al., 1991). Therefore, piglets weaned around 21 DOA, as in most current industry practices; do not have a completely developed GIT that can handle the change to plant-based ingredients. Traditionally, in order to mitigate these challenges in industry, early nursery diets are formulated with ingredients that are highly digestible, promote feed intake and maximize performance (Tokach et al., 1994). In order to reduce the post-weaning growth lag early wean diets typically contain highly complex ingredients that are nutrient dense and highly digestible such as animal-based protein sources like whey protein, blood plasma and fishmeal.

Numerous studies have examined the effects of feeding LC nursery diets (mostly corn-soybean meal-with reduced or eliminated amounts of whey protein and blood plasma) in the early nursery period. These studies are in agreement, that piglets experienced lower average daily gain (ADG) and BW at the start of the nursery period, but within a few weeks appear to adjust and regain weight rapidly reaching market weight at the same age as pigs fed HC nursery diets (Dritz et al., 1996a; Whang et al., 2003 and Skinner et al., 2014).

Previous studies have shown that feeding newly weaned pigs soybean meal (SBM) is the cause of some gastric upsets due to the presence of indigestible carbohydrates (CHO), antigenic soy proteins and residual trypsin inhibitors (Li et al., 1990, Lalles, 2000 and Cervantes-Pham and Stein, 2010). Certain soy proteins such as glycinin and beta-conglycinin have antigenic properties and cause an allergic reaction in the intestinal lumen and damaging the microvillus (Newby et al., 1984).

When examining the standardized ileal digestibility (SID) of certain protein ingredients in 11kg pigs, casein protein has significantly greater SID values than SBM. The SID of crude protein (CP) in casein is around 96.7% versus 84.3% for SBM and lysine digestibility for casein is 97% versus 85% for SBM (Cervantes-Pahm and Stein, 2010). Therefore, reduced digestibility of SBM suggests that feeding low complexity nursery diets restricts the bioavailability of protein and specific AA for the newly weaned pig. However, the current literature suggests there may not be a negative long-term effect to feeding LC nursery diets, meaning they may be an economical option for the swine industry.

1.2. Compensatory Growth

1.2.1. Introduction to Compensatory Growth

The evidence to support the idea that maximizing production efficiency does not necessarily equal maximum growth and performance is growing (Chiba et al., 2000). Compensatory growth has been characterized in animal production as a means to manipulate feed efficiency, making it a cost effective mechanism to improve feed efficiency (Fabian et al., 2002 and Skinner et al., 2014). Compensatory growth could also be a means to manipulate carcass composition and quality (Lebert et al., 2008). However, the end result of a nutritional restriction followed by a re-alignment period varies depending on many factors such as: animal age, length of restriction, severity of restriction, genetically determined leanness, type of restriction (disease, energy and amino acids) and protein deposition (pd) potential (Hornick et al., 2000; Fabian et al., 2002; Martinez-Ramirez et al., 2008). For example, Fabian et al., (2002) determined that pigs genetically selected to be more lean failed to express full compensatory growth by the end of the finisher period when lysine was restricted during the grower period. This could be due to the mechanisms behind compensatory growth for when protein or specific amino acids are limited. When amino acids are restricted during the growing phase; lean muscle deposition decreases and fat deposition significantly increases (Fabian et al., 2002; Martinez-Ramirez, 2008), therefore, if the animal is genetically programmed to be lean, it will not lay down lipid mass when limited AA are available, meaning more muscle protein will be mobilized as a protein and energy source for the animal (Foot et al., 1977).

When an animal experiences an energy or protein restriction, their body adapts metabolically to adjust to the incoming nutrient supply. Under feed restriction, animals are able to reduce the size of internal tissues with high cell turnover such as the visceral organs in order to

reduce the energy cost of maintenance (Drouillard et al., 1991). This is particularly evident if energy is restricted; the animal will then begin utilizing free fatty acids and ketone bodies from adipose and liver tissues as an energy source (Jarrett et al., 1976 and Bosset et al., 1985). In order to accomplish the metabolic remodelling that is required, the pig changes various plasma hormone concentrations including: insulin, thyroid hormones (T3/T4), insulin-like growth factor one (IGF-1), cortisol and growth hormone (GH) (Renaville et al., 2000). The reduction in circulating thyroid hormones is one the most significant contributors to directly sparing energy by reducing metabolic rate (Renaville et al., 2000).

The direct influence that plasma cortisol has on compensatory growth is controversial as some have found it increases, and others have found it decreases during feed restriction (Renaville et al., 2000). Interestingly, increased cortisol levels have a negative impact on protein deposition and tends to increase protein breakdown, therefore reduced cortisol would reduce protein turnover and encourage muscle protein deposition (Ferrando et al., 2001), which is not usually the case when pigs are amino acid restricted. Cortisol is capable of quickly fluctuating in plasma concentration, making it difficult to draw precise and accurate conclusions in terms of relationships and interactions.

Compensatory growth may be limited by the age of the pig. For example, if the animal is no longer in the energy-dependent phase (over 60kg BW), a restriction of amino acids can possibly be compensated for by just increasing feed intake (Fabian et al., 2002), and therefore, compensatory growth is more readily achieved during the intake-dependent phase (Heyer and Lebret, 2007).

1.2.2. Control Mechanisms of Compensatory Growth

There are various theories that attempt to explain compensatory growth and the mechanisms that allow animals to catch up in growth during the re-alignment phase. Pigs restricted during the grower phase, then allowed to re-align are 9-11% more efficient in lean muscle deposition after the restriction (Oksbjerg et al., 2002, Martinez-Ramirez et al., 2009 and Skinner et al., 2014). A mechanism that has been identified to play a role is the decreased insulin sensitivity brought on by feed restriction and increased circulating GH (Blum et al., 1985). The visceral organs are also still relatively smaller than unrestricted pigs suggesting that they require less energy and protein (Williams et al., 1985; Koong et al., 1983 and Drouillard et al., 1991). In addition plasma IGF-1 concentration are increased for restricted pigs when compared to control pigs during a re-alignment period, pointing to another possible mechanism which may be responsible for the sudden increase in lean protein deposition (Ellenberger et al., 1989 and Hornick et al., 1998). IGF-1 as a mechanism involved in compensatory growth is also supported by the fact that after re-feeding previously AA restricted pigs, the pigs remain more N efficient (reduced nitrogen excretion) compared to the controls (Lovatto, 2006). This improvement in N efficiency is not only significant in terms of growth performance but also has a positive effect on nitrogen and phosphorus excretion leading to reduced environmental burden and also is more cost effective (Fabian, 2004 and Chiba, 2001).

1.3. Performance Bio-markers

1.3.1. Insulin-Like Growth Factor-1

Insulin-like growth factor- one (IGF-1) is a multi-functional protein secreted by liver and essential for growth. Many studies have shown a strong positive correlation with circulating IGF-1 and bodyweight as well as back fat depth (Blair et al., 1989 and Bunter et al., 2002). IGF-1

expression can be manipulated by environmental factors such as nutritional status. Hornick et al., (2000) reported that circulating IGF-1 is decreased during a feed or nutrient restriction, and then is elevated during the re-alignment period. Gender appears to not influence circulating IGF-1 until around 13 weeks of age where barrows have higher levels of IGF-1 that was strongly related to increased ADG (Slifierz et al., 2013). Interestingly, a study examining IGF-1 RNA gene expression in the liver of commercially raised pigs from various farms showed a high level of variability (Hathway et al., 1996). The study concluded that many factors including, production management, feed composition and antimicrobial usage may influence IGF-1 expression (Hathway et al., 1996). Therefore, serum IGF-1 levels may be a valuable biomarker to identify periods of increased or depressed growth before the animal's body weight changes.

1.3.2. Triiodothyronine (T3) and Thyroxine (T4)

Triiodothyronone and thyroxine are believed to be important regulators of compensatory growth. The down-regulation of certain hormones such as the thyroid hormones contributes to the down regulation of metabolism that in turn spares valuable protein and energy during a nutritional restriction. This down regulation is temporarily maintained even during a re-feeding period and allows the animal to be efficient at utilizing dietary nutrients for growth and muscle deposition (Renaville et al., 2000). These findings in pigs are in agreement with studies done on steers. Animals with similar baseline T3 concentrations, experience significant decreases in circulating T3 concentrations during a feed restriction, followed by a steady increase in T3 levels during a re-feeding period resulting in increased efficiency and energy utilization (Blum et al., 1985). Therefore, evaluating circulating thyroid hormones may aid in identifying a nutrient restriction, or the occurrence of compensatory growth.

1.4. Characterization of the immune system

The immune system is vital to protect all mammals from infection, morbidity and mortality. It is especially important in newly weaned piglets, as passive immunity from the sow is diminishing around weaning. With the stress of weaning (environmental and dietary), the piglet is left vulnerable to infectious agents. Reducing weaning stress has been thought to significantly reduce the chances of a piglet becoming ill with an infectious agent. This is achieved through providing an adequate environment (ideal room temperature) and nutrients (to prevent GIT upsets and inflammation). Previous work had shown that pigs receiving a diet containing higher levels of soy protein tend to have a lower humoral and inflammatory response (Che et al., 2012) indicating a possibly compromised immune function.

It has been well characterized that exposing an animal to a pathogen results in changes to metabolism and cell mediated actions. Initial changes in metabolism are a result of the inflammatory cascade started by pro-inflammatory cytokines, such as interleukin (IL) 1-beta, IL-6 and tumor necrosis factor (TNF)-α, which are primarily produced by mononuclear myeloid cells (Jacobi et al., 2006). The initial immune reaction can be characterized by a series of fast reacting proteins called acute phase proteins (APP) that are typically synthesized in the liver and released in response to trauma, stress, inflammation or infection (Pradeep, 2013). Longer term and more significant metabolic changes occur from alterations to secretions of glucocorticoids, leptin, glucagon, insulin and insulin-like growth factor and these changes result in a 'sickness' type behaviour and more significantly a lack of appetite (Johnson, 1997; Klasing and Leshchinsky, 2000; Orellana et al., 2004). The changes in these hormone secretions typically result in decreased protein deposition in skeletal muscle and increased mobilization of lipids from adipose stores (Johnson, 1997; Klasing and Leshchinsky, 2000; Orellana et al., 2004).

Studies in growing pigs have shown that even subclinical illness can result in up to a 35% decrease in protein deposition and a reduced feed efficiency of 10 to 20% (Williams et al., 1997a; Williams et al., 1997b; Le Floc'h et al., 2009).

1.4.1. Innate Immunity Bio-marker: Tumor Necrosis Factor alpha

The vertebrate immune system can be broken into two major aspects; innate immunity and adaptive immunity (Colditz, 2002). Innate immunity is the animal's first line defense, and involves rapid reaction once a foreign body is detected. Inflammation is the first response which directs non-specific immune components (most importantly the mononuclear phagocytes) to the site of injury or infection and initiates the healing process (Elgert, 2009).

Tumor necrosis factor alpha (TNF-α) is a strong pro-inflammatory APP and helps induce the cytokine cascade in which inflammation is a result and 'clinical' symptoms of an infection or trauma are observed (Maini et al., 1995 and Elsasser et al., 2008). TNF-α is released by activated macrophages, and the longevity of a macrophage is solely dependent on TNF-α signalling (Witsell and Schoolk, 1992 and Lombardo et al., 2007). TNF-α is also capable of altering metabolism and behaviour by affecting lipoprotein lipase activity resulting in reduced fat deposition and glucose uptake through insulin signalling (Coppak, 2001; Ramsay et al., 2013). This is thought to be in preparation of diverting energy and nutrients away from growth and towards the immune response.

1.4.2. Innate Immunity Bio-marker: Haptoglobin

Haptoglobin (HP) is considered a second line positive acute phase protein (APP) that is released after the cytokine cascade, and tends to stay in circulation for several weeks (Murata et al., 2004 and Peterson et al., 2004). The major role of HP is to bind up free hemoglobin; which reduces the loss of iron through the kidney, acts as a bacterio-stat and induces apoptosis (Katoh

and Nakagawa, 1999; Kim et al., 1995 and Murata et al., 2004). Due to the apparent involvement of HP in bovine fatty liver syndrome, it may also be involved in the regulation of lipid metabolism (Yoshino et al., 1992). Serum concentrations of HP can be utilized as a biomarker for the indication and extent of a subclinical disease and inversely related to performance; as low serum APP's have been related to improved performance in swine (Eurell et al., 1992, Piniero et al., 2009, Murata et al., 2004 and Peterson et al., 2004). Numerous studies have characterized serum HP levels in healthy and ill animals. At 9-12 weeks of age pigs deemed healthy had serum HP concentrations between 0-2.4g/L and animals deemed ill or infected had HP concentrations between 2.5-5g/L (Lampreave et al., 1994; Hulten et al., 2003; Parra et al., 2006 and Rakhshandeh and de Lange, 2012). However, the exact correlation between HP concentrations, animal health and animal performance are still being determined.

1.4.3. Innate Immunity: Albumin

Albumin is considered a significant negative acute phase protein in pigs. It is considered one of the most abundant proteins in plasma, making up 40-60% of total plasma protein content in swine (Murata et al., 2004). Albumin is well known as a carrier protein for steroids, fatty acids and hormones (Peters, 1996). When an animal experiences an immune reaction, serum levels of albumin notably decrease (Pradeep, 2013), which is a result of the main function of albumin during an immune challenge which is to act as an antioxidant by scavenging harmful free radicals (Peters, 1996). Therefore, decreased serum albumin can be an indicator of clinical or sub-clinical disease.

1.4.4. Adaptive Immunity

Adaptive (or acquired) immunity is highly specialized cells that can remain in circulation for days or as long as years, and are important for prevention or elimination of specific

pathogens. The adaptive immune system consists of T and B lymphocytes which employ antigen receptors, meaning once they are exposed to a foreign body and multiply they are genetically encoded to react only to specific antigens (Iwasaki and Medzhitov, 2010), giving way to specific immunoglobulins. Swine, like other mammals have a relatively long life span, therefore they direct more energy into developing an adaptive immune response (Lee, 2006). An adaptive immune response is more metabolically costly to develop, but relatively cheap to utilize, therefore it is a long-term investment for the animal (Lee and Klashing 2004 and Lee 2006). The direct effects of dietary protein source fed during the nursery phase and its influence on the development of an adaptive immune response has not been well characterized and should be further investigated.

1.5. The interaction between diet, performance and immune function

Infectious disease can greatly affect the metabolism, growth and overall performance of an animal. During a disease challenge pigs experience an inflammatory response that results in a reduction in skeletal muscle protein synthesis. This is due to the animal diverting nutrients away from growth and towards mounting the immune response in order to fight off the pathogen. Physiological changes such as reduced feed intake, increased inflammatory proteins, increased protein catabolism and an increase in protein deposition to visceral organs are all functions that divert nutrients away from protein deposition (Breuille et al., 1998; Orellana et al., 2004 and Klasing, 2007). This is due to the animal's priority to survive and maintain homeostasis. However, the amount of reduced muscle protein deposition appears to be in part dependent on the degree of inflammation (Orellana et al., 2004). Synthesis of inflammatory proteins has a much greater nutrient demand than immune cell development, the lysine requirements are estimated at about 7-10% of total lysine requirements (Klasing, 2007). This means 7-10% of

lysine is diverted from growth to inflammatory cell development. Other ways nutrition interacts with the body's immune function is through 'feeding the pathogen'. Invading pathogens also utilize nutrients, typically seen are requirements for biotin and iron, hence the increase in haptoglobin in an inflammatory response as it scavenges free hemoglobin (Klasing, 2007). Lastly, nutrition can influence the immune system through allergenic stimulation through lectins and protein antigens that cause an allergic reaction and ultimately result in inflammatory mediated damage of the intestinal lumen (Klasing, 2007). Soybean meal is known to have allergenic properties due to soy proteins such as glycinin and beta-conglycinin (Cervantes-Pahm and Stein, 2010).

1.6. Conclusions and Implications

Previous research indicates that although feeding HC nursery diets is beneficial to the weaned piglet, it may not be necessary for optimal growth performance and carcass quality. In addition, HC nursery diets are costly and if high quality protein ingredients such as whey protein, blood plasma and fish meal can be reduced or eliminated and replaced with soybean meal in early nursery diets there may be feed cost savings for swine producers. However, the importance of high quality ingredients in early nursery diets on immune function and morbidity is not well understood in commercial settings. The known allergenic properties of SBM and associated gastric upsets could have long term detrimental effect on intestinal health and overall pig health.

A large number of studies that utilize LC nursery diets are reported in the literature (Dritz et al., 1996a; Whang et al., 2003; and Skinner et al., 2014). Previous studies have reported that even when feeding LC diets, optimal growth is reached, and days to market weight and carcass quality is not impacted. However, these studies are conducted in controlled research settings and the results may not be replicated in commercial farm settings. The increased pressures found in

commercial farms, along with genetics, management and health variability make transferring these findings to commercial settings potentially unpredictable. More applied studies in commercial settings should be conducted so that nutritionist may more confidently use the findings of these previous studies to make recommendations to commercial producers.

It is possible that implementing the use of LC nursery diets on commercial farms will result in a temporary decrease of ADG during the nursery phase, but through compensatory growth the pigs will reach optimal growth performance. Once the pigs reach market weight, those fed the LC nursery diets will have no observed differences in any carcass quality traits that are examined at the time of commercial processing. At present, it is unknown whether the sometimes less than ideal conditions on commercial farms such as high stocking density and disease challenges may influence how the pigs react to being fed LC nursery diets. Therefore, the objectives of this thesis is to identify the impact of implementing LC nursery diets in commercial farms and its effect on long term growth performance, health status and carcass quality.

2.0. Hypotheses and Objectives

The hypothesis of the research reported in this thesis is that pigs fed low complexity (LC) nursery diets on commercial farms will experience reduced growth during the early nursery phase but will under-go compensatory growth and reach targeted market weight (time of processing) at the same time as pigs fed high complexity (HC) nursery diets. Carcass quality traits such as; hot dress weight (HDW), back fat depth, loin eye depth and percent lean yield will be uninfluenced by nursery diet complexity. Serum haptoglobin (HP) concentrations used as a general health biomarker will also not differ due to nursery diet complexity at any stage of production.

The first of this study was to identify the life-long impact on growth performance when utilizing LC nursery diets on commercial swine farms. The second objective was to compare carcass quality traits at market weight for pigs fed HC or LC nursery diets to ensure quality and value is not influenced by nursery diet complexity. Lastly, the third objective was to identify the impact of nursery diet complexity on the general health status of pigs during various stages of production with HP used as a general biomarker.

3.0 Impact of nursery pig diet complexity on lifetime growth performance, carcass characteristics and serum haptoglobin when implemented on commercial farms.

3.1 Abstract

A reduction in the complexity of diets fed to nursery pigs using plant (soybean meal) rather than animal (whey, blood plasma) protein sources could reduce the cost of feed during the nursery phase, but effects on overall growth and health performance have not been determined on commercial farm settings. The objectives of this study were to investigate the impact of nursery diet complexity on lifelong growth performance, carcass traits at time of processing as well as serum haptoglobin (HP), when implemented on commercial farms. A total of 774 pigs were enrolled during 13 cohorts across 7 commercial farms with moderate-to-high health status. Pigs were individually weighed 5 times over the study; within 96 hours after birth (2.8 ± 0.25 days old), at weaning (27.97 ± 0.63 days old), at the end of the nursery period (67.0 ± 1.9 days old), at the end of the grower period (108.1 ± 1.7 days old) and at the end of the finisher period (154.0 ± 3.8 days old). Individual blood samples were also collected starting at weaning and the following 3 time points and were analyzed for serum HP concentrations. During the nursery period, half of the enrolled pigs on each farm were assigned one of two dietary treatments, either high complexity (HC) or low complexity (LC). Both diets were fed in three phases over the 6 week nursery period. After the nursery period, all the pigs were fed the grower-finisher diets common to each farm. At a targeted live market weight a subset of pigs were processed, and individual carcass traits were collected. Overall, no difference was observed for any growth performance parameters at any time point during the study due to nursery diet complexity (P>0.05). The cost of feed per pig during the nursery period was significantly reduced for the LC fed pigs (P<0.001). Carcass quality traits such as HDW, loin eye depth, back fat depth and

percent lean yield were not influenced by nursery diet complexity (P>0.05). Carcass value at time of processing was found to be similar for pigs fed HC and LC nursery diets (P=0.98). Serum haptoglobin (HP) concentrations used as a general health biomarker was not influenced by nursery diet complexity at any stage of production (P>0.05). The current study indicated that utilizing LC nursery diets in commercial settings may be a feasible way to reduce feed costs without negatively impacting lifetime pig growth and carcass value.

3.2 Introduction

Feed is the greatest expense in pork production, with nursery diets being the most costly. This is due to the inclusion of highly complex protein ingredients (whey, fishmeal and blood plasma). At weaning pigs are still developing their ability to produce important digestive enzymes (Owsley et al., 1986), and therefore are still more adapted to digesting milk. Currently on commercial farms it is common for early nursery diets to include highly complex ingredients as they are more digestible for the newly weaned pig (Cervantes-Pahm and Stein, 2010) and improve piglet growth performance (Tokach et al., 1994; Whang et al., 2000). The use of soybean meal (SBM) as an alternative protein source has been repeatedly examined under research settings and demonstrated that feeding SBM based diets results in growth reduction during the nursery phase but similar BW was achieved by the finishing period (Whang et al., 2000; Wolter et al., 2003; Skinner et al., 2014). Most of these studies also concluded that the pigs fed these low complexity (LC) nursery diets, underwent compensatory growth in order to catch up in BW to the high complexity (HC) fed pigs (Dritz et al., 1996a; Whang et al., 2000 and Skinner et al., 2014). Previous work has also concluded that nursery diet complexity and early life nutritional interventions do not influence carcass quality traits at the time of slaughter (Martin et al., 1974; Gaines et al., 2002; Skiba et al., 2005; Skinner et al., 2014). Therefore,

feeding LC diets during the nursery phase may reduce feed costs without negatively impacting life-time growth performance and carcass quality (Skinner et al., 2014).

When pigs are healthy, they grow and perform optimally which is the goal in all stages of swine production. The diets and specific nutrients provided to an animal can influence their ability to resist pathogens and perform optimally. SBM has been shown to induce an inflammatory response in pigs due to allergenic properties and residual anti-trypsin inhibitors (Cervantes-Pahm and Stein, 2010). Inflammation and the production of inflammatory proteins in response to a pathogenic load or allergen impose a metabolic stress on the animals, through the increased energy and nutrient demand needed to mount an immune response (Klasing, 2007). An immune response results in a number of metabolic changes that ultimately reduce lean muscle deposition or even cause muscle catabolism (Breuillet et al., 1998, Orellana et al., 2004 and Klasing, 2007). Therefore, the ability for an animal to remain healthy or recover from a disease challenge quickly is highly important in commercial production.

Haptoglobin (HP) is an acute phase protein released after the cytokine cascade and tends to remain in circulation for several weeks (Murata et al., 2004 and Peterson et al., 2004). Serum HP concentrations can be used as a general health biomarker (Saco et al., 2010), but can be influenced by both infectious and non-infectious agents. When serum concentrations are above 2.0g/L this can indicate the animal is experiencing a non-specific infection or inflammation (Fransico et al., 1996, Eurell et al., 1992). A pervious study reported no association between nursery diet complexity and immune status when HP was the biomarker and pigs underwent an LPS challenge (Dritz et al., 1996b). In contrast, a large production study reported a numerical increase in mortality for pigs fed LC nursery diets when pigs were naturally challenged with *Streptococus suis* and *Erysipelothrix rhusiopathiae* (Skinner et al., 2014). Therefore, the

understanding of how nursery diet complexity may affect a pig's ability to respond to a disease challenge is still limited.

To our knowledge, the use of LC nursery diets has not been studied under commercial farm settings. Commercial farms may invoke selective pressures that are not always present or repeated in research settings such as, stocking density, variable management practises and disease pressures. Therefore, the application of LC nursery diets in commercial production needs to be assessed.

We hypothesize that feeding a LC nursery diet at commercial farms will reduce pig growth during the early nursery phase, but similar BW and carcass quality traits will be achieved by the time of market. The purpose of the current study was to compare the lifetime growth performance, carcass quality traits at the time of market, and on serum HP used as a biomarker, for pigs fed either HC or LC nursery diets.

3.3 Materials and Methods

The project was approved by the University of Guelph Animal Care Committee (AUP# 3124) and follow Canadian Council of Animal Care guidelines (CCAC, 2009).

3.3.1 Animals and General Management

The study was conducted on seven commercial farms in Southern Ontario (ON), Canada located within a 200 km radius of the University of Guelph (ON, Canada) over the course of two years (May 2014-June 2016). Four of the farms were part of a large-scale production system, one farm was part of a smaller scale production system, and the other two farms were independent farrow-to-finish systems. Six farms participated in two seasonal cohorts, one cohort comprised of piglets born during the summer months (May-August) and the other cohort comprised of piglets

born during the winter months (November-January) resulting in thirteen cohorts. Sixty piglets were selected at random from eight to ten sows within four days of birth on each farm for each cohort. The randomly selected piglets were individually weighed and given two ear tags with a unique identification. At this time half of the pigs from each litter, were assigned to be destined for one of two (high complexity or low complexity) dietary treatments during the nursery period, gender was balanced across treatments were possible. The selected piglets were a three way cross (Yorkshire x Landrace x terminal boar line) common to commercial production. A questionnaire was conducted to determine farm demographic, disease history and feed management strategies (Table 3.1). A total of 774 commercial barrows and gilts (372 and 402, respectively) were weaned at 28.0 ±0.62 days of age and at 5.34± 1.5 kg of BW. The piglets were subsequently moved to either an on- or off-site nursery room and sorted into two pens; half of the piglets from each litter were randomly assigned to one of these two pens which were assigned to one of the two dietary treatments. The nursery rooms were environmentally controlled as per individual farm standard operating procedure. The nursery period lasted 39.1± 4.7 days. After the nursery period, pigs moved to an on- or off-site grower/finisher facility where treatment groups were mixed together in one common pen. The grower/finisher phase was between eleven and thirteen weeks in length. The grower/finisher facilities ranged from fully to partially slatted flooring, natural to mechanical air ventilation, floor feeding to automatic dry feeders and large auto sort to small group barns.

Pigs were weighed within four days of birth, at weaning before the dietary treatments began and at the end of the nursery period (67.0 ± 1.9 days of age), end of the grower period (108.1 ± 1.7 days of age) and the end of the finisher period prior to market (154.0 ± 3.8 days of age). Each time pigs were weighed individual blood samples were also collected except when

pigs were within four days of birth. Since records for specific pig mortality and morbidity were not consistently recorded on each farm, pig loss was calculated as a percentage of pigs removed from the study due to any reason. The reason for pig removal from the study was not always due to death and could include the loss of both identification tags. When death occurred, the reason was not always due to an infectious cause and could include injury, ridgling, poor growth or small at weaning, and scrotal or umbilical ruptures.

3.3.2 Diet, Feed Management and Nutrient Analysis

At weaning, pigs were assigned to one of two dietary treatments, high complexity (HC) or low complexity (LC) nursery diets, which were delivered in three phases. Both dietary treatments supplied similar formulated nutrient levels but varied in ingredient composition (Table 3.2). The HC diet contained highly digestible, complex protein sources, (ie. whey, fishmeal and hamlet protein) barley and feed flavouring. The LC diet contained primarily corn (*Zea mays*) and soybean (*Glycine max*) meal, with reduced amounts of whey and fishmeal, only included in the first phase. In-feed antibiotic (AB) (type and concentration) and therapeutic zinc-oxide usage was unique to each farm and determined by each farm manager in accordance with the current usage standard operating procedure (SOP) at the time of the trial. Both of the nursery diets were delivered in a three phase feeding program with phases I, II and III fed for 8.7± 0.2, 14.9± 0.59 and 14.1± 0.92 days, respectively. Phase I was delivered in a crumble form and phases II and III were delivered in a short pellet form. After the nursery period, all the pigs were fed common commercial grower-finisher diets that were not limiting in essential nutrients. The commercial grower-finisher diets were delivered in multiple phases that varied according to each farm's specific feeding program. The form of the grower-finisher diets varied depending on individual farm and ranged from a regular pellet, short pellet to a mash.

Feed was provided ad libitum at all times, along with free choice access to fresh water. Due to barn design, in some nurseries the feeders were shared across two pens. Since the study was performed in commercial farms all pens were needed to house pigs at an appropriate stocking density. Therefore, one side of the feeder was able to house all of the trial pigs that were assigned to one diet (n=30). The pen adjacent to the trial pigs that shared the same feeder housed 25-35 (dependent on pen size at each farm) 'non-trial' pigs. These non-trial pigs had access to only one of the trial diets. In order to more accurately calculate average daily feed offered (ADFO) and feed conversion the non-trial pigs were weighed at the start and at the end of the nursery period on the same day as the trial pigs. ADFO was calculated rather than average daily feed intake since refusals and weigh backs were unable to be recorded. ADFO was recorded just during the nursery period and was calculated based on the average amount of feed added each day to the feeder for each phase divided by the number of pigs that had access to that feeder. Feed intake or ADFO was not recorded during the grower and finisher phases due to barn design and limitation of automatic refill feeders.

The cost of feed during the nursery period was calculated for each treatment and each diet, by obtaining individual commodity prices. Personal Communications, with D. Skinner a local nutritionist, provided monthly average commodity prices from May 2014 to June 2016 for corn, soybean meal, whey protein, fishmeal, 6 row barley and wheat. Average commodity prices for the remainder of the ingredients were also provided by personal communications, with another local nutritionist. Monthly prices were obtained to get an average diet cost over the course of the entire study. The cost of each diet and each phase was calculated on a per tonne basis. Using the actual feed offered data of each phase from the trial, feed usage per pig per

phase was calculated, and the total cost per pig over and phase and the entire nursery period was calculated.

The nursery diets were analyzed for CP (N × 6.25), Ca, and P contents (Agrifood Laboratories, Guelph, ON, Canada). Nitrogen content was determined by an automatic analyzer (LECO-FP 428; Leco Instruments Ltd., Mississauga, ON, Canada; AOAC, 1997). Phosphorus content was determined as described by Heinonen and Lahti (1981), and Ca content was determined as described by Themelis et al. (2001).

3.3.3 Carcass Quality

At a targeted live BW of at least 118kg, pigs were sent to an Ontario abattoir for processing. Due to limitations in handling and shipping pigs were required to be sent in groups of 18-25 pigs at a time, this resulted in some pigs being shipped at a heavier BW than is typical for Ontario. Within each farm a subset of pigs were sent in two groups when18-25 trial pigs reached at minimum 118kg BW. Producers ultimately selected the pigs to send for processing based on their size or projected weight. Carcass trait information from 275 and 258 -HC and LC-fed pigs, respectively, was collected. The loss of carcass information was due to a variety of reasons: including the loss of ear tag identification prior to or at slaughter, communication errors or rapid growth which resulted in early shipment outside the subset. Pigs that reached the processing plant with their individual ID tag were individually assessed for carcass trait information. The carcass trait information collected was hot dress weight (HDW), loin eye depth, back fat depth and lean yield percent, these traits measured according to the Canadian carcass grading system.

Individual carcass value was calculated based on individual trait information collected. A payment grid that is largely used for an Ontario provincial processing plant, was used to

calculate premiums or discounts on each carcass (Personal Communications, Conestoga Meat Packers). Price per BW was calculated based on a mid-range value of a $1.55/ kg of dressed weight, which is the average pig price over the past decade (Personal Communications, Synergy Services Inc). Utilizing the dress weight price, premiums from the grid and a formula provided by Personal Communications, Synergy Services Inc. a dollar value was calculated for each carcass.

3.3.4 Serum Haptoglobin Analysis

Blood samples were collected from individual pigs at the same time as body weight during the last four visits; at weaning, end of nursery, end of grower and end of finisher periods. Blood was collected in plain vacutainer tubes by either via jugular vena-puncture or orbital-sinus puncture. Individual blood samples were spun at 1500 x **g** for 20 minutes. Serum was removed and stored at -20℃ until further analysis.

The serum haptoglobin (HP) concentrations were measured in a subset of selected pigs. The selection criteria was based on the ADG during the nursery phase for each farm. For each farm the pigs were split based on dietary treatment assignments, then were either categorized as a high, medium or low based on their ADG during the nursery (categories were kept as equal as possible). From those categories five pigs were randomly selected from each category, so there was 15 HC and 15 LC fed pigs selected in the end from all ranges of ADG during the nursery. The same selected pigs had their serum analyzed for HP concentrations for all four visits.

Serum HP concentrations were analyzed using a commercially available HP (pig) ELISA kit (Abnova, St., Taipei, Taiwan) according to the manufacturer protocol. Serum samples were prepared using a 40,000 fold dilution prior to kit use. Single samples were analyzed with random duplication of 2-4 samples per plate, for confidence of repetition.

3.3.5 Statistical Analysis

Data were analyzed by SAS (version 9.4; SAS Inst. Inc., Cary, NC) using the MIXED procedure. Growth performance (ADG and BW) and haptoglobin (HP) was analyzed using a repeated measures model. Average daily gain (ADG) was analyzed from suckling-finisher period, bodyweight (BW) was analyzed from weaning to the end of finisher period, with birth weight and age at weaning considered covariates for the model. HP was analyzed from weaning to the end of finisher period. For all repeated measures models, individual pig and farm were regarded as random effects. All outcomes were tested for the main effect of nursery diet treatment. Other independent fixed effects were considered such as, visit (stage of production), seasonal cohort (summer or winter determined by when the pig was born), nursery phase in-feed antibiotic and therapeutic zinc oxide usage. The possible interaction between independent variables and the main effect was also examined. Individual means were compared using LS means and a Tukey-Kramer adjusted p-value. Interactions with the main effect and stage of production as well as season were compared using pre-planned orthogonal contrasts.

The cost of diet was analyzed using a repeated measures model for average cost per month from May 2014-June 2016. Cost was analyzed for the main effect of dietary treatment, and time as well as their interaction.

Carcass quality traits, carcass value and carcass premiums were analyzed for the main effect of nursery dietary treatment. The farm and farm by diet interactions were regarded as random effects. Other independent fixed effects that were considered was seasonal cohort (summer or winter, depending when the pig was born), in-feed antibiotic or therapeutic zinc-oxide usage during the nursery phase, and gender of the pig. The possible interaction between the main fixed effect and independent variables were also examined. Hot dressed weight (HDW)

was considered as a covariate for back fat depth, loin eye depth, percent lean yield and days to market. The Tukey-Kramer adjustment was used to assess differences among the main effect, independent variables and their interactions.

To test the population uniformity of ADG and BW across the nursery dietary treatments, the Npar1way median test procedure and the Kolmogorov-Smirnov two-sample test were applied. In all analysis, means were considered significantly different with when $P < 0.05$ and considered a trend when $0.10 < P > 0.05$.

3.4 Results

3.4.1 General Observations

The analysis of the nursery diets were comparable to calculated values (Table 3.2). Some farms displayed symptoms consistent with common swine disease, such as observed neurological disease assumed to be streptococcal meningitis, skin lesions consistent with greasy pig and swine erysipelas as well as some respiratory diseases. The average stocking density across the farms for the nursery period was 0.34± 0.03 m^2 per pig, and for the grower-finisher period was 0.77± 0.09 m^2 per pig. Individual farm information such as, in-feed antibiotic and therapeutic zinc usage and average weaning age is outlined in Table 3.1.

3.4.2 Growth Performance

The number of pigs in the study was reduced between the start of the study at birth and the end of the study at time of market; this is due to many reasons including: death, loss of both ear tags, injury or producers decision to remove pig (Table 3.3). Piglet bodyweight (BW) was equal across dietary treatment at the initial visit after birth (Table 3.3, P=0.96). Birth weight was

influenced by seasonal cohort, piglets born in the winter months were 1.97 kg versus those born in the summer months were 1.76 kg of BW(P<0.001). Pig BW was not influenced by nursery diet complexity, at any measured stage of production (P=0.10). Seasonal cohort in which the pig was born influenced significantly influenced BW, piglets born during the winter months were significantly heavier at all stages of production apart from at weaning (P<0.001, Figure 3.2). In-feed antibiotic (AB) usage during the nursery period influenced overall growth performance, pigs that received in-feed AB during the nursery period were on average significantly heavier than those that did not receive in-feed AB (P=0.01).

ADG during all stages of production was unaffected by nursery diet complexity (P=0.14). Lifetime ADG was influenced by seasonal cohort, those born in the summer months had an ADG of 664 grams per day versus those born in the winter had an ADG of 648 grams per day (P<0.01). Piglet ADG was also influenced by an interaction of seasonal cohort and visit (stage of production) (P<0.001, Figure 3.3.). Figure 3.1 is a box plot graph showing pig bodyweight across dietary complexity at each visit (stage of production). Statistical analysis of ADG and BW across dietary treatment revealed that there are no differences in variation however, the box plot graph indicates a possible numerical decrease in uniformity at the end of the finisher period for the LC fed pigs. Pig removal percent (P=0.52) and average daily feed offered (ADFO) during the nursery period (P=0.80) was not influenced by nursery diet complexity. Cost of feed per pig during the nursery phase, was significantly reduced for the pigs fed the LC nursery diets by $2.82 per pig ($P$<0.001).

Overall, there were no differences in lifetime average serum HP concentrations across dietary treatments, 0.827g/L versus 0.849 g/L, for the HC and LC fed pigs, respectively (P=0.73). There was however a significant effect of visit (stage of production) on serum HP

concentrations (P<0.001) and a tendency for a diet by visit interaction (P=0.09, Table 3.4.). Serum HP concentrations were significantly influenced by seasonal cohort (P=0.03), the pigs in the summer cohort had on average higher serum HP concentrations, 0.912 g/L versus 0.763 g/L for the summer and winter cohorts, respectively. Serum HP concentrations were also influenced by an interaction of seasonal cohort and visit (P<0.001, figure 3.12).

3.4.3 Carcass Characteristics

The carcass quality data collected was from a subset of pigs, this was due to shipping and slaughter plant limitations, and a loss of pigs at the processing plant from loss of pig identification or communication errors. The total number of observations for carcass traits was 533; 275 being from HC fed pigs and 258 from LC fed pigs (Table 3.5.). Of the 275 HC fed pigs 134 were gilts and 141 where barrows, of the 258 LC fed pigs 117 were gilts and 141 were barrows. At the time of slaughter pig hot dress weight (HDW) was not influenced by nursery diet complexity (P=0.39, Table 3.5). However, HDW was influenced by other considered factors such as the use of in-feed therapeutic zinc oxide during the nursery period and the seasonal cohort in which the pigs were born. The use of therapeutic zinc oxide during the nursery period resulted in a greater HDW at the time of processing, 104.91 kg versus 100.24 kg, respectively for zinc oxide used versus not used (P=0.05). Pigs born in the summer cohort also had a greater HDW, 104.07 kg versus 101.08 kg, for the summer versus the winter cohorts, respectively (P<0.001). Loin eye depth at the time of processing was not influenced by nursery diet complexity (P=0.48). Carcass loin eye depth, was influenced by the use of therapeutic zinc oxide during the nursery period. Pigs that did not receive therapeutic zinc oxide during the nursery period tended to have greater loin eye depth at the time of processing, 69.55 mm versus 67.22 mm, respectively (P=0.07). Back fat (BF) depth was also uninfluenced by nursery diet

complexity (*P*=0.67). Back fat depth was however, influenced by seasonal cohort, those processed during the summer cohort had significantly great back fat depth than those processed during the winter cohort, 20.11 mm versus 19.25 mm, respectively (*P*=0.01). Percent lean yield was also not influenced by nursery diet complexity (*P*=0.74). Percent lean yield was influenced by seasonal cohort, the pigs processed in the winter cohort had 60.80 percent lean yield versus those in the summer cohort had 60.43 percent lean yield (P<0.01). The number of days between birth and processing (days to market) tended to be reduced for the pigs fed LC nursery diets (*P*=0.05). The value of each carcass at the time of processing was not impacted by nursery diet complexity (*P*=0.98). Carcass value was influenced by seasonal cohort, with those processed during the winter cohort having a greater value of $176.11 per carcass versus the summer cohort average carcass was valued at $174.47 (*P*=0.04). When looking at just the value of a premium on each carcass according to a major Ontario grid there was no difference due to nursery diet complexity, the premiums were $22.25 versus $22.18, for the HC and LC fed pigs respectively (*P*=0.93).

3.5. Discussion

The purpose of the current study was to determine if feeding low complexity (LC) nursery diets to newly weaned pigs influenced long-term growth performance and carcass characteristics, when implemented in a commercial farm setting. Commercial settings add selective pressures that are not always observed or replicated in experimental settings and may include, but are not limited to, stocking density and competition, ventilation, differences in farm management, genetics, and clinical and sub-clinical disease challenges. There are a large number of studies evaluating nursery diet complexity in an experimental setting (Whang et al., 2000;

Dritz et al., 1996a and Skinner et al., 2014) but to our knowledge, evaluating nursery diet complexity in multiple commercial farms has not been reported.

The significant differences observed in average pig age at weaning, end of the nursery, end of the grower and end of the finisher periods, is due to an unequal representation due to pig removal throughout the study. The influence of age at weaning due to the use of in feed antibiotics (AB) during the nursery period is due to the antibiotic free farm implemented a later weaning age. Association between seasonal cohort and the age of pig at the initial visit, end of nursery, end of grower and end of finisher were results of unequal number of days between sampling points across the seasonal cohorts. It was attempted to keep the visits equally spread apart for all farms and seasons, but was not always achievable and therefore resulted in some minor influences.

A previous study conducted in our laboratory found a significant reduction in average daily gain (ADG) during the nursery period and lower bodyweight (BW) at the end of the nursery period for pigs fed LC diets versus those fed high complexity (HC) diets (Skinner et al., 2014). A possible explanation as to why weights were found similarly in the present study could be due to the length of time between the sampling points, therefore, treatment differences that occurred earlier in the nursery phase may not have been detected. Most previous studies reported the biggest deviation in growth due to diet complexity occurred during the first couple of weeks after weaning (Dritz et al., 1996; Wang et al., 2000 and Skinner et al., 2014). In addition, previous studies conducted on nursery diet complexity used either, Yorkshire x Landrace or pure bred Yorkshire pigs, rather than hybrid terminal crosses used in the present study. Terminal cross pigs are commercial hybrids genetically selected to deposit body protein more efficiently in a short period time. The genetic robustness to grow quickly and efficiently may have positively

influenced the pig's ability to maintain optimal growth performance despite nursery diet complexity. The overall growth performance finding that there are no long-term consequences to feeding LC diets is in agreement with most previous studies that examined nursery diet complexity on long-term growth (Zimmerman and Khajarern, 1973; Whang et al., 2000; Fabian et al., 2002; Wolter et al., 2003 and Skinner et al., 2014).

The seasonal cohort influence on pig BW is not likely a result of seasonal effects, but an interaction of the seasonal influence on age of the pig at each visit/sampling point. For example, initial body weight was greater for the piglets born in the winter cohort, however, age of the pig at the first visit during the winter cohort was 1.3± 0.1 days greater. The same is accurate for BW at the end of the nursery, end of the grower and end of the finisher periods, pigs born in the summer cohort were significantly heavier, but they were also significantly older, therefore it is more likely the affect of age at the time of sampling rather than the season of birth that influenced BW.

The use of in-feed antibiotics during the nursery period has been shown to improve growth performance. Low levels of in-feed AB results in improved ADG (Coffey and Cromwell, 1995 and Skinner et al., 2014), the current study was in agreement with this, as pigs fed in-feed AB during the nursery period were on average heavier.

In commercial production the average BW of a group of pigs in a barn is not the only important assessment of performance but rather the variation of BW in the population is highly important. Unequal growth in a commercial farm can mean economical losses. Barns that work on an all-in/all-out system are especially dependent on uniform growth, as slow growing pigs in the finisher barn result in loss of income as they are small at market or never make it to market. Holding back slow growing animals, and introducing a new batch of pigs creates a disease risk

which most production systems avoid and justify the all-in/all-out management system, making it critical to keep the entire population growing at the same rate. According to two statistical tests, the npar test and one-way median test the current study found no statistical difference in BW and ADG variation due to dietary treatment. However, the box plot graph does raise a potential question regarding uniformity specifically at the end of the finisher period, as the inter-quartile range is increased for the LC fed pigs. Although not significant, it is an important point to note as this small difference has potential to become bigger if less than ideal conditions occur such, as more serve disease challenges. The influence of nursery diet complexity on lifelong pig growth uniformity and possible risk factors associated with slow growth should be identified, as this is a significant limitation in all-in/all-out management systems.

Elevated serum haptoglobin (HP) levels are an indication of a non-specific infection or inflammation and serum concentrations can be used to identify the pig's general health status (Eurell et al., 1992 and Saco et al., 2010). Overall, in this study the average serum HP concentrations were in agreement with the pigs' growth performance, there was no observed differences due to nursery diet complexity. A previous study also indicated that nursery diet complexity appeared to have no impact on immune status when pigs underwent a lipo-polysaccharide (LPS) challenge (Dritz et al., 1996b). This indicates that nursery diet complexity may not influence the way in which a pig reacts to a forced challenge. However, it is still unclear if utilizing LC nursery diets influence a pig's susceptibility to disease. Soybean meal is allergenic and can cause gastric upset and inflammation, which may encourage or provide a route for pathogens to enter the body. The tendency for the LC fed pigs to have greater serum HP concentrations at the weaning, occurred prior to any application of dietary treatment, meaning the influence was independent of nursery diet complexity. Disease risk and pathogen presence is

influenced by many factors such as herd flow (all-in/all-out versus continual), ventilation, feed management, stocking density and season. The presence and survivability of pathogens is highly influenced by temperature and humidity, which can be greatly influenced by outdoor conditions even in indoor intensive production systems (Webster ,1981). Seasonal cohort in which the pig was born greatly influenced serum HP concentrations at different stages of production. Elevated serum HP concentrations during the summer cohort at weaning could be due to a variety of influences. In particular, one farm's sow source during the summer cohort was experiencing a porcine respiratory and reproductive syndrome (PRRS) outbreak meaning the piglets in that cohort were exposed to the virus while suckling and likely were more susceptible to secondary infections, especially at the time of weaning. The grower-finisher stage during the summer cohort occurred during September to December, which is considered the fall season and depending on the year can be wet with highly variable outdoor temperatures, the grower-finisher period during the winter cohort occurred between March-May which is considered winter and early spring, which also can have highly variable humidity and temperature. Therefore, it is difficult to conclude that season was the only influence on disease challenges during this stage of production as season, temperature and humidity was not strictly controlled. The elevated serum HP concentrations observed at the end of the grower phase during the winter cohort is likely due to clinically diagnosed infection in one or two farms during that cohort and phase of growth. Overall, it is difficult to isolate an individual reason for an increase in serum HP concentrations without more controlled measures; however, serum HP concentrations can be a useful tool to assess and compare the general health of a group of pigs in the same environment.

The reduced feed cost per pig during the nursery period for the LC diets is because of the reduction or elimination of expensive protein sources. Whey protein, blood plasma and fishmeal

are costly ingredients. The average cost per tonne of whey protein and fishmeal between May 2014 and June 2016 was $1,372.93 and $2,188.79, respectively (Personal Communication, Swine Nutritionist D. Skinner). In comparison, the average cost per tonne of soybean meal between May 2014 and June 2016 was $537.19 (Personal Communication, Swine Nutritionist D. Skinner).

Previous studies have shown that early life nutritional intervention, does not influence carcass quality traits, nor does nursery diet complexity (Dritz et al., 1996a and Skiba et al., 2010). The current study is in agreement with these findings as no differences were observed in any of the carcass quality traits or carcass value. Previous studies conducted on nursery diet complexity and its influence on lifelong performance and carcass traits showed no differences in any measured traits at the time of processing (Skinner et al., 2014). The tendency for reduced number of days to market for the LC fed pigs must be interpreted with caution. Selecting pigs to go to market can be a subjective or an objective decision, and the decision was ultimately left up to the producer. Producers were provided with the individual pigs BW at the end of the finisher period and their growth projections, however it was up to them to select which pigs were ready for market. However, when looking at the average BW of the LC fed pigs in comparison to the HC pigs, although not statistically different the LC fed pigs were consistently heavier than the HC fed pigs, and this may have influenced when the producers decided to ship the pigs to market.

The greater dressing weight observed when the pigs were born in the summer cohort is not likely an influence of the season but rather a result of the pigs being with held from processing due to a lack of shackle space available during the fall of 2015 in Ontario provincial processing plants. The tendency for therapeutic zinc-oxide usage during the nursery phase to

influence HDW and loin eye depth is likely an actual influence of pig genotype and gender and not the usage of zinc-oxide carrying over to time of processing.

In conclusion, the current study suggests that LC nursery diets utilized on Ontario commercial swine farms with limited disease pressures, does not influence lifetime pig growth performance from weaning to finishing. Nursery pig diet complexity also does not influence carcass value, through negatively impacting carcass characteristics at the time of processing.

Table 3.1. Farm demographics, raw means and standard deviation of growth performance for each enrolled farm

Farm[1]	Season[2]	Initial[3]	*Bodyweight*				*Average Daily Gain*				
			Weaning	End Nursery	End Grower	End Finisher	Suckling	Nursery	Grower	Finisher	Wean Age[5]
1[4]	S	1.94±0.40	9.14±2.22	25.92±2.93	50.6±6.39	110.1±9.76	0.266±0.04	0.480±0.08	0.840±0.18	1.02±0.13	29.7
	W	2.04±0.46	9.82±2.21	26.51±5.28	54.3±9.35	108.4±13.9	0.277±0.07	0.456±0.1	0.790±0.17	1.02±0.15	31.4
2	S	1.72±0.38	4.33±1.64	20.82±3.83	59.9±6.69	94.9±9.7	0.155±0.08	0.389±0.08	0.928±0.11	0.857±0.11	21.5
	W	2.21±0.37	6.10±1.18	20.14±3.06	54.1±6.63	101.9±10.4	0.242±0.06	0.370±0.07	0.790±0.11	1.10±0.18	21.2
3	S	1.91±0.29	7.39±1.1	25.21±3.3	62.0±6.6	99.5±9.9	0.262±0.05	0.522±0.63	1.01±0.42	1.21±0.81	24.3
	W	1.91±1.1	7.39±1,1	25.15±3.3	61.9±6.6	99.5±9.8	0.261±0.05	0.436±0.08	0.95±0.15	1.11±0.24	23.7
4	S	1.75±0.28	6.98±1.66	26.0±3.62	68.1±8.35	109.8±14.31	0.238±0.04	0.438±0.07	0.898±0.12	0.949±0.20	25.8
	W	2.10±0.35	6.56±1.55	17.00±2.08	50.0±5.84	83.3±7.86	0.293±0.05	0.305±0.11	0.761±0.14	0.978±0.98	20.0
5	S	1.96±0.39	6.89±1.73	29.0±3.74	73.6±6.96	107.1±8.75	0.238±0.06	0.516±0.08	0.962±0.10	1.12±0.15	23.1
	W	2.13±0.37	6.22±1.21	30.0±4.14	59.6±9.96	101.8±9.96	0.255±0.07	0.488±0.08	0.852±0.13	1.03±0.15	20.1
6	S	1.90±0.32	6.02±1.42	23.0±3.01	59.3±5.67	105.0±0.11	0.240±0.04	0.410±0.06	0.884±0.09	1.09±0.11	20.6
	W	1.70±0.35	5.73±1.13	20.0±3.55	56.7±7.12	104.0±11.36	0.201±0.05	0.416±0.08	0.845±0.10	1.01±0.19	22.4
7	S	1.59±0.27	5.83±1.36	25.0±4.34	66.1±6.26	98.1±8.01	0.193±0.05	0.464±0.09	0.856±0.11	1.00±0.12	23.1

[1] The farm identification number (7 participating farms, 13 cohorts)

[2] Season in which the study was conducted [S=summer W=winter], note farm 7 was only conducted once during the summer season

[3] Each value is the raw mean ± the standard deviation

[4] All farms except Farm 1 used in feed antibiotics in some or all phases during the treatment period (nursery phase) [+ = antibiotics included in some or all phases, - = antibiotics not included]. All AB inclusion is was included in levels for improved ADG and feed efficiency and to mitigate some minor enteric and respiratory diseases

[4] All farms except farm 1 and farm 6 Summer used therapeutic zinc oxide in some or all phases during the treatment period (nursery phase), therapeutic zinc oxide is deemed at inclusion levels greater than 2500 ppm [+ = inclusion of zinc oxide at >/=2500ppm in one or more nursery phases; - = inclusion of zinc oxide </=250ppm in all phases]

[5] Average age of the pig at the day of weaning/start of trial

Table 3.2. Ingredient composition and calculated and analyzed nutrient analysis of experimental nursery diets (%, as-fed basis)[1]

	Phase I diets		**Phase II diets**		**Phase III diets**	
Ingredient Composition, %	HC	LC	HC	LC	HC	LC
Corn (NRC; 8.3% CP)	13.70	47.40	32.30	48.92	47.04	46.84
Wheat, soft red winter	-	10.00	-	10.00	-	10.00
Barley, 6 row	25.04	-	25.00	-	20.00	-
Whey, dried	20.00	8.00	8.00	-	-	-
Animal Fat	2.50	2.50	2.50	2.50	2.50	2.50
Fishmeal, mixed	5.00	5.00	3.00	-	-	-
Hamlet protein	6.25	-	6.25	-	3.75	-
Soybean meal 48	10.80	24.00	17.00	34.00	21.00	37.00
Alltech Nupro	3.75	-	2.50	-	1.25	-
Oat groats	10.00	-	-	-	-	-
Lysine, HCL	0.30	0.16	0.25	0.25	0.35	0.05
Methionine	0.19	0.11	0.16	0.17	0.17	0.08
Threonine	0.08	0.02	0.08	0.09	0.13	-
Typtophan	0.02	-	0.02	-	0.02	-
Limestone	0.50	0.64	0.58	1.13	0.92	1.00
Salt	0.30	0.61	0.34	0.59	0.44	0.45
Mon-dicalcium phosphate	0.07	0.69	0.52	1.48	1.29	1.27
Potassium diformate	0.20	-	0.20	-	0.10	-
Calcium proprionate	0.40	-	0.40	-	0.20	-
Sweetener, saccharine	0.03	-	0.03	-	0.03	-
Vitamin & mineral mix	0.87	0.87	0.87	0.87	0.81	0.81
Calculated composition[2]						
DE, MJ/kg	14.74	14.78	14.55	14.62	14.39	14.71
Crude Protein, %	21.10	19.90	20.80	21.00	18.70	21.90
Total LYS, %	1.43	1.23	1.35	1.34	1.25	1.27
SID LYS, %	1.29	1.10	1.21	1.21	1.13	1.13
Ca, %	0.94	0.94	0.83	0.83	0.74	0.74
P, %	0.68	0.71	0.62	0.67	0.61	0.64
Analyzed composition[3]						
Crude Protein, %	21.14	20.58	20.18	21.06	19.46	21.00
Ca, %	0.91	1.09	0.77	0.79	0.76	0.74
P, %	0.69	0.75	0.63	0.73	0.69	0.72

[1] Experimental diets were based on diet complexity (High complexity versus Low complexity)

[2] Calculated on the basis of NRC (1998) ingredient values.

[3] For each of the diets the analyzed nutrient content for each diet differed by less than 10%.

Table 3.3. Growth performance from the start of the nursery period to the end of the finisher period for pigs fed either HC or LC nursery pig diets during the nursery period[1]

	Treatment			*P Value*
Item	HC	LC	SEM[2]	Diet
N, pigs[3]				
Birth[4]	387	387		
Weaning[5]	370	366		
End of Nursery[6]	353	354		
End of Grower[7]	349	344		
End of Finisher[8]	346	340		
Age, days				
Birth	2.8	2.8	0.25	0.97
Weaning	27.6	28.4	0.62	<0.001
End of Nursery	67.7	66.4	1.9	<0.001
End of Grower	107	109.4	1.7	<0.001
End of Finisher	153.3	154.9	3.8	<0.001
BW, kg				
Birth	1.87	1.87	0.06	0.96
Weaning	5.08	5.59	1.51	0.36
End of Nursery	22.42	22.82	1.51	0.48
End of Grower	58.41	58.91	1.54	0.38
End of Finisher	100.42	101.06	1.55	0.27
ADG,g				
Suckling	255	258	15	0.77
Nursery	444	449	15	0.56
Grower	871	885	15	0.13
Finisher	1,040	1,047	15	0.45
Pig Removal,%[9]	3.8	4.2	0.80	0.52
ADFO, g[10]	620	627	38	0.80
Feed Cost/pig, $[11]	12.01	9.19	0.05	<0.001

[1] HC (highly complex) or LC (low Complexity) nursery pig diets fed post weaning for 6 weeks

[2] Maximum value of standard error of the means

[3] Number of observations (pigs) per treatment

[4] Birth is the first visit when pigs were selected, ages between 24-96 hours after birth

[5] Weaning is the time of weaning and also the point in which marks the start of the trial diets being fed

[6] Approximately 6 weeks post weaning (end of the nursery period), and marks the end of the trial diets being fed

[7] Approximately 12 weeks post weaning (end of the grower period)

[8] Approximately 18 weeks post weaning (end of the finisher period) and marks the final observation

[9] Pig removal encompasses the rate at which pigs were lost from the study, either from mortality, identification loss or severe morbidity

[10] ADFO (average daily feed offered) is a calculation of how much feed was offered to the pigs daily, since weigh backs were never calculated

[11] Calculated based on average cost of feed per pig during the nursery period, using ingredient monthly commodity prices from May 2014-June 2016. Feed usage per phase and diet based on calculated total feed budget during the trial per pig per phase, Phase I 1.74kg, Phase II 8.88kg and Phase III 12.78kg

Table 3.4. Serum haptoglobin concentrations used as a general health biomarker from the start of the nursery period to the end of the finisher period for pigs fed either HC or LC nursery pig diets during the nursery period[1]

	Treatment			*P value*
	HC	LC	SEM[2]	Diet
N, pigs[3]				
Weaning[4]	170	172		
End of Nursery[5]	190	183		
End of Grower[6]	184	181		
End of Finisher[7]	162	148		
HP, g/L[8]				
Weaning	0.537	0.766	0.128	0.06
End of Nursery	0.866	0.968	0.121	0.38
End of Grower	1.003	0.859	0.121	0.22
End of Finisher	0.900	0.802	0.128	0.44

[1] HC (highly complex) or LC (low Complexity) nursery pig diets fed post weaning for 6 weeks

[2] Maximum value of standard error of the means

[3] Number of observations (pigs) per treatment

[4] Weaning is the time of weaning and also the point in which marks the start of the trial diets being fed

[5] Approximately 6 weeks post weaning (end of the nursery period), and marks the end of the trial diets being fed

[6] Approximately 12 weeks post weaning (end of the grower period)

[7] Approximately 18 weeks post weaning (end of the finisher period) and marks the final observation

[8] Serum haptoglobin concentrations in g/L, used as a general biomarker for health assessment

Table 3.5. Carcass quality traits at ~118kg of live BW for pigs fed either HC or LC nursery pig diets during the nursery period[1]

	Treatment			*P value*[4]			
Item	HC	LC	SEM[2]	Diet	Zinc	AB	Season
N,pigs[3]	275	258					
HDW, kg	102.85	102.3	1.45	0.30	0.05	-	<0.001
Loin Eye, mm	68.63	68.14	0.73	0.48	0.07	-	-
Back Fat, mm	19.61	19.75	0.91	0.67	-	-	0.01
Lean yield, %	60.64	60.59	0.40	0.74	-	-	0.01
Days to Market, d[5]	178.8	176.1	1.1	0.05	-	-	<0.001
Carcass Value, $[6]	175.28	175.30	1.26	0.98	-	-	0.04

1 Both the HC and LC nursery feeding program consisted of three phases, the HC feeding program was most consistent with current industry nursery diets containing whey protein, hamlet protein and fish meal as main protein sources. The LC feeding program formulated to provide the same amount or energy and protein contained soybean meal as the main protein source, with reduced or eliminated whey, and hamlet protein.

[2] Maximum value of standard error of the means

[3] Number of observations (pigs) per treatment. A random subset of 40-50 pigs from each farm where sent to a local provincial processing plant once they reached or exceeded 118kg of live BW. Each carcass was individually graded based on the Canadian carcass grading system. Number of observations decreased due to loss of pig identification tags at slaughter and other communication issues.

[4] A reduced model was used wherever possible, a hyphen (-) is denoted wherever a fixed variable was not significant (P >0.05) and removed from the model

Zinc: is the dietary inclusion or exclusion of therapeutic zinc oxide in one or more nursery phase diets (inclusion was deemed at =/> 2500ppm, exclusion was deemed at =/< 250ppm)

AB: AB+ or AB-; is the dietary inclusion or exclusion of therapeutic in-feed antibiotic usage in one or more nursery phase diets (inclusion was deemed at any AB concentration or type in one or more diets, exclusion was deemed completely antibiotic free in a nursery phase diets)

Season: Summer or Winter; summer is deemed by the piglets in the study were born between May-August and winter is deemed by the piglets in the study were born between October-January

Gender: castrated males (barrows) and gilts

[5] The number of days between birth and day of processing, the number of observations for the HC fed pigs is 288 and for the LC fed pigs is 271

[6] The average value of each individual carcass based of a largely used payment grid in Ontario and the mid-value price of $1.55 / kg of dressed weight

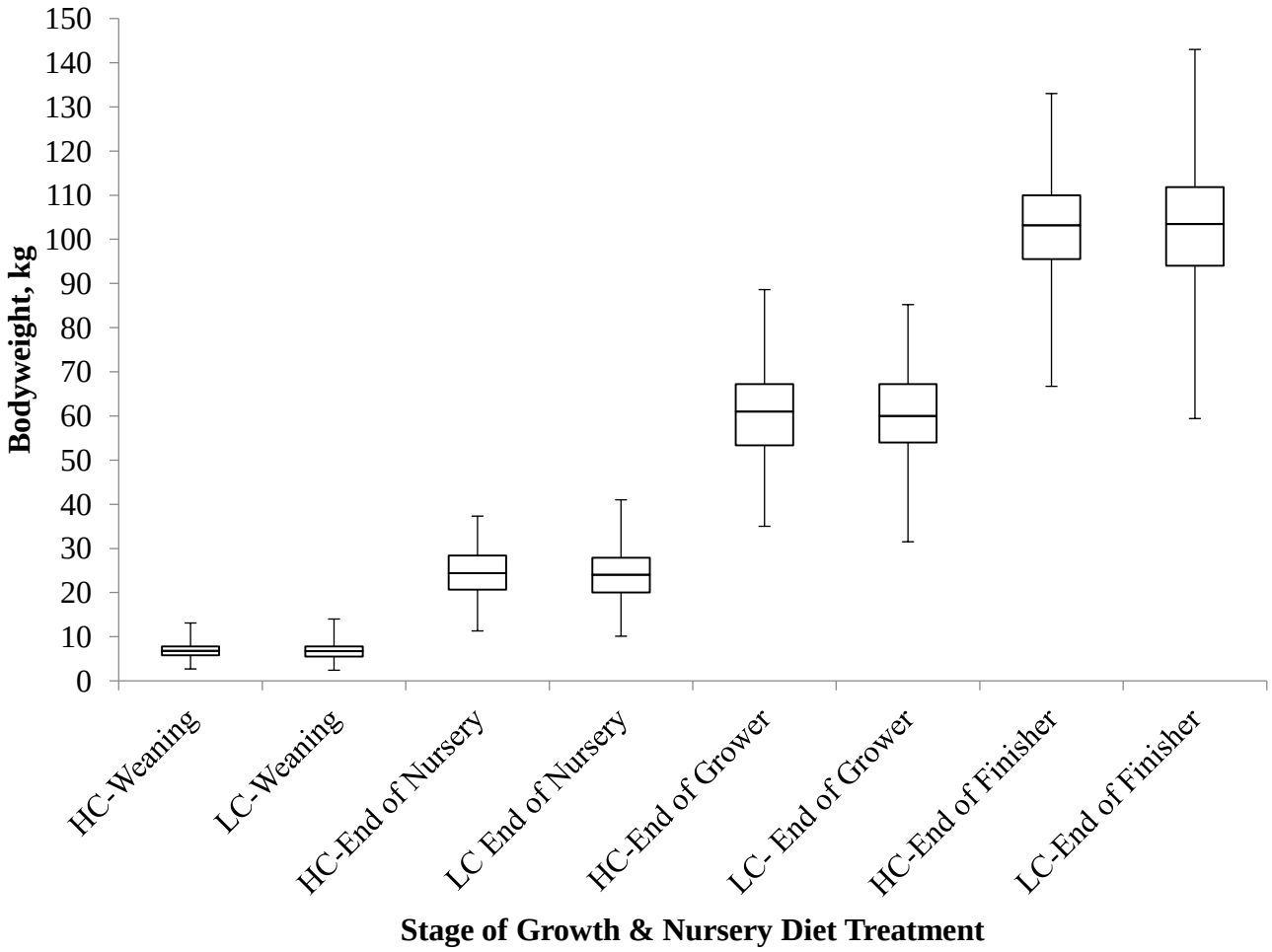

Figure 3. 1. Box and whisker plots of population variation for each stage of production across dietary treatments. The minimum number of observations is 326. Weaning HC min/max=2.7kg and 13.1kg, inter-quartile range=10.4kg, weaning LC min/max= 2.4kg and 14kg, inter-quartile range=11.6kg. Visit 2 HC min/max=11.3kg and 37.3kg, inter-quartile range=26kg, visit 2 LC min/max=10.1kg and 41kg, inter-quartile range=30.9kg. Visit 3 HC min/max=35kg and 88.6kg, inter-quartile range=53.6kg, visit 3 LC min/max 31.5kg and 85.2kg, inter-quartile range=53.7kg. Final visit HC min/max=66.7kg and 133kg, inter-quartile range=66.3kg, Final visit LC min/max=59.4kg and 143kg, inter-quartile range=83.6kg.

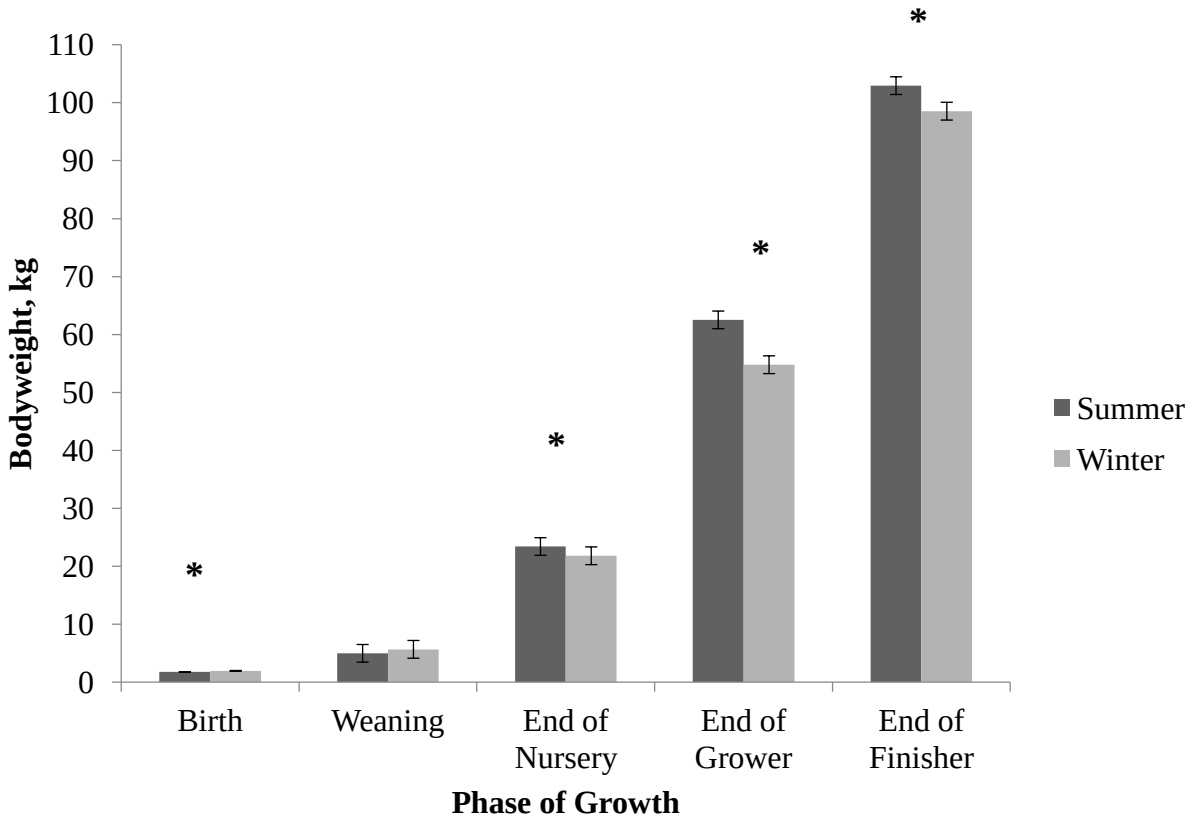

Figure 3.2. Differences observed in BW at each stage in production by seasonal cohort. Summer is considered piglets born between May-August; winter is considered piglets born between October-January. The minimum number of observations is 326. Differences denoted by * are significant (P<0.05).

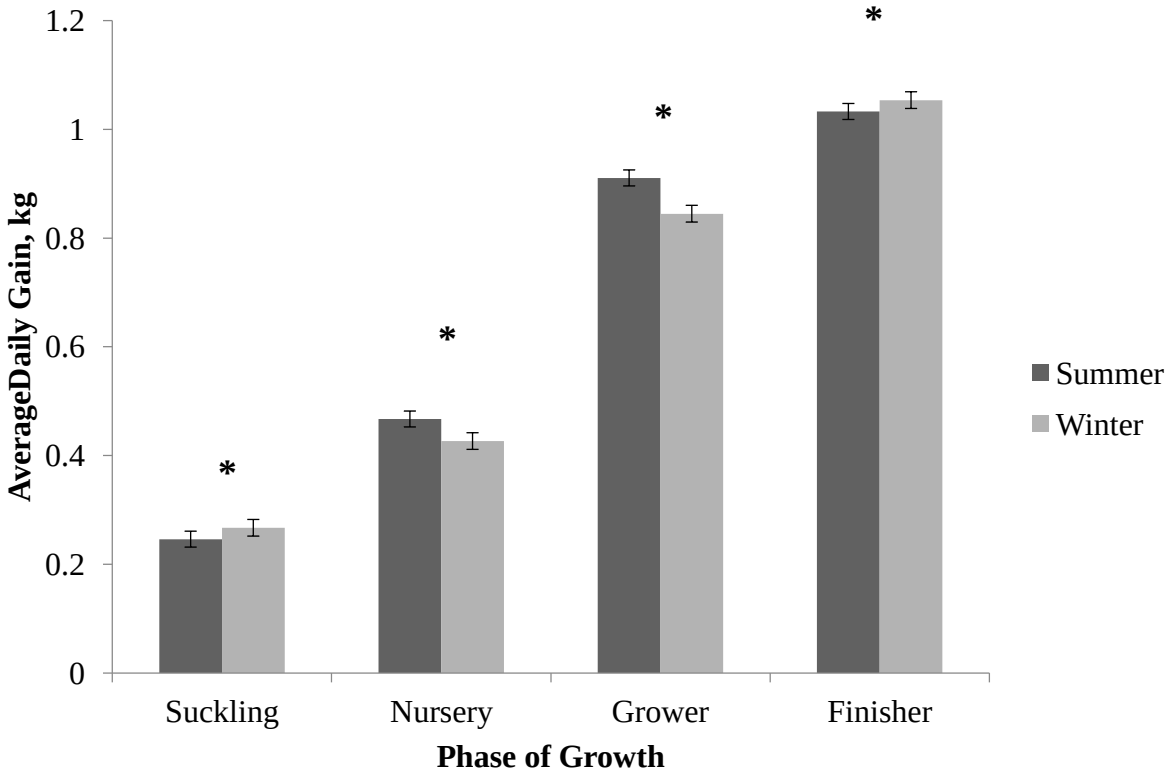

Figure 3.3. Differences observed in ADG at each stage of production by seasonal cohort. Summer is considered piglets born between May-August; winter is considered piglets born between October-January. The minimum number of observations is 325. Differences denoted by * are significant ($P<0.05$).

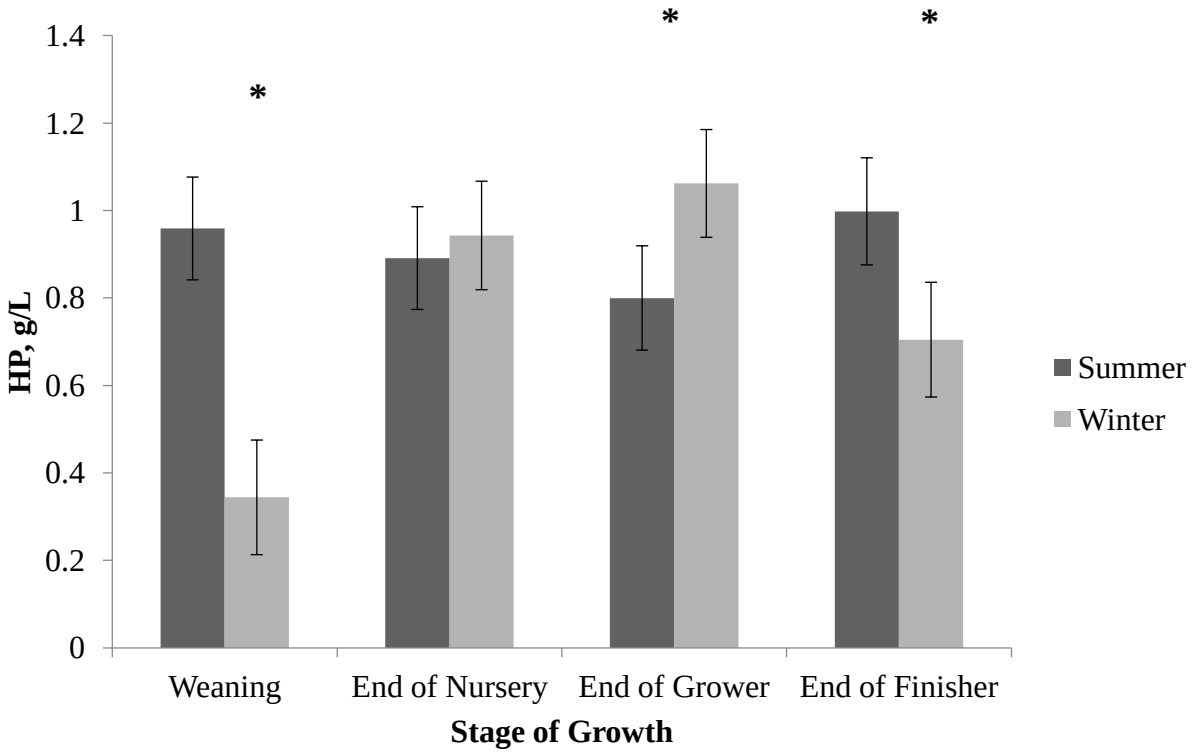

Figure 3.4. Differences in serum HP concentration (g/L) at each stage of production by seasonal cohort. The minimum number of observations per season and time point is 148. Differences denoted by * are significant (P<0.05).

4.0. GENERAL DISCUSSION, IMPLICATIONS AND FUTURE DIRECTIONS

Feed is the main cost of pork production, with the nursery period being the most costly. This is due to the inclusion of highly digestible complex ingredients designed to support the piglets developing GIT after weaning (Mahan and Lapine, 1991). Many studies have assessed the possibility of reducing nursery pig diet complexity in research settings and its effect on pig growth performance with positive results (Dritz et al., 1996a; Heyer and Lebret, 2007; Skinner et al., 2014). The purpose of this study was to assess the life-long growth performance and carcass quality traits at time of processing when pigs were fed LC nursery diets on commercial farms. As well as to assess differences in general health status of pigs fed highly complex (HC) or low complexity (LC) nursery diets, at various stages of production. Commercial farms create variable conditions such as high stocking density, competition, varying management practises and disease challenges.

Overall, the LC nursery diets had no negative impact on pig growth performance between weaning and market. The overall result was expected and in agreement with previous studies examining nursery pig diet complexity (Dritz et al., 1996a, Whang et al., 2003 and Skinner et al., 2014). Carcass quality traits such as HDW, loin eye depth, back fat depth and percent lean yield were unaffected by nursery diet treatment, these results were also expected and in agreement with previously reported studies (Skinner et al., 2014). The value of the carcass at the time of processing was the same regardless of nursery diet complexity, which is important, if the diet complexity negatively impacted the value of the carcass, saving money in feed is not worth it. Serum haptaglobin (HP) concentrations appeared to be uninfluenced by nursery diet treatment, indicating that the LC fed pigs may not be anymore susceptible to disease challenges as the HC fed pigs. This is in agreement with a previously reported study (Dritz et al., 1996b). Both the

growth performance and serum HP concentrations indicate that the pigs were generally healthy and performing optimally.

In previous controlled studies low complexity nursery diets resulted in decreased growth performance, especially during the start of the nursery phase (Dritz et al., 1996 and Skinner et al., 2014). This decrease in growth was unobserved in the current study; this could be due to the length between sampling periods. The pigs' were weighed at the start and at the end of the 6 week nursery period in the current study, where in previous studies the pigs typically were weighed weekly. Another explanation could be because the pigs used in the current study were commercial terminal crosses rather than purebred Yorkshire or Landrace common to previous studies.

The farms used in the current study had relatively moderate to high health status and did not have any major disease outbreaks during the study. Further studies should be conducted in less than ideal conditions in order to assess how pigs fed LC nursery diets may react to different pathogenic challenges. Previous studies have indicated some possible associations with increased mortality and the LC fed pigs when faced with a major disease challenge (Skinner et al., 2014). The serum HP levels in this study indicated that the LC fed pigs were not anymore susceptible to disease than the HC fed pigs, however HP is only one biomarker and an acute phase protein that can be relatively variable over time. More frequent blood sampling and more accurate illness and death records could improve the understanding of how LC fed pigs react to an immune challenge.

Feeding a LC nursery diet in a commercial setting may be a feasible way to reduce input costs in the form of nursery pig feed while achieving optimal pig growth performance and

carcass quality. However, further investigations should be conducted to identify the effects of feeding LC nursery diets during a clinical disease outbreak, and in other various conditions.

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6.0 APPENDIX I: Preliminary Bio-marker Results

6.1 Materials and Methods

A subset of pigs from 4 of the 13 cohorts (all different farms) were selected based on health status and performance. Two of the farm s were selected as high health status, with good and poor ADG during the nursery phase, two farms were selected as low health status, with good and poor ADG during the nursery phase. Half of the pigs from each farm were selected based on the same criteria as mentioned previously in material and methods 3.3.4. Serum was collected, handled and stored the same as mentioned in methods 3.3.4.

Serum levels of T3 were analyzed using a commercially available Total T3 (pig) ELISA kit (Abnova, St., Taipei, Taiwan). Serum levels of IGF-1 were analyzed using a commercially available IGF-1 (pig) ELISA kit (Sunlong biotech Co. LTD, Zhejiang,China). Serum levels of IgG1 were analyzed using a commercially available IgG1 (pig) ELISA kit (Elabscience Biotechnology Co., St., Taipei, Taiwan). Serum levels of TNF-α was analyzed using a commercially available TNF-α (pig) ELISA kit (Invitrogen Corporation, Frederick, MD, USA). Serum levels of IFN-λ was analyzed using a commercially available IFN-λ (pig) ELISA kit (Invitrogen Corporation, Frederick, MD, USA).

6.2 Results

Table 6.1. Growth performance bio-markers analyzed on a subset of pigs from the trial to identify an average difference over four time periods across dietary treatments.[1]

	Treatment			P value		
	HC	LC	SEM[2]	Diet	Visit	AB
IGF-1[3], ng/mL	66.91	63.77	2.32	0.07	0.03	0.003
T3[4], ng/mL	0.62	0.70	0.19	0.09	0.03	ns[5]

[1] Both the HC and LC nursery feeding program consisted of three phases, the HC feeding program was most consistent with current industry nursery diets containing whey protein, hamlet protein and fish meal as main protein sources. The LC feeding program formulated to provide the same amount or energy and protein contained soybean meal as the main protein source, with reduced or eliminated whey, and hamlet protein. Diets were fed at weaning until 6 weeks post weaning.

[2] Maximum value of standard error of the means

[3] The n values for IGF-1, HC fed pigs=57 over 4 time points (n=213) and LC fed pigs= 57 over 4 time points (n=212)

[4] The n value for T3, HC fed pigs= 44 over 4 time points (n=158) and LC fed pigs=40 over 4 time points (n=164)

[5] ns meaning a non-significant value from the model, therefore removed in the final analysis

Table 6.2. Immune and inflammatory bio-markers analyzed on a subset of pigs from the trial to identify an average difference over four time periods across dietary treatments.[1]

	Treatment			P value		
	HC	LC	SEM[2]	Diet	Visit	AB
INF-gamma[3], pg/mL	95.52	97.01	4.96	0.82	<0.001	<0.001
TNF-alpha[4], pg/mL	0.24	0.091	0.22	0.42	0.07	0.07
IgG1[5], ng/mL	1.033	1.020	0.062	0.79	0.06	ns[6]

[1] Both the HC and LC nursery feeding program consisted of three phases, the HC feeding program was most consistent with current industry nursery diets containing whey protein, hamlet protein and fish meal as main protein sources. The LC feeding program formulated to provide the same amount or energy and protein contained soybean meal as the main protein source, with reduced or eliminated whey, and hamlet protein. Diets were fed at weaning until 6 weeks post weaning.

[2] Maximum value of standard error of the means

[3] The n value for INF-gamma, HC fed pigs= 21 over 4 time points (n=83) and LC fed pigs=23 over 4 time points (n=81)

[4] The n value for TNF-alpha, HC fed pigs= 52 over 4 time points (n=202) and LC fed pigs=58 over 4 time points (n=197)

[5] The n value for IgG1, HC fed pigs= 52 over 4 time points (n=172) and LC fed pigs=54 over 4 time points (n=166)

[6] ns meaning a non-significant value from the model, therefore removed in the final analysis

7.0 APPENDIX II: Simple Cost Benefit Analysis

7.1 Materials and Methods

From a commercial standpoint understanding both the investment and the cost to a decision is an important part of pork production. Cost-benefit analysis are a major part of decision making. In the current study a feed cost savings during the nursery period is identified for the LC fed pigs. However, there is also a small but significant increase in carcass BF at the time of slaughter, which may influence the value of the carcass. Therefore, a very simple cost benefit analysis between the average value of each carcass and feed costs during the nursery period is assessed.

Carcass value was calculated by utilizing the individual pigs' carcass quality traits from the trial. Carcasses were valued based on a major payment grid in Ontario (provided by Synergy Services Inc.). Carcasses were valued at a 'mid-level' payment of $1.55 per kg of dressed weight, this was determined by the average pig price over the past decade. Specific grading formulas and premiums unique to the grid were appropriately applied. Feed cost during the nursery feed period is the same that is referenced in methods 3.3.2.

Table 7.1. Simple cost difference of carcass values based on two major Ontario pork payment grids and the nursery diet costs per pig

	Treatment		
	HC	LC	Value differences[3]
Grid 1	$175.28[1]	$175.30[2]	+$0.02
Feed cost, $ per pig[4]	$12.01	$9.19	-$2.82

[1] n= 276 for Grid 1
[2] n=258 for Grid 1
[3]Value differences is sum= (HC – LC)
[4]Feed cost per pig during the entire nursery period