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# EVALUATION OF DIETARY ALTERATIONS THAT HAVE POTENTIAL TO AFFECT FEED INTAKE AND FEED PREFERENCE IN SWINE

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# ABSTRACT OF THESIS

# EVALUATION OF DIETARY ALTERATIONS THAT HAVE POTENTIAL TO AFFECT FEED INTAKE AND FEED PREFERENCE IN SWINE

Feed intake is a key factor affecting pig performance; thus, the objective of these studies was to assess a variety of factors that could potentially affect intake in pigs in different production stages. Studies were conducted to determine the effects of flavor and diet complexity, Appetein™ (an alternative protein source), and graded levels of salt on swine feed intake and feed preference. Two newly developed flavors were used in nursery pig diets. The use of the two flavors did not increase feed intake ($P > 0.05$). Nursery pigs actually showed a preference for the control diet. Complex diet formulation does increase feed intake ($P < 0.03$) in nursery pigs when diets are not over-formulated. When flavor was added to lactation diets sow feed intake did not change compared to the control. The flavor did not affect litter performance ($P > 0.05$). When Appetein™ was added to lactation diets at 0.5%, pig weight and litter weight were numerically greater for the sows fed Appetein™ but not significantly so. Appetein™ did not affect feed intake. When nursery pigs were fed graded levels of salt (0.1, 0.5, and 0.8%) feed intake increased ($P < 0.01$) as salt level increased. Nursery pigs also preferred ($P < 0.05$) 0.8% salt over other levels the first two weeks after weaning when given a choice among diets.

KEYWORDS: Feed intake, flavor, preference, protein, salt, pigs

James Seth Monegue

October 14th, 2009

# EVALUATION OF DIETARY ALTERATIONS THAT HAVE POTENTIAL TO AFFECT FEED INTAKE AND FEED PREFERENCE IN SWINE

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# RULES FOR THE USE OF THESIS

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THESIS

James Seth Monegue

The Graduate School

University of Kentucky

2009

# EVALUATION OF DIETARY ALTERATIONS THAT HAVE POTENTIAL TO AFFECT FEED INTAKE AND FEED PREFERENCE IN SWINE

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THESIS

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An abstract of a thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in the
College of Agriculture at the University of Kentucky

By

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Lexington, KY

2009

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Thank you to my loving parents Jim and Sharon Monegue, for their encouragement and support throughout my journey as a graduate student and for pushing me to accomplish my goals. A special thank you to Dad for stimulating my interest in pigs at such a young age.

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF FILES

MonegueThesis.pdf

# CHAPTER 1. Introduction

Many of the challenges of modern pig production systems can be related to feed intake. The objective of the feeding program is to ensure that all animals consume sufficient feed on a daily basis to meet their energy and nutrient requirements for growth or reproduction. A balanced swine diet should contain the necessary nutrients in the correct proportions to nourish the animal for proper growth. Diet formulation should consider amino acids, minerals, and vitamins with enough energy to drive growth and any reproductive needs. Fat is required to supply essential fatty acids, but it is usually adequate in practical diets without supplementation. Water is an important nutrient and normally is provided with free access, so it is not considered for diet formulation purposes. A palatable energy source like corn can be transformed into a nutritionally balanced diet if nutrient deficiencies are corrected by using additional ingredients. One result of a properly formulated diet should be adequate feed intake. However, other factors can affect feed intake and if not monitored closely, inadequate attention to feed intake can have detrimental effects on all stages of pigs.

Appropriate feed intake in sows during gestation and lactation is crucial for the development of the litter, maintaining the sow’s body condition, reproductive performance, and longevity. In reproducing animals, because all phases of the reproductive cycle are related, deviations of the normal body condition in one phase can have significant effects on performance in another phase and the effects of underfeeding in any one phase of the cycle may not be seen for several months or parities (Coffey et al., 1994; Whittemore, 1998). Survey data shows that average sow feed intake during lactation is only 5.2 kg per day (ranges from 3.6-6.8 kg per day in the United States, Aherne, 2000). Some of the feed intake differences among farms may be explained by differences in genotype, lactation length, parity distribution, disease levels, etc., but much of the difference is still due to feeding management. Even so, with more research on feed intake we may be able to overcome the limitations of these factors and optimize feed intake in all types of herds.

Initiation of feeding at weaning is vital to getting pigs off to a good start in life. Delays in feed intake at this stage may result in digestive disorders or stunt the pig’s growth, slowing its entire productive period. To alleviate low feed intake during this period dietary alterations such as feed additives, alternative ingredients, and nutrient concentration have been investigated.

Why are we really interested in feed intake? To find the answer we must look beyond pigs to the bigger picture - humans. It is estimated that humans domesticated pigs between 6000 and 9000 years ago (Mellen, 1952). The purpose for their domestication was similar to that of other animals which was to provide food. Since that time pork has been a staple of many civilizations. In the U.S. from 1970 (22.1 kg) to 2001(22.05 lb) per capita consumption of pork has remained relatively constant (Pork Industry Handbook, 2007). If the trend of decreasing number of swine farms continues, producers must become more efficient in order to meet the world's demand for pork. It is evident that understanding feed intake in the pig and factors that alter it will play a major role in efficient swine production and that more research must be conducted to find answers.

# CHAPTER 2. Literature Review

When examining the effects of feed intake there are several factors to consider. First, as the diet is presented to the animal feed intake effects are mediated through smell and taste. This is followed by any post-digestive or post-absorptive effects that might influence any further feed intake. In addition to dietary effects on feed intake there are non-dietary effects. The following section will discuss dietary and non-dietary effects on feed intake further.

## 2.1. The sense of taste

### *2.1.1. Anatomy of the taste system*

The headgut is the first part of the digestive tract that is involved in nutritional decisions made by the animal. This is the site at which the senses prepare the digestive tract for a meal. This is an anticipatory response and is referred to as the cephalic phase of digestion in which sensory neurons convert sensory information into electrical impulses and carry them toward the central nervous system for processing. Taste (gustation) and smell (olfaction) are important senses to consider when formulating a diet. The sense of taste and smell in higher animals function in several processes, among which are: control of ingestive behavior, onset of specific appetites, and reinforcement in learning situations (Goatcher and Church, 1970). Both taste and smell can affect how well the animal likes the diet (feed intake) and subsequently may affect growth performance. Thus, these have meaning in the area of nutrition.

In swine, the nasal cavity contains nasal scrolls which significantly increase the surface area of olfaction. The epithelium of the scrolls contains olfactory cells whose cilia and microvilli trap and react with the chemicals in the air producing a signal to the brain resulting in a specific smell. The sense of taste is achieved through taste buds. Taste buds are located throughout the oral cavity but the majority can be found on the tongue. Different locations on the tongue have different types of papillae and taste bud location. The anterior portion of the tongue has fungiform papillae while the posterior has filiform, foliate, conical, lenticular, and circumvallate papillae. Figure 2.1 shows three of the papillae forms and taste bud location. The different location of taste bud types was originally thought to relate to their function. The anterior of the tongue primarily detects sweetness and the posterior detects bitterness. Recent molecular and functional data have revealed that, contrary to popular belief, there is no tongue 'map'. Responsiveness to the five basic tastes is believed to be present in all areas of the tongue (Chandrashekar et al., 2006). Pigs differ from most mammals in the number of taste buds, which exceeds most species including humans (Bradley, 1971). The domestic pig possesses at least 10,000 vallate taste buds, whereas the human has 6,000 (Chamorroc et al., 1993). Also, there are 5,000 fungiform taste buds in pigs compared to the 1,600 in humans (Miller, 1986).

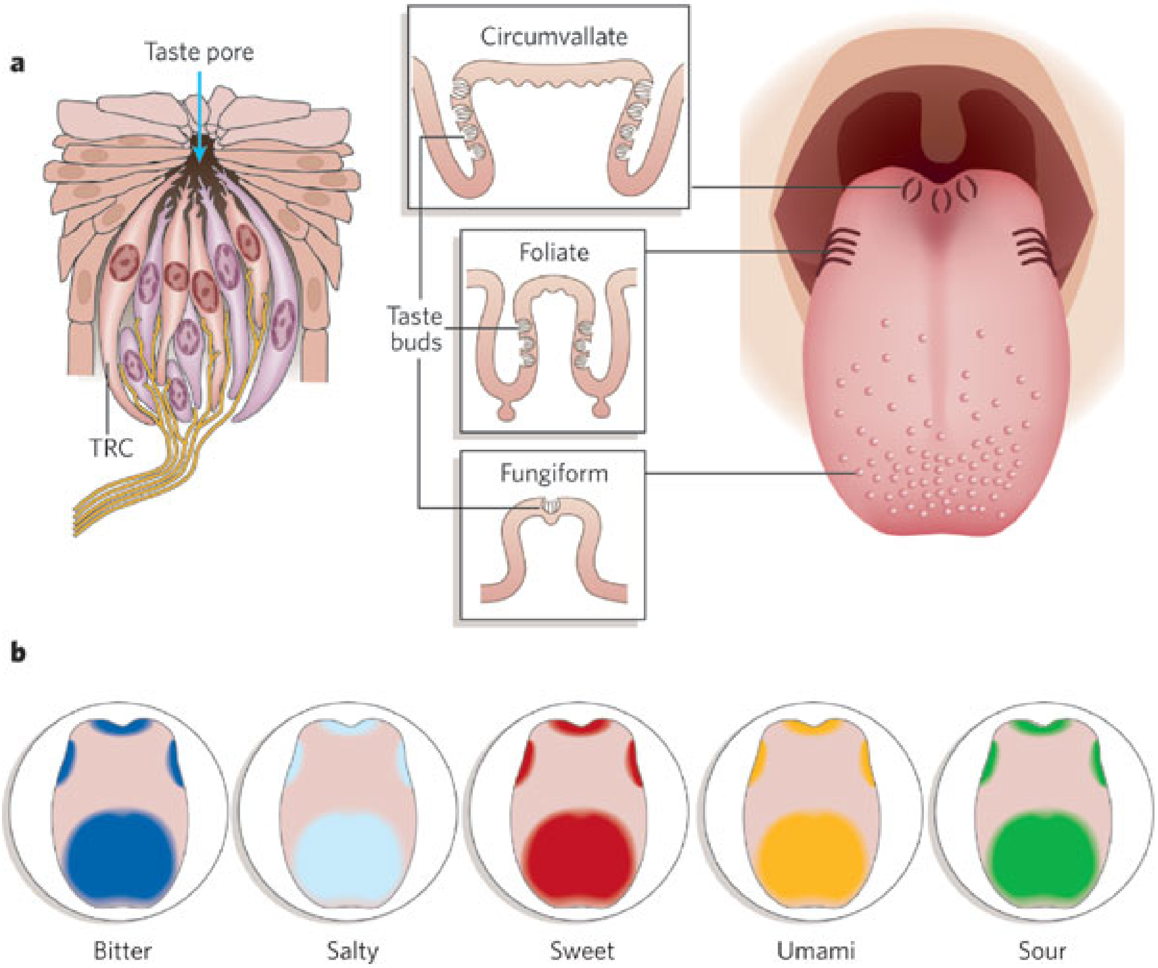

Figure 2.1. Shape and location of circumvallate, foliate, and fungiform papillae and taste buds. **a,** Taste buds (left) are composed of 50–150 taste receptor cells (TRCs) (depending on the species), distributed across different papillae. Circumvallate papillae are found at the very back of the tongue and contain hundreds to thousands of taste buds. Foliate papillae are present at the posterior lateral edge of the tongue and contain a dozen to hundreds of taste buds. Fungiform papillae contain one or a few taste buds and are found in the anterior two-thirds of the tongue. TRCs project microvillae to the apical surface of the taste bud, where they form the 'taste pore'; this is the site of interaction with tastants. **b,** Recent molecular and functional data have revealed that, contrary to popular belief, there is no tongue 'map': responsiveness to the five basic modalities — bitter, sour, sweet, salty and umami — is present in all areas of the tongue. (Taken from Chandrashekar et al., 2006).

### *2.1.2. How the sense of taste works*

Tastes can be classified into five categories known as sweet, salty, sour, bitter, and umami. All taste buds undergo a depolarization of their membrane to produce these different taste signals, but the mechanisms of depolarization differ for each category. Avenet and Kinnamon (1991), as well as others, have done extensive research in taste signal transduction. In salty and some sour tastes, $Na^+$ ions and protons pass through channels in the apical membrane and directly depolarize the cell. Other sour tastes and some bitter tastes have compounds that block potassium channels trapping the cation in the receptor cell. Sweet compounds bind to a receptor on the cell which then activates a G protein (part of the receptor complex). The G protein activates adenylate cyclase resulting in an increase in cAMP which causes depolarization by closing potassium channels. The degree of depolarization and duration of signaling by these mechanisms is directly proportional to the amount of stimulating substance. Also, the medium and surrounding of the stimuli can have different effects. The taste medium may exert its influence in several ways: by changing the solubility of the stimuli, by adsorbing the taste substance, by physically interfering with the migration of taste molecules to receptor sites, or by combinations of these processes (Mackey and Valassi, 1956; Mackey, 1958). Other factors that may contribute to the ability to taste include age, health status, and sex. It is unclear what absolute effect each of these factors have on the ability to taste, but it has been shown that taste sensitivity is lower in young animals (early postnatal to weaning), since it has not fully developed, and in older animals when the replacement of dying cells with new ones declines (Cooper et al., 1959; Glanville et al., 1964).

The senses of taste and smell often work together so animals can identify and evaluate potential food to determine if it is suitable for consumption. Many studies have shown that pigs will refuse food based on taste and smell and are described in later sections. Therefore, with the information known about how these two senses work, compounds such as flavors can be developed to enhance the acceptability of an otherwise non-palatable diet.

## 2.2. Factors affecting feed intake and nutritional requirements in swine production

### *2.2.1. Housing conditions: Pen space*

From an economical stand point, due to the increased cost of building supplies and the fluctuating price of pork, producers are interested in maximizing the use of their facilities by efficiently utilizing the floor space area allotted to pigs. Reducing the fixed costs per kg of pork produced involves placing more pigs/pen than would occur if the objective were to maximize growth. This brings up questions on how space allowance affects feed intake and growth. Kornegay et al. (1993) determined pigs (average initial weight, 8.4 kg) housed with restricted floor space (0.14 vs. 0.28 $m^2$/pig) ate 21% less ( $P < .001$) and grew 18% slower ($P < 0.001$) than pigs housed with adequate floor space, but their gain:feed ratio was 4% higher ($P < 0.08$). The effects of crowding may not be as simple as what Kornegay et al. (1993) presented. Brumm and Dahlquist (1995) reported that when pigs were crowded in the nursery (0.55 vs. 0.82 $m^2$/pig) they were less affected by crowded growing-finishing conditions (1.86 vs. 2.56 $m^2$/pig) when compared to those not crowded in the nursery. In contrast, when grower-finisher pigs were exposed to crowded conditions for 1 to 3 months feed intake and growth rate were dependent on the current degree of crowding and not previous conditions (Gonyou, 1999). These results suggest that by acclimating pigs at a younger age to crowding, decreases in growth performance will be minimized if subjected to crowded conditions at a later stage.

The optimum space per pig varies based on weight. The early floor space recommendations suggest supplying 0.46 $m^2$ (27 to 45 kg), 0.56 $m^2$ (45 to 68 kg), and 0.74 $m^2$ (68 kg to market) per pig (Fritschen and Muehling, 1986). More recent research suggests a range of 0.56 $m^2$ to 1.11 $m^2$ for finishing pigs (Powell et al., 1993) but when barrows were taken to 136 kg there was little improvement in performance with the floor space allowance increasing from 0.83 $m^2$ to 0.93 $m^2$/pig (Brumm and NRC-89, 1996).

### *2.2.2 Housing conditions: Feeder space*

In addition to pen space, feeder space/pig has effects on feed intake. In situations where feeder space is limited, pigs will only expend a certain amount of energy to obtain food and as a consequence they restrict their feed intake (Morrow and Walker, 1994a). Also, aggressive behavior becomes more prevalent with more competition to get to the feeder (Walker, 1991). Walker (1991) also suggests too much feeder space may lead to feed wastage from playing in the feed or an increase in the incidence of defecation and urination in the feeder trough. Research on feeder space allocation shows differences based on stage of production. When pens of eight nursery pigs were offered one, three, or five 14 x 14 cm holes the best performance was seen with three holes (Brumm and Carlson, 1985). In contrast, Lindemann et al. (1987) showed feeder space allowance (9.1 cm/pig vs. 18.2cm/pig) did not result in any differences of within-pen variation in ADFI or ADG. In growing-finishing pigs three studies concluded that one feeder space was the requirement per 10 pigs when using a meal diet fed ad libitum (McGlone et al., 1993; Bates et al., 1993; Morrow and Walker, 1994b). Nielson et al. (1995) provided one single-space feeder for 5, 10, 15, or 20 grower pigs and found no differences between group sizes in ADFI (avg. 1.5 kg/d) or ADG (avg. 0.72 kg/d). There are clearly discrepancies between studies with no clear answer as to how much feeder space is actually required.

### *2.2.3. Water*

Water is responsible for physiological functions needed to live (Roubicek, 1969). This includes cell turgidity, temperature regulation, transporting nutrients to the proper location in the body, lubrication of joints, and almost every chemical reaction that takes place. Pigs can obtain water from three main sources: 1) water that is consumed or drinking water; 2) moisture that is trapped in feedstuffs; and 3) water produced from metabolic processes. The consumption of drinking water is usually related to feed intake in pigs. Weanling pigs show two patterns of water intake (McLeese et al., 1992). The first phase follows weaning (~5 days) in which water intake does not seem to be related to growth or feed intake and is random. Water intake during the second phase follows a consistent pattern that parallels growth and feed intake. The relationship between feed intake and water consumption is described (Brooks et al., 1984) by the following equation:

$$\text{Water intake (l/day)} = 0.149 + (3.053 \times \text{kg daily dry feed intake})$$

Growing-finishing pigs and lactating sows show a similar relationship between water and feed intake compared to weanling pigs. The minimum suggested requirement for 20 to 90 kg pigs is around 2:1 water to feed or, when receiving restricted amounts of feed, 3.7:1 water to feed (Cumby 1986). Altering the diet is another way shown to increase or decrease water intake. Shaw et al. (2006) gave barrows free access to diets containing low protein (16.9% CP), high protein (20.9% CP), or excess protein (25.7% CP) levels. Excess CP in the diet increased average daily water intake, but lowering dietary CP did not lower water intake (5.5, 4.9, and 6.3 kg of water for 16.9, 20.9, and 25.7% CP respectively). Shaw et al. (2006) also investigated the effects of mineral concentration on water intake. They diets containing excessive Ca (1.00 vs. 0.51%), P (0.76 vs. 0.51%), Na (0.36 vs. 0.14%), and K (0.70 vs. 0.28%), compared to the high protein diet from the previous experiment. The minerals did not have a significant effect on ADFI. In order to fulfill the water requirements during lactation, sows have been shown to consume between 12 to 40 l/day (Bauer, 1982; Klopfenstein, 1994). Studies have also investigated the effects of water flow rate during lactation. Greater feed intakes and lower weight loss were observed in sows with a water flow rate of 700 vs. 70 ml/min (Hoppe et al., 1987). One study suggests that a flow rate of 1.8 l/min is adequate for sows (Phillips et al., 1995). While not documented, optimum performance may require a water flow rate even higher than 1.8 l/min.

### *2.2.4. Temperature*

Ambient temperature affects heat production and heat loss, body temperature, feed intake, and growth performance. Mount (1974) defined the thermoneutral zone (TNZ) as “the range of ambient temperature over which, at a fixed level of feed intake, heat production is minimized and constant”. The farthest points of the thermoneutral zone are the lower critical temperature (LCT) and the upper critical temperature (UCT). When the ambient temperature is below the LCT sensible heat loss increases and evaporative heat loss is constant. In higher temperatures of the TNZ, evaporative heat loss increases as ambient temperature increases. Because both hot and cold thermal stressors affect an animal’s energy expenditure, and subsequently growth performance and feed intake, changes in nutrient intake through diet composition have the potential to alleviate any detrimental effects from thermal stress.

Depending on the stage of development, temperature has varying effects on feed intake and growth performance. Newborn pigs have a greater ratio of surface area to body mass which results in a greater amount of heat loss in cold environments when compared to grow-finish pigs. In order to produce heat to stay warm the metabolic rate must be increased. For example, metabolic rate is 30% higher at 18 than 31˚C within the first 20 min after birth (Noblet and Le Dividich, 1981). Providing an adequate thermal environment (32 to 34˚C) to minimize heat loss allows young pigs to utilize dietary metabolizable energy (ME) not for heat production but for growth. If an adequate temperature is not provided, feed intake may be affected depending on the pigs' stage of production. At 18 to 20˚C pigs consume 27% less colostrum than those kept at 30 to 31˚C at birth (Le Dividich and Noblet, 1981). As the pigs grow, fat accretion provides warmth by insulating the pig and a cold environment, one approaching the LCT, is not a major issue until weaning. The period immediately after weaning is a critical period of low feed intake as the pig becomes accustomed to its new surroundings and solid feed. The first 2 weeks after weaning may show a decrease in body fat since feed intake is low. To alleviate the problem nursery facilities should provide an environment around 95˚C the first week after weaning. After this period the temperature can be lowered 2 to 3˚C weekly to the temperature used in the grow-finishing facility (Feenstra, 1985).

When allowed ad libitum access to feed and water, growing and finishing pigs will adjust their feed intake in response to changes in ambient temperature. The amount of increase or decrease in feed intake is determined by weight and the magnitude of temperature change (Rinaldo and Le Dividich, 1991; Quiniou et al., 2000). In all cases there is a decrease in feed intake as the temperature rises and exceeds the UCT, with heavier pigs having the largest decrease. In contrast, as the temperature drops towards the LCT, there is an increase in feed intake. However, at a certain point below the LCT the animal may not be able to consume enough feed to provide adequate energy and heat to sustain life.

A rise in temperature in the farrowing house decreases feed intake in pregnant sows (Black et al., 1993). As a result, heat stressed sows have been shown to wean litters with a 23% lower weight (Quiniou and Noblet, 1999). This suggests a negative effect of high temperature on milk production. In fact, a 10% decrease in milk yield was found from sows housed in temperatures increasing from 20 to 30˚C (Schoenherr et al., 1989). There is currently no evidence to suggest that cold temperatures have an effect on pregnancy but in these situations the sow must consume 40 to 70 g more feed per ˚C drop to compensate for loss in body energy reserves (Noblet et al., 1997).

### *2.2.5. Management procedures*

As stated previously, temperature has the potential to increase and decrease feed intake depending on the specific situation. This is just one item controlled by swine management that can result in changes in feed intake and performance. Management procedures or guidelines have been developed to ensure human safety (handlers being injured by animals or transmitting diseases) as well as the safety and well being of the animals (prevent injuries, reduce susceptibility to disease, improve performance, and improve meat quality). The decrease in feed intake and growth performance in association with management procedures may be due to the stress the animal might be experiencing. Stress can be identified by both physiological and behavioral indicators. Physiological indicators include adrenocorticotropic hormone (ACTH), cortisol (indicates short term stress), adrenaline, creatine phosphokinase (CPK), beta endorphins, and heart rate. ACTH is released from the pituitary gland into blood activating secretion of cortisol from the adrenal cortex. Adrenaline, also released from adrenal cortex, increases heart rate and suppresses nonemergency processes such as digestion. The decrease in digestion is a good example of how stress affects performance. CPK is an indicator of damaged muscle and beta endorphins are present in the blood in response to damaged muscle as an analgesic to numb or dull any pain the animal might be experiencing. Behavioral indicators include attempting to escape or struggling while being restrained, vocalizations, and lack of appetite.

One of the most critical times for good management is at farrowing. Newborn pigs are usually handled the day they are born for such things as needle teeth clipping, tail docking, iron injections (if in confinement), identification (tattoo, ear tag, ear notch), and castration of male pigs a week or two before weaning. Needle teeth clipping and tail docking have been shown to increase the stress level in pigs. Prunier et al. (2005) submitted gilts either to tooth clipping with pliers, tooth resection with a grinder apparatus, control handling (animals were handled for the same amount of time but no procedures were administered), or no handling. For tail docking they submitted gilts to one of the following treatments: 1) tail docking with an electric-heated scissor docking iron, 2) control handling, and 3) no handling. Neither tail docking nor tooth resection procedures had effects on plasma cortisol or ACTH (Table 2.1, Figures 2.2 and 2.3). The significant increase in plasma cortisol and ACTH for time was primarily from the grinding method which took longer than all other treatments. There is no current evidence in the literature suggesting that these procedures affect voluntary feed intake (suckling) in piglets prior to weaning but needle teeth clipping may have an indirect effect on feed intake. The purpose of clipping needle teeth in new born pigs is to decrease the incidence of injury when the pigs play and to decrease the damage done to the sow's teats while the pigs are nursing. This damage to the teats is in the form of punctures and lacerations that may become infected and result in mastitis. As a result, milk composition may be altered as seen in sheep (Leitner et al., 2004) and/or milk production will decrease as seen in dairy cows (Hagnestam et al., 2007). In any case, growth of the nursing pigs will decline due to a decrease in milk consumption.

Table 2.1. Main effects and treatment × time interactions (P-values) in experiments designed to assess the effects of tail docking and tooth resection on plasma variables in pigs[1]

| Item[2] | Treatment | Time | Treatment x time |
|---|---|---|---|
| Tooth resection (n= 6 or 7 per trt) | | | |
| Plasma ACTH | 0.60 | <0.01 | 0.29 |
| Plasma cortisol | 0.91 | <0.01 | 0.86 |
| Tail docking (n= 5 or 6 per trt) | | | |
| Plasma ACTH | 0.39 | 0.12 | 0.29 |
| Plasma cortisol | 0.89 | 0.15 | 0.85 |

[1] Adapted from Prunier et al. (2005)

[2] ACTH = adrenocorticotropin hormone.

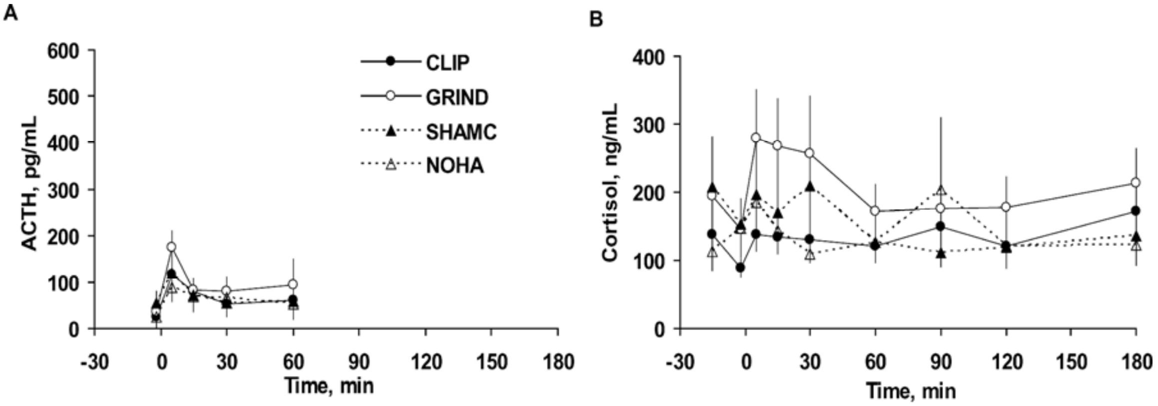

Figure 2.2. Plasma profiles of adrenocorticotropin hormone (ACTH) and cortisol in 1-d-old pigs (CLIP = tooth clipping; GRIND = tooth grinding; SHAMC = sham clipping; NOHA = no handling; n = 6 or 7 per group). Values shown are means ± SEM. (Adapted from Prunier et al., 2005)

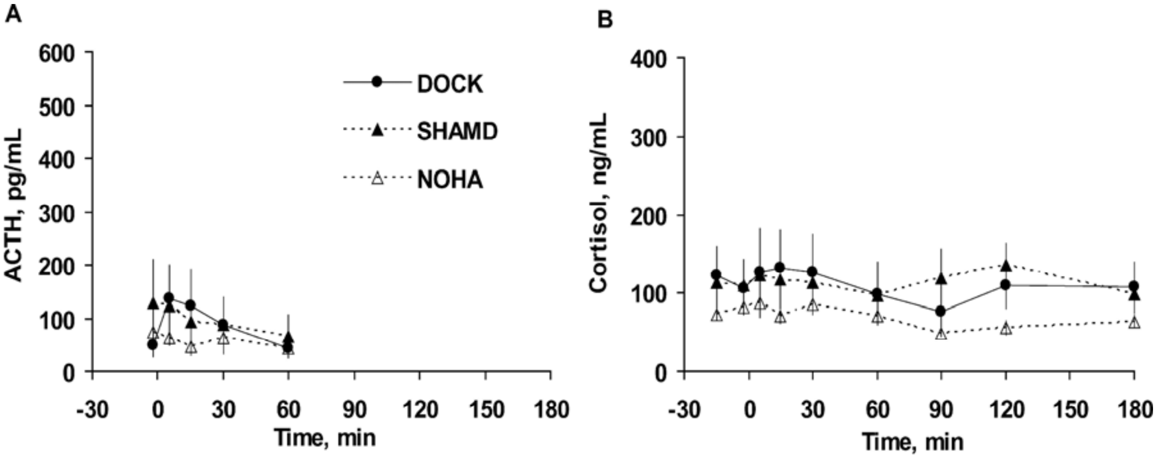

Figure 2.3. Plasma profiles of adrenocorticotropin hormone (ACTH) and cortisol in 1-d-old pigs (DOCK = tail docking; SHAMD = sham docking; NOHA = no handling; n = 5 or 6 per group). Values shown are means ± SEM. (Adapted from Prunier et al., 2005)

Similar to teeth clipping and tail docking, castration showed increases in cortisol levels with little effect on feed intake (Carroll et al., 2006). In contrast, weaning does have an effect on feed intake in varying amounts depending on the age at weaning. Main et al. (2004) weaned litters at d 12, 15, 18, or 21 after farrowing. The results (Table 2.2) show younger pigs at weaning consume less feed than older pigs through d 42 postweaning. Daily gain and weight at d 42 postweaning follow the same trend.

Table 2.2. Influence of weaning age on nursery performance[1]

| | Weaning age | | | | | P < | |
|---|---|---|---|---|---|---|---|
| Item | 12 | 15 | 18 | 21 | SE | Linear | Quadratic |
| ADG, g | 299 | 368 | 409 | 474 | 7 | 0.001 | 0.66 |
| ADFI, g (as-fed basis) | 426 | 511 | 565 | 654 | 11 | 0.001 | 0.64 |
| d 42 postweaning, kg | 16.9 | 20.3 | 22.6 | 25.8 | 0.26 | 0.001 | 0.60 |

[1] Adapted from Main et al. (2004). Based on 2,272 pigs, with 34 or 36 pigs per pen (50% barrows, 50% gilts), and 16 replications (pens) per treatment, or a total of 64 pens on test.

In the typical wean to finish production system today there would be very few instances where the producer would need to handle the animals between weaning and market. This is advantageous since it reduces the risk of causing stress to the animals. In situations where pigs must be handled, the intensity of the handling has an effect. In a review article, Hemsworth (2003) reported that aggressively or intensively handled pigs have increased cortisol levels and decreased ADFI and ADG compared to pigs not handled at all or gently handled regardless of the stage of production.

Since man has domesticated pigs they rely on us for care and protection. The way we approach these “care taker” responsibilities has an effect on their quality of life and performance. As stated above, the way we handle the animals and the level of intensity used have the potential to decrease their quality of life effecting how efficiently the animals grow which is the reason for their domestication in the first place.

### *2.2.6. Health status*

Most modern production systems have a high density of animals that are surrounded by pathogenic microorganisims such as bacteria, viruses, and parasites. Regardless, the frequency of pigs becoming ill is low due to their highly evolved immune system and steps taken by management to provide a sanitary environment. In situations where animals are reared in unsanitary environments with a high level of pathogen interaction there may be a decrease in feed consumption and growth. This is because nutrients that might have gone to support growth are now being used by the immune system. These results were first seen in chicks. Coates et al. (1963) demonstrated that chicks housed in a germ free environment had a greater ADFI and ADG than those housed in a conventional environment. In a less than germ free environment, antibiotics could be added to the diet at subtherapeutic levels to improve performance and feed intake (Roura et al., 1992). In pigs, Williams et al. (1997) subjected pigs to a low and a high level chronic immune system (IS) activation created by physically isolating pigs from, or continuously exposing pigs to, major vectors of environmental antigen transmission. Minimizing the degree of chronic IS activation resulted in no change in ADFI ($P < 0.09$) but an improvement in ADG and G:F ($P < 0.01$). The same study fed graded levels of lysine (0.60, 0.90, 1.20, or 1.50%) to pigs with high and low IS. An IS x lysine interaction ($P < 0.01$) was seen. To allow their greater capacity for body growth and protein accretion to be expressed, the low IS pigs required greater dietary lysine concentrations and daily lysine intakes than high IS pigs. This is evidence that state of health alters nutrient needs. Since housing conditions are not always ideally sanitary, the nutrient requirements of the immune system must be considered to maximize production and have an optimum level of immunity. Details of the nutritional needs of the immune system have been investigated but it is not in the scope of this paper and will not be discussed further.

### *2.2.7. Feed composition / palatability / preference*

It is likely that one of the most predominant factors influencing feed intake is the composition of the diet and how those ingredients affect the overall palatability. While it might be argued that pigs will eat anything and a lot of it, it is often dependent on the composition of the diet. This is because pigs tend to choose a diet that is balanced and meets their nutritional needs (Herren, 1999). Palatability, which changes depending on the composition of the diet, refers to a feedstuff's acceptability by the animal. This determination of acceptability by the animal is because taste and smell have evolved to associate beneficial (or nutritious) compounds and detrimental (or toxic) compounds with pleasant and unpleasant sensations, respectively (Goff and Klee, 2006). The development of palatability tests for the pig is more difficult than that for man where taste panels are used with a high degree of reliability. The pig's free-choice selection referred to as preference has been used to compare the relative palatability of various feedstuffs and additives offered simultaneously.

Feed palatability in pigs is clearly affected by the nature of the feedstuffs and their inclusion level in a diet, as shown in a series of preference experiments (Solà-Oriol, 2009). Short grain rice (whole, brown, or extruded white), long-grain white rice (raw and cooked), extruded barley, extruded corn, extruded wheat, oats (2 sources), thick rolled oats, cooked oats, and naked oats (raw, extruded, or micronized) were tested at inclusion rates of 150, 300, and 600 g/kg diet . Relative preference of cereals (% of total feed intake) was affected by type of cereal and by rate of inclusion. The diets containing extruded rice (150 g/kg), extruded naked oats (150, 300, and 600 g/kg), or naked oats (150 and 300 g/kg) were preferred ($P < 0.05$) by pigs to the reference diet (white broken rice and soybean meal, 56% CP). The same study investigated the palatability of oats and barley when offered as mash and pelleted diets. The results showed that barley is preferred over oats and pelleted diets are preferred over mash form. These results agree with previous research that pelleting swine diets has generally resulted in improved feed intake (Dinusson *et al.,* 1956; Dinusson and Bolin, 1958). Recent research on pelleted swine diets is limited.

## 2.3. Feeding nursery pigs

### *2.3.1. Factors affecting nutrient requirements*

The nutrient requirements of nursery pigs are affected by many factors such as weaning age, antigen exposure, and sex of the pig. Also, since feed intake is influenced by the learning abilities of the animal, any negative post-ingestive experiences with digestion may be linked to the feed and decrease feed intake. These factors must be kept in mind when formulating diets for nursery pigs in order to stimulate consumption of feed soon after weaning.

Weaning is a critical time for the young pig. It is a time when the digestive tract must adjust to a change from a liquid diet to a solid diet which is accompanied by a change in carbohydrate source, fat level, and many other dietary alterations. Early weaning, as early as 2 weeks of age, has been accomplished by using milk products (i.e., complex diet) to fulfill the young pig’s requirements. Early on it was discovered that the earlier the weaning the greater the need for a complex diet (Okai et al., 1976). This was supported by a more recent study (Dritz et al., 1996) that showed a higher weight gain increase in pigs weaned at 9 days compared to those weaned at 19 days when fed a complex diet.

Exposure to antigens results in the release of cytokines and activation of the immune system (Spurlock, 1997). This causes a decrease in protein synthesis (Jepson et al., 1986) and an increase in protein degradation (Zamir et al., 1994). The degraded protein is sent to the liver to make acute-phase proteins needed by the immune system. The limiting amino acid for this process is phenylalanine. This changes the nutrient requirements of the pig because now it has to meet the nutritional demands of the immune system as well. In an attempt to reduce the chance of disease transfer from the dam to the pig, early weaning to an isolated site, segregated early weaning (SEW), is frequently used. This method has been successful with an improvement in feed intake and gain of 16.1 and 21.3%, respectively (Williams et al., 1997) when compared to pigs reared in conventional systems. Reducing the exposure to antigens to 0% is obviously desirable but not totally feasible. For now SEW and sanitation of the environment between groups of pigs will suffice until research reveals its newest breakthrough in pig health.

The sex of the animal is another factor to consider. Barrows and gilts do not have the same nutrient requirements. Kornegay et al. (1994) reported that gilts ate more feed and grew faster than barrows during the first 5 weeks after weaning when weaned at 25 d of age, regardless of the CP concentration (16 vs. 22%) of the diet. A report by Cromwell et al. (1996) showed a 4.7% faster gain in gilts than in barrows and the gilts were heavier at the end of the experiment. These results suggest that feed intake and nutrient requirements are not equal between barrows and gilts. These results contradict early theories that barrows usually grow faster than gilts (Friend and MacIntyre, 1970). While research suggests these theories are not true for the nursery phase they may apply to other stages of growth. Regardless, it may not practical for barrows and gilts to be reared separately based availability of facilities and it may not be economical to have to feed each group a different diet to maximize growth based on sex. For the most part, sex effects on feed intake of pig have been ignored.

### *2.3.2. Simple vs. complex diets*

When nursery diets are formulated, a primary objective is selecting ingredients that will stimulate feed intake and maximize performance. Complex dietary formulations including dried milk products are often used in attempts to alleviate the effects of digestive disturbances due to a sudden change from sows' milk to solid feed, but have the potential to make the diets costly. Dritz et al. (1996) fed high, medium, or low complexity diets to 180 high-health status barrows from weaning at either d 9 or 19 (average initial BW 3.4 and 5.4 kg, respectively) to an average weight of 18.7 kg. They then were fed common corn-soybean meal-based diets from 18.7 to 109 kg. Diet complexity was altered by varying the levels of dried whey, lactose, soy products, spray-dried plasma protein, spray-dried blood meal, and select menhaden fish meal. Table 2.3 provides a summary of the results. For the period from weaning to 7 kg BW, the results showed that pigs weaned at d 19 gained faster than pigs weaned at d 9, and pigs fed the high and medium complexity diets gained faster than pigs fed the low complexity diets. Pigs weaned at d 9 had similar G:F across diet complexity, whereas pigs weaned at d 19 had higher G:F when fed the high or medium complexity diets than when fed the low complexity diets. From 7 to 18.7 kg BW, diet complexity did not seem to influence ADFI or ADG. The period from 18.7 to 109 kg BW showed an increase in ADFI and ADG on the medium complexity diet compared to the high and low complexity diets. Overall, from weaning to 109 kg pigs gained weight faster and had increased feed intake as diet complexity increased. But the increases in ADFI and ADG from medium to high complexity diets is small suggesting little benefit in diets formulated with that degree of complexity.

Table 2.3. Influence of weaning age and nursery diet complexity on growth performance[1]

| | Weaning age: | 9 d | | | 19 d | | | P-value | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | Diet complexity: | High | Medium | Low | High | Medium | Low | Age | Diet | A x D[2] |
| Weaning to 7.0 kg | | | | | | | | | | |
| ADG, kg | | .29 | .27 | .25 | .36 | .36 | .31 | .01 | .01 | .36 |
| ADFI, kg | | .32 | .29 | .27 | .31 | .32 | .30 | .02 | .01 | .03 |
| G/F | | .91 | .94 | .92 | 1.16 | 1.15 | 1.04 | .01 | .01 | .01 |
| 7.0 to 18.7 kg | | | | | | | | | | |
| ADG, kg | | .52 | .52 | .50 | .54 | .54 | .54 | .01 | .46 | .09 |
| ADFI, kg | | .73 | .75 | .73 | .70 | .72 | .73 | .07 | .11 | .20 |
| G/F | | .71 | .69 | .68 | .77 | .74 | .74 | .01 | .01 | .85 |
| 18.7 to 109 kg | | | | | | | | | | |
| ADG, kg | | .88 | .91 | .88 | .89 | .92 | .87 | .82 | .01 | .40 |
| ADFI, kg | | 2.54 | 2.56 | 2.50 | 2.52 | 2.67 | 2.56 | .01 | .01 | .01 |
| G/F | | .34 | .36 | .35 | .35 | .34 | .34 | .01 | .22 | .01 |

[1] Adapted from Dritz et al. (1996). Pigs weaned at 9 ± 1 d of age were initially 3.4 kg, and pigs weaned at 19 ± 1 d of age were initially 5.4 kg. Pigs were fed dietary regimens of varying complexity in the nursery from weaning to 18.7 kg. Pigs then were fed common diets from 18.7 to 109 kg. Each number is the mean for six pens (five barrows per pen from weaning to 11.9 kg, four barrows per pen 11.9 to 18.7 kg, and three barrows per pen 18.7 to 109 kg).

[2] Weaning age x diet-complexity regimen interaction.

As mentioned in the previous discussion on floor space, the amount of floor space the pig has can affect feed intake. Wolter et al. (2003) investigated the interactions of diet complexity and space allocation on ADFI using crossbred pigs (Ausgene Line 5 sires × Ausgene Line 13 dams) that were weaned at 15 d of age (average initial BW 5.0 kg). The treatments consisted of: 1) diet complexity (Complex vs. Simple), and 2) space allocation (Unrestricted vs. Restricted) in a 2 x 2 factorial arrangement. The Simple diet was based on corn-soybean meal with minimal inclusion of milk products, processed cereals, and animal protein-based ingredients compared to the Complex diet (Table 2.4). Pens assigned to the Unrestricted space treatment provided 0.63 $m^2$ of floor area per pig and 4 cm of feeder-trough space per pig. For the Restricted space treatment, pigs were allowed 0.21 $m^2$ of pig floor area and 2 cm of pig feeder-trough space. All pens housed 54 pigs. The results are seen in Table 2.5. Pigs fed Simple diets gained less for the overall period (weaning to Wk 8) than pigs fed complex diets. The greatest difference between Simple and Complex diets on pig growth performance was during the first 2 wk after weaning in which pigs fed the Simple diet had lower ADFI, ADG, and G:F ratio than those fed the Complex diet. For wk 3-4, pigs fed the Simple diet had a lower ADFI and ADG but similar G:F ratio than those fed the Complex diet. Diet treatment did not impact ADFI or ADG significantly from Wk 5-23 (pigs were provided the same diet regimen and space allocation from wk 8-23) but pigs fed the Simple diet during Wk 5-8 had a lower G:F than those fed the Complex diet. While it might be expected that increased complexity might counter decreased floor space related effects on ADFI due to increased palatability of ingredients, there were no interactions seen between diet complexity and space allocation.

The results from Dritz et al. (1996) and Wolter et al. (2003) agree with other research (Himmelberg et al., 1985; Whang et al., 2000) that has also shown that feeding pigs simple as opposed to complex diets during the early postweaning period results in lower BW gain. Moreover, Wolter et al. (2003) and Dritz et al. (1996) found that the increased feed intake associated with increased diet complexity was most pronounced in the immediate postweaning period and decreased thereafter.

Table 2.4. Dietary phases, duration of phases, and diet composition (as-fed basis) of diets fed from weaing to the end of Wk 8[1]

| | Complex diet phase | | | Simple diet phase | | |
|---|---|---|---|---|---|---|
| Item | I | II | III | I | II | III |
| Duration of feeding, wk | 2 | 2 | 4 | 2 | 2 | 4 |
| Approximate BW range, kg | 6 to 8 | 8 to 12 | 12 to 28 | 6 to 8 | 8 to 12 | 12 to 28 |
| Ingredients | | | | | | |
| Corn | 35.29 | 56.13 | 66.27 | 56.13 | 60.27 | 64.47 |
| Soybean meal (dehulled) | 10.50 | 25.00 | 25.00 | 25.00 | 30.00 | 30.00 |
| Dried whey | 22.00 | 7.50 | — | 7.50 | — | — |
| Lactose | 5.00 | — | — | — | — | — |
| Oat groats | 10.00 | — | — | — | — | — |
| Fishmeal, menhaden | 6.75 | 5.25 | 4.50 | 5.25 | 2.50 | — |
| Sprayed-dry plasma | 6.00 | — | — | — | — | — |
| Other[2] | 4.46 | 6.12 | 4.23 | 6.12 | 7.23 | 5.53 |

[1] Adapted from Wolter et al. (2003)

[2] Includes vitamin and mineral mixes, amino acids, antibiotic, fat, limestone, dicalcium phosphate, zinc oxide, and copper chloride.

Table 2.5. Effects of diet complexity and space allocation during the first 8 wk postweaning on pig growth performance from weaning to wk 23 postweaning in a wean-to-finish system[1]

| | Diet complexity[2] | | Space allocation[3] | | | P-value | | |
|---|---|---|---|---|---|---|---|---|
| | Simple | Complex | Restricted | Unrestricted | SEM | Diet | Space | Diet x space |
| ADG, g | | | | | | | | |
| Start to wk 2 | 147 | 182 | 163 | 166 | 2.7 | 0.001 | 0.43 | 0.38 |
| Wk 3 to 4 | 344 | 356 | 342 | 359 | 4.5 | 0.08 | 0.01 | 0.24 |
| Wk 5 to 8 | 574 | 580 | 548 | 607 | 5.3 | 0.41 | 0.001 | 0.21 |
| Wk 9 to 23 | 829 | 819 | 836 | 812 | 4.8 | 0.17 | 0.01 | 0.82 |
| Start to wk 23 | 680 | 679 | 680 | 678 | 2.9 | 0.87 | 0.61 | 0.82 |
| ADFI, g | | | | | | | | |
| Start to wk 2 | 205 | 239 | 217 | 227 | 2.3 | 0.001 | 0.01 | 0.70 |
| Wk 3 to 4 | 476 | 495 | 473 | 498 | 5.8 | 0.04 | 0.01 | 0.46 |
| Wk 5 to 8 | 942 | 937 | 903 | 977 | 7.8 | 0.62 | 0.001 | 0.74 |
| Wk 9 to 23 | 2,240 | 2,240 | 2,261 | 2,215 | 12.0 | 0.80 | 0.01 | 0.77 |
| Start to wk 23 | 1,671 | 1,673 | 1,678 | 1,666 | 8.0 | 0.90 | 0.34 | 0.68 |
| Gain:feed, g:g | | | | | | | | |
| Start to wk 2 | 0.71 | 0.76 | 0.75 | 0.73 | 0.008 | 0.001 | 0.10 | 0.37 |
| Wk 3 to 4 | 0.72 | 0.72 | 0.72 | 0.72 | 0.003 | 0.55 | 0.85 | 0.30 |
| Wk 5 to 8 | 0.60 | 0.61 | 0.60 | 0.62 | 0.003 | 0.03 | 0.01 | 0.12 |
| Wk 9 to 23 | 0.36 | 0.36 | 0.37 | 0.36 | 0.001 | 0.16 | 0.01 | 0.50 |
| Start to wk 23 | 0.40 | 0.40 | 0.40 | 0.40 | 0.001 | 0.91 | 0.41 | 0.67 |

[1] Taken from Wolter et al., 2003

[2] Diet complexity: Simple consisted of cereal-soybean meal-based diets that minimized the inclusion of milk, processed carbohydrates, and animal-source protein based ingredients vs Complex diets.

[3] Space allocation: Restricted = 2 cm/pig feeder trough and 0.21 $m^2$/pig of floor space and Unrestricted = 4 cm/pig feeder trough and 0.64 $m^2$/pig of floor space.

## 2.4. Feeding during gestation and lactation

The feeding goal for both sows and gilts is to optimize reproductive productivity. With gilts, longevity is also a concern since those which do not perform well at their first parturition are often not rebred and are culled from the herd. Body condition and structural soundness are two factors that affect longevity and reproductive performance. Maintenance of an optimal body condition of all sows in a herd is not always easy. A small error in the amount of feed distributed over the whole gestation period may lead to overweight and sometimes underweight sows at the time of parturition. Also, in addition to absolute feed intake, the concentration of nutrients in the diet is related to growth and reproductive performance.

To maintain a body condition that is healthy for the animal, what kind of feeding program should be used? Weldon et al. (1994) investigated the effects of feeding either a standard level of feed (SL; 1.85 kg/d) or ad libitum (AL) access to feed using 18 crossbred, primiparous sows. The sows were on treatment from d 60 of gestation throughout lactation. During gestation AL sows ate more (148.8 vs. 73.7 kg, $P < 0.0001$) and gained more weight (47.1 vs. 27.3 kg, $P = 0.002$) than SL sows. This increased intake was balanced by reduced feed intake during lactation, when AL sows ate less (83.8 vs. 151.9 kg, $P < 0.001$) and lost more weight (34.7 vs. 15.1 kg, $P = 0.06$) than did the SL sows. Feed level did not affect litter performance ($P > 0.05$) and you would not expect it to from a single parity study. From the results it appears that limiting the feed to a standard level prevents dramatic fluctuations in body weight and is a good management procedure for maintaining adequate body condition. In other words, feed should be restricted during gestation. Holt et al. (2006) tested standard level feeding to determine if it was more advantageous to offer the whole allotment of feed at once or divide it into two separate meals each day. Sows fed once daily gained less BW (27.7 vs. 36.1 kg, $P < 0.01$) and lost backfat (-1.3 vs. 0.01 mm, $P < 0.05$) compared with sows fed twice daily. Thus, not only total daily intake but also the manner of providing that intake can affect the sow. Adjusting meals based on this information, producers could tailor their feeding system based on each sows body condition and reproductive needs.

The ability of the sow to provide nutrients for its offspring is dependent on her ability to secrete milk. If milk production of sows is to be maximized, feeding strategies during gestation must provide for proper development of the mammary gland. Weldon et al. (1991) evaluated the effects of increased dietary energy and CP during late gestation on mammary development using 32 gilts. On d 75 of gestation, gilts were assigned randomly in a 2 **x** 2 factorial arrangement to adequate (5.76 Mcal ME/d) or increased (10.5 Mcal ME/d) energy and adequate (216 g CP/d) or increased (330 g CP/d) protein. On d 105 of gestation, gilts were slaughtered and total mastectomies were performed. Mammary parenchymal weight was 27% greater ($P < 0.03$) and parenchymal DNA was 30% greater ($P < 0.03$) in gilts fed adequate energy than in gilts fed increased energy. Total mammary parenchymal RNA ($P < 0.02$) and total mammary parenchymal protein ($P < 0.02$) also were greater in gilts fed adequate energy than in gilts fed increased energy. Dietary protein level did not affect mammary variables measured ($P > 0.10$). There have also been mixed results on feed intake when feeding protein. Feeding high levels of protein during gestation has been shown to increase feed intake in lactation (Mahan and Mangan, 1975). The experiment included three gestation CP levels (9, 13, or 17%, starting at breeding) and two lactation CP levels (12 or 18%). As CP level increased in the gestation diet, feed intake increased (5.2, 5.7, and 6.0 kg/d, $P < 0.01$) in lactation. Regardless of gestation diet, ADFI was the highest during lactation in sows fed 18% CP (4.2, 6.2, 4.8, 6.5, 5.9, and 6.2 kg/d for 9/12, 9/18 13/12, 13/18, 17/12, and 17/18 respectively). In contrast, Johnston et al. (1993) observed that sows fed 14% CP during gestation did not show differences in feed intake when fed various levels of protein (13.6, 15.5, 17.5, and 19.2%) in lactation. Sinclair et al. (2001) fed 60 gilts from d 40 of gestation throughout lactation a basal diet (14.4 MJ of DE/kg) that allowed enough nutrients for maintenance or basal diet with energy supplement (16.4 MJ of DE/kg). Average feed intake over the first 21 d of lactation was greatest for the sows on the basal diet (basal = 5.7 kg/d, basal + energy = 4.9 kg/d, $P < 0.001$). The results from Weldon et al. (1991) and Sinclair et al. (2001) agree. Energy in the diet appears to need strict control since surplus energy in gestation has a negative effect on mammary tissue and on lactation feed intake. Protein's effects are inconsistent and require more investigation.

A small weight loss during the lactation period and substantial net weight gain over successive pregnancies to enable the sow to grow to mature size is desirable (Close and Cole, 1986). As described for gestation, monitoring feed intake and nutrient concentration, as well as identifying the specific nutritional needs that some sows may require, will help control weight gain and body condition. Also, adequate feed intake during lactation is important to optimize lactation output since approximately 50% of preweaning deaths are related to insufficient milk production (Kertiles and Anderson, 1979). Even though the information on preweaning deaths is dated and might not represent the current situation, it makes the point that milk production should be a major objective (and perhaps concern) in lactating sows. During a reproductive cycle, maintenance represents 75 to 85% of the total requirements with uterine and fetal development and lactation making up the other 15 to 25% (Noblet et al., 1990). Generally the sow will adjust voluntary feed intake to match the requirements for milk production (Revell and Williams, 1993).

In addition to the amount of energy supplied in the diet affecting feed intake and performance, the source of energy may be important. Adding supplemental dietary fat to diets during late gestation and lactation increases milk production and the fat concentration of colostrum and milk (Pettigrew, 1981). As a result, higher fat stores in the liver were seen in the pigs at weaning. Seerley (1989) fed sows a control diet or one containing 5% added fat from gestation d 80 through lactation and found that the survival rate of pigs to d 21 was numerically greater (91.9 vs. 88.5 %) from sows fed the added fat but there were no significant differences between treatments. The increase in survival rate may be because control sows ate less during lactation than those on added fat (105 kg vs. 108 kg). The difference was not significant. Similar to Pettigrew (1981), Seerly (1989) found that the addition of fat in the sows diet increased the fat stores in livers of the pigs at weaning (129 and 152 mg/g for the control and 5% added fat, respectively; $P < 0.05$) possibly through an increase in milk fat. Postweaning performance showed pigs from fat-fed sows ate less feed (625 vs. 642 g, $P < 0.05$) than pigs from control sows. These data confirmed an earlier report by Stahly et al. (1981) in which they found that pigs from sows fed high oleic acid safflower oil or sunflower oil during lactation ate less than did pigs from control sows from weaning to d 49.

Dietary fiber serves to decrease the energy and bulk density of the diet because of the lower concentration of usable energy in fibrous feedstuffs compared with common energy and protein sources (NRC, 1998). As noted previously, energy levels must be controlled since too much energy in the diet during gestation decreases sow and litter performance. Also, feeding large quantities of a bulky diet in gestation will increase gut size and increase feed intake in lactation (Farmer et al., 1996). Research investigating fiber concentration and solubility in sow feed has returned inconsistent results. Holt et al. (2006) fed a corn-soybean meal (control) diet vs. a corn-soybean meal–40% soybean hulls diet during gestation (starting d 1 postweaning). Sows fed the high-fiber diet had increased feed intake (2.2 vs. 2.6 kg/day, $P < 0.05$) compared to sows on the control diet. As a result, high fiber sows gained less BW (29.9 vs. 34.1 kg, $P < 0.01$) and lost backfat (-1.0 vs. 0.3 mm, $P < 0.05$) during gestation compared with sows fed the control diet. Other effects of the diets include sows fed the high-fiber diet having fewer pigs born (10.8 vs. 11.7, $P < 0.05$) compared with sows fed the control diet. Renteria-Flores et al. (2008) conducted two experiments to evaluate the effects of soluble (SF) and insoluble (ISF) dietary fiber during gestation. Animals were fed 1 of 4 experimental diets: a corn-soybean meal control (C); a 30% oat bran diet high in SF (HS); a 12% wheat straw diet high in ISF (HIS); and a 21% soybean hull diet (HS+HIS). Sows fed the HS+HIS diet had a greater ADFI (2.0 vs. 1.9 kg, $P = 0.05$) and lost less BW (-9.4 vs. -14.9 kg, $P < 0.01$) during gestation than sows fed C. They also found inclusion of SF and ISF in gestation diets did not affect litter size compared to the control (11.2, 11.4 and 11.35 pigs/litter for SF, ISF, and C respectively). This differs from what Holt et al. (2006) discovered. When fed to gilts, feed intake has the highest (1.97 kg/d) with the HIS diet but not significantly different from the HS+HIS gilts (1.90 kg/d). There were no differences in ovulation rate among gilts fed the experimental diets (avg. = 14.1) but the number of live embryos was less for HIS and HS+HIS gilts (9.9 and 9.1) compared with C and HS (11.9 and 10.6, $P < 0.05$).

Feeding during gestation and lactation clearly involves many aspects, from diet formulation to feeding management, that can affect feed intake and performance. In addition, variation occurs in herds and further complicates finding a clear answer to nutritional needs during gestation and lactation. However, the goal should be to optimize reproductive performance. During gestation, feeding should focus on preparing the sow for parturition and lactation. The desired outcome of a successful gestation feeding program should be large litters of pigs and healthy sows equipped with adequate mammary development and body stores of nutrients to produce large quantities of milk. Lactation is just a continuance of gestational feeding in which adequate feed quantity and quality are needed to maintain milk production and subsequent reproductive performance such as ovulation, rebreeding, and conception. In both stages of production, research shows dietary energy, CP, and fat must be monitored to avoid the disadvantages associated with surplus amounts.

### 2.5. Flavors in swine diets

Flavors can be added to feed for a variety of different reasons. They can be used to cover up an undesirable flavor or odor that the feed may have or they can be used to try to improve the palatability of the feed in an attempt to increase feed intake. Although the use of flavors is claimed to improve feed intake, not all flavors are successful. This may be because most compounds used to flavor feed also give the feed a scent. Olfactory cues, which can provide sensory information before ingestion begins, may determine whether or not ingestion occurs. Much of the early research in flavors investigated the effects of sweet tasting compounds using preference trials.

Aldinger et al. (1959) conducted three experiments involving 186 pigs weaned at an average of 16 d of age (average initial BW 3.7 kg) to determine if weanling pig had a preference for a starter diet containing saccharin. Experiments I and II used five feeders/pen each with a different level of saccharin (0, 57, 114, 227, and 454 g/ton) and with the feed offered in three different forms (meal, pellets, and crumbles). In both experiments pigs preferred some level of saccharin over no saccharin. The preference was greater when either pellets or crumbles were offered than when meal was offered. There was a linear ($P < 0.05$) increase in feed consumption (8%, averaged over all forms of the diet) with increasing levels of saccharin. In Experiment III, two self-feeders were placed in each pen offering one of the six possible combinations of four levels of saccharin (0, 57; 0, 227; 0, 454; 57, 227; 57, 454; 227, 454 g/ton) with diets offered only in pelleted form. The results supported the previous experiments in that pigs preferred ($P < 0.05$) saccharin in the diet and consumed 3.5 times more of the saccharin diets than the non-saccharin diets. The highest feed intakes were recorded from feeders containing 454 g/ton suggesting a preference for increased amounts of saccharin.

Measuring the effects of a wide range of flavors, McLaughlin et al. (1983) investigated 129 flavors using a T-maze test in which pigs (average initial age 5 wk) were initially allowed to sample feed from one side containing flavor and the other side containing no flavor. The pigs were then allowed to select feed from either side of the T-maze five times. The 129 flavors were organized into eight different categories including buttery, cheesy, fatty, fruity, green, meaty, musty, and meaty. Five of the highest preferred flavors by the pigs were selected for a preference test in which a preference was shown for three (cheese, meaty and sweet molasses caramel) of the five flavors. Two of these preferred flavors (cheese and sweet molasses caramel) were then chosen to evaluate their effects on feed intake and growth performance. The pigs offered feed containing the cheesy flavor had increased feed intake ($P < 0.05$) and ADG ($P < 0.05$) compared to pigs offered the other flavor or a corn-soybean meal control diet from weaning to 3 wk after weaning. More specifically, those fed the cheesy flavor gained an average of 20 g/d more and consumed 24% more feed. There was a trend for feed intake and weight gain to remain increased up to 5 wk of age, but at 7 wk of age, there were no differences among treatments.

Langendijk et al. (2007) hypothesized that prenatal and postnatal exposure to certain flavors would increase the intake of feed containing the same flavors pre- and postweaning. This was tested by feeding multiparous sows a garlic and aniseed flavor during the last month of gestation and during lactation and evaluating the effects of pre- and postweaning feed intake in the sows' pigs. During lactation, all litters were offered creep feed which had 40 g garlic and 20 g aniseed per kg of feed. Piglets were weaned at 4 or 6 wk and half of the litters received the flavor in their post-weaning diet. After weaning, there was no effect of sow diet on feed intake, and no interaction between sow diet and post-weaning diet. However, litters weaned at wk 6 with the additive in their post-weaning diet had a higher feed intake from 3 days to 10 days after weaning ($P=0.05$) when compared to those fed the diet without the flavor. Since all litters had garlic and aniseed added to their creep feed during lactation, and since addition of garlic and aniseed to the dam diet did not affect post-weaning feed intake, the difference observed post-weaning may have been due to the piglets familiarity with the additive, due to their exposure to the additive in the creep feed during lactation. Millet et al. (2008) also found that flavor addition to creep feed did not increase feed intake (P = 0.963) or other performance parameters before or after weaning. The flavor used was not described.

Since Aldinger et al. (1959) investigated the effects of sweetly flavored feeds others have researched a variety of other possible flavor compounds. As described above, the results vary with some flavors increasing ADG and ADFI while others have little effect. Since flavors are intended to cover up undesirable flavor or odor and increase palatability, the quality of the diet (i.e. quality of ingredients) must be in question. Low quality and palatability diets should benefit more from the addition of a desirable flavor than those of high quality and palatability. The eventual goal should be to develop a flavor that will enhance even the highest quality diets and improve ADG and ADFI.

## 2.6. Salt

A salt, in chemistry, is the product formed from the neutralization reaction of acids and bases. Salts are ionic compounds composed of cations and anions forming an electrically neutral product. They come in a variety of colors and have various uses. Salt, the dietary mineral, is composed primarily of 40% sodium and 60% chloride and is essential for animal life, but toxic to most land plants. Salt flavor is one of the basic tastes, an important preservative, and a popular food seasoning. Chloride and sodium ions, the two major components of salt, are necessary for the survival of all known living creatures, including humans. Salt is involved in regulating the water content (fluid balance) of the body. Salt cravings may be caused by trace mineral deficiencies as well as by a deficiency of sodium chloride itself. Conversely, overconsumption of salt increases the risk of health problems.

### *2.6.1. Salt’s role in cellular transporters*

After ingestion, salt in the diet is dissociated into sodium and chloride ions which are coupled to cellular transporters throughout the body. In the production of saliva, sodium and chloride are absorbed by the acini cells in the salivon from the acinar capillaries. Then, in the striated duct of the salivary gland, sodium is responsible for increasing potassium in saliva through a series of proton exchanges and chloride is involved in an antiport exchange which draws bicarbonate into the saliva. These same transporters utilizing sodium and chloride are also used in the absorption of short chain fatty acids in ruminants, gastric acid secretion by parietal cells in the stomach of non-ruminants, and bicarbonate secretion by the centroacinar cells of the pancreas. In nerve cells, sodium-coupled neurotransmitter transporters serve to keep the extracellular transmitter concentrations below neurotoxic levels using a sodium ATPase. The ATPase generates an inwardly directed electrochemical sodium gradient, which is utilized by the transporters to drive ‘‘uphill’’ transport of the neurotransmitters (Kanner, 1983). These transporters can couple the flow of neurotransmitters not only to that of sodium, but also to that of additional ions such as potassium or chloride (Kanner & Schuldiner, 1987).

### *2.6.2. Dietary requirements*

Salt, that which is specifically made up of sodium and chloride, plays an important role in the growth of pigs and is required in different concentrations of the diet in each growth phase. The positive sodium ion and the negative chloride ion are the main cation and anion in the body responsible for the proper function of many physiological systems. The exact amount of salt needed for each size pig has not been adequately determined. It is often noted as a range such as 0.20 to 0.25 percent salt (NaCl) for growing-finishing pigs on a corn-soybean meal diet (NRC 1998). This is around 0.09% Na in the diet and has been found to be an adequate amount with no detrimental effect on growth (Alcantara, 1980). Many experiments have been conducted to try to determine the amount of salt needed and have returned varying results. The Na requirement has been shown to be dependent on age. Lighter, 10 kg pigs, showed a 25% reduction in growth when fed 0.065% compared to 0.09% Na while heavier, 27 kg, pigs showed no significant reduction in growth when fed the same amounts (Alcantara, 1980).

Cromwell et al. (1989) fed sows three different salt levels of 0.5, 0.25, and 0.125 % in the diet and found there was no affect on gestation weight gain or lactation weight loss. The lower salt concentrations did cause lower birth weights (1.42 vs. 1.45 kg for 0.25 and 0.5 % salt, $P = 0.01$) and lower 21 day weights (5.23 vs. 5.29 kg for 0.25 and 0.5 % salt, $P = 0.19$) of the piglets and feeding less than 0.50 % salt for more than one reproductive cycle caused a reduction in the number of pigs in the litter. In contrast to this, two diets of 0.4 and 0.1 % Na (1 and 0.25 % salt respectively) showed no affect on piglet growth performance or lactation but the interval from weaning to estrus was shorter and conception rate was higher for the sows on the high salt diet. An increased level of salt also showed an increase in water consumption (Seynaeve et al., 1996). More specifically, when diets containing salt levels ranging from 0.06 to 0.48 % were fed, there was approximately a 10 to 20 % lower water intake in sows fed 0.06 to 0.14 % salt compared to those fed 0.17 to 0.48 % salt (Hagsten et al., 1976).

These results have shown that lower salt concentrations can have a negative effect on physiological functions and growth performance. In addition, high salt concentrations can have detrimental effects and cause what is known as salt poisoning. Bohstedt (1954) fed pigs (12 pigs with average initial BW of 29.5 kg) a low salt diet consisting of only corn, soybean meal, and limestone (no added salt) for 99 days. After this period the pigs were divided into two groups. One group was fed a diet with 1.5% added salt and the other fed a diet with 2% added salt. The amount of added salt was arbitrarily chosen due to the lack of information on salt at the time and the same results were seen from both treatments. Due to the sudden excessive salt and water intakes, the pigs exhibited distress and a staggering gait within 24 hr regardless of diet. One pig had convulsions and a total of 3 died, including this pig, of the original 12. This is a very extreme case that can be avoided by providing an adequate amount of salt at all times in the diet and ad libitum access to water.

There is no specific treatment for salt poisoning. Immediate removal of offending feed or water is imperative. The Merk Veterinary Manual (2009) suggests that fresh water must be provided to all animals, initially in small amounts at frequent intervals. Ingestion of large amounts of water with large amounts of salt may lead to seizures or coma and may exacerbate neurologic signs due to brain edema. Severely affected animals should be given water via stomach tube. The mortality rate may be >50% in affected animals regardless of treatment (Merk Veterinary Manual, 2009).

### 2.7. Plasma protein

In the typical swine diet in the U.S., soybean meal is generally the principle ingredient when it comes to protein supplementation. While it is a good source of protein there are alternatives. Aside from economics, research to evaluate the utilization of these different protein sources has been done because of the limited and developing digestive capacity of weanling pigs. The development of proteases such as trypsin and chymotrypsin for protein digestion in the gut is not complete until 6 to 8 weeks of age

(Pekas, 1991; Corring et al., 1978). One of these alternative protein sources is spray-dried plasma protein and it originates from many sources including porcine, bovine, and animal plasma.

### *2.7.1. Plasma protein compared to other protein sources*

Plasma protein is a much more concentrated source of protein compared to soybean meal (78% CP vs. 47.5% CP). This is economically important since it would take less plasma protein, on a weight basis, to fulfill the animal's protein requirement when compared to soybean meal. However, plasma protein is not identical to soybean meal and the amino acid profiles of each need to be considered. Plasma protein can be included in the diet from several different products depending on the species from which it originated. Porcine plasma protein (SDPP) and bovine plasma protein (SDBP) are from their respective species. Animal plasma protein (SDAP) is a third type that is a mixture of plasma from several species. Research on plasma protein has primarily investigated growth performance to determine if it is a suitable alternative protein source compared to the conventional sources. If it is a suitable alternative, then is it the best alternative source of protein? Other protein sources commonly used include milk products such as dried skim milk and dried whey. A more complete list of alternative protein sources can be seen in Table 2.6.

When soybean meal and SDPP are compared, the results generally show a trend for increasing feed intake and growth performance in favor of the SDPP. Coffey and Cromwell (1995) measured growth performance of pigs (average initial BW 7.3 kg, average initial age 30 d) fed a corn-soybean meal-dried whey (20%) basal diet or a SDPP diet in which 5% SDPP was added at the expense of SBM in the basal diet from d 0 to 14 after weaning and a common diet fed the remainder of the trial. Pigs fed the soybean meal control diet grew more slowly ($P < 0.01$) and consumed less feed ($P < 0.05$) from d 0 to 14 than pigs receiving the diet containing SDPP. Daily gain and daily feed intake from d 14 to 28 were not affected by the diet fed during the initial 2 wk of the study. Hansen et al. (1993) used similar ingredients in their diets with the exception that 10% SDPP was used at the expense of SBM. They used lighter pigs (average initial BW 5.3 kg, average initial age 21 d) fed from d 0 to 35 after weaning. Pigs fed the soybean meal/whey diet grew more slowly ($P < 0.05$) but had no noticeable difference in G/F ($P < 0.08$) from d 0 to 7 or d 7 to 14. During the period from d 14 to 35, when all pigs were fed a common diet, pigs previously fed the diets containing porcine plasma had greater ADFI ($P < 0.05$) and poorer G/F ($P < 0.05$) with no differences between these treatments for ADG. Using amounts of SDPP greater than 10% has also been tested. De Rodas et al. (1995) fed 14% SDPP to pigs (average initial BW 6.1 kg, average initial age 19.5 d) from d 0 to 14 postweaning. From d 14 to 28 all pigs were fed a common corn-soybean meal diet similar to the previous experiments. During d 0 to 7, pigs fed SDPP had greater ADG and ADFI ($P < 0.05$) than pigs fed soybean meal. Gain/feed was numerically greater (0.64 vs. 0.49) in pigs fed SDPP but the difference was not significant. During d 7 to 14, pigs fed the SDPP diet continued to consume more feed ($P < 0.05$) than those fed soybean meal. However, ADG differences were not significant. During d 0 to 14 postweaning, ADG and ADFI were greater ($P < 0.05$) in pigs fed SDPP than in those fed soybean meal. However, contrary to what Hansen et al. (1993) observed, the diet fed from d 0 to 14 had no effect ($P > 0.10$) on growth performance from d 14 to 28.

Dried skim milk (34.6 % CP) has a lower concentration of protein compared to both soybean meal and plasma protein. Early research by Hansen et al. (1991) found that when SDPP was used in place of dried skim milk (DSM) there were positive effects on both feed intake and gain when diets were made isolysinic and isolactosic. To find out how much DSM could be replaced by SDPP Kats et al. (1994) assigned pigs (average initial BW 6.4 kg, average initial age 21 d) randomly to one of six dietary treatments containing 0, 2, 4, 6, 8, or 10% spray-dried porcine plasma. SDPP replaced DSM and L-lysine HC1 on an equal lysine basis. Diets contained 2, 4, 6, 8, or 10% added lactose, respectively, to maintain approximately 24.4% lactose. From d 0 to 14 postweaning, ADG increased (linear, $P < .01$) with increasing level of SDPP. Average daily feed intake also increased (quadratic, $P < .04$) and inflection point analysis projected maximum feed intake with 8.5% SDPP. Pigs receiving 8 and 10% SDPP consumed 95 g/d more feed than those receiving no SDPP. Feed efficiency was not ($P > 0.l0$) affected by dietary treatment. From d 14 to 28 postweaning, when all pigs were fed the same diet, a reduction (linear, $P < 0.03$) in ADG occurred with increasing level of SDPP fed during d 0 to 14. This may represent a period when ADG among pigs on all treatments begins to equalize. Pigs previously on SDPP diets would no longer have the advantage of the protein supplement and thus their growth would slow to a corn-soybean meal standard. This may be due to physiological reasons in the digestive tract from switching diets (i.e. digestibility). However, no differences in ADFI or G/F occurred from d 14 to 28 as a result of SDPP level fed d 0 to 14.

A possible explanation for increased consumption of diets containing SDPP is that they are more palatable than those containing milk products. Ermer et al. (1994) conducted a preference study to test this theory. Weanling pigs (average initial BW 6.2 kg, average initial age 26 d) were given a choice between a SDPP diet (8.5% SDPP, 20% dried whey, 10% lactose, and .13% DL-methionine) and a DSM diet (20% each of DSM and dried whey) throughout from d 0 to 21 postweaning. Results of repeated measures analysis of variance indicated that pigs preferred ($P < 0.01$) diets containing SDPP to those containing DSM. Also, the preference for the SDPP diet increased from 60% of total feed consumption on d 2 to 71% of total feed consumption on d 21($P < .01$; diet x day interaction).

Whey, which is a byproduct of the cheese industry, is another alternative protein source. Grinstead et al. (2000) investigated the differences in growth performance between a high protein, whey protein product (WPP; 73% CP, 6.8% lysine, 12.8% fat, and 5% lactose) and SDAP. Weanling pigs (average initial BW 4.1 kg, average initial age 12 d) were fed a control diet containing 2.5% SDAP or experimental diets, which were similar to the control diet, but contained an additional 2.5 or 5.0% SDAP or 2.5 or 5.0% WPP. From d 0 to 14 after weaning, ADG, ADFI, and G/F increased (quadratic, $P < .05$) with increasing SDAP up to 5.0%. Increasing WPP increased ADG (quadratic, $P < .07$) and ADFI (linear, $P < .09$). Also, pigs fed a 1:1 blend (2.5% of SDAP and WPP) of each protein source had a better ADG (quadratic, $P < 0.04$) than pigs fed other ratios (5:1.7 and 1.7:5). The 1:1 blend had a similar ADG (182 vs. 180 g/d) compared to those only fed SDAP. While feeding SDAP alone resulted in similar performance compared to feeding both SDAP and WPP, there may be a synergistic effect when the two are fed together in equal amounts. Additional information comparing SDPP and WPP in the literature is absent.

When considering alternative sources of protein, the addition of SDPP seems to consistently result in increases in feed intake and gain which are usually of similar magnitude. This may be due to SDPP acting as a flavor or palatability enhancer in the feed or through mechanisms involving immunoglobulins, protein quality, unidentified factors in plasma protein, or some combination. Evidence supporting the involvement of immunoglobulins was discovered by Pierce et al. (2005). Various levels of the immunoglobulin G (IgG)-rich fraction of SDPP (ranges from 17.9 to 22.5% of SDPP) was evaluated and compared to the other fractions (albumin-rich, 48% of SDPP; low molecular weight fraction, 0.46% of SDPP). The first week after weaning pigs fed SDPP grew faster (229 g vs. 141g, $P < 0.05$) and consumed more feed (462 g vs. 311 g, $P < 0.05$) than the controls. The IgG-rich fraction resulted in improvements in ADG (241 g vs. 141g, $P < 0.05$) and ADFI (410 g vs. 311 g, $P < 0.05$) that were similar to those of pigs fed the complete SDPP product, compared to the control. The albumin-rich fraction had no effect on growth rate (150 g vs. 141g ) compared to the control, but the low molecular weight fraction decreased feed intake (300 g vs. 311 g) as well as growth rate (119 g vs. 141 g).

In conclusion, while SDPP appears to increase growth performance and feed intake it may be a novelty that begins to wane after the first 2 wk postweaning. Evidence of this, presented in the research above, is seen from diminishing differences in performance between SDPP and diets with other protein sources beyond d 14 postweaning. While it appears that the IgG-rich fraction plays a significant role in the beneficial effects of SDPP, it is worth noting that SDPP as well as dried whey have a high Na content because of the manner in which they are made. In an earlier section the beneficial effects of salt on feed intake were discussed so it is possible that the Na content may be a portion of the response.

### *2.7.2 Optimum level of SDPP*

Most of the research conducted has used an arbitrary level of SDPP. This is because there have been few studies attempting to quantify the optimum amount. However, there does seem to be a trend in maximum growth performance with increasing SDPP in the diet as weaning age decreases. Kats et al. (1994) used pigs weaned at 21 days of age who showed increased performance up to 10% SDPP (results described above). Dritz et al. (1994) found increased performance with inclusion of up to 15% SDPP when pigs were weaned at 10 days of age. So, younger pigs at weaning, which typically have a lower body weight, seem to benefit from diets with a more concentrated amount of SDPP. It is likely that factors other than weaning age and weight, such as health status, are involved. More research that specifically focuses on the optimum level of SDPP is needed.

Table 2.6. Composition of protein sources used in feed[1]

| | | | | Amino acid composition (%)[2] | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Protein source | Dry Matter (%) | Crude Protein (%) | Lactose (%) | Ile | Lys | Met | Cys | Try | Thr |
| Plasma, spray dried | 91 | 78 | - | 2.7 | 6.8 | 0.7 | 2.6 | 1.3 | 4.7 |
| Blood cells, spray dried | 92 | 92 | - | 0.4 | 8.5 | 0.8 | 0.6 | 1.3 | 3.3 |
| Fish meal, menhaden | 92 | 62.3 | - | 2.5 | 4.8 | 1.7 | 0.5 | 0.6 | 2.6 |
| Meat and bone | 93 | 51.5 | - | 1.3 | 2.5 | 0.6 | 0.5 | 0.2 | 1.5 |
| Soybean meal | 90 | 47.5 | - | 2.1 | 3.0 | 0.6 | 0.7 | 0.6 | 1.8 |
| Dried skim milk | 96 | 34.6 | 50 | 1.8 | 2.8 | 0.9 | 0.3 | 0.5 | 1.6 |
| Dried whey | 96 | 12.1 | 65 | 0.6 | 0.9 | 0.1 | 0.2 | 0.1 | 0.7 |

[1] Values based on NRC (1998) requirements

[2] Selected amino acids

## 2.8. Conclusion

In swine production various factors have the potential to increase or decrease feed intake and growth performance. This includes pen and feeder space allowance, water, temperature, health, management procedures, and feed composition and palatability. Many approaches can be taken with respect to diet composition and palatability such as feed additives (flavors), ingredient choice, and nutrient composition.

However, the addition of flavor compounds has not been totally successful. Some flavors improve ADFI and ADG while others have little to no effect. Also, the majority of flavor research has been with weanling pigs with little attention to its possible effects on reproducing animals and subsequent generations. In contrast, alternative protein sources such as SDPP and dried whey have consistently shown increased ADFI and ADG in weanling pigs when compared to soybean meal. In addition, while mineral research is quite expansive there is a lack of new information on salt. Previous research has not adequately examined the requirements of salt for pigs.

Therefore, the objective of the present research was to determine what effects newly developed flavors have on growth performance and feed intake in nursery pigs (Chapter 3) and in sows (Chapter 4). Additionally, the effects of Appetein™ (a plasma protein product) as an alternative protein source for sows (Chapter 5) and the effects of graded salt levels in nursery diets (Chapter 6) on ADFI was examined.

# CHAPTER 3. Effect of a Flavoring Compound in Simple and Complex Nursery Diets on Performance of Young Pigs

## 3.1. Introduction

The immediate post weaning period for a weanling pig has a huge impact on growth performance to market. The stress from weaning is varied and is often accompanied by body weight loss. Pigs must start eating a solid diet quickly to reduce or avoid the weight loss. One possible means to overcome the generally low feed intake when changing from liquid to a solid diet and enhance feed intake is through the addition of flavors. Flavors can be added to feed for a variety of different reasons. They can be used to cover up an undesirable flavor or odor that the feed may have or they may be used to try to improve the palatability of the feed in an attempt to improve feed intake. Although use of flavors is claimed to improve feed intake in several species (Baldwin, 1978; Zivkovic, 1978), not all flavors would be expected to accomplish this. Diet complexity is another way in which the diet can be altered to prompt the young animal to eat or to improve digestibility. Complex diets include specific ingredients or feedstuffs beyond the routine cereal and protein supplement and usually result in more expensive diets, but an increase in feed intake and growth performance can also be seen (Dritz et al., 1996). Therefore, the objectives were: 1) to compare the growth performance of weanling pigs offered diets with and without a new, pre-market flavor, 2) to determine if there is an interaction between the complexity of the diet and the addition of a flavor with regard to that performance, and 3) to determine if there is a preference for a flavored diet.

## 3.2. Materials and methods

These experiments were conducted under protocols approved by UK's Institutional Animal Care and Use Committee. Pigs were brought into the nursery facility at approximately 3 wk of age (weaning), and immediately placed on an experimental diet, based on a typical corn–soybean meal nursery diet, adequate in all nutrients.

### *3.2.1. Experiment 1 – Animals and treatments*

Experiment 1 (experiment ID: UK 0720) was carried out in October and November 2007 and utilized a total of 96 crossbred pigs [60 barrows, 36 gilts; Yorkshire x Landrace, (Yorkshire x Landrace) x Duroc, (Yorkshire x Landrace x Duroc) x Chester White] with an initial BW of 6.26 ± 0.91 kg. Pigs were allotted to 4 dietary treatments on the basis of sex, initial BW, and breed of sire in a randomized complete block design. The experiment was conducted as a 2 x 2 factorial arrangement of treatments with main effects of flavor (with flavor and without) and diet type (simple and complex). This experimental design allowed 6 replicates of the 4 treatments with 4 pigs/pen (12 pens consisted of 3 barrows and 1 gilt and 12 pens of 2 barrows and 2 gilts). The pigs were housed in elevated nursery pens (1.22 m x 1.22 m) with plastic coated, welded wire flooring. Each pen was equipped with a nipple waterer and a single sided, three–hole plastic and metal feeder. The pigs were allowed ad libitum access to feed and water during the entire experimental period. Dietary treatments consisted of complex diet with flavor, complex diet without flavor, simple diet with flavor, and simple diet without flavor.

### *3.2.2. Experiment 2 – Animals and treatments*

Experiment 2 (experiment ID: UK 0723) was carried out in November and December 2007 and utilized 80 crossbred pigs [40 barrows, 40 gilts; Yorkshire x Duroc, (Yorkshire x Duroc) x Chester White, (Yorkshire x Landrace) x Duroc, (Yorkshire x Landrace x Duroc) x Chester White)] with an initial BW of 7.03 ± 1.03 kg. Dietary treatments, allotment criteria and experimental design, housing, and feeding management were as in Exp. 1. This allowed for 5 replicates of the 4 treatments with 4 pigs/pen (2 barrows and 2 gilts).

### *3.2.3. Experiment 3 – Animals and treatments*

Experiment 3 (experiment ID: UK 0805) was carried out in March and April 2008 and utilized 96 crossbred pigs [48 barrows, 48 gilts; Yorkshire x Duroc, (Yorkshire x Landrace) x Duroc, (Yorkshire x Duroc) x Chester White] with an initial BW of 6.04 ± 0.71 kg. Dietary treatments, allotment criteria and experimental design, housing, and feeding management were as in Exp. 1. This design allowed for 6 replicates of the 4 treatments with 4 pigs/pen (2 barrows and 2 gilts).

### *3.2.4. Experiment 4 – Animals and treatments*

Experiment 4 (experiment ID: UK 0806) was carried out in March and April 2008 and utilized 24 crossbred pigs [12 barrows, 12 gilts; (Yorkshire x Landrace) x Duroc] with an initial BW of 7.05 ± 1.08 kg. Pigs were allotted to pens on the basis of sex, initial BW, and breed of sire in a randomized complete block design. This experimental design allowed 4 replicates of each sex. The pigs were housed 3 pigs/pen (3 barrows or 3 gilts) in elevated nursery pens (1.22 m x 1.22 m) with plastic coated, welded wire flooring. Each pen was equipped with a nipple waterer and two single sided, three–hole plastic and metal feeders that were separated by a 15 cm gap. The pigs were provided with ad libitum access to feed and water during the entire experimental period. Dietary treatments consisted of simple diet with flavor and simple diet without flavor.

### *3.2.5. Experimental diets*

The diets for all four experiments were formulated to meet or exceed NRC (1998) requirement estimates for nursery pigs based on body weight. All flavors were provided by Lucta USA (Northbrook, IL). Exp. 1 and 2 (Table 3.1) utilized the same diet formulation. Simple and complex diets were fed using a three phase feeding system. Phase I lasted 7 d while Phase II and III were 14 d each. An antioxidants (Santoquin$^{®}$ – Ethoxyquin; Novus Intl. Inc., St. Louis, MO) and a broad–spectrum antibiotic (Mecadox – 10; Phibro Animal Health, Fairfield, NJ) were added to the Phase I and II diets at 0.02% and 0.25%, respectively, to minimize any health–related issues. Antioxidant products are added to feed to inhibit oxidation of fats and vitamins. Phase III diets included the antibiotic but no antioxidant since a supplemental fat source (grease in Phase I and II) was not included in the diet. All experiments utilized the same diet mixing procedure in which simple and complex diets had either corn starch (the diet without flavor) or flavor added to the diets in a manner in which the concentration of other ingredients remained unchanged. Corn starch or flavor was added at 0.15 % (Phase I), 0.10% (Phase II), and 0.05% (Phase III). Diet complexity was increased by increasing the amounts of spray-dried animal plasma (SDAP), fish meal, and lactose in the diet. The flavor included in Exp. 1 and 2 was described by the supplier as a “creamy and milky cheese with a sweet and vanilla bottom note and toasted and roasted notes of liver” (Flavor 1).

Table 3.1. Diet composition for Exp. 1 and 2 (as-fed basis)

| | Phase I | | Phase II | | Phase III |
|---|---|---|---|---|---|
| Item | Complex | Simple | Complex | Simple | Simple |
| Ingredient, % | | | | | |
| Corn, ground | 19.975 | 25.675 | 53.555 | 57.655 | 60.305 |
| Soybean meal, 48% CP | 20.00 | 30.00 | 25.00 | 32.00 | 36.00 |
| Oats, rolled | 20.00 | 20.00 | - | - | - |
| Spray dried animal plasma[1] | 5.00 | 1.60 | - | - | - |
| Fish meal, menhaden | 5.00 | 2.50 | 3.50 | - | - |
| Lactose | 10.00 | - | - | - | - |
| Whey dried | 14.00 | 14.00 | 14.00 | 6.00 | - |
| Grease, choice white | 2.60 | 3.00 | 0.25 | 0.25 | - |
| L-Lysine | 0.10 | 0.10 | 0.25 | 0.25 | - |
| DL-Methionine | 0.10 | 0.10 | 0.14 | 0.14 | 0.02 |
| L-Tryptophan | - | - | 0.04 | 0.04 | - |
| L-Threonine | 0.03 | 0.03 | 0.12 | 0.12 | - |
| Corn starch/flavoring | 0.15 | 0.15 | 0.10 | 0.10 | 0.05 |
| Dicalcium phosphate | 1.20 | 1.00 | 1.20 | 1.60 | 1.80 |
| Limestone | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Salt | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |
| Trace mineral premix[2] | 0.075 | 0.075 | 0.075 | 0.075 | 0.075 |
| Vitamin premix[3] | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Antioxidant[4] | 0.02 | 0.02 | 0.02 | 0.02 | - |
| Antibiotic[5] | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Total | 100 | 100 | 100 | 100 | 100 |
| Calculated nutrient composition | | | | | |
| ME, kcal/kg | 3,267 | 3,272 | 3,265 | 3,269 | 3,281 |
| Crude protein, % | 23.16 | 24.50 | 21.75 | 22.52 | 23.59 |
| Lysine, % | 1.59 | 1.58 | 1.48 | 1.48 | 1.37 |
| Calcium, % | 0.83 | 0.81 | 0.83 | 0.88 | 0.89 |
| Phosphorus, % | 0.65 | 0.65 | 0.65 | 0.72 | 0.75 |
| Available phosphorus, % | 0.48 | 0.40 | 0.41 | 0.41 | 0.41 |

[1] Source is combination of bovine and porcine plasma

[2] Supplied per kg of diet: Zn, 131 mg as ZnO; Fe, 131 mg as $FeSO_4 \cdot H_2O$; Mn, 45 mg as MnO; Cu, 13 mg as $CuSO_4 \cdot 5H_2O$; I, 1.5 mg as $CaI_2O_6$; Co 0.23 mg as $CoCO_3$; Se, 0.28 mg as $NaSeO_3$.

[3] Supplied per kg of diet: vitamin A, 6,600 IU; vitamin $D_3$, 880 IU; vitamin E, 44 IU; vitamin K (as menadione sodium bisulfate complex), 6.4 mg; thiamin, 4.0 mg; riboflavin, 8.8 mg; pyridoxine, 4.4 mg; vitamin $B_{12}$, 33 µg; folic acid, 1.3 mg; niacin, 44 mg; pantothenic acid, 22 mg; D-biotin, 0.22 mg.

[4] Santoquin (Novus Intl. Inc., St. Louis, MO) supplied 130 mg ethoxyquin per kg of diet.

[5] Mecadox - 10 (Phibro Animal Health, Fairfield, NJ) supplied 55 mg carbadox per kg of diet.

Table 3.2. Diet composition for Exp. 3 (as-fed basis)

| | Phase II | | Phase III | |
|---|---|---|---|---|
| Item | Complex | Simple | Complex | Simple |
| Ingredient, % | | | | |
| Corn, ground | 51.815 | 42.925 | 52.225 | 66.325 |
| Soybean meal, 48% CP | 20.000 | 36.000 | 25.000 | 30.000 |
| Spray dried animal plasma | 5.000 | - | - | - |
| Fish meal, menhaden | 5.000 | 2.500 | 5.000 | - |
| Lactose | 15.000 | 15.000 | 15.000 | - |
| Corn oil | 0.500 | 0.500 | 0.500 | 0.500 |
| L-Lysine | 0.040 | 0.040 | 0.030 | 0.100 |
| DL-Methionine | 0.050 | 0.090 | 0.050 | 0.030 |
| Corn starch/flavoring | 0.150 | 0.150 | 0.100 | 0.100 |
| Dicalcium phosphate | 0.900 | 1.200 | 0.700 | 1.100 |
| Limestone | 0.700 | 0.750 | 0.550 | 1.000 |
| Salt | 0.400 | 0.400 | 0.400 | 0.400 |
| Trace mineral premix[1] | 0.075 | 0.075 | 0.075 | 0.075 |
| Vitamin premix[2] | 0.100 | 0.100 | 0.100 | 0.100 |
| Antioxidant[3] | 0.020 | 0.020 | 0.020 | 0.020 |
| Antibiotic[4] | 0.250 | 0.250 | 0.250 | 0.250 |
| Total | 100 | 100 | 100 | 100 |
| Calculated nutrient composition | | | | |
| ME, kcal/kg | 3,375 | 3,332 | 3,360 | 3,328 |
| Crude protein, % | 20.94 | 22.39 | 19.44 | 19.86 |
| Lysine, % | 1.35 | 1.35 | 1.15 | 1.16 |
| Calcium, % | 0.80 | 0.80 | 0.71 | 0.72 |
| Phosphorus, % | 0.67 | 0.67 | 0.60 | 0.60 |
| Available phosphorus, % | 0.42 | 0.37 | 0.33 | 0.28 |

[1] Supplied per kg of diet: Zn, 131 mg as ZnO; Fe, 131 mg as $FeSO_4 \cdot H_2O$; Mn, 45 mg as MnO; Cu, 13 mg as $CuSO_4 \cdot 5H_2O$; I, 1.5 mg as $CaI_2O_6$; Co 0.23 mg as $CoCO_3$; Se, 0.28 mg as $NaSeO_3$.

[2] Supplied per kg of diet: vitamin A, 6,600 IU; vitamin $D_3$, 880 IU; vitamin E, 44 IU; vitamin K (as menadione sodium bisulfate complex), 6.4 mg; thiamin, 4.0 mg; riboflavin, 8.8 mg; pyridoxine, 4.4 mg; vitamin $B_{12}$, 33 µg; folic acid, 1.3 mg; niacin, 44 mg; pantothenic acid, 22 mg; D-biotin, 0.22 mg.

[3] Santoquin (Novus Intl. Inc., St. Louis, MO) supplied 130 mg ethoxyquin per kg of diet.

[4] Mecadox - 10 (Phibro Animal Health, Fairfield, NJ) supplied 55 mg carbadox per kg of diet.

The objective of Exp. 3 was the same as Exp. 1 and 2 but the diets were formulated a bit differently and included a different flavor. This flavor was described by the supplier as a "milk flavor with creamy nuances of fresh butter and vanilla" (Flavor 2). The diets for Exp. 3 (Table 3.2) did not include oats, dried whey, or grease like those in

Exp. 1 and 2 but had an increased amount of lactose. These changes resulted in increased metabolizable energy and decreased crude protein and lysine in Exp. 3 diets compared to Exp. 1 and 2. Also, in Exp. 3 only Phase II and III diets were used and fed for 14 d each.

Exp. 4 was conducted as a preference trial in which the simple diets with and without flavor from Phases I and II of Exp. 3 were compared. Two feeders were placed in each pen with one on the left side and the other on the right side of the front gate and approximately 15 cm between them. One contained the diet with no flavor and the other contained the diet with flavor. Every other day, throughout the entire trial, the feeders were moved to the opposite side of the front gate from which they were on the previous period to avoid the potential of feeder location being confounded with potential feed preference.

### *3.2.6. Response measures*

Weights of the pigs and the feeders were recorded every week in order to calculate ADG, ADFI, and G:F. Feed was added to the feeders when there was approximately 2.5 kg left. The feeders were checked twice daily to remove waste in the feeder trough and to make sure the feed had not become blocked preventing normal flow. When diets were changed at the end of each phase, the feeders were emptied completely before the new diet was added. Water nipple heights were adjusted on an as-needed basis based on the growth of the pigs in each pen to ensure easy access.

### *3.2.7. Statistical analysis*

Prior to analyses, the growth performance was evaluated to identify any potential statistical outliers within individual pens. First, the pens displaying within pen CV values greater than 25% for ADG were identified for further examination. Then individual pig performances within the selected pens were evaluated to identify the pig most divergent from its pen mates. This performance was then compared with littermates on other treatments in the experiment to determine whether the observed abnormalities were simply a genetic response. When a pig was removed from the experimental analysis, the pen feed intake was adjusted based on a model that allocated feed relative to metabolic body weight and  weight gain (Lindemann and Kim, 2007).

The experimental data was then analyzed using the least squares analysis of variance (Proc GLM) procedure of SAS® (SAS Inst. Inc., Cary, NC) for Exp. 1, 2, and 3. The data from Exp. 1 and 2 were pooled for analysis. The preference data from Exp. 4 was analyzed by unpaired T-tests using the GraphPad Prism program (GraphPad Software, Inc., San Diego, CA). The experimental unit for all experiments was the pen. The statistical model included treatment, experiment, replicate, treatment by experiment, and replication within experiment. Differences were considered significant at $\alpha = 0.05$.

## 3.3. Results

### *3.3.1. Experiments 1and 2*

In Exp. 1 one pig was removed due to poor health and one pig died. Feed intake correction was applied to these pens prior to analysis. Data from Exp. 1 and 2 (Table 3.3) were pooled for the analysis. For the entire experimental period daily gain was not affected by diet complexity ($P = 0.47$) or flavor ($P = 0.29$). Similarly, feed intake was not affected by diet complexity ($P = 0.58$) or flavor ($P = 0.98$).

Table 3.3. Growth performance for Exp. 1 and 2

| | Treatment mean[1] | | | | | P-value[3] | |
|---|---|---|---|---|---|---|---|
| Complexity: | Complex | Complex | Simple | Simple | | Complex | Flavor |
| Item[2] Flavor: | - | + | - | + | SE | vs. simple | effect |
| Body weight, kg | | | | | | | |
| Initial | 6.6 | 6.6 | 6.6 | 6.6 | 0.01 | 0.56 | 0.52 |
| Phase I | 7.7 | 7.7 | 7.6 | 7.6 | 0.08 | 0.41 | 0.92 |
| Phase II | 14.8 | 14.8 | 14.9 | 14.8 | 0.17 | 0.93 | 0.74 |
| Phase III | 24.9 | 24.6 | 24.8 | 24.7 | 0.26 | 0.92 | 0.57 |
| Daily gain, g | | | | | | | |
| Phase I | 140.7 | 135.1 | 130.8 | 130.2 | 20.2 | 0.47 | 0.76 |
| Phase II | 501.4 | 497.2 | 519.9 | 502.8 | 20.1 | 0.24 | 0.30 |
| Phase III | 701.8 | 686.8 | 707.6 | 697.8 | 26.7 | 0.53 | 0.36 |
| Phase I & II | 376.2 | 371.2 | 384.8 | 373.1 | 17.7 | 0.56 | 0.35 |
| Phase I, II & III | 504.0 | 495.3 | 511.9 | 500.9 | 18.4 | 0.47 | 0.29 |
| Daily feed, g | | | | | | | |
| Phase I | 204.0 | 202.7 | 203.5 | 207.8 | 21.2 | 0.83 | 0.89 |
| Phase II | 681.1 | 687.1 | 683.1 | 680.3 | 29.1 | 0.87 | 0.91 |
| Phase III | 1102.1 | 1124.4 | 1148.1 | 1121.8 | 40.3 | 0.29 | 0.92 |
| Phase I & II | 529.2 | 513.6 | 511.2 | 510.8 | 29.0 | 0.48 | 0.59 |
| Phase I, II & III | 743.8 | 753.6 | 761.5 | 750.9 | 26.6 | 0.58 | 0.98 |
| Gain:feed | | | | | | | |
| Phase I | 0.69 | 0.67 | 0.64 | 0.63 | 0.34 | 0.21 | 0.39 |
| Phase II | 0.74 | 0.72 | 0.76 | 0.74 | 0.15 | 0.27 | 0.28 |
| Phase III | 0.64 | 0.61 | 0.62 | 0.62 | 0.14 | 0.86 | 0.54 |
| Phase I & II | 0.71 | 0.72 | 0.75 | 0.73 | 0.18 | 0.38 | 0.61 |
| Phase I, II & III | 0.68 | 0.66 | 0.67 | 0.67 | 0.13 | 0.91 | 0.36 |

[1] Values represent means of 11 pens/treatment. The addition of flavor is denoted as (-) for no flavor in diet and (+) for flavor in diet.

[2] Phase I diets were fed for 7 days and Phase II and III diets were fed for 14 days.

[3] Interactions were calculated but none were significant with P > 0.45.

### *3.3.2. Experiment 3*

The results for Exp. 3 can be found in Table 3.4. In contrast to Exp. 1 and 2, increased diet complexity increased daily gain (P = 0.002) and feed intake (P = 0.017). The addition of flavor did not affect daily gain (P = 0.177) or feed intake (P = 0.786).

Table 3.4. Growth performance for Exp. 3

| | Treatment[1] | | | | | P-value[3] | |
|---|---|---|---|---|---|---|---|
| Complexity: | Complex | Complex | Simple | Simple | | | |
| Item[2] Flavor: | - | + | - | + | SE | Complex vs. simple | Flavor effect |
| Body weight, kg | | | | | | | |
| Initial | 6.0 | 6.0 | 6.0 | 6.0 | 0.03 | 0.62 | 0.43 |
| Phase II | 10.5 | 10.2 | 9.9 | 10.0 | 0.31 | 0.010 | 0.51 |
| Phase III | 19.6 | 19.1 | 18.3 | 17.9 | 0.74 | 0.002 | 0.18 |
| Daily gain, g | | | | | | | |
| Phase II | 320.6 | 297.8 | 275.9 | 283.8 | 10.0 | 0.011 | 0.46 |
| Phase III | 652.7 | 640.0 | 605.9 | 564.9 | 15.4 | 0.001 | 0.10 |
| Phase II & III | 486.7 | 468.9 | 440.9 | 424.3 | 12.1 | 0.002 | 0.17 |
| Daily feed, g | | | | | | | |
| Phase II | 377.0 | 361.1 | 334.5 | 348.6 | 11.0 | 0.02 | 0.93 |
| Phase III | 955.3 | 968.7 | 899.7 | 866.2 | 30.5 | 0.02 | 0.74 |
| Phase II & III | 666.1 | 664.9 | 617.1 | 607.4 | 19.8 | 0.01 | 0.78 |
| Gain:feed, g | | | | | | | |
| Phase II | 0.85 | 0.82 | 0.82 | 0.81 | 0.02 | 0.27 | 0.33 |
| Phase III | 0.68 | 0.66 | 0.67 | 0.65 | 0.02 | 0.44 | 0.19 |
| Phase II & III | 0.73 | 0.71 | 0.71 | 0.70 | 0.02 | 0.35 | 0.19 |

[1] Values represent the mean for 6 pens/treatment. The addition of flavor is denoted as (-) for no flavor in the diet and (+) for flavor in the diet.

[2] Phase II and III diets were fed for 14 days each.

[3] Interactions were calculated but none were significant with $P > 0.15$

### *3.3.3. Experiment 4*

A preference (or an increase in feed intake) was shown for the non-flavored diet over the flavored (Table 3.5). The preference was exhibited in week 1 (61.99% vs. 31.01%; $P = 0.05$) and continued throughout the entire 4 wk period (72.14% vs. 27.86%; $P < 0.0001$). Even though growth performance was not a response variable in this experiment it was recorded (Table 3.6) and was of similar magnitude as that in Exp. 3 (Table 3.4).

Table 3.5. Percentage of diets consumed for Exp. 4[1]

| Period | No flavor | Flavor | SEM | P |
|---|---|---|---|---|
| Week 1 | 61.99 | 38.01 | 8.08 | 0.0546 |
| Week 2 | 75.24 | 24.76 | 3.51 | <0.0001 |
| Week 3 | 77.71 | 22.29 | 5.65 | <0.0001 |
| Week 4 | 69.71 | 30.29 | 7.10 | 0.0015 |
| Weeks 1-2 | 70.93 | 29.07 | 3.51 | <0.0001 |
| Weeks 3-4 | 72.97 | 27.03 | 6.24 | 0.0001 |
| Weeks 1-4 | 72.14 | 27.86 | 5.21 | <0.0001 |

[1] Means represent 8 pens.

Table 3.6. Growth Performance results Exp. 4[1]

| Period | Performance Trait | | | |
|---|---|---|---|---|
| | Body weight, kg | Daily Gain, g | Daily Feed, g | Feed Efficiency (G:F) |
| Week 1 | 8.91 | 265.1 | 301.4 | 0.88 |
| Week 2 | 11.74 | 404.3 | 564.7 | 0.72 |
| Week 3 | 15.27 | 504.1 | 720.7 | 0.70 |
| Week 4 | 20.35 | 725.7 | 1036.7 | 0.70 |
| Weeks 1-2 | - | 334.7 | 433.0 | 0.77 |
| Weeks 3-4 | - | 614.9 | 878.7 | 0.70 |
| Weeks 1-4 | - | 474.8 | 655.9 | 0.72 |

[1] Means represent 8 pens.

## 3.4. Discussion

A variety of different flavored compounds have been used in swine diets with inconsistent results (Aldinger et al., 1959; McLaughlin et al., 1983; Nofre et al., 2002). The theory behind using the current milk and cheese flavors comes from the thought that if the corn-soybean meal diet mimics the taste and smell of the dam's milk the piglet will be more attracted to it and enticed to consume it. McLaughlin et al. (1983) investigated many flavors. One of these was classified as "cheesy", as was Flavor 1 of the current study. Their results showed increased feed intake ($P < 0.05$) and ADG ($P < 0.05$) with this flavor over a corn-soybean meal control diet from weaning to 3 wk after weaning. The current study did not produce the same results even though the diets used a similar flavor and pigs were similar in age and body weight at weaning. Langendijk et al. (2007) fed sows either a corn-soybean meal control or a garlic and aniseed diet during gestation and lactation, and introduced the piglets to the garlic and aniseed flavored feed pre-weaning by creep feeding. At weaning (4 or 6 weeks of age), litters were not mixed and 50% of the litters received the same diets they were fed before weaning whereas the other litters received the opposite diet. There were no interactions between sow diet and pig diet after weaning. However, litters weaned at wk 6 with the flavor additive in their post-weaning diet had a higher feed intake from 3 days to 10 days after weaning ($P = 0.05$) when compared to those fed the diet without the flavor regardless of the sows diet. Since all litters had garlic and aniseed added to their creep feed during lactation, and since addition of garlic and aniseed to the dam diet did not affect post-weaning feed intake, the difference observed post-weaning may have been due to the piglets familiarity with the additive, due to their exposure to the additive in the creep feed during lactation. The piglet's familiarity may have nothing to do with it at all and it may be due to some physiological factor in the digestive tract. The young digestive tract had become accustomed to the compounds in the flavor during lactation and a change in diet may disturb this state and discourage the piglet from consuming a different diet.

Age is another factor to consider. The pigs older at weaning had increased feed intake. Is this because taste buds for this specific flavor are not fully developed at 4 weeks of age? The answer to this is unclear. Even though taste buds can be visually seen on the tongue of a new born piglet, there is no evidence to when the sensory neurons are fully functioning and sending identifiable taste signals to the brain. Early exposure to flavors (i.e. during lactation) may be a clue into how to make use of flavor additives and could be the reason why the current flavors were unsuccessful.

While a milky flavor might seem as an obvious choice, there is a lack of information in the literature to make comparisons with Flavor 2. Under the conditions in Exp. 3 it does not seem to affect feed intake. Follow up studies may need to be conducted. The problem may be that we are basing these flavors on what we believe they should taste like. When 60 compounds perceived as sweet by humans were evaluated, only 35 of the compounds offered in aqueous solution were preferred in pigs compared to the water control (Nofre et al., 2002). The preference was measured by the difference in number of times the pig visited the flavored and control waterers and the time spent drinking. This suggests that taste is different in pigs than in humans. Pigs do have significantly more taste buds than humans suggesting more sensitivity to flavors (Bradley, 1971). Since the flavors were based on sweet tasting compounds for humans this could be why the flavors in the current experiment were unsuccessful.

Although pigs may have an apparent preference for a starter diet containing sweet flavors (Aldinger, 1959), the current study's results are similar to others (Wahlstrom *et al.,* 1974) that suggest that where a diet choice is not available, there is no difference in feed intake or daily gain between pigs fed sweetened or flavored and non-sweetened or non-flavored diets. This is the basis for conducting Exp. 4 since Exp 1, 2, and 3 did not offer a choice. However, a preference was not exhibited for the flavor when pigs were given a diet choice. They actually preferred the corn-soybean meal diet and discriminated against the flavor.

Previous research has demonstrated that feeding a corn-soybean meal diet with minimal inclusion of milk products, processed cereals, and animal protein-based ingredients can restrict growth rate during the nursery period (Himmelberg et al., 1985; Whang et al., 2000). These results do not agree with the current study in which there was no difference in feed intake or growth performance between simple and complex diets in Exp. 1 and 2. This may be due to the over-formulation of the simple diets preventing the complex diet from permitting an increase in growth performance. For example, in Phase 1 of Exp. 1 the complex diet had 3.4% more spray-dried animal plasma, 2.5% more fish meal, and 10% lactose at the expense of corn compared to the simple diet. Wolter et al. (2003) investigated diet complexity using a complex Phase 1 diet that had 4.5% more dried whey, 5% more lactose, 1.5% more fish meal, and 6% more spray-dried animal plasma. The magnitude of difference between simple and complex diets is less than the current research. The results from (Wolter et al. 2003) showed pigs fed Simple vs. Complex diets were lighter ($P < 0.01$). Diet complexity had its greatest impact on pig growth performance during the first 2 wk after weaning in which pigs fed the Simple diet had lower ADG ($P < 0.001$), ADFI ($P < 0.001$) and G:F ratio ($P < 0.001$) than those fed the Complex diet. This mirrors the results from Exp.3 which, like Wolter et al. (2003), had a smaller magnitude of difference in ingredients between simple and complex diets.

Since there are contrasting results between Wolter et al. (2003) and Exp. 1 and 2, when formulating simple and complex diets, the ingredients chosen to increase complexity and the magnitude of difference between the ingredients may determine how much of an increase in performance and feed intake occur. Not only must the ingredients be considered but also the ultimate nutrient levels of the diet. With respect to amino acids, lysine was intentionally increased beyond the estimated requirement (1.35 to 1.59 and 1.15 to 1.48 in Phases 1 and 2 respectively) in the diets fed in Exp. 1 and 2 (Table 3.1) to represent current industry trends. Research shows that while the estimated requirements are just that, estimates, there are upper critical limits that show diminishing returns beyond that point. Kornegay et al. (1993) fed corn-soybean meal-whey diets containing 1.15, 1.25, and 1.35% lysine to pigs averaging 7 – 10 kg. They estimated the lysine requirement to be 1.25% with no appreciable increase in growth performance at 1.35%. Mahan et al. (1993) used similar pigs and similar diets containing 0.95, 1.10, and 1.25% lysine. Their requirement estimate was also 1.25% with increased growth performance up to this level but since they did not test a higher level of lysine it is unknown if they had reached the maximal point of response for the pigs. There is little evidence suggesting increased lysine levels could confound the results preventing the expected difference between simple and complex diets but the possibility exists. The possibility that increased lysine levels could confound the results (Exp. 1 and 2) is supported by the results from Exp. 3 where the diets (Table 3.2) were formulated to have the NRC (1998) requirement estimate. As a result, there was an increase in feed intake and growth performance with complex diets compared to simple diets.

In conclusion, the current flavors were unsuccessful in increasing feed intake and growth performance in nursery pigs. The current studies did reinforce that complex diets have the potential to increase feed intake and growth performance. Also, it was showed there can be a clear preference in diet choice without there being a difference in performance in a non-choice situation.

# CHAPTER 4. The effects of flavor in lactation diets on sow feed intake and litter performance from farrowing to weaning

## 4.1. Introduction

A lot of flavors exist and diverse flavors are incorporated in varied concentrations in feed. Flavors have been added to feed for a variety of reasons. They can be used to mask an undesirable flavor or odor that the feed may have or they can be used to try to improve the palatability of the feed in an attempt to increase feed intake. Although the use of flavors is claimed to improve feed intake, not all flavors are successful. The use of flavors has been widespread in weanling pig feed but little research has been done looking at its effects in sow diets. Langendijk et al. (2007) hypothesized that prenatal and postnatal exposure to garlic and aniseed flavors would increase the intake of feed containing the same flavors pre- and postweaning. Sow diet did not affect litter size or pig size at weaning ($P > 0.05$). After weaning, there was no effect of sow diet on feed intake, and no interaction between sow diet and post-weaning diet of the pigs. However, litters with the additive in their post-weaning diet had a higher feed intake from 3 days to 10 days after weaning ($P = 0.05$) when compared to those fed the diet without the flavor. Since all litters had garlic and aniseed added to their creep feed during lactation, and since addition of garlic and aniseed to the dam diet did not affect post-weaning feed intake, the difference observed post-weaning may have been due to the piglets increased familiarity with the additive, due to their exposure to the additive from creep feed and the sows diet during lactation, compared to those pigs who were only exposed to the flavor from creep feeding. Other information on the use of flavors in sow diet is absent from the literature.

Therefore, an experiment was conducted to evaluate the effects of a “milky cheese” flavor when fed during lactation on sow feed intake and litter performance from farrowing to weaning.

## 4.2. Material and methods

### *4.2.1. Animals and treatments*

This experiment (experimental ID: UK 0721) was conducted under protocols approved by the University of Kentucky Institutional Animal Care and Use Committee in

October and November of 2007. Two farrowing groups were used consisting of 14 sows in group 1 and 8 sows and 10 gilts in group 2 (Yorkshire, Yorkshire x Duroc, Yorkshire x Landrace, and [Yorkshire x Landrace] x Duroc). Prior to the experiment, sows and gilts were housed in individual gestation stalls with solid concrete in the front and slatted flooring in the back. Around one week before the expected parturition date they were moved to farrowing crates with plastic-coated, expanded metal flooring and immediately allotted to 2 experimental diets. The experimental treatments consisted of a lactation diet with flavor and a lactation diet without flavor.

### *4.2.2. Experimental diets*

The diets (Table 4.1) were formulated to meet or exceed NRC (1998) requirement estimates for sows during lactation. The flavor was provided by Lucta USA (Northbrook, IL) and described as having a “creamy and milky cheese with a sweet and vanilla bottom note and toasted and roasted notes of liver” taste. This experiment utilized a diet mixing procedure in which diets had either flavor or corn starch (diets with and without flavor, respectively) added at the expense of corn. Corn starch or flavor was included at 0.10%. Feed was offered in meal form once a day at 7 am throughout lactation. At farrowing, meal size was 3.2 kg of feed. Throughout lactation the amount of the meal increased every three days as long as the sow was consuming all of the previous days feed to a maximum of 7.3 kg in the days prior to weaning. In cases where the sow did not eat the whole meal for three consecutive days the meal size was not increased until consumption increased. Creep feed was not offered to the pigs, but access to the sow’s feed was not restricted.

Table 4.1. Ingredient composition of experimental diets (as-fed basis)

| Item | Gestation | Lactation |
|---|---|---|
| Ingredient, % | | |
| Corn | 83.320 | 67.455 |
| Soybean meal, 48% CP | 10.050 | 25.600 |
| Alfalfa Meal | 2.500 | 2.500 |
| Grease | 1.000 | 1.000 |
| Corn starch/Flavoring | - | 0.100 |
| Dicalcium Phosphate | 1.550 | 1.210 |
| Limestone | 0.830 | 0.885 |
| Salt | 0.500 | 0.500 |
| Trace mineral premix[1] | 0.050 | 0.050 |
| Vitamin premix[2] | 0.100 | 0.100 |
| Choline Mix, 60%[3] | 0.100 | 0.100 |
| Dynamate[4] | - | 0.500 |
| Calculated nutrient composition | | |
| ME, kcal/kg | 3,682 | 3,679 |
| Crude protein, % | 12.11 | 18.19 |
| Lysine, % | 0.54 | 0.97 |
| Calcium, % | 0.75 | 0.75 |
| Phosphorus, % | 0.60 | 0.60 |

[1] Supplied per kg of diet: Zn, 131 mg as ZnO; Fe, 131 mg as $FeSO_4{\cdot}H_2O$; Mn, 45 mg as MnO; Cu, 13 mg as $CuSO_4{\cdot}5H_2O$; I, 1.5 mg as $CaI_2O_6$; Co 0.23 mg as $CoCO_3$; Se, 0.28 mg as $NaSeO_3$.

[2] Supplied per kg of diet: vitamin A, 6,600 IU; vitamin $D_3$, 880 IU; vitamin E, 44 IU; vitamin K (as menadione sodium bisulfate complex), 6.4 mg; thiamin, 4.0 mg; riboflavin, 8.8 mg; pyridoxine, 4.4 mg; vitamin $B_{12}$, 33 µg; folic acid, 1.3 mg; niacin, 44 mg; pantothenic acid, 22 mg; D-biotin, 0.22 mg.

[3] Supplies 0.6 g of choline per kg of diet as choline chloride.

[4] Contains sulfur (22.5%), potassium (18%), and magnesium (11.5%) to aid in prevention of constipation.

### *4.2.3. Management procedures*

Litter size was standardized within 2 days after farrowing by cross fostering within each treatment. The number of pigs born alive and dead, as well as the birth weight of each pig, was recorded within 24 h of farrowing. Pigs were ear-notched, injected with 1.5 ml of Fe as Fe dextran, and needle teeth clipped. Male pigs were castrated at approximately 2 wk of age. Sow feed intake was recorded daily and sow and pig weights were recorded at farrowing, castration, and weaning.

### *4.2.4. Statistical analysis*

Prior to analyses, sow feed intake and litter performance was evaluated to identify any potential statistical outliers. Sows having less than 8 pigs per litter after transfer were identified and removed prior to analysis. Also, sow feed intake was evaluated for values displaying a CV higher than 5 %. No sows were removed as statistical outliers.

The experimental data were then analyzed using the least squares analysis of variance (Proc GLM) procedure of SAS® (SAS Inst. Inc., Cary, NC). The experimental unit for this experiment was the sow. Differences were considered significant at $\alpha = 0.05$.

## 4.3. Results

The results are shown in Table 4.2. All of the sows were exposed to the flavor on approximately day 110 of gestation and farrowed on relatively the same day of gestation. No statistical differences were seen in pigs/litter, piglet weight, or litter weight between flavor and control sows but sows on the control diet did have heavier litters at weaning. While not statistically significant, sows on the control diet did eat an average of 8 kg more than sows on the flavored diet.

Table 4.2. Effects of flavor in lactation diets

| | Control | Flavor | SEM | P-value |
|---|---|---|---|---|
| Gest. Day of Flavor Exposure | 110.00 | 109.50 | 0.32 | 0.27 |
| Day of Gest. Farrowed | 115.44 | 114.81 | 0.38 | 0.26 |
| Days Farrowing -Wean | 20.00 | 19.56 | 0.47 | 0.52 |
| Pigs/Litter | | | | |
| Total | 10.88 | 12.13 | 0.69 | 0.21 |
| Born live | 10.06 | 10.88 | 0.69 | 0.41 |
| Post transfer | 12.13 | 12.19 | 0.43 | 0.92 |
| Castration | 10.56 | 10.44 | 0.49 | 0.86 |
| Wean | 10.19 | 10.31 | 0.47 | 0.85 |
| Litter Weight, kg | | | | |
| Total | 18.83 | 19.38 | 2.32 | 0.72 |
| Born live | 17.51 | 17.41 | 2.15 | 0.94 |
| Post transfer | 21.33 | 20.02 | 6.37 | 0.34 |
| Castration | 42.08 | 41.37 | 5.43 | 0.84 |
| Wean | 67.13 | 64.94 | 2.11 | 0.60 |
| Piglet Weight, kg | | | | |
| Total | 1.73 | 1.60 | 0.15 | 0.15 |
| Born live | 1.74 | 1.60 | 0.15 | 0.21 |
| Post transfer | 1.76 | 1.64 | 0.15 | 0.27 |
| Castration | 3.98 | 3.96 | 0.64 | 0.66 |
| Wean | 6.59 | 6.30 | 0.41 | 0.38 |
| Sow Feed, kg | | | | |
| Total farrowing - wean | 112.88 | 104.69 | 14.79 | 0.40 |
| ADFI | 5.66 | 5.31 | 0.72 | 0.45 |

[1]Each value represents the mean of 16 sows

## 4.4. Discussion

A variety of different flavored compounds have been used in nursery diets with inconsistent results. However, information on the effects of flavors in sow diets is absent. The results of the present study are consistent with what Langendijk et al. (2007) reported. The addition of a "creamy and milky cheese flavor" did not increase sow feed intake. In fact, since the control diet was the typical lactation diet fed to the herd, it would appear that the flavor decreases feed intake. While these results may represent the true response to the flavor, the design of the experiment (sows were fed once daily) would have prevented those sows that had a larger appetite from consuming more feed. The flavor also appears to have no effect on litter traits. Sows fed the flavored diet had numerically larger litters and, as would be expected, the pigs were smaller. However, weaning sows on the control diet had litters that weighed more than those from sows on the flavored diet.

One could theorize that the number of experimental units was inadequate for a sow study. Generally, the smaller the variability among experimental units treated alike, the more precise the experiment will be in detecting treatment differences. Increasing the number of replications is probably the most used technique as a means of improving the precision of the experiment. The number of replicates needed depends on the magnitude of the difference to be detected, the desired precision, and the variability of the experimental unit as described by Aaron and Hays (2004). For example, if the herd had low variation (20%) and we wanted to see no less than a 12% difference in litter size between treatments, the minimum number of replications is 45 at a significance level of 0.05. This number increases as the variation in the herd increases and as the expected difference in litter size decreases. Based on Aaron and Hays (2004), at the significance level chosen for the current study (0.05), 16 observations per treatment is not enough to accurately determine if there are any differences between treatments. Of course there is always the possibility that the results are accurate with a small number of replicates. In order to grasp a better understanding of the effects this flavor may have on sow feed intake and litter performance more observation may be needed.

This is just one of a countless number of flavors available for use. The fact that this flavor was unsuccessful should not deter attempts of flavor usage in lactation diet as the history of flavors in nursery diets has shown that they are not uniform in response. With the importance of feed intake during lactation for milk production and sow body condition, it is a mystery as to why more flavors have not been explored. In conclusion, this flavor appears to be unsuccessful in increasing sow feed intake or increasing litter characteristics.

# CHAPTER 5. The effects of Appetein™ on sow feed intake and litter performance from farrowing to weaning

## 5.1. Introduction

The feeding goal for both sows and gilts is to optimize reproductive productivity. This includes gaining weight over parities to reach a mature size, and producing large, healthy litters that survive to weaning. Feeding during gestation and lactation plays an important role in development for both the sow (future reproductive performance) and piglets. The sow must consume an adequate amount of nutrients in the right concentrations to provide for herself and her pigs at the same time. Manipulating the dietary nutrients has been investigated in an attempt to increase reproductive productivity. Protein, a nutrient needed in all stages of production, has had various effects on feed intake in sows. Feeding high levels of protein during lactation has been shown to increase feed intake in lactation (Mahan and Mangan, 1975). In contrast, when fed various levels of protein in lactation sows did not show differences in feed intake (Johnston et al., 1993). Also, varying the dietary protein level during gestation does not affect total mammary parenchymal RNA or total mammary protein (Weldon et al., 1991). This suggests that increased protein does not increase milk yield.

While protein levels have been studied in lactation diets, alternative protein sources have not. In nursery pigs, alternative protein sources such as dried whey and spray-dried animal protein (SDAP) have shown increased feed intake and daily gain over soybean meal (Grinstead et al., 2000; Coffey and Cromwell, 1995; Hansen et al., 1993). The effects of these products tend to wane as the pigs age. The success of alternative protein sources in nursery diets compared to soybean meal has opened the door for newer, better products to be developed and tested in growth stages other than the nursery. Therefore, an experiment was conducted to evaluate Appetein™, a high quality protein source, when added to a typical lactation diet and its effects on sow feed intake and litter performance from farrowing to weaning.

## 5.2. Materials and methods

### *5.2.1. Animals and treatments*

This experiment (experimental ID: UK 0808) was conducted under protocols approved by the University of Kentucky Institutional Animal Care and Use Committee. Five farrowing groups were used (Table 5.1). Prior to the experiment, sows and gilts were housed in individual gestation stalls with solid concrete in the front and slatted flooring in the back. Around one week before expected parturition date they were moved to farrowing crates with plastic-coated, expended metal flooring and immediately allotted to 2 experimental diets. The experimental treatments consisted of lactation with Appetein™ and lactation without Appetein™ (positive control).

Table 5.1. Farrowings used to evaluate effects of Appetein™ in lactation diets

| Date | Animals used | Breed |
|---|---|---|
| May-08 | 10 gilts, 8 sows | Yorkshire, Yorkshire x Landrace |
| Jul-08 | 3 gilts, 17 sows | Yorkshire, Yorkshire x Landrace |
| Nov-08 | 3 gilts, 18 sows | Yorkshire, Yorkshire x Landrace |
| Feb-09 | 26 sows | Yorkshire, Yorkshire x Landrace |
| Apr-09 | 2 gilts, 17 sows | Yorkshire, Yorkshire x Landrace |

### *5.2.2. Experimental diets*

The diets (Table 5.2) were formulated to meet or exceed NRC (1998) requirement estimates for sows during lactation. Appetien™ was provided by APC Inc. (Ankeny, IA) and is a high quality protein source composed of albumin and globulin proteins from animal plasma of mixed pork and beef origin. The chemical composition of Appetein can be seen in Appendix 4. Appetein™ was included at 0.5% (primarily replacing soybean meal) and corn and soybean meal were adjusted to maintain nutrient composition. Feed was offered in meal form once a day at 7 am. At farrowing, meal size was 3.2 kg of feed. Throughout lactation the amount of the meal increased every three days as long as the sow was consuming all of the previous days feed. Creep feed was not offered to the pigs, but access to the sow's feed was not restricted.

Table 5.2. Ingredient composition of experimental diets (as-fed basis)

| | Lactation diets | | |
|---|---|---|---|
| Ingredient, % | Control | Appetein | Gestation diet |
| Corn, ground | 67.82 | 68.37 | 81.54 |
| SBM, 47.5% CP | 25.15 | 24.09 | 12.31 |
| Appetein | - | 0.5 | - |
| Fat or oil | 3 | 3 | 2 |
| Dicalcium phosphate | 2.36 | 2.36 | 2.63 |
| Limestone | 0.74 | 0.75 | 0.69 |
| Salt | 0.5 | 0.5 | 0.5 |
| Vitamin premix[1] | 0.05 | 0.05 | 0.05 |
| Mineral premix[2] | 0.08 | 0.08 | 0.08 |
| Chromax[3] | 0.05 | 0.05 | 0.05 |
| Choline chloride – 60%[4] | 0.15 | 0.15 | 0.15 |
| L-Lys·HCl | 0.1 | 0.1 | - |
| Calculated Composition | | | |
| Crude protein, % | 17.76 | 17.6 | 12.69 |
| ME, Kcal/kg | 3,412 | 3,414 | 3391 |
| Calcium, % | 0.9 | 0.9 | 0.9 |
| Phosphorus, % | 0.8 | 0.8 | 0.8 |
| Available phosphorus, % | 0.5 | 0.51 | 0.54 |
| Total Lys | 1.02 | 1.02 | 0.58 |
| SID Lys, % | 0.9 | 0.9 | 0.5 |
| SID TSAA, % | 0.53 | 0.53 | 0.41 |
| SID Thr, % | 0.57 | 0.57 | 0.39 |
| SID Trp, % | 0.18 | 0.18 | 0.11 |
| SID Val, % | 0.73 | 0.73 | 0.52 |
| SID Ile, % | 0.65 | 0.64 | 0.44 |

[1] Supplied per kg of diet: vitamin A, 6,600 IU; vitamin $D_3$, 880 IU; vitamin E, 44 IU; vitamin K (as menadione sodium bisulfate complex), 6.4 mg; thiamin, 4.0 mg; riboflavin, 8.8 mg; pyridoxine, 4.4 mg; vitamin $B_{12}$, 33 µg; folic acid, 1.3 mg; niacin, 44 mg; pantothenic acid, 22 mg; D-biotin, 0.22 mg.

[2] Supplied per kg of diet: Zn, 131 mg as ZnO; Fe, 131 mg as $FeSO_4 \cdot H_2O$; Mn, 45 mg as MnO; Cu, 13 mg as $CuSO_4 \cdot 5H_2O$; I, 1.5 mg as $CaI_2O_6$; Co 0.23 mg as $CoCO_3$; Se, 0.28 mg as $NaSeO_3$.

[3] Supplied 200 ppb Cr from CrPic and was added at the expense of 0.05% limestone.

[4] Supplied 780 ppm choline in the final diet.

### *5.2.3 Management procedures and response measures*

Litter size was standardized within 2 days after farrowing by cross fostering within each batch and within treatment. The number of pigs born alive and dead, as well as the birth weight of each pig, was recorded within 24 h of farrowing. Pigs were ear-notched, injected with 1.5 ml of Fe as Fe dextran, and needle teeth clipped. Male pigs were castrated at approximately 2 wk of age. Pig weights and number of pigs in the litter were also recorded at castration and weaning. Sow weights were recorded at breeding, late gestation (approximately 5 days prior to farrowing), farrowing, castration, and weaning to determine gestation weight gain and lactation weight change. Sow feed intake was recorded daily.

### *5.2.4 Statistical methods*

Prior to analyses, gestation weight gain, lactation weight change, sow feed intake and litter performance were evaluated to identify any potential statistical outliers. First, sows having less than 8 pigs per litter after transfer were identified and removed. Then distributions of the data were plotted for gestation weight gain, lactation weight loss, ADFI, average pig weight at weaning, and litter weight at weaning. Values that fell outside of the normal distribution were considered outliers and removed.

The experimental data was then analyzed using the least squares analysis of variance (Proc GLM) procedure of SAS® (SAS Inst. Inc., Cary, NC). The experimental unit for this experiment was the sow. Differences were considered significant at $\alpha = 0.05$.

## 5.3. Results

Out of the original 104 sows/gilts put on trial, only 85 were used for analysis. Outliers removed can be seen in Appendix 3. The results shown in Table 4.2 illustrate the effects of Appetein™ compared to the control diet for all farrowing groups. A separate analysis for each farrowing group was conducted to determine if there were effects that were season dependent. The results between seasons were not significantly different and can be seen in Appendix 1. Overall, none of the results proved to be significant. Even without statistical significance it appears there may some improvement in litter characteristics. Numerically, piglet weight and litter weight at weaning were higher for Appetein™ sows than those on the control diet. Also, Appetein™ sows ate on average

2.86 kg more feed and gained weight during lactation compared to the control sows, which lost weight.

Table 5.3. Effects of Appetein™ in lactation diets[1]

| Item | Control | Appetein™ | RMSE[2] | P-value |
|---|---|---|---|---|
| Parity | 2.71 | 2.43 | 1.22 | 0.28 |
| Gestation weight gain, kg | 43.21 | 43.83 | 22.34 | 0.89 |
| Lactation weight change, kg | -1.47 | 0.43 | 14.64 | 0.55 |
| Pigs/Litter | | | | |
| Total | 12.87 | 12.58 | 3.00 | 0.65 |
| Born Live | 11.53 | 11.10 | 2.65 | 0.45 |
| Post transfer | 11.38 | 11.38 | 1.47 | 0.99 |
| Castration | 10.80 | 10.80 | 1.40 | 1.00 |
| Wean | 10.71 | 10.73 | 1.43 | 0.96 |
| Piglet Weight, kg | | | | |
| Total | 1.53 | 1.54 | 0.27 | 0.83 |
| Born Live | 1.56 | 1.57 | 0.27 | 0.85 |
| Post transfer | 1.54 | 1.56 | 0.26 | 0.77 |
| Castration | 3.96 | 4.10 | 0.61 | 0.26 |
| Wean | 6.46 | 6.60 | 0.87 | 0.45 |
| Litter Weight, kg | | | | |
| Total | 19.32 | 18.96 | 4.06 | 0.68 |
| Born Live | 17.63 | 17.18 | 3.93 | 0.59 |
| Post transfer | 17.39 | 17.64 | 3.04 | 0.70 |
| Castration | 42.42 | 44.15 | 7.24 | 0.27 |
| Wean | 68.63 | 70.44 | 9.87 | 0.40 |
| Sow Feed, kg | | | | |
| Total Farrowing – Wean[3] | 119.58 | 122.44 | 20.57 | 0.52 |
| ADFI | 6.09 | 6.24 | 0.94 | 0.46 |

[1] Values represent the mean of 45 sows on the control treatment and 40 sows on the Appetein™ treatment.

[2] RMSE—Root mean square error; when divided by the square root of the number of observations provides the standard error associated with each mean.

[3] The average length of lactation for control and Appetein™sows was 20 days.

## 5.4. Discussion

The purpose of the current research was to evaluate Appetein™, a high quality protein source composed of albumin and globulin proteins from animal plasma of mixed pork and beef origin, as an alternative protein source in a lactation diet and determine its effects on sow feed intake and litter performance. Even though sow feed intake and litter performance characteristics were not significantly affected by the addition of Appetein™, the numerical differences in the traits suggest there is potential for this product.

The increase in sow feed intake may be due to Appetein™ acting as a flavor or palatability enhancer in the feed. That seems to be the case when nursery pigs are fed diets containing SDPP. Ermer et al. (1994) conducted a preference study to test this theory. Weanling pigs (average initial BW 6.2 kg, average initial age 26 d) were given a choice between a SDPP diet (8.5% SDPP, 20% dried whey, 10% lactose, and .13% DL-methionine) and a DSM diet (20% each of DSM and dried whey) throughout from d 0 to 21 postweaning. Results of repeated measures analysis of variance indicated that pigs preferred ($P < 0.01$) diets containing SDPP to those containing DSM. Also, the preference for the SDPP diet increased ($P < .01$; diet x day interaction) from 60% of total feed consumption on d 2 to 71% of total feed consumption on d 21.

The fact that Appetein™ is an animal derived protein source replacing soybean meal, a plant derived source, requires mentioning. Protein of animal origin has frequently been suggested to have greater nutritional value for swine reproduction than protein of plant origin. Moustgaard (1952) reported that gilts fed a diet in which the supplemental protein was of animal origin reached puberty earlier and had a greater ovulation rate and greater embryo survival and litter size at 26 to 29 days of gestation than gilts fed a diet in which the supplemental animal protein was replaced with protein of plant origin. Reports since then (Teague and Rutledge, 1960; Mayrose *et al.,* 1964) indicate little if any beneficial effect on reproductive performance from replacing part or all of the supplemental protein in adequately fortified all-plant diets with protein of animal origin. It is not suggested that this applies to the current study since the protein source was not fed very long prior to farrowing and since litter size pre-transfer was not significantly different between treatments. The point is that animal protein sources may have some unknown advantages over plant sources and may lead to higher feed intake and litter performance.

Appetein™ may have influenced piglet growth through mechanisms involving immunoglobulins, protein quality, unidentified factors in plasma protein, or some combination. The pig immune system is acquired through passive antibody-mediated immunity, derived from colostral immunoglobulins, which reaches a maximum in the pig when 24 to 36 h old and then decreases logarithmically to low levels when about 3 wk old (Speer et. al., 1959; Miller et al., 1962). This time course of passively acquired immunity emphasizes the immunological vulnerability of the young pig at a time when it is exposed to a variety of different management stressors (litter management practices after farrowing and weaning). Evidence supporting the involvement of immunoglobulins was discovered by Pierce et el. (2005) using SDPP. Remember, Appetein™ is composed of SDPP and SDBP. Various levels of the immunoglobulin G (IgG)-rich fraction (ranges from 17.9 to 22.5% of SDPP) of SDPP were evaluated and compared to the other fractions (albumin-rich, 48% of SDPP; low molecular weight fraction, 0.46% of SDPP). The first week after weaning pigs fed SDPP grew faster (229 g vs. 141g, $P < 0.05$) and consumed more feed (462 g vs. 311 g, $P < 0.05$) than the controls. The IgG-rich fraction resulted in improvements in ADG (241 g vs. 141g, $P < 0.05$) and ADFI (410 g vs. 311 g, $P < 0.05$) that were similar to those of pigs fed SDPP when compared to the control. If the increased in immunoglobulins from Appetein™ in the sow diet is transferred to the milk, this could be the reason for the Appetein™ sows weaning numerically heavier pigs. If this is true, it would appear that not all of the immunoglobulins are transferred to milk or there are unknown mechanisms at work since the same increase in growth that Pierce et el. (2005) demonstrated was not seen. In order to understand how the milk immunoglobulin concentration is affected by Appetein™, milk from sows on Appetein™ and control diets must be analyzed.

In conclusion, there were no significant differences between means for parameters measured. Numerically, piglet weight and litter weight at weaning were higher for Appetein™ sows than those on the control diet. Also, Appetein™ sows ate on average 2.86 kg more feed and gained weight during lactation compared to the control sows, which lost weight. A more extended use of the product will be needed to determine any possible advantages in feeding it.

# CHAPTER 6. Growth and preference of pigs fed varying levels of salt

## 6.1. Introduction

Salt enters into all of the vital processes of the body including respiration, blood circulation, digestion, assimilation, secretion (saliva and other various buffers), and excretion. The very fact that of all body tissues blood is richest in $Na^+$ and $Cl^-$ suggests that salt is needed in the diet daily and a deficiency could cause multiple physiological disturbances. But, with the high availability, cheap price of salt, and quality of ingredients used in modern diets, deficiencies of salt are rare occurrences in pigs. With this in mind, research has mainly focused on determining the optimum level of salt in the diet.

The estimated dietary requirements (NRC, 1998) of $Na^+$ for nursery pigs is 0.25% from 3 to 5 kg, 0.20% from 5 to 10 kg, and 0.15% from 10 to 20 kg. These amounts are greater than previously thought as a result of research by Mahan et al. (1996). They discovered that nursery pigs fed diets containing dried whey or dried plasma (both are relatively high in sodium) still responded to added $Na^+$ (in the form of salt) in the diet. The literature lacks more current and detailed research on the effects of salt in nursery diets.

Therefore, an experiment was conducted to investigate the effects on growth performance when graded levels of salt are fed to nursery pigs. In addition, a preference study was conducted to determine if nursery pigs prefer certain levels of salt and in what proportion they are consumed.

## 6.2. Materials and methods

### *6.2.1. Experiment 1 – Animals and treatments*

Experiment 1 (experiment ID: UK 0820a) was carried out in December 2008 and January 2009 and utilized a total of 48 crossbred pigs [24 barrows, 24 gilts; Yorkshire x Duroc; (Yorkshire x Landrace) x Duroc] with an initial BW of 6.49 ± 0.81 kg. Pigs were randomly allotted to 3 dietary treatments from blocks based on sex, initial BW, and breed of sire in a randomized complete block design. This experimental design allowed 4 replicates (2 complete replicates by sex) with 4 pigs/pen (6 pens of 4 barrows and 6 pens of 4 gilts). The pigs were housed in elevated nursery pens with plastic coated, welded wire flooring (1.22 m x 1.22 m). Each was equipped with a nipple waterer and a single sided, three–hole plastic and metal feeder. The pigs were provided with ad libitum access to feed and water during the entire experimental period. Dietary treatments consisted of 0.1, 0.5, and 0.8% added salt.

### *6.2.2. Experiment 2 – Animals and treatments*

Experiment 2 (experiment ID: UK 0820b) was carried out in December 2008 and January 2009 and utilized a total of 48 crossbred pigs [24 barrows, 24 gilts; Yorkshire x Duroc; (Yorkshire x Landrace) x Duroc] with an initial BW of 7.53 ± 0.49 kg. Allotment, experimental design, and housing were as in Exp. 1. Each pen was equipped with a nipple waterer and two single sided, three–hole plastic and metal feeders separated by a 15 cm gap containing the two diets of the comparison allotted to the pen. Dietary treatments consisted of three comparisons of added salt level: 1) 0.1% vs. 0.5%, 2) 0.1% vs. 0.8%, and 3) 0.5% vs. 0.8%.

### *6.2.3. Experimental diets*

The diets for both experiments were formulated to meet or exceed NRC (1998) requirement estimates for nursery pigs based on body weight with the exception of Na. Exp. 1 and 2 (Table 6.1) utilized the same diet formulation and enough feed for both experiments was mixed at one time to prevent any differences in diet between experiments. Table 6.2 shows the Na and Cl contributions to the diet from ingredients other than salt. The diets were fed using a two phase feeding system. Phase I and II were 14 d each. An antibiotic (Mecadox – 10; Phibro Animal Health, Fairfield, NJ) was added to the diets at 0.25% to avoid any health–related issues. Dietary treatments for Exp. 1 were 0.1, 0.5, or 0.8% added salt. Exp. 2 was conducted as a preference trial in which the three treatments from Exp. 1 were compared (0.1% vs. 0.5%, 0.1% vs. 0.8%, 0.5% vs. 0.8%).

Table 6.1. Ingredient composition of experimental diets (as-fed basis)

| | Phase 1 | | | Phase 2 | | |
|---|---|---|---|---|---|---|
| Item | Diet 1 | Diet 2 | Diet 3 | Diet 1 | Diet 2 | Diet 3 |
| Ingredient, % | | | | | | |
| Corn, ground | 47.88 | 47.48 | 47.18 | 53.83 | 53.43 | 53.13 |
| Soybean meal, 48% CP | 33.50 | 33.50 | 33.50 | 33.50 | 33.50 | 33.50 |
| Lactose | 15.00 | 15.00 | 15.00 | 10.00 | 10.00 | 10.00 |
| L-Threonine | 0.10 | 0.10 | 0.10 | - | - | - |
| L-Lysine | 0.28 | 0.28 | 0.28 | - | - | - |
| DL-Methionine | 0.12 | 0.12 | 0.12 | - | - | - |
| Dicalcium Phosphate | 1.80 | 1.80 | 1.80 | 1.40 | 1.40 | 1.40 |
| Limestone | 0.80 | 0.80 | 0.80 | 0.75 | 0.75 | 0.75 |
| Salt | 0.10 | 0.50 | 0.80 | 0.10 | 0.50 | 0.80 |
| Trace mineral premix[1] | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Vitamin premix[2] | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Antibiotic[3] | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Calculated nutrient composition | | | | | | |
| ME, kcal/g | 3,285 | 3,271 | 3,261 | 3,317 | 3,303 | 3,293 |
| Crude protein, % | 20.37 | 20.33 | 20.31 | 20.41 | 20.38 | 20.35 |
| Lysine, % | 1.35 | 1.35 | 1.35 | 1.15 | 1.15 | 1.15 |
| Calcium, % | 0.81 | 0.81 | 0.81 | 0.71 | 0.71 | 0.71 |
| Phosphorus, % | 0.70 | 0.70 | 0.70 | 0.64 | 0.64 | 0.64 |
| Available phosphorus, % | 0.41 | 0.40 | 0.40 | 0.33 | 0.33 | 0.33 |
| Sodium, % | 0.05 | 0.21 | 0.33 | 0.05 | 0.21 | 0.38 |
| Chlorine, % | 0.11 | 0.37 | 0.57 | 0.11 | 0.33 | 0.58 |

[1] Supplied per kg of diet: Zn, 131 mg as ZnO; Fe, 131 mg as $FeSO_4 \cdot H_2O$; Mn, 45 mg as MnO; Cu, 13 mg as $CuSO_4 \cdot 5H_2O$; I, 1.5 mg as $CaI_2O_6$; Co 0.23 mg as $CoCO_3$; Se, 0.28 mg as $NaSeO_3$.

[2] Supplied per kg of diet: vitamin A, 6,600 IU; vitamin $D_3$, 880 IU; vitamin E, 44 IU; vitamin K (as menadione sodium bisulfate complex), 6.4 mg; thiamin, 4.0 mg; riboflavin, 8.8 mg; pyridoxine, 4.4 mg; vitamin $B_{12}$, 33 µg; folic acid, 1.3 mg; niacin, 44 mg; pantothenic acid, 22mg; D-biotin, 0.22 mg.

[3] Mecadox - 10 (Phibro Animal Health, Fairfield, NJ) supplied 55 mg carbadox per kg of diet.

Table 6.2. Na and Cl contribution from items other than salt[1]

| Ingredient | Na % | Cl % |
|---|---|---|
| Corn, ground | 0.02 | 0.05 |
| Soybean meal, 48% CP | 0.01 | 0.05 |
| Lactose | 1.85 | 3.43 |

[1] Values based on NRC (1998).

### *6.2.4. Management procedures*

Weights of the pigs and the feeders were recorded every week in order to calculate ADG, ADFI, and G:F. Feed was added to the feeders when there was approximately 2.5 kg left. The feeders were checked twice daily to remove waste in the feeder trough and to make sure the feed had not become blocked preventing normal flow. When diets were changed at the end of each phase, the feeders were emptied completely before the new diet was added. Water nipple heights were adjusted on an as-needed basis based on the growth of the pigs in each pen to ensure easy access. For the preference trial (Exp. 2), feeders were moved every other day to the opposite side of the front gate from which they were on the day before.

### *6.2.5. Statistical analysis*

Prior to analyses, the growth performance was evaluated to identify any potential statistical outliers within individual pens. First, the pens displaying intrapen CV values higher than 25% for ADG were identified for further examination. Then individual pig performances within the selected pens were evaluated to identify the pig most divergent from its pen mates. This performance was then compared with littermates on other treatments in the experiment to determine whether the observed abnormalities were simply a genetic response. When a pig was removed from the experimental analysis, the pen feed intake was adjusted based on a model that allocated feed relative to metabolic body weight and  weight gain (Lindemann and Kim, 2007).

The experimental data was then analyzed using least squares analysis of variance (Proc GLM) procedure of SAS® (SAS Inst. Inc., Cary, NC) for Exp. 1. The preference data from Exp. 2 was analyzed by unpaired T-tests using the GraphPad Prism program (GraphPad Software, Inc., San Diego, CA). The experimental unit for all experiments was the pen. The statistical model included treatment and replicate and differences were considered significant at $\alpha = 0.05$.

## 6.3. Results

### *6.3.1. Experiment 1*

The results for Exp. 1 can be found in Table 6.3. During Wk 1 a pig on Treatment 1 died. Feed intake correction was applied to the pen prior to analysis. Body weight across treatments was initially the same. By the end of Phase II pigs on Treatment 3 with the highest amount of salt (0.8%) were on average 1.33 kg heavier than those on Treatment 2 (0.5% salt) and pigs on Treatment 2 were on average 3.97 kg heavier than pigs on Treatment 1 (0.1% salt). The increase in weight with increased salt level is a result of increased feed intake and feed efficiency. Throughout Phases I (P, linear = 0.007) and II (P, linear = 0.0007) and over the entire period (P, linear = 0.001), feed intake increased with increasing salt level. G:F also shows improvement from Treatment 1 to 2 but little difference between Treatments 2 and 3. It is worthwhile to notice that even though daily gain and feed intake increase as salt level increases, the magnitude of difference seems to be decreasing. This is supported by quadratic P-values of 0.003 and 0.0322 for Phases I and II respectively for ADG. A quadratic effect is also seen for G:F but not for feed intake which linearly increases.

Table 6.3 Effects of added salt on growth performance

| | Treatment[1] | | | | P-value | |
|---|---|---|---|---|---|---|
| Performance trait | 0.10% | 0.50% | 0.80% | SE | Linear | Quadratic |
| Body weight, kg | | | | | | |
| Initial | 6.43 | 6.52 | 6.52 | 0.07 | 0.4219 | 0.58 |
| Phase I | 8.81 | 9.94 | 10.79 | 0.24 | 0.0011 | 0.64 |
| Phase II | 14.06 | 18.03 | 19.36 | 0.42 | 0.0001 | 0.04 |
| Daily gain, g | | | | | | |
| Phase I | 169.6 | 243.8 | 304.9 | 12.95 | 0.0003 | 0.69 |
| Phase II | 375.4 | 577.6 | 612.6 | 14.27 | <0.0001 | 0.003 |
| Phase I & II | 272.5 | 410.7 | 458.7 | 13.27 | <0.0001 | 0.03 |
| Daily feed, g | | | | | | |
| Phase I | 290.3 | 307.5 | 392.6 | 18.03 | 0.007 | 0.17 |
| Phase II | 783.3 | 912.3 | 987.9 | 22.58 | 0.0007 | 0.37 |
| Phase I & II | 536.8 | 609.9 | 690.2 | 18.07 | 0.001 | 0.87 |
| Gain:feed | | | | | | |
| Phase I | 0.58 | 0.79 | 0.78 | 0.02 | 0.0011 | 0.0096 |
| Phase II | 0.48 | 0.63 | 0.62 | 0.01 | <0.0001 | 0.0002 |
| Phase I & II | 0.51 | 0.67 | 0.66 | 0.01 | <0.0001 | 0.0006 |

[1] Values represent the mean of 4 pens/treatment. Treatments included 0.1, 0.5, and 0.8% added salt.

[2] Phase I and II were fed for 14 days each.

### *6.3.2. Experiment 2*

During Wk 2 one pig died on comparison 3. Feed intake correction was applied to both feeders in the pen based on feed disappearance from feed weigh back records for Wk 1 and 2 to totally remove the pig from the experiment prior to analysis. The proportion of diets consumed in Exp. 2 is shown in Tables 6.4, 6.5, and 6.6. Table 6.4 shows the proportions of treatments consumed for all replicates. In all cases, except Wk 4 of comparison 3, pigs ate a greater proportion of the diet with the higher level of salt. The majority of these differences are not statistically different. Wk 1 (27.30% vs. 72.70%, P = 0.0332) and 2 (20.44% vs. 79.56%, P = 0.0008) of comparison 1 and Wk 2 (19.78% vs. 80.22%, P = 0.0012) of comparison 3 had the greatest differences in proportions eaten. To determine if there were any differences between sex the replicates of barrows and gilts were also analyzed independently. Table 6.5 shows barrows do prefer a diet with more salt with proportions around 70:30 after Wk 1. The magnitude of difference tends to decrease gradually to around 60:40 by Wk 4. The gilts (Table 6.6) initially consumed greater proportions of the higher salt diet but after Wk 1the ratio of diets was around 1:1.

By Wk 4 the proportion of diets was near 60:40 in favor of the lower salt diet. The differences in proportions of diets consumed were not statistically different. Absolute feed intakes can be seen in Appendix 1.

Table 6.4. Proportion (%) of diets consumed (all replicates, n=4)[1]

| | Comparison 1 | | | Comparison 2 | | | Comparison 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| Week | 1 | 2 | P | 2 | 3 | P | 1 | 3 | P |
| 1 | 27.3 | 72.7 | 0.03 | 46.5 | 53.4 | 0.76 | 31.6 | 68.3 | 0.07 |
| 2 | 20.4 | 79.5 | 0.0008 | 46.2 | 53.7 | 0.72 | 19.7 | 80.2 | 0.001 |
| 3 | 41.1 | 58.9 | 0.18 | 49.9 | 50.0 | 0.99 | 42.2 | 57.7 | 0.43 |
| 4 | 46.1 | 53.8 | 0.70 | 46.7 | 53.2 | 0.66 | 50.2 | 49.7 | 0.97 |
| 1 & 2 | 22.2 | 77.7 | 0.002 | 46.0 | 53.9 | 0.60 | 23.4 | 76.5 | 0.003 |
| 3 & 4 | 44.0 | 55.9 | 0.47 | 48.2 | 51.7 | 0.79 | 46.7 | 53.3 | 0.72 |
| 1 to 4 | 38.2 | 61.7 | 0.08 | 47.7 | 52. | 0.60 | 40.2 | 59.7 | 0.26 |

[1] 1, 2, and 3 are 0.1, 0.5, and 0.8% inclusion of salt, respectively.

Table 6.5. Proportion (%) of diets consumed by barrows (n=2)[1]

| | Comparison 1 | | | Comparison 2 | | | Comparison 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| Week | 1 | 2 | P | 2 | 3 | P | 1 | 3 | P |
| 1 | 27.4 | 72.6 | 0.16 | 59.2 | 40.7 | 0.65 | 28.5 | 71.4 | 0.0003 |
| 2 | 21.5 | 78.5 | 0.05 | 27.2 | 72.7 | 0.12 | 19.3 | 80.6 | 0.07 |
| 3 | 28.7 | 71.2 | 0.08 | 47.3 | 52.7 | 0.34 | 39.8 | 60.1 | 0.66 |
| 4 | 34.0 | 65.9 | 0.40 | 36.8 | 63.1 | 0.16 | 42.4 | 57.5 | 0.70 |
| 1 & 2 | 22.9 | 77.0 | 0.07 | 34.4 | 65.5 | 0.02 | 22.6 | 77.4 | 0.04 |
| 3 & 4 | 31.7 | 68.2 | 0.25 | 41.6 | 58.3 | 0.06 | 41.1 | 58.8 | 0.68 |
| 1 to 4 | 29.7 | 70.4 | 0.18 | 39.8 | 60.1 | 0.01 | 36.5 | 63.4 | 0.47 |

[1] 1, 2, and 3 are 0.1, 0.5, and 0.8% inclusion of salt, respectively.

Table 6.6. Proportion (%) of diets consumed by gilts (n=2)[1]

| | Comparison 1 | | | Comparison 2 | | | Comparison 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| Week | 1 | 2 | P | 2 | 3 | P | 1 | 3 | P |
| 1 | 27.20 | 72.80 | 0.31 | 33.84 | 66.16 | 0.40 | 34.74 | 65.26 | 0.54 |
| 2 | 19.38 | 80.62 | 0.08 | 65.33 | 34.67 | 0.36 | 20.24 | 79.76 | 0.08 |
| 3 | 53.44 | 46.56 | 0.44 | 52.64 | 47.36 | 0.87 | 44.65 | 55.35 | 0.64 |
| 4 | 58.22 | 41.78 | 0.61 | 56.74 | 43.26 | 0.65 | 58.16 | 41.84 | 0.55 |
| 1 & 2 | 21.51 | 78.49 | 0.13 | 57.63 | 42.37 | 0.62 | 24.23 | 75.77 | 0.17 |
| 3 & 4 | 56.31 | 43.69 | 0.56 | 54.87 | 45.13 | 0.75 | 52.20 | 47.80 | 0.85 |
| 1 to 4 | 46.97 | 53.03 | 0.50 | 55.62 | 44.38 | 0.46 | 43.99 | 56.01 | 0.64 |

[1] 1, 2, and 3 are 0.1, 0.5, and 0.8% inclusion of salt, respectively.

## 6.4. Discussion

The purpose of this experiment was to evaluate feed intake and growth performance of nursery pigs fed added salt. The estimated dietary requirement (NRC 1998) of $Na^+$ for pigs weighing 5 to 10 kg is 0.20% and this investigation involved supplemental salt levels of 0.1, 0.5, and 0.8% (0.04, 0.20, and 0.32% $Na^+$ respectively). Increasing dietary salt significantly improved the performance of nursery pigs. The literature lacks information on the effects of different salt levels on weanling pigs but its effects on feed intake and growth performance of grow-finish pigs and sows are varied compared to those presented here. Cromwell et al. (1989) fed three different salt levels of 0.5, 0.25, and 0.125% to sows during gestation and lactation. There was no affect on gestation weight gain or lactation weight loss between the three levels of salt. The lower salt concentrations did cause numerically lower birth weights and 21 day weights of the piglets and feeding less than 0.5% salt for more than one reproductive cycle caused a reduction in the number of pigs in the litter. Hagsten et al. (1976) fed salt levels ranging from 0 to 1.0% of the diet to pigs from 18 to 100kg. Pigs fed supplemental salt (0.1 to 1.0%) had an increased ADG compared to pigs fed no additional salt. There were no statistically significant differences between any of the supplemental salt levels (between 0 and 0.1%). They also report that gains were maximized at a level of 0.2% salt. This is not the case in the current study where pigs showed increased gains up to 0.8%

supplemental salt. This suggests that different weight pigs may not have the same salt requirements and will respond differently to varying levels.

Exp. 1 showed that when nursery pigs are not given a diet choice, feed intake increases with increased levels of supplemental salt. In Exp. 2, where pigs were given a diet choice, a preference for the high salt diet within comparisons was exhibited when analyzing all replicates. When barrow and gilt replicates are separated, the barrows showed similar results to the analysis of all replicates by preferring the diet in the comparison with the highest amount of added salt. The gilts differed in that they also preferred the diet with the higher amount of added salt at the beginning of the trial, but at the end of the trial they preferred the diet with the lower amount of added salt. We know that due to hormonal origin barrows usually grow faster than gilts but gilts are more efficient and have less backfat and larger loin eye area (Comstock et al., 1944). These different growth characteristics may be the reason why gilts tend to balance their diet with a lower amount of salt compared to barrows. The effects of varying salt intake on meat quality are unknown.

Dersjant et al. (2001) conducted an experiment to test the effect of dietary cation-anion difference (CAD, $Na^+ + K^+ - Cl^-$, mEq/kg diet) on feed consumption and growth performance using barrows (5 weeks old) with an initial body weight of 9.34 ± 0.28 kg. Three dietary CAD levels (-100, 200, and 500 mEq/kg) were used. The designed dietary CAD levels were achieved by addition of $CaCl_2$ or $NaHCO_3$ Growth rates were higher ($P < 0.05$) in pigs receiving dietary CAD of 200 mEq/kg (657 g/d) and dietary CAD of 500 mEq/kg (603 g/d) than in pigs receiving dietary CAD of 100 mEq/kg (484 g/d). These results suggest that cations such as $Na^+$ and $K^+$ are needed more than anions since the animals performed better at higher CAD levels. However, this does not mean that $Cl^-$ is not needed for growth. Mahan et al. (1996) demonstrated a linear growth ($P < 0.01$) and feed intake ($P < 0.08$) response during the 0- to 7-d and the 0- to 14-d period post weaning to increasing levels of $Cl^-$ in pigs ≤ 10 kg. Clearly $Na^+$ and $Cl^-$ are both needed in the diet but in different proportions.

In conclusion, supplemental salt, in addition to that already contributed to the diet by other ingredients, will increase feed intake and growth performance in nursery pigs. An improvement in G:F is seen up to 0.5% but little difference between 0.5 and 0.8%.

When given a choice in diets, barrows prefer high levels of salt. Gilts prefer high levels immediately after weaning but by wk 4 they have a preference for a diet lower in salt. The results of supplemental salt in nursery pigs above 0.8% are unclear. The results from the current study suggest that in a performance trial feed intake and growth would continue to increase. If given a preference, the barrows may continue to consume the highest concentration available while the gilts may continue consuming the low salt diet. However, since the present study only included 2 replications per gender these theories should be followed up with additional research.

# CHAPTER 7. Summary

The research presented in this thesis was conducted to evaluate effects of dietary alterations that have potential to affect feed intake and preference in swine. More specifically, the use of newly developed flavors in nursery and sow diets (Chapters 3 and 4), Appetein™ as an alternative protein source in sow diets (Chapter 5), and the effects of varying levels of added salt to nursery diets (Chapter 6). In the literature, the addition of flavors (sweet compounds) to the diet was first reported by Aldinger et al. (1959). More flavor research followed, but inconsistent results and a lack of effective flavors seems to have lead to a decreased interest in flavor research. Also, the majority of flavor research has been done using nursery and grow-finishing pigs, thus, the potential for flavor usage in sow diets is unknown.

In the evaluation of newly developed flavors (Chapter 3), nursery pigs did not respond to the dietary treatments, displaying no differences in feed intake and growth performance between flavored and control diets (Exp. 1, 2, and 3). In the preference experiment (Exp. 4) pigs actually preferred the corn-soybean meal diet and discriminated against the flavor. The current studies did reinforce that complex diets have the potential to increase feed intake and growth performance. Also, it was shown there can be a clear preference in diet choice without there being a difference in performance in a non-choice situation.

In Chapter 4, the flavor used in Exp. 1 and 2 of Chapter 3 was evaluated for effects on feed intake in sows and litter performance. The flavor did not significantly affect feed intake or litter performance A variety of different flavored compounds have been used in nursery diets with inconsistent results. However, information on the effects of flavors in sow diets is absent. The results of the present study are consistent with what Langendijk et al. (2007) reported. The addition of a “creamy and milky cheese flavor“ did not increase sow feed intake. In fact, since the control diet was the typical lactation diet fed to the herd, it would appear that the flavor decreases feed intake. The flavor also appears to have no effect on litter traits. Even though sows fed the flavored diet had numerically larger litters, the pigs were smaller. This may be an artifact of allotment. By weaning, sows on the control diet had litters that weighed more than those from sows on the flavored diet.

In Chapter 5, Appetein™ was evaluated to determine its effects on sow feed intake and litter performance when used as an alternative protein source in lactation diets. There were no significant differences between means for parameters measured. Numerically, piglet weight and litter weight at weaning were higher for Appetein™ sows than those on the control diet. Also, Appetein™ sows ate on average 2.86 kg more feed and gained weight during lactation compared to the control sows, which lost weight. A more extended use of the product will be needed to determine any possible advantages in feeding it.

In Chapter 6, three graded levels of salt were used to evaluate growth performance and preference in nursery pigs. Adding supplemental salt to the diet increased ADFI and ADG in nursery pigs (Exp. 1). The improvements in feed intake and performance increased as added salt level increased. When given a choice in diets (Exp. 2), barrows prefer high levels of salt. Gilts prefer high levels immediately after weaning, but by wk 4 they have a preference for a diet lower in salt. The results of supplemental salt in nursery pigs above 0.8% are unclear. The results from the current study suggest that in a performance trial feed intake and growth may continue to increase.

With the rising cost of feed ingredients and inclusion of alternative feedstuffs in swine diets it has become standard practice to maximize least–cost feed formulation. Promoting efficiency becomes valuable from both an environmental and economic point of view. With specific regard to the current research, it exemplifies how there are many alternative feed ingredients that must be tested to evaluate their usefulness in hopes of providing a more nutritional diet that will produce more efficient livestock. The current research shows that some alternative ingredients and feed additives increase feed intake while others have no effect.

# Appendices

## Appendix 1. Appetein™ results by farrowing group.

Table A.1.1. Effects of Appetein™ in lactation diets (May 2008)[1]

| Item | Control | Appetein | RMSE[2] | P-value |
|---|---|---|---|---|
| Parity | 1.75 | 1.57 | 0.74 | 0.651 |
| Gestation weight gain, kg | 61.12 | 59.28 | 15.38 | 0.821 |
| Lactation weight change, kg | 3.86 | 3.18 | 11.02 | 0.511 |
| Pigs/Litter | | | | |
| Total | 11.38 | 11.43 | 2.51 | 0.968 |
| Born Live | 10.50 | 10.29 | 2.41 | 0.866 |
| Post transfer | 10.75 | 10.86 | 1.19 | 0.864 |
| Castration | 10.38 | 10.29 | 0.93 | 0.856 |
| Wean | 10.38 | 10.00 | 1.03 | 0.495 |
| Piglet Weight, kg | | | | |
| Total | 1.70 | 1.57 | 0.28 | 0.368 |
| Born Live | 1.72 | 1.58 | 0.31 | 0.408 |
| Post transfer | 1.71 | 1.55 | 0.29 | 0.323 |
| Castration | 4.18 | 3.92 | 0.54 | 0.373 |
| Wean | 7.06 | 6.60 | 0.87 | 0.321 |
| Litter Weight, kg | | | | |
| Total | 19.17 | 17.56 | 3.81 | 0.430 |
| Born Live | 17.69 | 16.09 | 3.80 | 0.433 |
| Post transfer | 18.38 | 16.69 | 3.27 | 0.336 |
| Castration | 43.45 | 40.24 | 6.80 | 0.379 |
| Wean | 73.10 | 65.53 | 8.88 | 0.124 |
| Sow Feed, kg | | | | |
| Total Farrowing - Wean | 121.24 | 109.35 | 22.06 | 0.317 |
| ADFI | 6.17 | 5.69 | 1.01 | 0.371 |

[1] Values represent the mean of 8 sows on the control treatment and 7 sows on the Appetein™ treatment.

[2] RMSE—Root mean square error; when divided by the square root of the number of observations provides the standard error associated with each mean.

Table A.1.2. Effects of Appetein™ in lactation diets (July 2008) [1]

| Item | Control | Appetein | RMSE[2] | P-value |
|---|---|---|---|---|
| Parity | 2.40 | 2.50 | 1.31 | 0.866 |
| Gestation weight gain, kg | 58.79 | 63.38 | 11.71 | 0.393 |
| Lactation weight change, kg | 12.21 | 12.94 | 10.61 | 0.880 |
| Pigs/Litter | | | | |
| Total | 14.90 | 13.60 | 2.46 | 0.254 |
| Born Live | 13.10 | 11.70 | 1.99 | 0.132 |
| Post transfer | 12.70 | 12.10 | 1.62 | 0.417 |
| Castration | 12.30 | 11.80 | 1.41 | 0.438 |
| Wean | 12.20 | 11.70 | 1.33 | 0.411 |
| Piglet Weight, kg | | | | |
| Total | 1.49 | 1.59 | 0.26 | 0.414 |
| Born Live | 1.53 | 1.63 | 0.29 | 0.421 |
| Post transfer | 1.51 | 1.62 | 0.29 | 0.385 |
| Castration | 3.77 | 4.11 | 0.62 | 0.243 |
| Wean | 5.92 | 6.35 | 0.75 | 0.214 |
| Litter Weight, kg | | | | |
| Total | 22.08 | 21.05 | 3.61 | 0.531 |
| Born Live | 19.82 | 18.73 | 3.27 | 0.467 |
| Post transfer | 19.01 | 19.48 | 3.58 | 0.774 |
| Castration | 46.35 | 48.24 | 8.61 | 0.631 |
| Wean | 71.82 | 74.13 | 10.39 | 0.625 |
| Sow Feed, kg | | | | |
| Total Farrowing - Wean | 104.96 | 96.66 | 16.79 | 0.283 |
| ADFI | 5.29 | 5.09 | 0.80 | 0.585 |

[1] Values represent the mean of 10 sows on the control treatment and 10 sows on the Appetein™ treatment.

[2] RMSE—Root mean square error; when divided by the square root of the number of observations provides the standard error associated with each mean.

Table A.1.3. Effects of Appetein™ in lactation diets (November 2008)[1]

| Item | Control | Appetein | RMSE[2] | P-value |
|---|---|---|---|---|
| Parity | 3.60 | 2.50 | 1.13 | 0.057 |
| Gestation weight gain, kg | 34.82 | 45.97 | 15.11 | 0.140 |
| Lactation weight change, kg | -4.13 | -0.40 | 12.84 | 0.549 |
| Pigs/Litter | | | | |
| Total | 12.70 | 13.75 | 3.51 | 0.538 |
| Born Live | 11.50 | 11.88 | 2.91 | 0.789 |
| Post transfer | 11.40 | 11.63 | 1.18 | 0.693 |
| Castration | 11.10 | 11.13 | 0.99 | 0.958 |
| Wean | 11.10 | 11.13 | 0.99 | 0.958 |
| Piglet Weight, kg | | | | |
| Total | 1.53 | 1.53 | 0.27 | 0.997 |
| Born Live | 1.57 | 1.57 | 0.26 | 0.997 |
| Post transfer | 1.52 | 1.55 | 0.26 | 0.814 |
| Castration | 3.60 | 4.15 | 0.56 | 0.056 |
| Wean | 6.39 | 7.05 | 0.85 | 0.121 |
| Litter Weight, kg | | | | |
| Total | 18.89 | 20.26 | 3.92 | 0.472 |
| Born Live | 17.62 | 18.21 | 3.48 | 0.724 |
| Post transfer | 17.25 | 17.81 | 2.10 | 0.581 |
| Castration | 39.93 | 45.78 | 5.21 | 0.031 |
| Wean | 69.79 | 79.16 | 7.80 | 0.022 |
| Sow Feed, kg | | | | |
| Total Farrowing - Wean | 122.73 | 135.97 | 14.35 | 0.070 |
| ADFI | 6.29 | 7.01 | 0.63 | 0.029 |

[1] Values represent the mean of 10 sows on the control treatment and 8 sows on the Appetein™ treatment.

[2] RMSE—Root mean square error; when divided by the square root of the number of observations provides the standard error associated with each mean.

Table A.1.4. Effects of Appetein™ in lactation diets (February 2009)[1]

| Item | Control | Appetein | RMSE[2] | P-value |
|---|---|---|---|---|
| Parity | 2.60 | 2.63 | 0.94 | 0.956 |
| Gestation weight gain, kg | 22.02 | 15.15 | 15.40 | 0.361 |
| Lactation weight change, kg | -12.35 | -18.61 | 9.20 | 0.170 |
| Pigs/Litter | | | | |
| Total | 10.80 | 11.63 | 2.36 | 0.473 |
| Born Live | 9.40 | 10.00 | 1.77 | 0.486 |
| Post transfer | 10.00 | 10.38 | 1.06 | 0.465 |
| Castration | 9.50 | 9.88 | 0.91 | 0.400 |
| Wean | 9.30 | 9.88 | 0.97 | 0.228 |
| Piglet Weight, kg | | | | |
| Total | 1.52 | 1.49 | 0.32 | 0.860 |
| Born Live | 1.55 | 1.52 | 0.31 | 0.800 |
| Post transfer | 1.56 | 1.49 | 0.27 | 0.564 |
| Castration | 4.22 | 3.96 | 0.65 | 0.407 |
| Wean | 6.23 | 7.04 | 0.78 | 0.042 |
| Litter Weight, kg | | | | |
| Total | 16.07 | 16.75 | 2.55 | 0.581 |
| Born Live | 14.38 | 14.79 | 2.42 | 0.720 |
| Post transfer | 15.33 | 15.34 | 1.92 | 0.989 |
| Castration | 39.67 | 38.96 | 4.92 | 0.764 |
| Wean | 62.52 | 62.50 | 6.82 | 0.996 |
| Sow Feed, kg | | | | |
| Total Farrowing - Wean | 128.77 | 123.47 | 11.55 | 0.348 |
| ADFI | 6.89 | 6.55 | 0.47 | 0.152 |

[1] Values represent the mean of 10 sows on the control treatment and 8 sows on the Appetein™ treatment.

[2] RMSE—Root mean square error; when divided by the square root of the number of observations provides the standard error associated with each mean.

Table A.1.5. Effects of Appetein™ in lactation diets (April 2009)[1]

| Item | Control | Appetein | RMSE[2] | P-value |
|---|---|---|---|---|
| Parity | 3.14 | 2.86 | 1.46 | 0.721 |
| Gestation weight gain, kg | 42.74 | 30.81 | 20.31 | 0.293 |
| Lactation weight change, kg | -7.78 | -2.01 | 11.79 | 0.378 |
| Pigs/Litter | | | | |
| Total | 14.86 | 12.00 | 2.87 | 0.087 |
| Born Live | 13.57 | 11.43 | 3.15 | 0.228 |
| Post transfer | 12.14 | 11.71 | 1.09 | 0.477 |
| Castration | 10.57 | 10.57 | 1.46 | 1.000 |
| Wean | 10.43 | 10.57 | 1.51 | 0.863 |
| Piglet Weight, kg | | | | |
| Total | 1.41 | 1.53 | 0.16 | 0.201 |
| Born Live | 1.41 | 1.53 | 0.14 | 0.156 |
| Post transfer | 1.41 | 1.57 | 0.19 | 0.130 |
| Castration | 4.09 | 4.40 | 0.64 | 0.383 |
| Wean | 6.87 | 6.09 | 0.83 | 0.108 |
| Litter Weight, kg | | | | |
| Total | 20.83 | 18.44 | 4.86 | 0.376 |
| Born Live | 19.13 | 17.60 | 5.46 | 0.609 |
| Post transfer | 17.11 | 18.42 | 2.90 | 0.415 |
| Castration | 43.11 | 46.28 | 7.86 | 0.465 |
| Wean | 66.02 | 69.19 | 10.34 | 0.576 |
| Sow Feed, kg | | | | |
| Total Farrowing - Wean | 133.37 | 139.51 | 14.76 | 0.452 |
| ADFI | 6.40 | 6.28 | 0.61 | 0.713 |

[1] Values represent the mean of 7 sows on the control treatment and 7 sows on the Appetein™ treatment.

[2] RMSE—Root mean square error; when divided by the square root of the number of observations provides the standard error associated with each mean.

Appendix 2. Absolute feed intakes for salt preference study (Chapter 6 Exp. 2).

Table A.2.1. Average daily feed intake (kg) by all replicates (n=4)

| | Comparison 1 | | | Comparison 2 | | | Comparison 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| Week | Trt 1 | Trt 2 | P | Trt 2 | Trt 3 | P | Trt 1 | Trt 3 | P |
| 1 | 0.05 | 0.11 | 0.05 | 0.08 | 0.11 | 0.54 | 0.06 | 0.14 | 0.14 |
| 2 | 0.10 | 0.39 | 0.002 | 0.25 | 0.26 | 0.97 | 0.10 | 0.46 | 0.006 |
| 3 | 0.34 | 0.47 | 0.19 | 0.42 | 0.43 | 0.95 | 0.34 | 0.51 | 0.34 |
| 4 | 0.50 | 0.55 | 0.78 | 0.48 | 0.56 | 0.65 | 0.51 | 0.55 | 0.86 |
| 1 & 2 | 0.07 | 0.25 | 0.005 | 0.17 | 0.18 | 0.80 | 0.08 | 0.30 | 0.01 |
| 3 & 4 | 0.42 | 0.51 | 0.52 | 0.45 | 0.49 | 0.77 | 0.42 | 0.53 | 0.58 |
| 1 to 4 | 0.25 | 0.38 | 0.08 | 0.31 | 0.33 | 0.69 | 0.25 | 0.41 | 0.22 |

1 Trt 1, Trt 2, and Trt 3 are 0.1, 0.5, and 0.8% inclusion of salt respectively

Table A.2.2. Average daily feed intake (kg) by barrow replicates (n=2)

| | Comparison 1 | | | Comparison 2 | | | Comparison 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| Week | Trt 1 | Trt 2 | P | Trt 2 | Trt 3 | P | Trt 1 | Trt 3 | P |
| 1 | 0.04 | 0.10 | 0.16 | 0.10 | 0.10 | 0.99 | 0.06 | 0.15 | 0.31 |
| 2 | 0.10 | 0.34 | 0.04 | 0.12 | 0.31 | 0.11 | 0.09 | 0.43 | 0.13 |
| 3 | 0.23 | 0.55 | 0.07 | 0.38 | 0.42 | 0.61 | 0.31 | 0.54 | 0.58 |
| 4 | 0.37 | 0.67 | 0.41 | 0.36 | 0.64 | 0.18 | 0.42 | 0.61 | 0.65 |
| 1 & 2 | 0.07 | 0.22 | 0.06 | 0.11 | 0.20 | 0.13 | 0.08 | 0.29 | 0.15 |
| 3 & 4 | 0.30 | 0.61 | 0.25 | 0.37 | 0.53 | 0.14 | 0.36 | 0.58 | 0.61 |
| 1 to 4 | 0.18 | 0.42 | 0.18 | 0.23 | 0.35 | 0.06 | 0.22 | 0.43 | 0.44 |

1 Trt 1, Trt 2, and Trt 3 are 0.1, 0.5, and 0.8% inclusion of salt respectively

Table A.2.3. Average daily feed intake (kg) by gilt replicates (n=2)

| | Comparison 1 | | | Comparison 2 | | | Comparison 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| Week | Trt 1 | Trt 2 | P | Trt 2 | Trt 3 | P | Trt 1 | Trt 3 | P |
| 1 | 0.05 | 0.12 | 0.33 | 0.07 | 0.12 | 0.44 | 0.07 | 0.13 | 0.55 |
| 2 | 0.10 | 0.43 | 0.09 | 0.38 | 0.20 | 0.35 | 0.11 | 0.50 | 0.13 |
| 3 | 0.45 | 0.39 | 0.44 | 0.46 | 0.44 | 0.93 | 0.37 | 0.48 | 0.60 |
| 4 | 0.63 | 0.43 | 0.58 | 0.61 | 0.48 | 0.68 | 0.61 | 0.48 | 0.69 |
| 1 & 2 | 0.08 | 0.28 | 0.13 | 0.22 | 0.16 | 0.59 | 0.09 | 0.31 | 0.20 |
| 3 & 4 | 0.54 | 0.41 | 0.55 | 0.53 | 0.48 | 0.80 | 0.49 | 0.48 | 0.98 |
| 1 to 4 | 0.31 | 0.35 | 0.51 | 0.38 | 0.31 | 0.49 | 0.29 | 0.40 | 0.59 |

1 Trt 1, Trt 2, and Trt 3 are 0.1, 0.5, and 0.8% inclusion of salt respectively

Appendix 3. Outliers and animals removed from the experimental analysis.

Prior to analyses of variance, the growth performance and feed intake of pens were evaluated to identify any statistical outliers within treatments. First, the pens displaying intra–pen CV values higher than 25% for average daily gain and feed intake were identified for further examination. Then individual pig performances within the selected pens were evaluated to identify the pig most divergent from its pen mates. This growth performance was then compared with littermates on other treatments in the experiment to determine whether the observed abnormalities were simply a genetic response. The suspected outliers were also compared to the performance of other pigs in other pens on that same dietary treatment. In the majority of evaluations, the pig was not removed from the data set; in a few instances it was decided that removal of the selected pigs from the study was appropriate. When a pig was removed from the experimental analysis (because of death or deemed a statistical outlier), the pen feed intake was adjusted based on a model that allocated feed relative to metabolic body weight and relative to weight gain (Lindemann and Kim, 2007).

A total of 4 pigs were removed from the experiments in Chapter 3. Two of these pigs came from Exp. 1. The first pig was removed due to decreasing body from d 0 to d 16. The second pig died on d 8 of the experiment. The other two pigs were removed from Exp. 3. The first pig had low weight gains throughout the experiment. The second pig died on d 13. The outliers for Chapter 3 are detailed in Tables A.5.1. – A.5.4.

Table A.3.1. Chapter 3: Exp. 1 pig removal from pen 21 (treatment = simple diet with flavor)

| | Body weight | | | | | |
|---|---|---|---|---|---|---|
| Pig | d 0 | d 7 | d 14 | d 21 | d 28 | d 35 |
| 7770M | 9.39 | 8.05 | 7.15 | Removed d 16 | | |
| 7810M | 11.83 | 13.70 | 20.18 | 29.08 | 39.54 | 51.38 |
| 7870M | 11.16 | 12.46 | 16.03 | 24.16 | 27.20 | 36.95 |
| 8003F | 11.73 | 14.22 | 21.90 | 30.64 | 40.86 | 51.18 |

Table A.3.2. Chapter 3: Exp. 1 pig death in pen 24 (treatment = complex diet without flavor)

| | Body weight | | | | | |
|---|---|---|---|---|---|---|
| Pig | d 0 | d 7 | d 14 | d 21 | d 28 | d 35 |
| 7821M | 9.48 | 7.22 | | Died d 8 | | |
| 8003M | 10.59 | 11.07 | 17.09 | 25.66 | 34.86 | 45.86 |
| 7880M | 11.25 | 11.76 | 17.11 | 25.20 | 34.60 | 46.47 |
| 7813F | 11.86 | 13.90 | 20.86 | 31.10 | 41.13 | 51.87 |

Table A.3.3. Chapter 3: Exp. 3 outlier from pen 15 (treatment = simple diet with flavor)

| | Body weight | | | | |
|---|---|---|---|---|---|
| Pig | d 0 | d 7 | d 14 | d 21 | d 28 |
| 8680M | 12.40 | 12.08 | 11.86 | 13.29 | 14.62 |
| 8633M | 12.85 | 15.49 | 21.29 | 28.16 | 35.34 |
| 8714F | 13.37 | 15.76 | 22.65 | 30.13 | 40.28 |
| 8700F | 12.85 | 14.63 | 21.86 | 31.21 | 42.12 |

Table A.3.4. Chapter 3: Exp. 3 pig death in pen 24 (treatment = complex diet without flavor)

| | Body weight | | | | |
|---|---|---|---|---|---|
| Pig | d 0 | d 7 | d 14 | d 21 | d 28 |
| 8733M | 11.27 | 15.16 | 20.79 | 28.93 | 39.51 |
| 8702M | 11.54 | 15.36 | 21.68 | 29.40 | 41.34 |
| 8741F | 11.53 | 14.56 | 19.83 | 27.36 | 38.50 |
| 8652F | 11.09 | 12.75 | | Died d 13 | |

There were no outliers or sow removals from Chapter 4. A total of 18 sows were removed prior to evaluation of the experiment in Chapter 5. Qualification for removal included incomplete body weight records, low litter size, and/or having a parameter outside the normal distribution of that trait compared to the other sows on test.

Table A.3.5 summarizes the sows removed and the cause of removal.

Table A.3.5. Chapter 5 outliers removed prior to analysis

| Sow | Breeding group | Treatment | Reason removed[1,2,3] |
|---|---|---|---|
| 6072 | May-08 | Appetein | PWW outside normal distribution |
| 6451 | May-08 | Control | Low feed intake |
| 6412 | May-08 | Appetein | Litter size below 8 post transfer |
| 7756 | Nov-08 | Control | Incomplete body weight records |
| 6062 | Nov-08 | Appetein | LWW and PWW outside normal distribution |
| 6463 | Nov-08 | Appetein | Incomplete body weight records |
| 7723 | Feb-09 | Appetein | Litter size below 8 post transfer |
| 5571 | Feb-09 | Control | GWG outside normal distribution |
| 6072 | Feb-09 | Appetein | Litter size below 8 post transfer |
| 7353 | Feb-09 | Control | Incomplete body weight records, litter size below 8 post transfer |
| 7360 | Feb-09 | Control | Litter size below 8 post transfer |
| 7355 | Feb-09 | Appetein | Incomplete body weight records, litter size below 8 post transfer |
| 7247 | Feb-09 | Control | GWG outside normal distribution |
| 7240 | Feb-09 | Appetein | Incomplete body weight records, litter size below 8 post transfer |
| 5581 | Apr-09 | Appetein | Litter size below 8 post transfer |
| 6070 | Apr-09 | Appetein | Incomplete body weight records |
| 6414 | Apr-09 | Appetein | Litter size below 8 post transfer |
| 3751 | Apr-09 | Control | Incomplete body weight records |

[1] Normal distributions were calculated and graphed for parameters and values greater than three standard deviations or did not correlate to the trend line were removed.
[2] Average pig weight at weaning (PWW), litter weight at weaning (LWW), and gestation weight gain (GWG).
[3] Sows removed due to low feed intake at less than 50% of the feed offered .

A total of 2 pigs were removed from the experiment in Chapter 6. One pig was removed from the performance trial (Exp. 1) and 1 pig was removed from the preference trial (Exp. 2). Both pigs were removed due to death. The details of these pigs and the pens they were removed from are seen in Tables A.1.6 and A.1.7.

Table A.3.6. Chapter 6: Exp. 1 outlier from pen 2 (treatment = 0.1% added salt)

| | Body weight | | | | |
|---|---|---|---|---|---|
| Pig | d 0 | d 7 | d 14 | d 21 | d 28 |
| 0883M | 18.92 | Died d 6 | | | |
| 1063M | 17.01 | 17.57 | 21.63 | 27.44 | 34.31 |
| 1011M | 15.67 | 15.57 | 20.60 | 24.60 | 31.31 |
| 1032M | 14.11 | 15.49 | 20.13 | 23.35 | 30.23 |

Table A.3.7. Chapter 6: Exp. 2 outlier from pen 2 (treatment = 0.5 vs. 0.8% added salt)

| | Body weight | | | | |
|---|---|---|---|---|---|
| Pig | d 0 | d 7 | d 14 | d 21 | d 28 |
| 0862M | 18.51 | 20.05 | 27.87 | 37.55 | 48.68 |
| 0831M | 17.17 | 22.19 | 31.03 | 40.17 | 49.56 |
| 1015M | 16.01 | 17.58 | Died d 12 | | |
| 1023M | 14.56 | 17.13 | 22.69 | 29.67 | 39.78 |

## Appendix 4. Specifications of Appetein™ product

Table A.4.1. Analytical values of Appetein™

| | | | |
|---|---|---|---|
| Typical amino acid profile, % | | Guaranteed analysis, % | |
| Alanine | 4.1 | Crude protein, minimum | 77 |
| Arginine | 4.6 | Crude fat, minimum | 0.3 |
| Aspartate | 7.7 | Crude fiber, maximum | 0.5 |
| Cystine | 2.7 | Typical analysis, kcal/kg | |
| Glutimate | 11.4 | DE | 4098 |
| Glycine | 2.9 | ME, swine | 3900 |
| Histidine | 2.7 | ME, poultry | 3831 |
| Isoleucine | 2.8 | Typical analysis, % | |
| Leucine | 7.6 | Calcium | 0.15 |
| Lysine | 6.6 | Phosphorus | 1.3 |
| Methionine | 0.7 | Sodium | 2.2 |
| Phenylalanine | 4.5 | Chloride | 1.1 |
| Proline | 4.4 | Potassium | 0.3 |
| Serine | 4.6 | Moisture | 8 |
| Threonine | 4.7 | Ash | 8.5 |
| Tryptophan | 1.4 | Typical analysis, ppm | |
| Tyrosine | 3.5 | Iron | 90 |
| Valine | 5.2 | | |

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# Vita

James Seth Monegue was born October 5th, 1984 in Lexington, KY to Jim and Sharon Monegue. Seth graduated from Dunbar High School in Lexington in 2003. Seth attended the University of Kentucky in Lexington, KY in the fall of 2003. He earned his bachelor's degree in Animal Science from UK in 2007.

Growing up as the son of a swine farm manager, Seth's interest and fascination for pigs started at a young age. This led to the pursuit of a master's degree in animal nutrition. Seth began his Master's research at the University of Kentucky in August of 2007.