Abstract

LANIER, CHRISTIAN LYNN. Feed Intake Patterns in Crossbred Pigs and their Relationship to Production Traits. (Under the direction of Joe Cassady and Todd See.)

The purpose of this research was to evaluate line and sex differences in swine feeding behavior traits. Barrows and gilts used in the study were from three sire lines and two dam lines. Data were provided by PIC in Franklin, KY. Feeding behavior traits considered were average daily feed intake (ADFI), average occupation time/day (AOTD), average feed intake/visit (AFIV), average number of visits/day (ANVD), average feeding rate/visit (AFRV), average occupation time/visit (AOTV), and daily consistency (DCON). Electronic feeders were used to measure feeding behavior traits on two pens per feeder. Use of the feeder alternated between the two pens weekly. Feeding behavior traits differed by line and sex. Production traits that were used in the study included: average daily gain (ADG), feed conversion ratio (FCR), backfat (BF), loin depth (LD), percent lean (% LEAN), and average daily feed intake (ADFI). For this study, ADFI was treated as both a feeding behavior and performance trait. Feeding behavior traits were used to determine principal components. Principal components were then analyzed.

**FEED INTAKE PATTERNS IN CROSSBRED PIGS AND THEIR RELATIONSHIP TO PRODUCTION TRAITS**

by
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# Dedication

To my parents, with love!

## Biography

My name is Christian Lanier, and I am a native North Carolinian. I was born in Goldsboro, NC, on May 26, 1980. My parents are Doug and Wanda Lanier of Chinquapin, NC. I grew up on a farm near Chinquapin, where we raise Red Angus cattle and tobacco. My family also owns a hog farm in Jones County, near Richlands, NC. After attending Harrells Christian Academy in Harrells, NC, I began my collegiate career at North Carolina State University (NCSU) in August of 1998. I graduated from NCSU with a Bachelor of Science in Animal Science in 2001 and again in 2003 with a Bachelor of Science in Biology with a concentration in Nutrition. In August of 2004, I began graduate school at NCSU, working with Drs. Joe Cassady and Todd See.

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# TABLE OF CONTENTS

## List of Tables

Page

## List of Figures

Page

# Literature Review

## I. Introduction / Background

Pigs are known to be social animals. They form social hierarchies and at times are playful, aggressive, and investigative creatures (McGlone and Pond, 2003). The importance of feeding behavior in pigs is becoming more apparent as commercial swine producers strive to make their operations more efficient.

Many factors may affect how much pigs eat during a visit or day. Feed consumption accounts for most of the investment that producers make in pigs (McDonald et al., 1991), so understanding factors that influence feed intake in pigs has become more important. If we can understand factors that influence pig feeding patterns, then we are more equipped to determine which patterns lead to increased production levels. This review of current literature evaluates: social interactions, environmental factors, and genetic links that influence feeding patterns and performance traits in pigs.

## II. Social Interactions

A. *Social Facilitation and Stereotypic Behaviors*. Social facilitation is an increase in a behavior, such as feeding, or beginning a response that is natural to the animal, in this case the pig, when the animal sees another animal engaged in the behavior (Hansen et al., 1982; Hsia and Wood-Gush, 1984; McGlone and Pond, 2003). Another behavior, synchrony, has been found in nursing piglets and in early weaned piglets (Hansen et al., 1982). Synchrony is not necessarily present when social facilitation is present. Hsia and Wood-Gush (1984) conducted a study to evaluate whether or not social facilitation, regardless of the presence or absence of synchrony, occurred in a group of feeding pigs. They also wanted to evaluate the effect of social rank on social facilitation and synchrony. Initially, rank order was established, and two groups of pigs, each consisting of three barrows, were off feed for 12 hours. At the end of the fasting period, one pig was left in its own pen and the others were removed. Pigs that had been fed until presumably full began feeding again when a hungry pen mate was reintroduced into the pen. The higher the social rank, the longer the pig fed after the reintroduction of the pen mate. In a second experiment, another group of three barrows was used in addition to groups from the first experiment. Pigs were taken off feed for 12 hours. Two pen mates were placed in neighboring stalls and fed until full. The third pen mate was then placed in a stall across from the two fed pigs. Upon seeing the third pig feed, the two fed pigs began eating again. Hsia and Wood-Gush (1984) concluded that social facilitation was present and that rank order has an effect on social facilitation, though the effect is not easy to characterize.

If social facilitation occurs in pigs, then another aspect to consider is a competition effect between pigs (Hsia and Wood-Gush, 1983). Pigs that have an established social hierarchy benefit from competition in that they eat more and spend less time doing it as compared to pigs that experience social facilitation but no competition (pigs housed individually but with other pigs in view). When a stable social hierarchy has not been established, a situation that allows for social facilitation but no competition is most beneficial for increased feeding (Hsia and Wood-Gush, 1983).

Lawrence and Terlouw (1993) investigated stereotypic behaviors or stereotypies, a term used to describe a pattern of behaviors that appear to have no known purpose. An example that they use to describe stereotypies is confined sows that have restricted feed. These sows will chew on the bars of their crates or make chewing motions without anything being in their mouth. These behaviors are known as oral stereotypies. By restricting feed, feed costs and reproductive problems are thought to be minimized. Stereotypic behaviors are generally considered to be bad for the animal as they may indicate high levels of stress, though this is a theory and not fact (Lawrence and Terlouw, 1993). Development of stereotypic behaviors appears to be more complicated than animals not having their hunger needs met. Animals that eat receive positive feedback from the feed that they consume. When the feed is gone, they chew on things close to them or drink water with the hopes of receiving the same positive feedback that they received from eating. Animals that are confined are prevented from exhibiting complex behaviors such as foraging. They express more simple behaviors repeatedly to compensate for the complex behaviors that they are unable to express. Arousal from the environment around the animals may also lead to expression of stereotypies. Stereotypic behaviors in pigs appear to focus on feeding behaviors, but other types of stereotypic behaviors may exist. Though expression of stereotypies has not been shown to be detrimental to animals, there seems to be no purpose for them.

B. *Individually-Penned vs. Group-Penned Pigs.* With the movement toward intensive swine production, pigs have increasingly been housed in large groups of 50 to 2,000 pigs (Turner et al., 2003). Bornett et al. (2000) assert that pigs housed in groups change their feeding behavior in response to their pen mates. Group – housed pigs make fewer visits to the feeder and eat more quickly as opposed to individually – housed pigs. Pigs that were penned in small groups eat less and gain less weight than pigs kept in pens individually (Gonyou et al., 1992). There is inconsistency in the conclusions drawn about meal length. While some research has found that fewer visits of longer length were made to the feeder by group – penned pigs (Bornett et al., 2000), other research has concluded that there were no differences in the amount of time spent in the feeder during a visit between group – penned and individually – penned pigs (Gonyou et al., 1992).

Mixing pigs is part of the process of housing pigs in groups. Upon mixing, new social hierarchies are formed. Demonstrations of aggression and competition are methods used by pigs to establish rank within a group. The need to establish social hierarchies may lead to changes in feeding patterns of group – housed pigs (Bornett et al., 2000). In research conducted by Bornett et al. (2000), pigs were housed individually after weaning, then mixed into groups of four pigs, and then separated and returned to individual pens, with each treatment lasting three weeks. Evolution of social behavior while pigs were in groups, as well as feeding behavior across treatments, was evaluated. Competition did not pose a strong enough influence to elicit changes in feeding patterns (Bornett et al., 2000). Their conclusion was drawn by observing few displacements at the feeder. If competition had a strong impact on feeding patterns, it would also follow that a dominant pig at the top of the social hierarchy would be distinguishable from other pigs (Bornett et al., 2000). A dominant pig in each pen was not recognizable, and it appeared that all pigs changed their feeding patterns regardless of each pig's rank.

Another hypothesis for the change in feeding patterns of pigs penned in groups is that of group cohesion which refers to pigs choosing to remain with pen mates rather than perform an activity alone such as feeding (Bornett et al., 2000). The pigs are in a constant mental battle of sorts: remaining with the group or leaving the group to feed. Eventually, the physical need to feed overtakes the desire to remain with the group (Bornett et al., 2000). When hunger needs are met, the pig returns to the group. The opposite situation also could be termed group cohesion where the animal feeds when not hungry in order to be a part of the group rather than not feeding and remaining alone. In this last scenario, the concept of synchrony competes with the concept of group cohesion (Bornett et al., 2000). Synchrony though is a behavior that occurs in unison, which is not necessarily how group cohesion occurs. Group cohesion may involve a variety of behaviors being displayed but with the pigs in the same physical area of the pen.

Pigs have been described as playful and curious and social, but perhaps another term used to describe pigs could be possessive. Gonyou et al. (1992) observed increased standing in pigs penned in groups. The standing behavior occurred while a pig was feeding but while another feeder was available for use. Avoiding eating while another pen mate is eating may be that pigs prefer one feeding space to another. Another idea is that pigs do not like to feel crowded while they eat. Gonyou et al. (1992) suggest that, regardless of the reason pigs spent more time standing, the increase in the amount of time standing lowered the amount of gain in group – penned pigs compared to individually – penned pigs.

Again, pigs are social creatures, which is beneficial to the swine industry since the swine production model is focused around group – penned pigs. Though research has shown individually – penned pigs do have higher gains than group – penned pigs, it is more economically advantageous to house pigs in groups due to better use of building space and reduced labor requirements (Turner et al., 2003). So far, a definitive number of pigs that should be grouped together to be most advantageous has not been determined. Turner et al. (2003) evaluated group sizes ranging from three to 120 pigs. As group size increased, weaner – aged pigs showed a significant decrease in average daily feed intake that was not found in grower and finisher pigs (Turner et al., 2003). A significant decrease in average daily gain was present in weaner and grower pigs as group size increased. Group – housed pigs are more physically active than individually – housed pigs as fighting is likely to occur when pigs are grouped together. An explanation for the decreased average daily gain in the grower stage is most likely explained by increased physical activity of the pigs. Turner et al. (2003) concluded that though growth in young pigs is affected by larger group sizes, there is no evidence that other performance traits are negatively impacted in the grower and finisher stages by increased group size.

C. *Benefit of CFIR (Computerized Feed Intake Recording) Systems*. Individually – housed pigs have different feeding patterns and performance than pigs housed in groups (de Haer et al., 1993). Initially, feed intake studies were conducted using individually – penned pigs and were very labor intensive. The information gained from research on individually – penned pigs was not applicable to pigs housed in groups since feed intake, number of visits to the feeder, average daily gain, and protein and fat deposition differ based on how the pigs are housed (de Haer and Merks, 1992; Hyun et al., 1997; Young and Lawrence, 1994). The development of computerized feed intake recording (CFIR) systems allow feed intake information to be recorded while pigs are housed in groups (Young and Lawrence, 1994). CFIR systems also allow for more information to be gleaned on the relationship between social factors and feeding behavior.

The basic principle behind CFIR system is to collect individual information on growing pigs that are housed in a group setting (de Haer et al., 1993; Young and Lawrence, 1994). In the CFIR system, one stall with one feed trough is provided for pigs to feed individually. The trough is attached to a load cell (Ellis and Hyun, 1998). Different amounts of protection for a feeding pig are provided depending on the CFIR system used. Some systems provide full protection while other systems provide protection of the shoulders and head only. When the pig enters the feeder, an antenna picks up a signal from the pig's transponder and the corresponding transponder number is recorded in a computer database (Ellis and Hyun, 1998). Depending on the CFIR system, information is recorded on feed intake, length of time spent in the electronic feeder, time that a visit began and ended, and even weight for animals between 20 to 150 kg (Ellis and Hyun, 1998). The idea is to provide accurate feed intake information on individuals while they are maintained in group settings similar to those found on many commercial operations. Several different types of CFIR systems are available commercially (Ellis and Hyun, 1998). Since CFIR systems may be used to evaluate social interactions and feeding behavior in pigs, research that sought to evaluate social interactions and feeding behavior will be discussed now. As CFIR systems are feeders and are part of the pigs' environment, papers that evaluated CFIR systems as an environmental influence on feeding behavior will be discussed later as an environmental effect.

Young and Lawrence (1994) investigated the relationship between social behavior, feeding behavior, and the CFIR systems in pigs. Sixty pigs, male and female, were mixed before the study. Pigs were allowed two weeks to adjust to the FIRE (Feed Intake Recording Equipment, Osborne Industries, Inc., Osborne, Kansas) system. Pens varied in terms of method of feeding behavior, but on average, pens had the same feed intake. High numbers of visits in which no feed was consumed were also recorded. Pigs that spent the most time in the feeder ate the most feed, which is how successfully adapting to the F.I.R.E. electronic feeders was defined (Young and Lawrence, 1994). Social facilitation, synchrony, and competition had a strong impact on feeding patterns (Young and Lawrence, 1994). Through the desire of the pigs to eat together and in unison, competition to gain access to the feeder developed.

**III. Environment**

A. *Diurnal Feeding Pattern*. Development of CFIR systems has allowed researchers to investigate feeding behavior of pigs. Feeding behavior of group – housed pigs is often characterized as having a diurnal pattern or two periods (peaks) of heavy feeding during a 24-hour period, though this is not always true (Hyun et al., 1997; Young and Lawrence, 1994). Diurnal feeding behaviors in pigs have often been attributed to their social nature and thus social facilitation and synchrony of feeding (Young and Lawrence, 1994). However, as Morrow and Walker (1994a) and Young and Lawrence (1994) proposed, environmental factors such as crowding, feeder type, light, and temperature may play an important role in presence or absence of diurnal feeding patterns.

B. *Group Size and Space Allowance*. Commercial farms in the United States house pigs in large groups to make the most efficient use of the buildings. In general, one modern building will maintain 1,000 pigs (McGlone and Pond, 2003). Group size within each building varies from one farm to another. Research has yielded conflicting results regarding the impact of group size on growth rate and feed efficiency (Hyun and Ellis, 2001). Hyun and Ellis studied effect of group size in growing and finishing pigs (Hyun and Ellis, 2002; 2001). In growing pigs, growth rate and feed intake decreased as group size increased from two to 12 pigs even with 0.9 $m^2$ allotted to the each pig. Group size had a greater impact on growing pigs than on finishing pigs. Pigs that eat quickly, spent less time in the feeder per day and had elevated feed intake and growth rates. In a similar study, finisher pigs were allotted 0.9 $m^2$ each (Hyun and Ellis, 2002). As expected, as group size increased, changes in feeding patterns occurred. As group size increased, pigs made less visits to the feeder, the visits were longer, ate more during a visit, and ate more quickly. While changes in feeding patterns in growing pigs were not sufficient to maintain feed intake and growth rate (Hyun and Ellis, 2001), changes in feeding patterns in finishing pigs were sufficient to maintain feed intake and growth rate (Hyun and Ellis, 2002). As pigs mature, they are more able to adapt to stresses such as increased group size.

There has been an attempt to determine the optimal amount of space required by a pig to achieve maximum performance (McGlone and Newby, 1994). In a group of growing pigs, those with restricted space allowance, 0.25 $m^2$/pig, grew more slowly than pigs with a greater space allowance, 0.56 $m^2$ / pig (Hyun et al., 1998a) for each week of the four-week study. However, pigs with the restricted space allowance had reduced feed intake for the fourth week of the study only. Pigs with restricted floor space have shown an increase in uncharacteristic behaviors and in amounts of aggression (Hyun et al., 1998a). As pigs become more aggressive, they use more energy and growth rates decline (Hyun et al., 1998a).

When grower / finisher pigs lack sufficient space allowances, they may not have optimal performance (McGlone and Newby, 1994). However, the benefits of space allowance for pigs must be considered against benefits of reducing building and maintenance costs of the facility in which the pigs are housed (McGlone and Newby, 1994). Free space allowance is determined not only by number of pigs in a pen but also by the way the pigs use the space in the pen (McGlone and Newby, 1994). Pens in which the pigs group themselves together when at rest have more free space available than pens in which pigs spread themselves out when at rest. Thus a pen with many pigs may have more free space available than a pen with fewer pigs. McGlone and Newby (1994) grouped pigs into group sizes of 10, 20, and 40. Each pig was allowed 0.74 $m^2$ of floor space. For group sizes of 10, 20, and 40 pigs, the pens had a total area of 7.4 $m^2$, 14.9 $m^2$, and 29.8 $m^2$, respectively (McGlone and Newby, 1994). The performance of the pigs did not suffer as group size increased. Pens with group sizes of 40 had higher injury and death rates amongst occupants than pens with fewer pigs. The amount of free space in a pen increased as group size increased. When half of the free space was removed, pig performance remained unchanged; when all of the free space was removed, pigs had a reduction in weight gain (McGlone and Newby, 1994). As group size increases, the free space requirements per pig decline but do not disappear.

Typically, the rule to follow with dry feeders has been one feeding space per three to four pigs (McGlone and Pond, 2003; Walker, 1991). As production demands increase, the goal is to use building space as efficiently as possible. Reducing building space occupied by feeders would allow for more space to house pigs. Walker tested the maximum number of pigs that one mono-place feeder could accommodate by penning pigs in groups of 10, 20, and 30, with each pen containing one feeder (Walker, 1991). Though pens with 30 pigs had lower growth rates during the first two weeks of the trial, overall growth rate was unaffected by group size (Walker, 1991). Feed conversion ratio was best for groups of 10 pigs, though the non-pelleted diet may have resulted in more feed spillage and wastage as group size increased (Walker, 1991). Queuing (defined by (Morrow and Walker, 1994a), or loitering in front of the feeder, also increased as group size increased possibly resulting in demonstrations of aggression as pigs attempted to displace a feeding pig from the feeder, possibly causing the feed spillage. Diurnal patterns were less pronounced in pens of 20 and 30 pigs than in pens of 10 pigs, indicating that pigs were able to accommodate reduced feeder space by feeding throughout the day and into the night rather than during peak daylight hours (Walker, 1991).

Gonyou and Stricklin (1998) looked at the relationship between group size and floor area allowance in growing and finishing pigs. Their design used group sizes of 3, 5, 6, 7, 10, and 15 pig per pen and floor area allowances 0.30, 0.39, and 0.48 $m^2$ x $BW^{.667}$ (Gonyou and Stricklin, 1998). As group size increased, daily feed intake and average daily gain decreased. Feed efficiency was best for group sizes of 7 or 10 pigs. The greatest effect of increasing group size was seen in the small and mid-size groups, perhaps indicating that there is a plateau in the effect of increasing group size somewhere between group sizes of 10 to 15 pigs. Average daily feed intake and average daily gain decreased as floor space allowance decreased from 0.39 to 0.30 $m^2$ x $BW^{.667}$, however, feed efficiency did not decrease as floor space allowance declined. It is feasible to reduce floor space allowance for a pig when average daily gain, as a measure of the animal's welfare, and the best use of floor space, in terms of gain per unit of floor area, are taken into account (Gonyou and Stricklin, 1998).

C. *Feeder Type*. Feeders are an important part of a commercial pig's environment. They hold feed so that it doesn't become contaminated, they reduce wastage of the feed by the pigs, and they save space (McGlone and Pond, 2003). Just as there have been questions regarding the optimal number of pigs per pen and space allowance per pig, questions have also arisen regarding the effect of feeder type on a pig's performance.

In the past, competition for feeder space was viewed as a bad thing (McGlone and Pond, 2003). More recently, the present line of thinking was that some competition at meal time was actually beneficial as that it would stimulate higher feed intakes. Morrow and Walker (1994b) fit stalls to half of the single – space hoppers used in the experiment to study the effect of the feeder on social behavior and growth performance. There was one feeder per pen. Pigs in pens that contained hoppers with stalls made fewer visits to the feeder each day and spent more time in the feeder during a visit. Fewer pigs were forcibly removed from the feeder during a visit and fewer pigs were queuing for the feeder, which was defined as lying or standing near the feeder while a pig was feeding with the intention of entering the feeder with the feeding pig left the feeder (Morrow and Walker, 1994b). There was less tail biting in pens containing the modified feeder, consequently aggression was reduced. Feed intake, feed conversion, and growth rate did not differ between feeder type, thus wastage of feed was assumed to be equal for the feeder types (Morrow and Walker, 1994b).

A variety of CFIR systems have been designed and used increasingly, especially in academia and by breeding companies, in recent years (Nielsen et al., 1995b). One example of a CFIR system is the Individual Voluntary Feed Intake Recording in Group Housing (IVOG, Technical and Physical Services in Agriculture, Wageningen, Netherlands) station (de Haer and Merks, 1992). In research conducted by de Haer and Merks (1992), the IVOG-station was used to study the feed intake patterns of growing pigs. Through use of the IVOG-station, the researchers were able do determine that both individually – penned and group – penned pigs exhibited a diurnal feeding pattern with the pattern being more distinctive in group – penned pigs (de Haer and Merks, 1992). Pigs penned in groups ate fewer times and less feed per day than individually – penned pigs. However, the feed that group – penned pigs ate was consumed more quickly and in greater quantity during a visit.

As noted earlier, CFIR systems differ in the amount of protection that they offer to the feeding pig (Ellis and Hyun, 1998; Nielsen et al., 1995b). Nielsen et al. (1995b) investigated three types of protection afforded by FIRE electronic feeders: low protection (head-guard), medium protection (full-length race), and high protection (enclosed pneumatic race). Pigs adapted their feeding behavior to meet the restrictions imposed by the feeder. Pigs that fed in feeders that offered low protection ate more quickly than pigs using feeders fitted with medium and high protection races (Nielsen et al., 1995b). Pigs on feeders with high protection would be expected to exhibit feeding behavior similar to that of an individually – penned pig, however that was not the case (Nielsen et al., 1995b). Pigs of feeders with high protection displayed feeding behavior similar to pigs penned in large groups. The high – protection feeder was the most difficult of the three types of feeders for the pigs to enter. Difficulty associated with accessing the feeder appeared to discourage pigs from making frequent visits and consuming many small meals. Race type did not affect performance of the pigs (Nielsen et al., 1995b).

Though data from CFIR systems is very valuable in terms of evaluating feeding and social behaviors in pigs, the point could be argued that because CFIR systems allow one pig to feed at a time and offer some protection to the feeding pig that they are not comparable to the commercial setting. If that is true, then the information that is gained from research using CFIR systems may be no more valuable than data from individually – penned pigs to make predictions for group – penned, commercial pigs. Several studies have compared conventional feeders to FIRE electronic feeders (Hyun and Ellis, 2002, 2001; Hyun et al., 1998a). Two of the studies looked at growing pigs while the third study looked at finishing pigs. Grower pigs did not differ in growth performance between the two types of feeders (Hyun and Ellis, 2001; Hyun et al., 1998a), but feed intake was lower for pigs using FIRE electronic feeders (Hyun and Ellis, 2001). Finishing pigs on the FIRE electronic feeders had lower daily feed intakes and higher gain : feed ratios, and growth rates did not differ between feeder types (Hyun and Ellis, 2002).

D. *Light, Temperature, and Multiple Stressors*. Diurnal feeding patterns in pigs are typically characterized by two peaks of increased feeding activity during daylight hours, often with one peak mid-morning and a second peak mid-afternoon. Social facilitation and synchrony are thought to influence the diurnal pattern (Young and Lawrence, 1994), but there seems to be other forces exerting influence over the presence or absence of a distinctive diurnal feeding pattern (Feddes et al., 1989). For example, ambient temperature affects a pig's thermoregulation (Feddes et al., 1989). Feeding patterns in pigs change when surrounding temperatures are elevated or lowered outside of their preferred range (Feddes et al., 1989; McGlone and Pond, 2003). There remain some questions as to how much external stressors such as light and temperature affect feed intake patterns.

In a study conducted by Feddes et al. (1989), influences of temperature and light on feeding patterns in growing pigs were examined. Pigs housed in a building in which temperature varied from 26°C to 40°C, with an average temperature of 33°C, had the similar feed intakes and visits to the feeder as pigs housed at a constant temperature of 33°C (Feddes et al., 1989). The majority feed intake and visits to the feeder of the pigs that were on the cyclic temperature treatment happened during the cooler portions of the day, thus shifting the diurnal feeding pattern by moving the peaks of feeding activity apart on a 24-hour horizontal axis (Feddes et al., 1989). Pigs on the cyclic temperature treatment also consumed fewer and larger meals than pigs on the constant temperature treatment. Temperature did not affect eating rate (Feddes et al., 1989).

In a similar study, Quiniou et al. (2000) evaluated a potential relationship between ambient temperature and body weight. Pigs were exposed to different patterns of temperatures that ranged from 12°C to 22°C. Pigs mostly exhibited a diurnal feeding pattern.

Quiniou et al. (2000) concluded that feed intake is dependent upon body weight and ambient temperature. Under exposure to colder temperatures, feed intake increased. When pigs were housed in hot temperatures, feed intake decreased, as did performance, especially for heavier pigs (Quiniou et al., 2000). Feeding rate and number of meals per day did not change with temperature. Pigs altered their daily feed consumption by changing the size of their meals.

Feddes et al. (1989) evaluated the effects of light on pigs in addition to the effects of temperature on pigs. Pigs were exposed to 16 hours of light and eight hours of darkness. In an environment with a constant ambient temperature, the pigs' feeding activity corresponded to the times at which lights are turned on and off (Feddes et al., 1989). Feddes et al. (1989) concluded that photoperiod had a greater effect than temperature on pig feeding behavior. In fact, Vargas et al. (1987) found that when pigs were denied food for 9 hours and the lights remained on for 24 hours, pigs preferred to eat during daytime hours. However, Hyun et al. (1997) employed a continuous light regimen over a 24-hour period and saw one peak in feeding activity rather than a diurnal feeding pattern.

Nienaber et al. (1990; 1991) conducted two studies in which they studied the effects of thermoneutral and cool temperatures on swine feeding behavior. Thermoneutral temperature was based on a model described by Bruce and Clark (1979) that takes animal weight, floor type, air speed, number of pigs per pen, and daily feed intake into account. Nienaber et al. (1990; 1991) found that pigs kept at cooler temperatures had reduced gains and increased feed intakes compared to pigs housed at a neutral temperature. Eating rate adjusted by age (Nienaber et al., 1990) and by metabolic body weight (Nienaber et al., 1991).

In contrast to the work of Nienaber et al. (1990; 1991), Hyun et al. (1998b) compared the effects of thermoneutral temperature to the effects of high cycling temperatures on pig feeding behavior. Hyun et al. (1998b) also studied the effects of stocking density and social rank on pig feeding behavior as well. Effects of the stressors independently were evaluated as well as interactions between the stressors (Hyun et al., 1998b). Pigs subjected to elevated temperature, stocking density, and regrouping as independent stressors had reduced average daily gain by 12, 16, and 10% and average daily feed intake by 7, 6, and 5%, respectively (Hyun et al., 1998b). The combination of elevated temperature, stocking density, and regrouping decreased average daily gain by 31% (Hyun et al., 1998b).

**IV. Genetics**

A. *Feeding Pattern Traits.* Interest in studying appetite in pigs first arose in the early 1980s due to genetic trends in selection (Labroue et al., 1997). As pigs have become leaner and had improved feed efficiencies, their daily feed consumption has decreased (de Haer et al., 1993; Hall et al., 1999b). There is concern that decreases in daily feed intake may also decrease the swine industry's ability to make genetic improvement in the future. In order to include daily feed intake in the breeding objectives for the swine industry, there needs to be a better understanding of swine feeding behavior and how it relates to production traits (Labroue et al., 1997).

To study feeding behavior, there must be a way to categorize its characteristics. Universal terms do not exist to describe feeding patterns, although most researchers break data down on a per meal or visit basis and by day (de Haer et al., 1993; Hall et al., 1999a; Labroue et al., 1997). Since a 24-hour period is a convenient way to look at feeding behavior, most of the past research has established feeding behavior criteria by the number of visits to the feeder or meals in a day and the amount of time spent in the feeder in a day (de Haer et al., 1993; Labroue et al., 1997). Feeding behavior has also been grouped by time spent in the feeder per visit or per meal, the amount of feed consumed during a visit or meal, and the average feeding rate (de Haer et al., 1993; Labroue et al., 1997). Terms and abbreviations for feeding behavior criteria vary by paper and author.

B. *Breed*. Many of the pigs on commercial farms are crossbred pigs. These pigs derive from breeds of pigs that are characterized by production traits such as growth and leanness. Certain feeding patterns are associated with different body compositions and thus breeds, and feeding patterns are related to production efficiency (de Haer and de Vries, 1993).

Breed effects were explored by de Haer and de Vries (1993). They found a breed effect on performance traits and on feed intake pattern when they compared Dutch Landrace and Great Yorkshire pigs (de Haer and de Vries, 1993). Yorkshire pigs had higher average daily gain, decreased backfat, and higher lean percentage at comparable levels of daily feed intake than Dutch Landrace pigs. Yorkshire pigs made more visits in which they consumed feed and lower feed intake during a visit than Dutch Landrace pigs (de Haer and de Vries, 1993). They concluded that the differences in performance were a result of physiological differences such as metabolism and less a result of feeding behavior (de Haer and de Vries, 1993).

Two other breeds, Large White and French Landrace, pigs also exhibited differences in feeding behavior (Labroue et al., 1994). Large White pigs visited feeders twice as many times as French Landrace pigs. There were no breed differences when breeds were penned separately for daily visits to the feeder and average feed consumed per visit (Labroue et al., 1994). When the breeds were mixed, French Landrace pigs altered their feeding behavior by making fewer but longer visits to the feeder and consuming more feed than Large White pen mates. Daily feed intake was similar for the two breeds, which is notable since this feeding pattern trait most related to growth and fatness (Labroue et al., 1994).

C. *Sex.* Growth patterns differ between sexes (de Haer and de Vries, 1993). Sexes differ in metabolism and in their capacity for protein deposition (de Haer and de Vries, 1993). de Haer and de Vries (1993) found that boars made fewer visits to the feeder and ate more during a visit than gilts. Hyun et al. (1997) concluded that feed intake did not differ between boars, barrows, and gilts, and Hyun and Ellis (2001) also concluded that feed intake and feed efficiency did not differ for barrows and gilts. The results of Hyun et al. (1997) and Hyun and Ellis (2001) are in contrast to the result of other studies that have also evaluated sex differences. Gonyou et al. (1992) found that barrows gained more weight and consumed more feed than gilts, while Labroue et al. (1994) concluded that barrows ate more feed per day than boars. Barrows tended to make more visits to the feeder than boars and gilts according to the results of Hyun et al. (1997). Hyun and Ellis (2001) found that barrows grew faster than gilts.

D. *Heritabilitie*s and *Correlations*. Some research into feeding behavior has focused on estimating genetic parameters for the feeding behaviors. In a data set of Large White and French Landrace boars and barrows over a period of 12 and 13 weeks, respectively, a multiple trait animal model DF-REML procedure was used to estimate feeding behavior heritabilities (Labroue et al., 1997). Production traits relating to carcass lean to fat ratio had the highest heritabilities, $h^2$, ranging from 0.60 to 0.76, while average daily gain had a heritability of 0.35 (Labroue et al., 1997). Average daily gain and feed conversion ratio were negatively and favorably correlated. Heritability estimates for feeding behavior traits ranged from 0.42 to 0.54, with the highest heritability being found for feeding rate (Labroue et al., 1997). Feed intake per day had a positive genetic correlation with feed intake per meal and feeding rate. With respect to genetic correlations between feeding behavior and performance traits, the highest genetic correlation (0.85) was between daily feed intake and average daily gain (Labroue et al., 1997). The genetic correlation between daily feed intake and feed conversion ratio was almost zero.

Hall et al. (1999a) also estimated heritabilities for feeding behavior criteria using boars and gilts from a Large White sire line. Heritabilities and correlations between feeding pattern and performance traits were estimated with restricted maximum likelihood (REML) (Hall et al., 1999a). The heritabilities and correlations found by Hall et al. (1999a) differed from those found by Labroue et al. (1997). The heritability of average daily feed intake was 0.21. The highest heritability was found for number of visits (0.34), while feeding rate had the lowest heritability (0.04) (Hall et al., 1999a). The production traits backfat depth, feed conversion ratio, and average daily gain had heritabilities of 0.38, 0.12, 0.25, respectively (Hall et al., 1999a), in sharp contrast to the production trait heritabilities found by Labroue et al. (1997). Daily feed intake had strong, favorable genetic correlations with production traits (0.61 to 0.78), but not with other feeding behavior traits. Strong genetic correlations were observed between time per visit and feed intake per visit (0.93), number of visits and feed intake per visit (-0.86), and time per visit and number of visits (-0.79) (Hall et al., 1999a). Moderate genetic correlations were noted between number of nonfeeding visits and average daily gain (-0.59) and feed intake per visit and average daily gain (0.49). Moderate to strong phenotypic correlations were found for time per visit and feed intake per visit (0.39), number of visits and feed intake per visit (-0.58), time per visit and feeding rate (-0.69) and time per visit and time in the feeder (0.81) (Hall et al., 1999a).

Another experiment, carried out by Von Felde et al. (1996), evaluated feed intake pattern and performance traits in a group of 3,188 group – housed Landrace and Large White boars.

Data were analyzed using the multivariate program MTDFS (Von Felde et al., 1996). Heritabilities for the feeding behavior traits ranged from 0.22 (average daily feed intake) to 0.51 (feed intake per visit) (Von Felde et al., 1996). The heritability for average daily feed intake in this study is consistent with the heritability estimate for daily feed intake found by Hall et al. (1999a). The estimated heritabilities for the other feeding behavior traits, food intake per visit, number of visits, time per visit, time per day, and feeding rate, ranged from 0.42 to 0.51 and were more similar to Labroue et al. (1997).

Once genetic and phenotypic parameters are established, traits can be incorporated into selection indices (Hall et al., 1999b). The selection objective was to combine lean growth rate and feed efficiency. Six indices were set up with different combinations of average daily gain, backfat, daily feed intake, feed intake per visit, number of visits, and time per visit (Hall et al., 1999b). Indices that contained more feeding behavior traits yielded increased predicted genetic gain. Simulations were run to test the effect of inaccurate parameter estimates against the robustness of the indices. Indices with the most feeding pattern traits as selection criteria were the least robust under the influence of inaccurate parameter estimates (Hall et al., 1999b). The index that proved most robust and likely to meet the selection objective would include daily gain, backfat depth, daily food intake, and average number of feeder visits per day (Hall et al., 1999b).

## V. Conclusion

Feeding behavior is an exciting and still relatively new area of study in the swine industry. There is a great deal of information to uncover. From the review of literature, it is immediately apparent that there are many unknowns and inconsistencies. It is important to establish specific, universally defined criteria and to give the criteria the same nomenclature.

A great deal more research needs to be carried out to understand discrepancies in heritabilities, genetic and phenotypic correlations, the effects of light on diurnal patterns, and sex differences. The effects of light and temperature on feeding behavior in pigs are not completely understood. When we are more fully aware of whether their impact on feeding behavior is significant, it will be easier to identify and decipher their interactions with other factors that affect feeding behavior. Most pigs are exposed to multiple stressors, so it is important to understand how multiple stressors interact with each other. More research needs to be conducted on the relationship between breed and feeding patterns. Many of the studies that have been carried out to evaluate breed differences studied Large White and Landrace pigs. Other breeds and crosses should be evaluated. There are obviously breed differences in production traits, so it seems feasible that there are breed differences in feeding pattern traits. The area of swine feeding behavior is filled with so many unknowns that it seems that there are, at least at this point, limitless possibilities in terms of discoveries that may be made. Even if tremendous improvement is not made in relation to production traits, maybe knowledge will be gained that allows for more efficient management of pigs in terms of building, feeder, and pen design.

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**Feed Intake Patterns in Crossbred Pigs and their Relationship to Production Traits**

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**ABSTRACT:**

Previous studies have shown that differences exist in feeding behavior patterns among purebred lines and between boars and gilts. It is unknown if these differences extend to commercial, crossbred barrows and gilts. The objectives of this research were to evaluate sex and line differences among feeding behavior traits and to determine the relationship between feeding behavior traits and performance traits in crossbred, commercial pigs. Feeding behavior traits considered were average daily feed intake (ADFI), average occupation time per day (AOTD), average feed intake per visit (AFIV), average number of visits per day (ANVD), average feeding rate per visit (AFRV), average occupation time per visit (AOTV), and daily consistency (DCON). Electronic feeders were used to measure feeding behavior traits on two pens per feeder. Use of the feeder alternated between the two pens weekly. Records were available on crossbred (3 sire lines by 2 dam lines) barrows and gilts (n = 1564). Pigs were penned by sex and off-tested at a target weight of 114 kg. On average, there were 16.3 pigs in each pen. Feeding behavior traits were analyzed using the GLM procedure of SAS and a fixed model including sire line, dam line, sex, feeder, switch, and the interactions of sire line × dam line, sire line × sex, and dam line × sex. Sex affected ADFI, AOTD, ANVD, AOTV, AFRV, and DCON ($P < 0.05$). Barrows ate more feed per day, had more visits, spent more time in the feeders per day, consumed feed at a greater rate, and had higher daily consistency values. Gilts spent more time in the feeders per visit (P <

0.05). Sire line affected AFRV, AFIV, AOTV, and DCON ($P < 0.05$). Sire line D pigs consumed more feed on average each day, spent more time in the feeder each day, and made more visits to the feeder each day than pigs from sire lines C and E. Dam line affected ADFI, AOTD, ANVD, AOTV, and AFIV ($P < 0.05$). Dam line A pigs ate more feed on average each day, spent more time in the feeder per day, and made more visits to the feeder each day than pigs from dam line B. Sire line by sex interaction affected ADFI, AOTD, and ANVD ($P < 0.05$). Sire lines D and E barrows ate more feed each day on average, spent more time in the feeder each day, and made more visits to the feeder each day than sire line C barrows and sire lines C, D, and E gilts. Sire line by dam line interaction affected AOTD ($P < 0.05$). Line and sex differences do exist in commercial, crossbred pigs. There appears to be a relationship between feeding behavior traits or principal components and performance traits as most of the main effects for the feeding behavior traits or principal components were significant ($P < 0.01$) in the regression analysis of the performance traits. Strong, favorable relationships were noted between ADG and ADFI, FCR and ADFI, $\Delta$ BF and ADFI, and ADFI and AOTD. Of the three principal components evaluated in this research, Prin. 3 demonstrated the strongest correlation with the production traits.

**Pigs, feeding behavior, performance traits, principal components analysis**

# INTRODUCTION

Understanding pig feeding behavior is important from a production perspective. There has been interest in individual pig feeding behavior for quite some time. However, before the development of electronic feeding systems, pig feeding behavior was measured using the expensive and labor intensive process of individually penning pigs (Nielsen et al., 1995a). Since pigs on commercial farms are housed in groups, making selection decisions on pigs in an environment that differs from the commercial environment has not been a popular idea (Nielsen et al., 1995a). Development of electronic feeders has made studying feeding behavior more plausible since researchers have the ability to collect accurate measurements of feeding behaviors on individual pigs that are housed in groups similar to those found out on commercial farms (Hall et al., 1999b).

Types of electronic feeders differ, but in general, they collect information such as pig identification number, amount of feed consumed during a visit or during a day, and amount of time spent in the feeder per visit or per day. While development of electronic feeders has allowed researchers to collect data necessary to establish feeding patterns, uncertainty remains in how to translate feed intake behaviors into improved swine production. Most recent research into swine feeding behavior has focused on breed differences and sex differences (de Haer et al., 1993; Labroue et al., 1994). Some research has focused on stressing pigs by varying the number of pigs sharing a feeder (Hyun and Ellis, 2002). There has been little research either into feeding pattern traits in crossbred pigs or into differences in feeding patterns between sexes of pigs.

The objectives of the work presented here were to evaluate line and sex differences in feed intake patterns and to determine if a relationship exists between feed intake patterns and production traits in commercial pigs when the pigs are housed in conditions.

## MATERIALS AND METHODS

*General*

Data were provided by PIC. Gilts and barrows (n = 1564) from sire lines, C, D, and E, and dam lines, A and B, were used in the study. Sire line C was a Duroc-based line and was selected for meat quality. Sire line D was a Hampshire-based line and was selected for lean growth efficiency. Sire line E was a synthetic line and was selected for growth and lean content.

Testing consisted of 2 replications. Replication 1 ran from February 26, to August 9, 2004, and replication 2 ran from July 1, until December 13, 2004. Pigs were placed on test at an average weight of 38 kg and were taken off test at an average weight of 114 kg. There were 48 pens per replication with 16 to 18 pigs ($\overline{x}$ = 16.3) pigs in each pen.

Twenty-four FIRE (Feed Intake Recording Equipment, Osborne Industries, Inc., Osborne, Kansas) electronic feeders were used per replication with 2 pens of pigs sharing each electronic feeder. An adjustable gate was placed between each pair of pens. One pen of pigs was placed on the FIRE feeder at the beginning of the replication, while the other pen was placed on conventional feeders. After 1 week, the gate was moved so that pigs originally on conventional feeders were now on electronic feeders, and pigs that were on electronic feeders were now on conventional feeders. Pigs were rotated between the 2 types of feeders on a weekly basis for the duration of the testing period. The variable switch was created to identify those pigs that were placed on FIRE electronic feeders first and those pigs that were initially placed on conventional feeders. Pigs that started the trial on the FIRE electronic feeders were assigned the number 1, while pigs that began the trial on the conventional feeders were assigned the number 0.

FIRE electronic feeders allow pigs access to feed 24 h/d. However, only 1 pig may feed at a time. The feeder was designed so that a pig moves into the feeder and is protected on 3 sides leaving its rear exposed.

Ear tags containing electronic transponders were placed in the right ear of each pig. When a pig entered the electronic feeder, the transponder number, feeder number, visit start time, and feed trough start weight were recorded. When a pig exited the feeder, the time departure and feed trough weight were recorded. Pigs had free access to water throughout testing. Weight, backfat, and loin depth measurements were collected every 28 d on pigs. Weight measurements were collected using a normal scale; backfat and loin depth measurements were measured between the $10^{th}$ and $14^{th}$ ribs using an Aloka 500 V ultrasound machine (Aloka, Inc., Wallingford, CT).

*Editing Data*

After both replications were completed, raw FIRE electronic feeder data and background information for each pig were merged. Background information included sire and dam information, birth date, birth weight, sex, ear tag number, transponder number, on-test weight, pig weight at the end of the test, and backfat and loin depth measurements. Visits were summarized by day for each pig using the PROC MEANS procedure of SAS (SAS Inst., Inc., Cary, NC).

Data from identified visits were then edited using a model designed by Casey et al. (2005). If a feed trough moved and a pig was detected in the feeder, the visit was labeled identified. When the feed trough weight changed but a pig was not detected in the feeder, the visit was labeled unidentified. Unidentified visits often result from the presence of rodents in the feed trough, gusts of wind moving the feeders, the feeders not being properly calibrated, or a transponder that is not working properly and not recognized by the feeder.

Errors were detected in the variables that were calculated on a per visit basis: feed intake per visit (FIV), average occupation time per visit (OTV), average feeding rate per visit (FRV), feed trough weight differences between subsequent visits in time, and time differences between subsequent visits (Casey et al., 2005). Weight and time differences were each divided into 2 error types: leading weight difference (LWD = entrance weight of trough of following visit – exit weight of trough of present visit), leading time difference (LTD = entrance time of following visit – exit time of present visit), following weight difference (FWD = entrance weight of trough of present visit – exit time of present visit), and following time difference (FTD = entrance time of present visit – exit time of preceding visit). For the 7 feeding behavior variables, 16 error types were developed (Casey et al., 2005). Thresholds were established for each error type and were used to determine if the visit had errors.

Three error types were associated with the variable FIV: FIV-lo, FIV-hi, and FIV-0. The thresholds for FIV were FIV is less than -20 g, FIV is greater than 2,000 g, and the absolute value for FIV is greater than 20 g. If FIV was less than -20 g for example, then the visit had a FIV-lo error. All visits were considered for FIV-lo and FIV-hi, and visits with an occupation time of zero were considered for FIV-0. All visits were evaluated for OTV errors (Casey et al., 2005).

Two types of errors characterized OTV: OTV-lo and OTV-hi. The thresholds for OTV-lo and OTV-hi were less than 0 s and greater than 3,600 s, respectively. When a visit was for less than 0 s, the visit was identified as having an OTV-lo error because it was below the established threshold for the OTV-lo error type.

The largest number of error types was associated with FRV (Casey et al., 2005). The first error type for FRV was FRV-hi-FIV-lo. Visits with a FIV between 0 and 50 g were considered, and the threshold was FRV greater than 500 g/min. The second error type developed for FRV was FRV-hi-strict, and visits with FIV greater than or equal to 50 g and preceded or followed by a visit with FIV less than -20 g. The threshold for this error type was FRV greater than 110 g/min. Visits with FIV greater than or equal to 50 g and not preceded or followed by a visit with FIV less than -20 g are used to evaluate FRV-hi. The threshold for FRV-hi was FRV greater than 170 g/min. Visits with FRV equal to 0 g/min and visits with FRV not equal to 0 g/min were used to determine if FRV-0 and FRV-lo error types were present, respectively. The thresholds for these 2 error types were OTV greater than 500 s and the absolute value for FRV less than or equal to 2 g/min, respectively.

All visits except for the last visit to the feeder in a test period were used to establish the presence of LWD-lo and LWD-hi error types, and all visits except for the first visit on the feeder in a test period were used to establish the presence of FWD-lo and FWD-hi error types (Casey et al., 2005). Leading weight difference was found by subtracting the exit weight of trough of the present visit from the entrance weight of the trough of the following visit. Following weight difference was found by subtracting the exit weight of the trough of the preceding visit from the entrance weight of the trough of the present visit. The thresholds for both LWD-lo and FWD-lo are LWD and FWD and are less than -20 g. The thresholds for both LWD-hi and FWD-hi are LWD and FWD and are greater than 1,800 g.

For the final 2 error types, LTD-lo and FTD-lo, all visits except for the last visit on the feeder in a test period and the first visit on the feeder in a test period, respectively, are considered (Casey et al., 2005). Leading time difference was calculated by subtracting the exit time of the present visit from the entrance time of the following visit. Following time difference was found by subtracting the exit time of the preceding visit from the entrance time of the present visit. The threshold for LTD-lo is LTD is less than 0 s. The threshold for FTD is less than 0 s. One more variable was created and named overall error (OE) to identify visits that had any type of error (1 = presence of at least one type of error in visit and 0 = no errors present in visit) (Casey et al., 2005).

Through the editing process, some pigs and their corresponding feeding records were discarded. At the beginning of the editing process, there were 555,795 FIRE electronic feeder records and 1,726 pigs. Pigs and their corresponding FIRE records were deleted due to 0 feed consumption being associated with a transponder, pig identification records that did not merge, transponders appearing more than once (e.g., in two pens at the same time), and pigs dying, leaving 432,831 FIRE records and 1,646 pigs. For the feeding behavior trait ADFI, error visits were identified and removed from the data set. Daily feed intake was then calculated using error-free visits, and a model was fit with the percentage of visits with each error type. Results from this process were used to adjust daily feed intake for missing visits with errors. For the remaining feeding behavior traits, AOTD, AFIV, ANVD, AFRV, AOTV, and DCON, visits with errors were removed and not replaced. Pigs with less than 15% of their FIRE records remaining were removed from the data set, leaving 297,307 FIRE records and 1,585 pigs in the data set. Twenty-one pigs and their FIRE records were removed from the data set due to incomplete maternal line records, for a total of 1,564 pigs (Table 1) remaining in the data set.

*Feeding Behavior Traits*

Time records and edited daily feed intake records were used to calculate average daily feed intake (ADFI = sum of daily feed intake / pig ÷ number of days on test), average occupation time per day (AOTD = sum of visit lengths ÷ number of days on test), average number of visits per day (ANVD = sum of number of visits ÷ number of days on test), average feed intake per visit (AFIV = sum of daily feed intake ÷ number of visits / d), average occupation time per visit (AOTV = sum of occupation time ÷ number of visits), average feeding rate per visit (AFRV = average feed intake / visit ÷ average occupation time / visit), and daily consistency (DCON = (actual daily feed intake / day – predicted daily feed intake / day) ÷ predicted daily feed intake / day). Normality of feeding behavior traits was established using the PROC UNIVARIATE procedure of SAS (SAS Inst., Inc., Cary, NC). Outlier values for feeding behavior traits were identified as those values that were more than 3 standard deviations above or below the trait mean. Feeding behavior trait values that were more than 3 standard deviations above or below the trait mean were removed only for the feeding behavior trait for which they were an outlier, not from the overall data set. Removing of outlier values was performed in addition to previous editing.

Least squares means for individual feeding behavior traits were calculated using the PROC GLM procedure of SAS (SAS Inst., Inc., Cary, NC). The model used included fixed effects of sire line, dam line, sex, contemporary group, feeder, start weight, and switch (except for the feeding behavior trait ADFI) and the interactions sire line × dam line, sire line × sex, dam line × sex, sire line × dam line × sex. Contemporary group was a concatenation of replication number and room number; feeder was a concatenation of replication number and feeder number. Interactions that were not significant ($P < 0.10$) were dropped from the model (Table 2).

Feeding behavior traits were preadjusted for initial weight of pigs at beginning of test and feeder differences prior to their incorporation into the regression models of performance traits. Adjustments were made to eliminate effects of factors that may have influenced feeding behavior trait values for pigs, such as large differences in initial weights, differences between replications, and feeders that were not working properly. Feeding behavior traits were regressed on feeder, a concatenation of replication and feeder, and initial weight using PROC GLM procedure of SAS (SAS Inst., Inc., Cary, NC). Estimates for regression coefficients were obtained from this procedure and used to make adjustments to feeding behavior traits. Initial weights were adjusted using 40 kg, and feeders were adjusted using feeder 1. The following equations demonstrate how adjustments were made:

[1] Standardized Initial Weight = Initial Weight of Pig – 40 kg;

[2] Adjusted Initial Weight Value = Standardized Initial Weight × Initial Weight Regression Coefficient Estimate;

[3] Adjusted Feeder Value= Regression Coefficient Estimate for Feeder 1 – Regression Coefficient Estimate for Pig's Feeder;

[4] Adjusted Feeding Behavior Trait Value = Feeding Behavior Trait Value – Adjusted Initial Weight Value – Adjusted Feeder Value.

*Principal Components Analysis*

To evaluate the impact that feeding behavior traits have on performance traits together as opposed to individually, principal components analyses were determined using the PROC

FACTOR procedure of SAS (SAS Inst., Inc., Cary, NC). Variables used in the principal components analysis included: ADFI, AOTD, AFIV, ANVD, AFRV, AOTV, and DCON. The Kaiser criterion was applied to determine the number of factors to retain for future analysis (StatSoft, 2006). This criterion indicates that factors that have eigenvalues greater than one are kept. Three factors met the Kaiser criterion: principal component 1 (Prin. 1), principal component 2 (Prin. 2), and principal component 3 (Prin. 3). With regards to Prin. 1, AOTD, ANVD, AFIV, and DCON were the feeding behavior traits that most strongly influenced it (Table 3). For Prin. 2, AOTD, AFIV, AOTV, and AFRV were most heavily emphasized. The feeding behavior traits ADFI, AFIV, AFRV, and DCON characterized Prin. 3.

Normality of principal components was established using the PROC UNIVARIATE procedure of SAS (SAS Inst., Inc., Cary, NC). Outlier values for principal components were identified as those values that were more than 3 standard deviations above or below the trait mean. Principal component values that were more than 3 standard deviations above or below the trait mean were removed only for the principal component for which they were an outlier, not from the overall data set. Removing of outlier values was performed in addition to previous editing.

Least squares means for the principal components were calculated using the PROC GLM procedure of SAS (SAS Inst., Inc., Cary, NC). The model used included fixed effects of sire line, dam line, sex, contemporary group, feeder, start weight, and switch and the interactions sire line × dam line, sire line × sex, dam line × sex, sire line × dam line × sex. Contemporary group was a concatenation of replication number and room number; feeder was a concatenation of replication number and feeder number. Interactions that were not significant ($P < 0.10$) were dropped from the model (Table 2).

*Performance Traits*

Performance traits calculated were: average daily gain (ADG), feed conversion ratio (FCR), change in backfat (Δ BF), change in loin depth (Δ LD), percent lean (LEAN), and average daily feed intake (ADFI), which was considered both an individual feeding behavior trait and a performance trait. The differences between the final and initial measurements were used to calculate Δ BF and Δ LD. Final backfat (BF) and loin depth (LD) measurements were used to calculate lean:

[5] $\% \text{ LEAN} = 58.9 + (0.112 \times \text{LD}) - (0.61 \times \text{BF})$.

Normality of the performance traits were established using the PROC UNIVARIATE procedure of SAS (SAS Inst., Inc., Cary, NC). Outlier values for performance traits were identified as those values that were more than 3 standard deviations above or below the trait mean. Performance trait values that were more than 3 standard deviations above or below the trait mean were removed only for the performance trait for which they were an outlier, not from the overall data set. Removing outlier values was performed in addition to previous editing. Performance traits were regressed on each feeding pattern trait and principal component individually using the PROC GLM procedure of SAS (SAS Inst., Inc., Cary, NC). Linear and quadratic models were fitted for each performance trait. The models were:

[6] $Y_{ijklm} = C_i + I_j + (LS)_{kl} + (FLS)_{klm}$,

[7] $Y_{ijklm}\ C_i + I_j + (LS)_{kl} + (FLS)_{klm} + (FFLS)_{klm}$,

[8] $Y_{ijklm} = C_i + I_j + L_k + S_l + (LS)_{kl} + (FL)_{km}$,

[9] $Y_{ijklm} = C_i + I_j + L_k + S_l + (LS)_{kl} + (FL)_{km} + (FFL)_{km}$,

where

$Y_{ijklm}$ = performance trait ADG, FCR, Δ BF, Δ LD, LEAN, or ADFI;

$C_i$ = contemporary group;

$I_j$ = pig's initial weight at the beginning of the test period;

$L_k$ = combination of pig's sire line and dam line;

$S_l$ = sex, barrow or gilt;

$F_m$ = feeding behavior trait ADFI, AOTD, AFIV, ANVD, AFRV, AOTV, DCON, Prin. 1, Prin. 2, or Prin. 3;

$(LS)_{kl}$ = line × sex interaction effect;

$(FL)_{km}$ = feeding behavior trait or principal component × line interaction effect;

$(FFL)_{km}$ = (feeding behavior trait or principal component)$^2$ × line interaction effect;

$(FLS)_{klm}$ = feeding behavior trait or principal component × line × sex interaction effect;

$(FFLS)_{klm}$ = (feeding behavior trait or principal component)$^2$ × line × sex interaction effect.

The coefficient of determination ($R^2$), mean square error (MSE), and the number of significant regression coefficients ($P < 0.10$) for the fixed effect that included the feeding behavior trait or principal component were all used to determine the model with the best fit for each performance trait that was regressed on a feeding behavior trait or principal component. In general, the model chosen, out of the four models considered for each combination of performance trait and feeding behavior trait or principal component, had the lowest MSE, greatest $R^2$ value, and largest number of significant regression coefficients ($P < 0.10$) for the fixed effect that included the feeding behavior trait or principal component.

When all three of the factors used to establish the model with the best fit were nearly equal, the simplest model was chosen.

Two equations were used to visualize the relationship between performance traits and feeding pattern traits or principal components. The equations reflect the response in a performance trait if the feeding pattern trait or principal component value is changed by one standard deviation. The equations used to related performance traits and feeding behavior traits or principal components are:

[10] D = $\beta_1$ × (-1 σ of feeding behavior trait or principal component – $\bar{x}$) + $\beta_2$ × ((-1 σ of feeding behavior trait or principal component)$^2$ – $\bar{x}^2$),

[11] I = $\beta_1$ × (+1 σ of feeding behavior trait or principal component – $\bar{x}$) + $\beta_2$ × ((+1 σ of feeding behavior trait or principal component)$^2$ – $\bar{x}^2$),

where

D = decrease in performance trait;

I = increase in performance trait;

$\bar{x}$ = mean value for feeding behavior trait or principal component by line or by line × sex, where line is a combination of sire line and dam line;

±1 σ = an increase or decrease by a single standard deviation from the mean value for a feeding behavior trait or principal component either by line or line × sex, where line is a combination of sire line and dam line;

$\beta_1$ = regression coefficient for a performance trait by feeding behavior trait or principal component x line or feeding behavior trait or principal component × line × sex;

$\beta_2$ = quadratic regression coefficient for a performance trait by feeding behavior trait or principal component × line or feeding behavior trait or principal component × line × sex.

The partial regression coefficients, containing the feeding behavior trait or principal component from the chosen model, are listed in Tables 5 to18. The feeding behavior trait and principal component mean values and standard deviations that were used in Equation 10 and Equation 11 were determined by the model selected as having the best fit. When the model chosen contained a fixed effect of feeding behavior trait or principal component × line, then mean values and standard deviations used in Equation 10 and Equation 11 were by line for that feeding behavior trait or principal component. If the model chosen contained a fixed effect of feeding behavior trait or principal component × line × sex, then mean values and standard deviations used in Equation 10 and Equation 11 were by line × sex for that feeding behavior trait or principal component. Once the amount of response, increase and decrease, in performance traits when the feeding behavior trait or principal component was changed by one standard deviation was calculated, the results were graphed (Figures 1 to 15). The response graphed, an increase or decrease in the feeding behavior trait or principal component, was based on producing a favorable change in the performance trait.

## RESULTS

### *Least Squares Means*

Dam line A pigs spent 24 s more in the feeder during a visit, ate 17 g more feed in a visit, and had a 7 g higher daily consistency than dam line B ($P < 0.05$) (Table 4). Dam line B pigs ate 40 g more feed daily, spent 125 s more in the feeder daily, and made 0.27 more visits to the feeder daily ($P < 0.05$) (Table 4). Principal component 1 was also different between the two dam lines ($P < 0.05$) (Table 4).

Sire line D pigs spent 195 and 199 s more time in the feeder each day than sire lines E or C, respectively (Table 4). Sire line D pigs also made more visits to the feeder and ate less feed each visit than either sire line C or E pigs (Table 3). Sire line D pigs ate the most feed each day but spent 44 s less time in the feeder than sire line C pigs (Table 4). Sire line E pigs ate 1.6 g/s more quickly than sire line D. Principal component 1 differed for sire line D pigs as compared to sire line C and E pigs ($P < 0.05$) (Table 4).

As compared to gilts, barrows ate 160 g more feed in a day, spent 151 more s/d in the feeder, made 0.41 more visits during a day to the feeder, and ate 2.2 g/s more feed ($P < 0.05$) (Table 4). Gilts spent 31 additional seconds in the feeder per visit than barrows ($P < 0.05$) (Table 4). Principal components 1 and 3 differed between gilts and barrows ($P < 0.05$) (Table 4).

Barrows from sire lines D and E ate the most feed each day while sire line E gilts ate the least amount of feed daily ($P < 0.05$) (Table 5). Sire line D barrows spent 275 more seconds in the feeders each day than sire line C gilts and barrows which spent the least amount of time in the feeders ($P < 0.05$) (Table 5). Sire line D barrows also made the most visits to the feeder on average each day, almost one whole extra visit than sire line C gilts, which made the fewest number of visits. Sire line E gilts had the highest percentage of daily consistency and the greatest value for Prin. 1 ($P < 0.05$) (Table 5).

*Response in Performance Traits*

With respect to the performance traits, the greatest amount of change in a performance trait occurred when ADFI, DCON, Prin. 1, and Prin. 3 were changed by 1 standard deviation (Figures 1 to 15). The main effects of the feeding behavior traits AFIV, AOTV, and AFRV did not significantly influence the performance traits ADG, FCR, Δ BF, and ADFI (Figures

1, 2, 3, and 8). The main effects of the feeding behavior traits ADFI and AOTD and the principal components Prin. 1, Prin. 2, and Prin. 3 did significantly influence performance traits (Figure 1 to 15). With regards to % LEAN, the main effects of the feeding behavior traits ADFI, AOTD, ANVD, and AFIV were significant (Figure 6), but the main effects of the feeding behavior traits AOTV, AFRV, and DCON were not significant (Figure 7).

## DISCUSSION

Pigs made between four and five visits to the feeder and spent around 4,000 s there per day and approximately 800 s in the feeder per visit (Table 4). These results differ from Hyun et al. (1997) and from Von Felde et al. (1996). Hyun et al. (1997) found that pigs made more visits to the feeder, about 12 visits/d, and spent half as much time, on average 396 s, in the feeder as the pigs in the present study. Von Felde et al. (1996) found that the pigs in their study made a similar number of visits to the feeder each day, about 5, and ate about the same amount of feed during a visit as pigs in this data set. But, the pigs in their study ate faster. Differences between these two studies and the research presented here are smaller group size, 10 pigs versus 16 to 18 pigs per FIRE electronic feeder, and sex, boars as opposed to barrows and gilts (Hyun et al., 1997; Von Felde et al., 1996). Competition to get in the feeder and the threat of being displaced by another pig may be a factor in pigs making less frequent and longer visits to the feeder. The fact that the pigs in the present study ate faster than the pigs in the study by Hyun et al. (1997) would seem to support this reasoning. Von Felde et al. (1996) penned 15 pigs together with access to a computerized electronic feeder, with one feeding stall, similar to the study presented here.

The crowded conditions, in terms of feeder space, between this study and that carried out by Von Felde et al. (1996), may explain why pigs made a similar number of visits to the feeder each day and ate similar amounts of feed during a visit. Up to 18 pigs were placed in a pen and used 1 FIRE electronic feeder, as opposed to the recommendation that 15 pigs use one FIRE electronic feeder. Nielsen et al. (1995a) concluded that a threshold effect occurs in feeding behavior when more than 15 pigs are placed on a single feeder. Pigs adapt to their environment by changing feeding patterns. Through changing their feeding patterns, pig performance does not decline as group size increases (McGlone and Newby, 1994; Nielsen et al., 1995a; Walker, 1991).

Boars, barrows, and gilts have different physiological requirements as illustrated by the fact that barrows had higher growth rates than gilts in a study carried out by Hyun and Ellis (2001). Boars have higher ADG values and better FCR values than gilts as they have greater levels of protein deposition (de Haer and de Vries, 1993). The way that each sex goes about meeting their needs may vary. Vargas et al. (1987) found that gilts participated in more aggressive attacks than barrows. With only one feeding space available with the FIRE electronic feeders, competition for feeding space may impact gilts more than barrows. In a study conducted by Nielsen et al. (1995a) that consisted of boars only, high rates of aggression were expected amongst the pigs. However, very little aggression was demonstrated by the pigs and was only exhibited by a few pigs. Aggression was not correlated with performance of the boars (Nielsen et al., 1995a).

The feeding behavior results from the current study indicate that sex differences between feeding pattern traits do exist. Barrows ate more feed, made more visits to the feeder, and spent more time in the feeder each day than gilts, which is consistent with the results of Hyun et al. (1997). The longer and less frequent visits to the feeder by gilts may be a result of increased aggression in gilts as opposed to males.

Line variation between pigs is another factor to consider with respect to feeding behavior trait differences. Several research experiments have looked at whether or not breed differences in feeding behavior traits exist, often times comparing Dutch or French Landrace pigs to other breeds such as Yorkshire or Large White pigs (de Haer and de Vries, 1993; Labroue et al., 1997; Labroue et al., 1994). Breed differences do appear to exist in feeding behavior traits. Though breed differences in feeding behavior traits are important, just as differences are important for other types of traits, questions remain as to how this translates to commercial pigs that are typically lines rather than breeds.

In the present study, least squares means for feeding behavior traits and principal components differed significantly ($P < 0.05$) (Table 4) by dam line and sire line. Sire line D pigs have been selected for lean growth efficiency and had the highest ADFI, highest AOTD, most visits to the feeder in a day, spent the least amount of time in the feeder during a visit, ate the least amount of feed during a visit, had the lowest residual feed intake value, and had the smallest Prin. 1 value. But, we cannot conclude that a pig with feeding patterns like those just described is the most productive type of pig.

To establish if there is a pig with a certain set of feeding patterns that is most productive, the relationship between feeding pattern traits and performance traits must first be understood. It is important to consider which feeding pattern traits are the most beneficial in terms of production. Some research has shown that by including too many feeding pattern traits that are not important in terms of production into a prediction model may be detrimental as opposed to beneficial (Hall et al., 1999b). Also, feeding pattern traits are lowly to moderately heritable, while production traits are moderately heritable (Hall et al., 1999a). The feeding pattern traits ANVD and AFIV had the highest heritabilities, 0.34 and

0.27, respectively, according to Hall et al. (1999b). Ironically, based on the results from the regression analysis of the performance traits, ANVD and AFIV do not have very strong relationships to the production traits.

Figures 1 to 15 demonstrate, based on the results of the current study, the relationship between feeding pattern traits or principal components, which are based on the feeding behavior traits, and production traits. According to the figures, it appears that there is a relatively strong relationship between ADFI, AOTD, DCON, Prin. 1, Prin. 2, and Prin. 3 and the 6 performance traits ADG, FCR, Δ BF, Δ LD, % LEAN, and ADFI. As expected, ADFI and ADG had a strong relationship. According to Hall et al. (1999b), FCR, Δ BF, and % LEAN actually have stronger genetic though not phenotypic correlations to ADFI than does ADG. Another factor to consider is the relationship between the feeding pattern traits themselves. By selecting a pig for a single feeding pattern trait, another feeding pattern trait may be unexpectedly impacted if a genetic or phenotypic correlation exists between the two traits.

## IMPLICATIONS

Feeding behaviors differ with regards to the influence of factors such as sex, feeder type, crowding, and environment on feeding patterns and performance in pigs. Though computerized electronic feeders have made studying feeding patterns and social behaviors more convenient, less expensive, and more applicable, they have not eliminated the questions that surround the results of many feeding behavior studies. It can be concluded based on the present research that sex differences and line differences exist for feeding behavior traits. There appears to be a relationship between feeding behavior traits and performance traits. More research is needed to firmly establish heritabilities for the feeding behavior traits, genetic and phenotypic correlations between feeding behavior traits, sex differences for feeding behavior traits, and line differences, or at least a wider variety of breed differences should be investigated. More work is also needed on the relationship between principal components and production traits.

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**Table 1.** Number of pigs by sire line, dam line, and sex

| | Dam line[1] | | Sire line[2] | | | Sex | |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | Gilts | Barrows |
| | 654 | 910 | 488 | 504 | 572 | 809 | 755 |
| Total | N = 1564[3] | | N = 1564[3] | | | N = 1564[3] | |

[1]Dam lines are represented by A and B. These letters are used to code actual dam lines.

[2]Sire lines are represented by C, D, and E. The selection objectives were for meat quality, lean growth, and lean growth and feed efficiency for sire lines C, D, and E, respectively.

[3]N = 1564 is the total number of animals used in the trial.

**Table 2.** P – Values to test fixed effects of sire line, dam line, sex, feeder, start weight, and switch and the interactions sire line × dam line, sire line × sex, dam line × sex, sire line × dam line × sex

| | Traits[1] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item[2] | ADFI | AOTD | AFIV | ANVD | AFRV | AOTV | DCON | P.C. 1 | P.C. 2 | P.C. 3 |
| $R^2$ | 0.44 | 0.07 | 0.30 | 0.23 | 0.20 | 0.22 | 0.17 | 0.04 | 0.01 | 0.05 |
| Sire line | 0.09 | 0.0002 | <0.0001 | <0.0001 | 0.002 | 0.001 | <0.0001 | <0.0001 | 0.11 | 0.51 |
| Dam line | 0.0005 | 0.01 | 0.004 | 0.0002 | 0.75 | 0.03 | 0.01 | <0.0001 | 0.70 | 0.08 |
| Sex | <0.0001 | 0.0006 | 0.93 | <0.0001 | <0.0001 | 0.01 | 0.62 | 0.05 | 0.32 | <0.0001 |
| Sire line × dam line | 0.05 | 0.05 | - | - | - | - | - | - | - | - |
| Sire line × sex | 0.01 | 0.02 | - | 0.02 | - | - | 0.03 | 0.04 | - | - |
| Dam line × sex | 0.33 | - | - | - | - | - | - | - | - | - |
| Sire line × dam line × sex | 0.01 | - | - | - | - | - | - | - | - | - |
| Feeder | <0.0001 | 0.06 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | 1.00 | 1.00 | 1.00 |
| Start weight | <0.0001 | 0.31 | <0.0001 | <0.0001 | 0.002 | <0.0001 | 0.86 | 0.91 | 0.62 | 0.44 |
| Switch | - | 0.46 | <0.0001 | 0.41 | 0.0004 | 0.004 | <0.0001 | 0.93 | 0.71 | 0.39 |

**Table 2.** (continued)

[1]ADFI = average daily feed intake; AOTD = average occupation time/day; AFIV = average feed intake/visit; ANVD = average number of visits/day; AFRV = average feeding rate/visit; AOTV = average occupation time/visit; DCON = daily consistency (DCON).

[2]$R^2$ = R – squared value indicating goodness of fit for the model; Sex = effect of sex, gilt versus barrow; Feeder = effect of FIRE electronic feeder; Start weight = weight at which pigs started testing; switch = effect of starting on FIRE electronic feeder first or second.

**Table 3**. Eigenvalues and eigenvectors for the major principal components of feeding pattern traits

| Item | Prin. 1[1] | Prin. 2[2] | Prin. 3[3] |
|---|---|---|---|
| Eigenvalue[4] | 2.81 | 2.06 | 1.37 |
| Proportion[5] | 0.401 | 0.294 | 0.196 |
| ADFI[6] | -0.242121 | 0.082938 | 0.684800 |
| AOTD[6] | -0.386700 | 0.501161 | -0.030488 |
| ANVD[6] | -0.551436 | -0.179777 | -0.057882 |
| AFIV[6] | 0.484972 | 0.240231 | 0.366344 |
| AOTV[6] | 0.265737 | 0.614900 | 0.027730 |
| AFRV[6] | 0.267163 | -0.516918 | 0.381778 |
| DCON[6] | 0.332517 | -0.081383 | -0.496022 |

[1]Prin. 1 = Principal component 1.

[2]Prin. 2 = Principal component 2.

[3]Prin. 3 = Principal component 3

[4]Eigenvalue is the variance on the principal component.

[5]Proportion is the amount of the total variance explained by individual principal components.

[6]ADFI = Average daily feed intake, AOTD = Average occupation time / day, ANVD = Average number of visits / day, AFIV = Average feed intake / visit, AOTV = Average occupation time / visit, AFRV = Average feeding rate / visit, DCON = Daily consistency.

**Table 4**. Least squares means for the effect of dam line, sire line, and sex on feeding pattern traits and principal components

| Feeding Pattern Trait | Dam Lines | | | Sire Lines | | | | Sex | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | SED[1] | C | D | E | SED[1] | Gilt | Barrow | SED[1] |
| ADFI (kg) | 2.11[a] | 2.15[b] | 0.009 | 2.12[ab] | 2.15[a] | 2.12[b] | 0.011 | 2.05[a] | 2.21[b] | 0.008 |
| AOTD (s) | 4050[a] | 4175[b] | 33.8 | 4045[a] | 4244[b] | 4049[a] | 39.7 | 4037[a] | 4188[b] | 31.7 |
| ANVD | 4.98[a] | 5.25[b] | 0.0559 | 4.89[a] | 5.41[b] | 5.04[a] | 0.065 | 4.91[a] | 5.32[b] | 0.053 |
| AOTV (s) | 861[a] | 837[b] | 8.7 | 872[b] | 828[a] | 847[ab] | 10.2 | 864[a] | 833[b] | 8.2 |
| AFIV (g) | 473[a] | 456[b] | 4.5 | 481[b] | 442[a] | 470[b] | 5.3 | 465[a] | 464[a] | 4.3 |
| AFRV (g / min) | 34.0[a] | 34.0[a] | 0.28 | 33.9[ab] | 33.1[a] | 34.7[b] | 0.33 | 32.8[a] | 35.0[b] | 0.26 |
| DCON (%) | 0.198[a] | 0.191[b] | 0.0021 | 0.195[b] | 0.187[a] | 0.201[c] | 0.00239 | 0.195[a] | 0.194[a] | 0.0019 |
| Prin. 1 | 0.134[a] | -0.107[b] | 0.0406 | 0.157[b] | -0.201[a] | 0.0856[b] | 0.0470 | 0.0663[a] | -0.0388[b] | 0.03853 |
| Prin. 2 | 0.0170[a] | -0.00434[a] | 0.041346 | 0.0643[b] | 0.0224[ab] | -0.0677[a] | 0.04790 | -0.0203[a] | 0.0330[a] | 0.03919 |
| Prin. 3 | -0.0392[a] | 0.0558[a] | 0.04041 | 0.0505[a] | -0.00460[a] | -0.0210[a] | 0.4682 | -0.207[a] | 0.224[b] | 0.0383 |

[1]SED is the most conservative standard error of the difference.

[a,b,c]For a particular feeding behavior trait, ls means without a common superscript differ ($P < 0.05$).

**Table 5.** Least squares means for the effect of sire line and sex on feeding pattern traits and principal components

| Sire Line | Sex | ADFI (kg)[1] | AOTD (s)[1] | ANVD[1] | DCON (%)[1] | Prin. 1[1] |
|---|---|---|---|---|---|---|
| C | Gilt | 2.06[b] | 4045[b] | 4.83[a] | 0.193[ab] | 0.122[cd] |
| C | Barrow | 2.18[c] | 4045[ab] | 4.95[ab] | 0.197[b] | 0.192[d] |
| D | Gilt | 2.07[b] | 4168[bc] | 5.15[bc] | 0.185[a] | -0.134[ab] |
| D | Barrow | 2.22[d] | 4320[d] | 5.68[d] | 0.189[ab] | -0.269[a] |
| E | Gilt | 2.01[a] | 3899[a] | 4.75[a] | 0.207[c] | 0.210[d] |
| E | Barrow | 2.22[cd] | 4199[cd] | 5.34[c] | 0.196[b] | -0.0390[bc] |
| SED[2] | | 0.015 | 56.5 | 0.094 | 0.0034 | 0.0687 |

[1]ADFI = Average daily feed intake, AOTD = Average occupation time / day, ANVD = Average number of visits / day, DCON = Daily consistency, Prin. 1 = Principal component 1.

[2]SED is the most conservative standard error of the difference.

[a,b,c,d]For a particular feeding pattern trait, ls means without a common superscript differ ($P < 0.05$).

[f]SED is the most conservative standard error of the difference.

**Table 6.** ADG regression coefficient estimates for feeding pattern traits by line

| | Feeding Pattern Traits | | | | | | |
|---|---|---|---|---|---|---|---|
| Line[1] | ADFI[2] | AOTD[3] | ANVD[4] | AFIV[5] | AOTV[6] | AFRV[7] | DCON[8] |
| CA | 216 | 0.031 | 12.7 | 0.0000591 | -0.00000656 | 0.00160 | -463 |
| CB | 203 | 0.0215 | 7.49 | 0.0000937 | 0.0000576 | 0.000242 | -418 |
| DA | 188 | 0.0154 | 7.41 | 0.0000998 | -0.0000117 | 0.00116 | -503 |
| DB | 169 | 0.00910 | -2.76 | 0.000149 | 0.0000308 | 0.00137 | -274 |
| EA | 134 | 0.0119 | 4.70 | 0.000191 | 0.0000435 | 0.00163 | -363 |
| EB | 157 | 0.0123 | 5.34 | 0.000101 | 0.0000250 | 0.000552 | -340 |

[1]Line represents sire lines C, D, and E by dam lines A and B.

[2]ADFI is in grams and has a standard error of 26.1.

[3]AOTD is in seconds and has a standard error of 0.0085.

[4]ANVD has a standard error of 5.23.

[5]AFIV is in kilograms per visit and has a standard error of 0.00005906.

[6]AOTV is in seconds and has a standard error of 0.00003189.

[7]AFRV is in grams per minute and has a standard error of 0.001034.

[8]DCON is a percentage and has a standard error of 121.7.

**Table 7.** ADG regression coefficient estimates for principal components by line

| | Principal Components | | |
|---|---|---|---|
| Line[1] | Prin. 1[2] | Prin. 2[3] | Prin. 3[4] |
| CA | -18.9 | 3.47 | 42.1 |
| CB | -9.31 | 14.6 | 39.9 |
| DA | -12.6 | 5.07 | 48.6 |
| DB | -1.35 | 8.82 | 38.0 |
| EA | -2.46 | 6.66 | 35.8 |
| EB | -11.0 | 10.7 | 29.1 |

[1]Line represents sire lines C, D, and E by dam lines A and B.

[2]Prin. 1 has a standard error of 6.592.

[3]Prin. 2 has a standard error of 7.193.

[4]Prin. 3 has a standard error of 6.02.

**Table 8.** FCR regression coefficient estimates for feeding pattern traits by line

| | Feeding Pattern Traits | | | | | | |
|---|---|---|---|---|---|---|---|
| Line[1] | ADFI[2] | AOTD[3] | ANVD[4] | AFIV[5] | AOTV[6] | AFRV[7] | DCON[8] |
| CA | 0.558 | 0.0000299 | 0.0553 | -0.000206 | -0.000202 | 0.00336 | -1.20 |
| CB | 0.615 | 0.0000614 | 0.0631 | -0.000388 | -0.000215 | 0.00271 | -1.59 |
| DA | 0.603 | 0.0000794 | 0.0639 | -0.000252 | -0.000107 | 0.00284 | -1.30 |
| DB | 0.367 | 0.0000366 | 0.0266 | -0.000252 | -0.000111 | 0.00261 | -0.601 |
| EA | 0.717 | 0.000100 | 0.0733 | -0.000184 | -0.000170 | 0.00279 | -1.51 |
| EB | 0.623 | 0.0000541 | 0.0354 | 0.0000414 | -0.0000515 | 0.00226 | -1.38 |

[1]Line represents sire lines C, D, and E by dam lines A and B.

[2]ADFI is in grams and has a standard error of 0.0844.

[3]AOTD is in seconds and has a standard error of 0.00002749.

[4]ANVD has a standard error of 0.01655.

[5]AFIV is in kilograms per visit and has a standard error of 0.000195.

[6]AOTV is in seconds and has a standard error of 0.00010388.

[7]AFRV is in grams per minute and has a standard error of 0.003361.

[8]DCON is a percentage and has a standard error of 0.392.

**Table 9.** FCR estimates regression coefficient for principal components by line and sex

| | | Principal Components | | |
|---|---|---|---|---|
| Line[1] | Sex | Prin. 1[2] | Prin. 2[3] | Prin. 3[4] |
| CA | Gilt | -0.0338 | -0.00449 | 0.0794 |
| CA | Barrow | -0.0870 | -0.0160 | 0.0892 |
| CB | Gilt | -0.0819 | -0.0429 | 0.111 |
| CB | Barrow | -0.0834 | -0.0000483 | 0.0801 |
| DA | Gilt | -0.00452 | -0.00516 | 0.0389 |
| DA | Barrow | -0.142 | -0.00705 | 0.118 |
| DB | Gilt | -0.0411 | -0.00254 | 0.0547 |
| DB | Barrow | -0.0375 | -0.00988 | 0.0230 |
| EA | Gilt | -0.104 | -0.0105 | 0.0836 |
| EA | Barrow | -0.0771 | 0.0323 | 0.115 |
| EB | Gilt | -0.0700 | -0.0390 | 0.111 |
| EB | Barrow | -0.0323 | 0.00602 | 0.0788 |

[1]Line represents sire lines C, D, and E by dam lines A and B.

[2]Prin. 1 has a standard error of 0.02997.

[3]Prin. 2 has a standard error of 0.03693.

[4]Prin. 3 has a standard error of 0.02973.

**Table 10.** Δ BF regression coefficient estimates for feeding pattern traits by line

| | Feeding Pattern Traits | | | | | |
|---|---|---|---|---|---|---|
| Line[1] | ADFI[2] | AOTD[3] | ANVD[4] | AFIV[5] | AOTV[6] | DCON[7] |
| CA | 4.68 | 0.0000632 | 0.403 | -0.00144 | -0.00220 | -5.71 |
| CB | 4.80 | 0.000879 | 0.597 | -0.00372 | -0.00109 | -8.71 |
| DA | 4.84 | 0.000502 | 0.290 | -0.000338 | -0.000887 | -16.3 |
| DB | 5.02 | 0.000654 | 0.250 | -0.00159 | -0.000413 | -7.56 |
| EA | 4.01 | 0.000938 | 0.224 | 0.00341 | 0.00264 | -0.0166 |
| EB | 3.44 | 0.0000735 | 0.024 | 0.00287 | -0.000223 | -0.709 |

[1]Line represents sire lines C, D, and E by dam lines A and B.

[2]ADFI is in grams and has a standard error of 1.13.

[3]AOTD is in seconds and has a standard error of 0.0003391.

[4]ANVD has a standard error of 0.2083.

[5]AFIV is in kilograms per visit and has a standard error of 0.002433.

[6]AOTV is in seconds and has a standard error of 0.001271.

[7]DCON is a percentage and has a standard error of 4.92727.

**Table 11.** Δ BF regression coefficient estimates for feeding pattern traits by line and sex

| | | Feeding Pattern Trait |
|---|---|---|
| Line[1] | Sex | AFRV[2] |
| CA | Gilt | 0.166 |
| CA | Barrow | -0.0439 |
| CB | Gilt | 0.0153 |
| CB | Barrow | -0.0866 |
| DA | Gilt | -0.0112 |
| DA | Barrow | 0.0320 |
| DB | Gilt | -0.0178 |
| DB | Barrow | 0.0222 |
| EA | Gilt | -0.0459 |
| EA | Barrow | -0.0118 |
| EB | Gilt | 0.0447 |
| EB | Barrow | 0.0430 |

[1]Line represents sire lines C, D, and E by dam lines A and B.

[2]AFRV is in grams per second and has a standard error of 0.05961.

**Table 12.** Δ BF regression coefficient estimates for principal components by line and sex

| | | Principal Components | | |
|---|---|---|---|---|
| Line[1] | Sex | Prin. 1[2] | Prin. 2[3] | Prin. 3[4] |
| CA | Gilt | -0.119 | -0.669 | 1.16 |
| CA | Barrow | -0.655 | 0.102 | 0.420 |
| CB | Gilt | -0.957 | -0.00956 | 0.943 |
| CB | Barrow | -0.701 | 0.422 | 0.0346 |
| DA | Gilt | -0.410 | 0.353 | 0.886 |
| DA | Barrow | -0.729 | -0.0475 | 1.31 |
| DB | Gilt | -0.109 | 0.516 | 0.574 |
| DB | Barrow | -0.870 | -0.107 | 0.792 |
| EA | Gilt | -0.476 | 0.849 | 0.669 |
| EA | Barrow | 0.0514 | 0.473 | 0.412 |
| EB | Gilt | -0.284 | -0.275 | 0.745 |
| EB | Barrow | 0.275 | 0.0623 | 0.445 |

[1]Line represents sire lines C, D, and E by dam lines A and B.

[2]Prin. 1 has a standard error of 0.3856.

[3]Prin. 2 has a standard error of 0.45087.

[4]Prin. 3 has a standard error of 0.3843.

**Table 13.** Δ LD regression coefficient estimates for feeding pattern traits by line

| | Feeding Pattern Traits | | | | | | |
|---|---|---|---|---|---|---|---|
| Line[1] | ADFI[2] | AOTD[3] | ANVD[4] | AFIV[5] | AOTV[6] | AFRV[7] | DCON[8] |
| CA | 5.22 | 0.000316 | 0.119 | 0.00237 | -0.00196 | 0.114 | -24.4 |
| CB | -2.51 | -0.00115 | -0.313 | 0.00392 | -0.00102 | 0.0942 | 13.4 |
| DA | 1.65 | -0.000873 | -0.136 | 0.00389 | -0.00222 | 0.109 | 5.16 |
| DB | 0.473 | -0.000113 | 0.480 | -0.00251 | -0.00191 | 0.0549 | -13.7 |
| EA | 2.90 | -0.0000768 | -0.394 | 0.00717 | 0.00153 | 0.0643 | -1.56 |
| EB | 2.26 | -0.000379 | -0.130 | 0.000224 | -0.000773 | 0.0371 | -7.39 |

[1]Line represents sire lines C, D, and E by dam lines A and B.

[2]ADFI is in grams and has a standard error of 1.896.

[3]AOTD is in seconds and has a standard error of 0.00055979.

[4]ANVD has a standard error of 0.3434.

[5]AFIV is in kilograms per visit and has a standard error of 0.0039718.

[6]AOTV is in seconds and has a standard error of 0.0020817.

[7]AFRV is in grams per second and has a standard error of 0.06727.

[8]DCON is a percentage and has a standard error of 8.182.

**Table 14.** Δ LD regression coefficient estimates for principal components by line

| | Principal Components | | |
|---|---|---|---|
| Line[1] | Prin. 1[2] | Prin. 2[3] | Prin. 3[4] |
| CA | -0.297 | -0.278 | 1.54 |
| CB | 0.768 | -0.642 | -0.295 |
| DA | 0.489 | -0.840 | 0.602 |
| DB | -0.483 | -0.467 | 0.169 |
| EA | 0.412 | 0.126 | 0.950 |
| EB | 0.0468 | -0.199 | 0.549 |

[1]Line represents sire lines C, D, and E by dam lines A and B.

[2]Prin. 1 has a standard error of 0.4314.

[3]Prin. 2 has a standard error of 0.4719.

[4]Prin. 3 has a standard error of 0.4326.

**Table 15.** % LEAN regression coefficient estimates for feeding pattern traits by line

| | Feeding Pattern Traits | | | |
|---|---|---|---|---|
| Line[1] | ADFI[2] | AOTD[3] | ANVD[4] | AFIV[5] |
| CA | -2.32 | -0.0000172 | -0.211 | 0.000999 |
| CB | -3.31 | -0.000642 | -0.436 | 0.00319 |
| DA | -2.81 | -0.000424 | -0.198 | 0.000616 |
| DB | -2.92 | -0.000431 | -0.0817 | 0.000496 |
| EA | -2.27 | -0.000565 | -0.180 | -0.00147 |
| EB | -1.91 | -0.0000701 | -0.0423 | -0.00165 |

[1]Line represents sire lines C, D, and E by dam lines A and B.

[2]ADFI is in grams and has a standard error of 0.687.

[3]AOTD is in seconds and has a standard error of 0.00020514.

[4]ANVD has a standard error of 0.12560.

[5]AFIV is in kilograms per visit and has a standard error of 0.0014713.

**Table 16.** % LEAN regression coefficient estimates for feeding pattern traits by line and sex

| | | Feeding Pattern Traits | | |
|---|---|---|---|---|
| Line[1] | Sex | AOTV[2] | AFRV[3] | DCON[4] |
| CA | Gilt | 0.00139 | -0.0990 | 1.15 |
| CA | Barrow | 0.000687 | 0.0521 | 0.985 |
| CB | Gilt | 0.000994 | 0.00125 | 8.00 |
| CB | Barrow | 0.000202 | 0.0438 | 5.46 |
| DA | Gilt | -0.00120 | 0.0318 | 11.7 |
| DA | Barrow | 0.00191 | -0.0127 | 10.7 |
| DB | Gilt | -0.00103 | 0.0146 | -3.67 |
| DB | Barrow | 0.00108 | -0.0170 | 8.49 |
| EA | Gilt | -0.000930 | 0.0209 | 4.05 |
| EA | Barrow | -0.00188 | 0.0210 | -5.56 |
| EB | Gilt | 0.00154 | -0.0272 | 2.74 |
| EB | Barrow | -0.000862 | -0.0245 | -2.86 |

[1]Line represents sire lines C, D, and E by dam lines A and B.

[2]AOTV is in seconds and has a standard error of 0.0011594.

[3]AFRV is in grams per second and has a standard error of 0.03603.

[4]DCON is a percentage and has a standard error of 4.450.

**Table 17.** % LEAN regression coefficient estimates for principal components by line and sex

| | | Principal Components | | |
|---|---|---|---|---|
| Line[1] | Sex | Prin. 1[2] | Prin. 2[3] | Prin. 3[4] |
| CA | Gilt | -0.0538 | 0.369 | -0.621 |
| CA | Barrow | 0.431 | -0.139 | -0.0496 |
| CB | Gilt | 0.612 | -0.0848 | -0.570 |
| CB | Barrow | 0.499 | -0.242 | -0.0540 |
| DA | Gilt | 0.302 | -0.388 | -0.487 |
| DA | Barrow | 0.532 | -0.0299 | -0.753 |
| DB | Gilt | 0.0103 | -0.328 | -0.270 |
| DB | Barrow | 0.492 | -0.0282 | -0.482 |
| EA | Gilt | 0.326 | -0.402 | -0.373 |
| EA | Barrow | 0.0150 | -0.340 | -0.152 |
| EB | Gilt | 0.183 | 0.211 | -0.389 |
| EB | Barrow | -0.145 | -0.0621 | -0.241 |

[1]Line represents sire lines C, D, and E by dam lines A and B.

[2]Prin. 1 has a standard error of 0.2334.

[3]Prin. 2 has a standard error of 0.27328.

[4]Prin. 3 has a standard error of 0.2175.

**Table 18.** ADFI regression coefficient estimates for feeding pattern traits by line

| | Feeding Pattern Traits | | | | | | |
|---|---|---|---|---|---|---|---|
| Line[1] | ADFI[2] | AOTD[3] | ANVD[4] | AFIV[5] | AOTV[6] | AFRV[7] | DCON[8] |
| CA | 1.00 | 0.0000965 | 0.0798 | -0.0000715 | -0.000217 | 0.00659 | -2.27 |
| CB | 1.05 | 0.000106 | 0.0703 | -0.0000324 | -0.0000297 | 0.000795 | -2.41 |
| DA | 1.05 | 0.000114 | 0.0836 | -0.00000799 | -0.000136 | 0.000786 | -2.35 |
| DB | 0.926 | 0.0000981 | 0.0344 | 0.000181 | 0.0000182 | 0.00202 | -2.01 |
| EA | 0.993 | 0.000122 | 0.0824 | 0.000268 | -0.0000707 | 0.00343 | -2.23 |
| EB | 0.992 | 0.0000874 | 0.0484 | 0.000300 | 0.0000323 | 0.00225 | -2.27 |

[1]Line represents sire lines C, D, and E by dam lines A and B.

[2]ADFI is in grams and has a standard error of 0.043.

[3]AOTD is in seconds and has a standard error of 0.00002402.

[4]ANVD has a standard error of 0.01470.

[5]AFIV is in kilograms per visit and has a standard error of 0.00017794.

[6]AOTV is in seconds and has a standard error of 0.00009410.

[7]AFRV is in grams per second and has a standard error of 0.00304857.

[8]DCON is a percentage and has a standard error of 0.324.

**Table 19.** ADFI regression coefficient estimates for principal components by line and sex

| | | Principal Components | | |
|---|---|---|---|---|
| Line[1] | Sex | Prin. 1[2] | Prin. 2[3] | Prin. 3[4] |
| CA | Gilt | -0.0902 | -0.00500 | 0.190 |
| CA | Barrow | -0.112 | -0.0231 | 0.164 |
| CB | Gilt | -0.0994 | 0.0338 | 0.190 |
| CB | Barrow | -0.0904 | 0.0389 | 0.181 |
| DA | Gilt | -0.0497 | 0.0193 | 0.162 |
| DA | Barrow | -0.156 | -0.0105 | 0.228 |
| DB | Gilt | -0.0477 | 0.0413 | 0.157 |
| DB | Barrow | -0.056 | 0.00883 | 0.155 |
| EA | Gilt | -0.0758 | 0.00618 | 0.157 |
| EA | Barrow | -0.106 | 0.0460 | 0.198 |
| EB | Gilt | -0.0876 | 0.0491 | 0.156 |
| EB | Barrow | -0.0717 | 0.0365 | 0.174 |

[1]Line represents sire lines C, D, and E by dam lines A and B.

[2]Prin. 1 has a standard error of 0.02576.

[3]Prin. 2 has a standard error of 0.03166.

[4]Prin. 3 has a standard error of 0.0202.

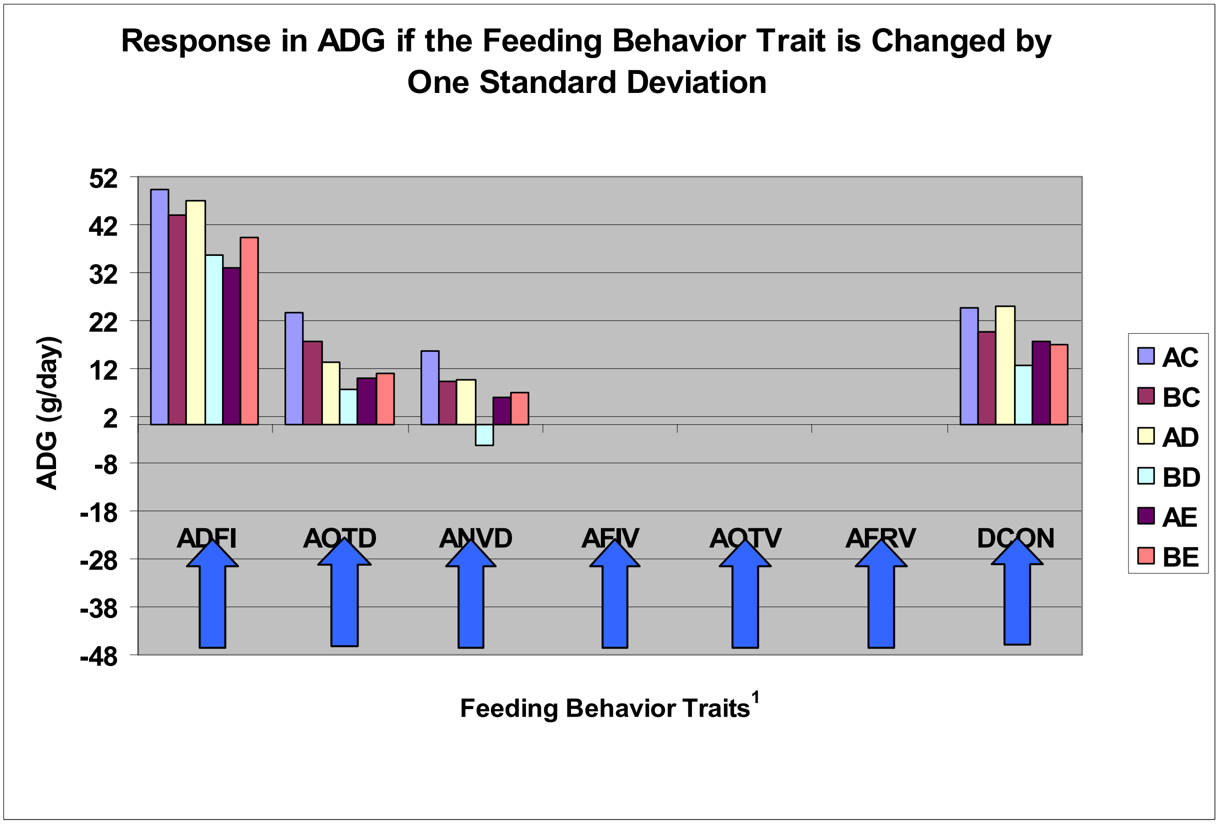


**Figure 1.** Response in ADG if the feeding behavior trait is changed by one standard deviation

[1]With the exception of AFIV, AOTV, and AFRV, the main effect of feeding behavior was significant at 0.01.

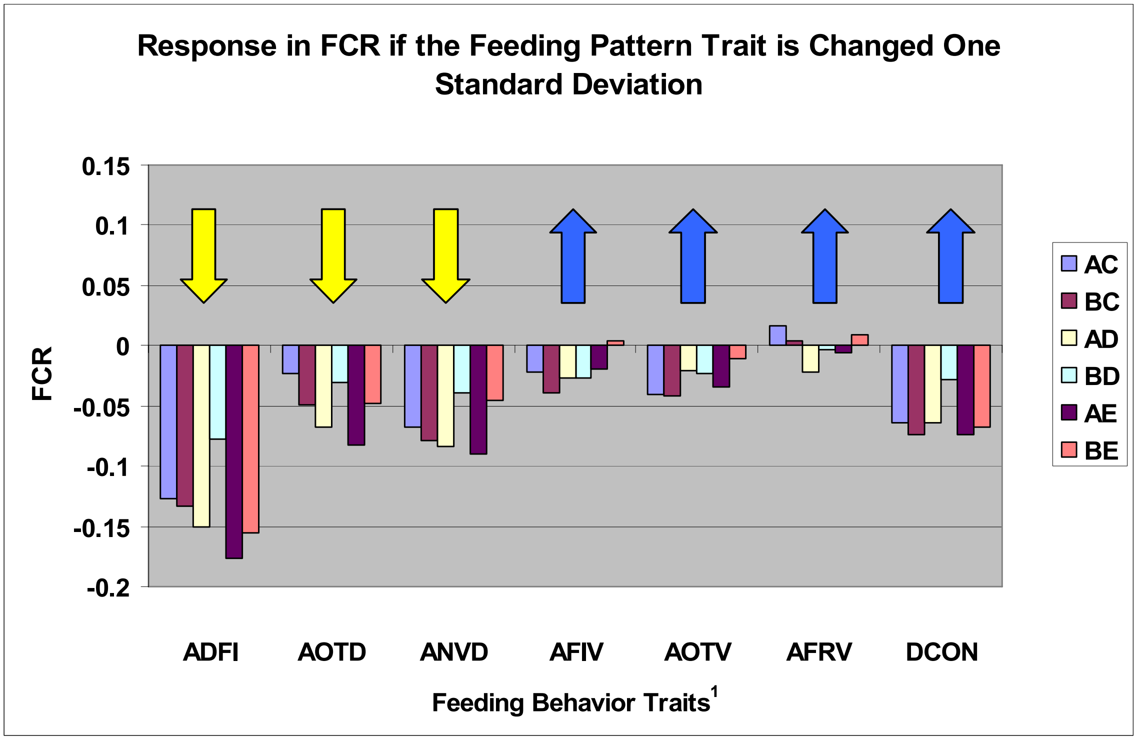


**Figure 2.** Response in FCR if the feeding behavior trait is changed by one standard deviation

[1]With the exception of AFIV, AOTV, and AFRV, the main effect of feeding behavior was significant at 0.01.

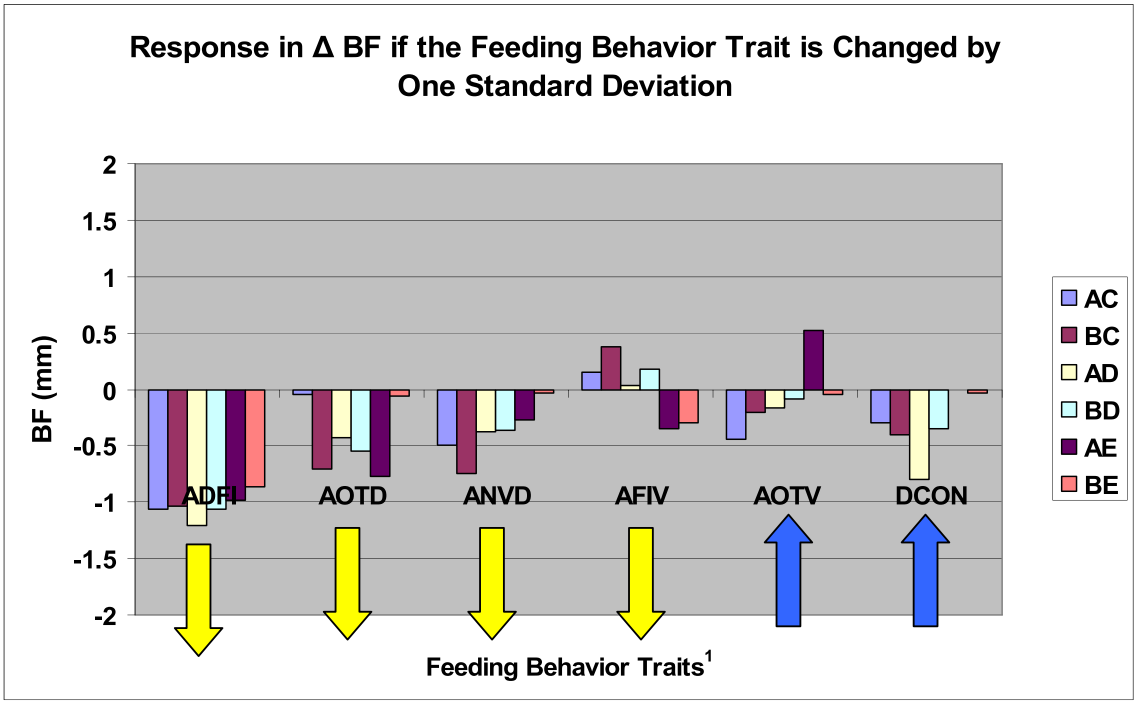


**Figure 3.** Response in Δ BF if the feeding behavior trait is changed by one standard deviation

[1]With the exception of AFIV and AOTV, the main effect of feeding behavior was significant at 0.01.

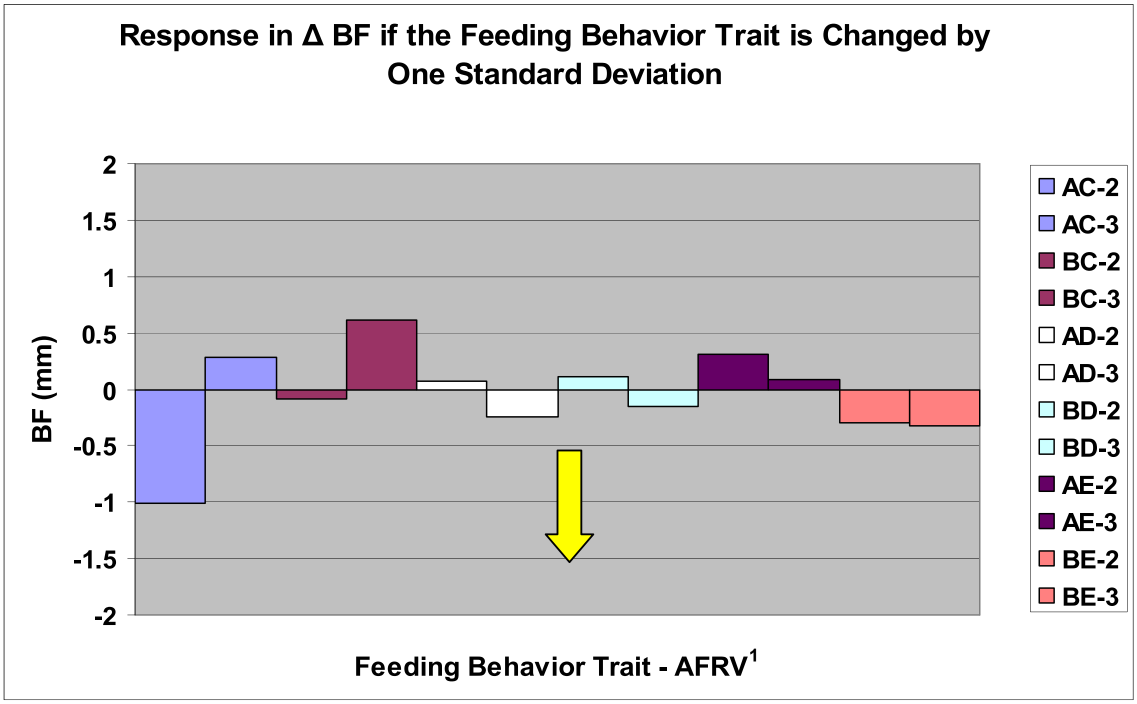


**Figure 4.** Response in Δ BF if the feeding behavior trait is changed by one standard deviation

[1]The main effect of AFRV was not significant at 0.01.

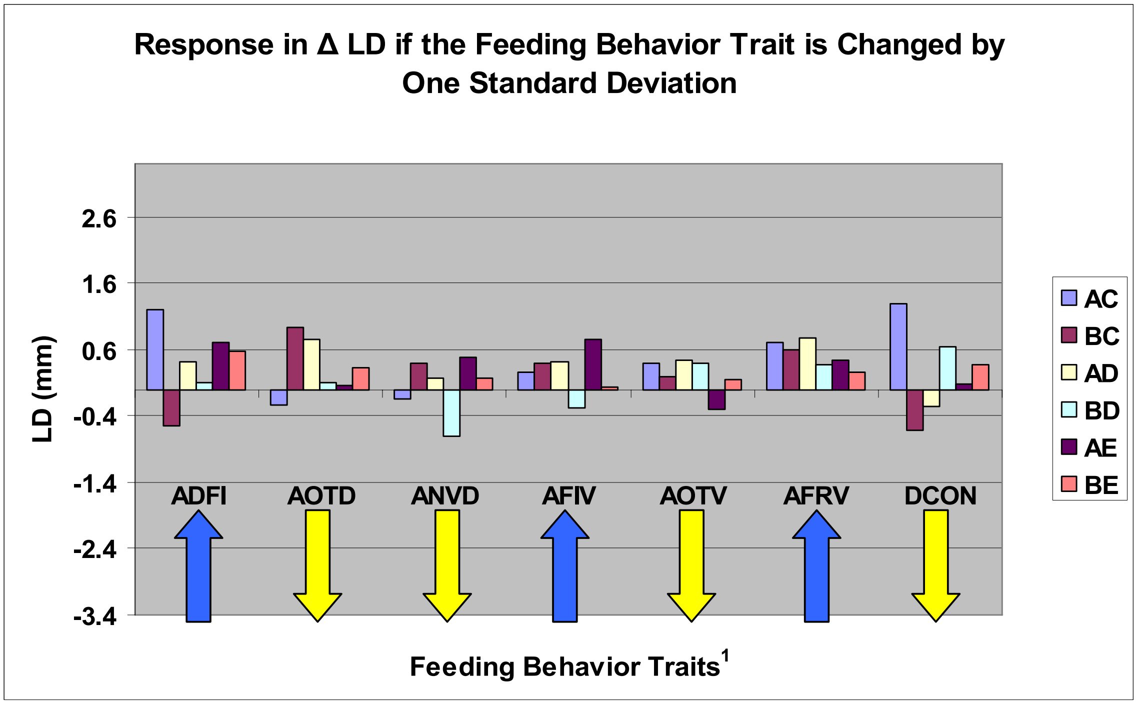


**Figure 5.** Response in Δ LD if the feeding behavior trait is changed by one standard deviation

[1]With the exception of ANVD, AFIV, and AOTV, the main effect of feeding behavior was significant at 0.10.

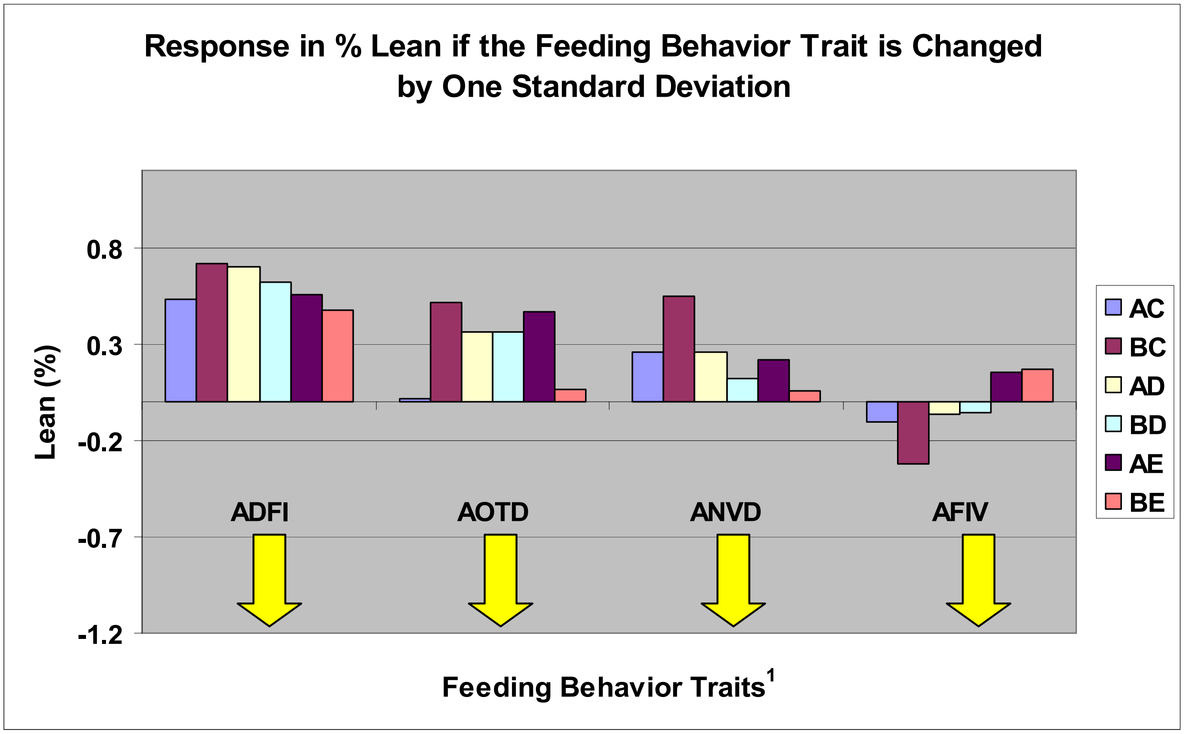


**Figure 6.** Response in % LEAN if the feeding behavior trait is changed by one standard deviation

[1]With the exception of AFIV, the main effect of feeding behavior was significant at 0.01.

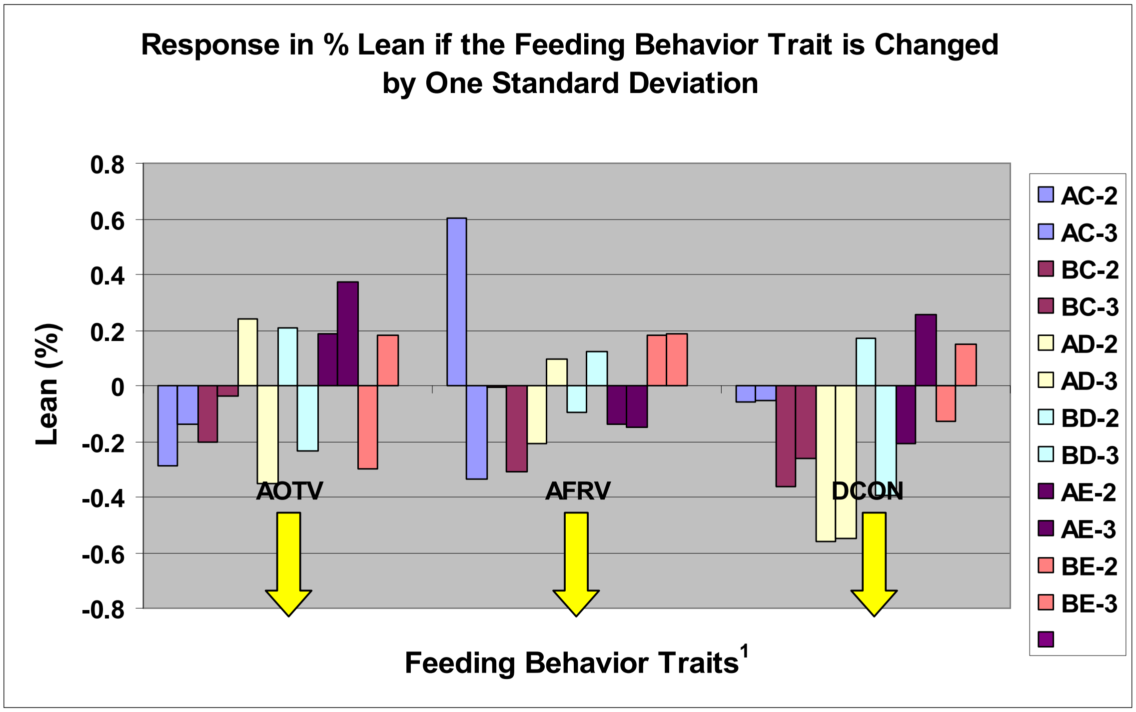


**Figure 7.** Response in % LEAN if the feeding behavior trait is changed by one standard deviation

[1]The main effect of feeding behavior was not significant at 0.01.

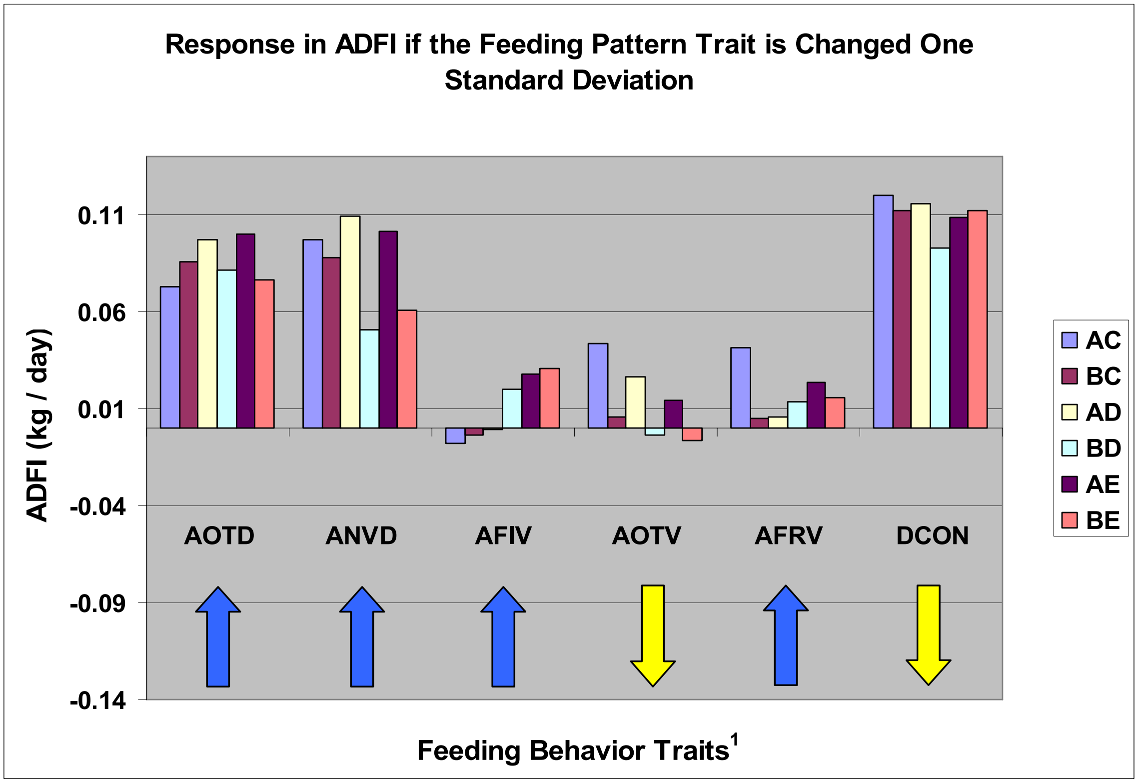


**Figure 8.** Response in ADFI if the feeding behavior trait is changed by one standard deviation

[1]With the exception of AFIV, AOTV, and AFRV, the main effect of feeding behavior was significant at 0.01.

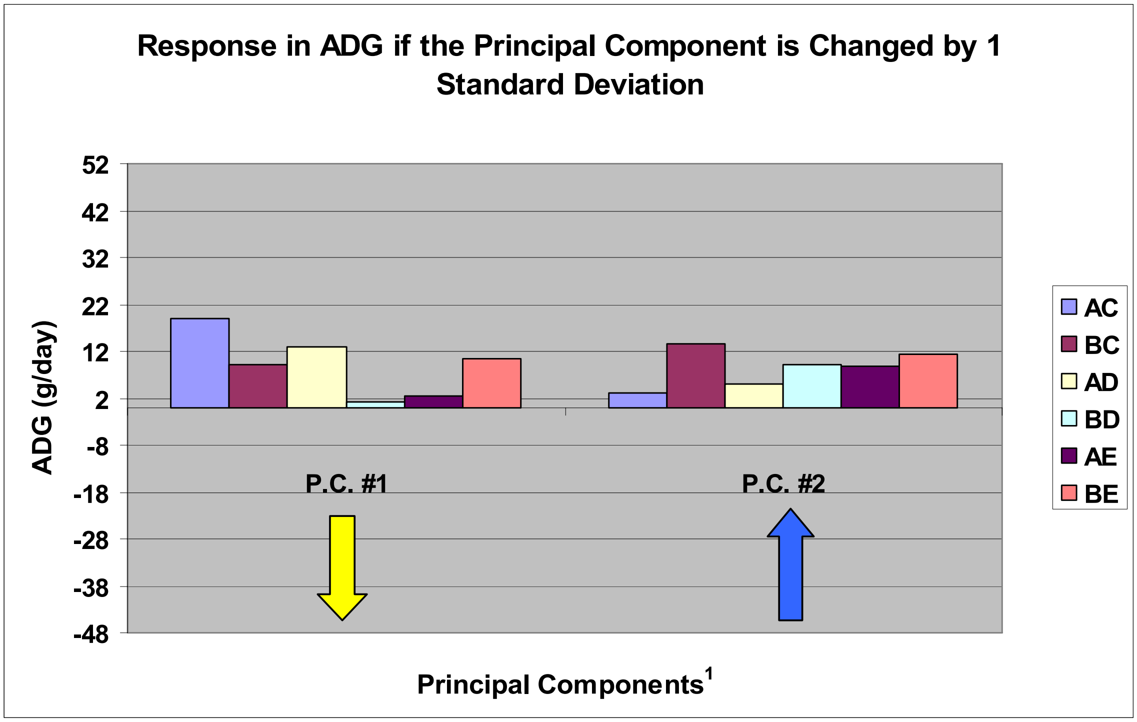


**Figure 9.** Response in ADG if the principal component is changed by one standard deviation

[1]The main effect of principal components was significant at 0.01.

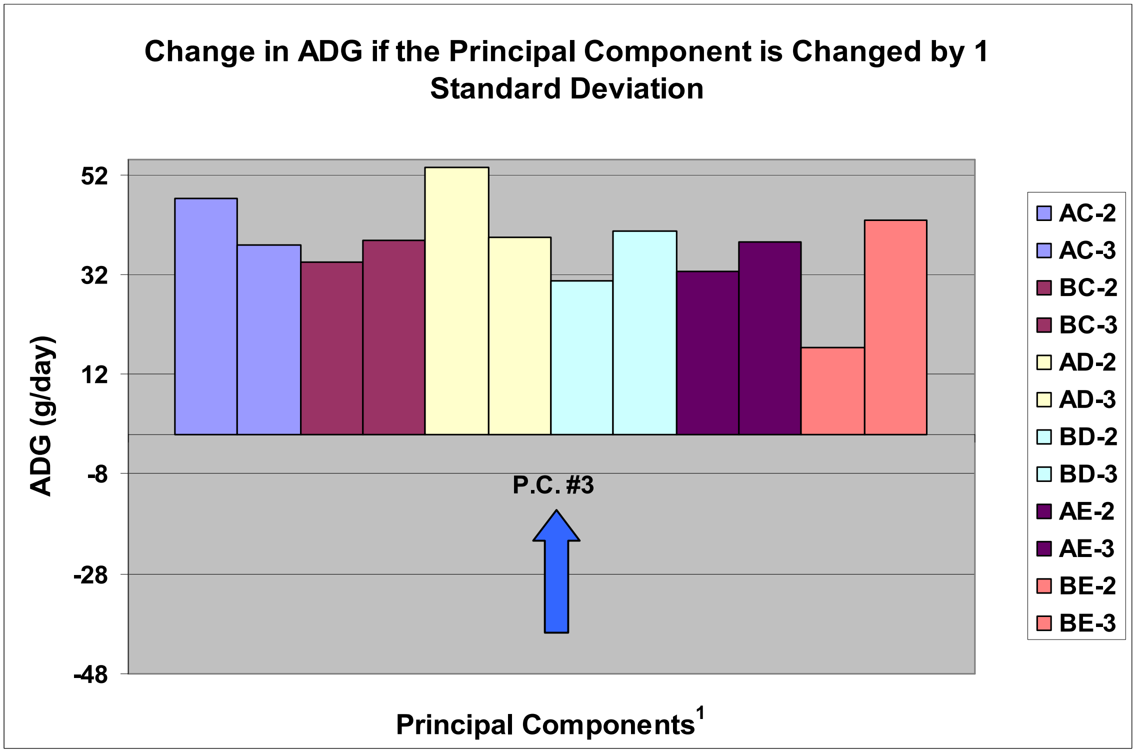


**Figure 10.** Response in ADG if the principal component is changed by one standard deviation

[1]The main effect of principal component was significant at 0.01.

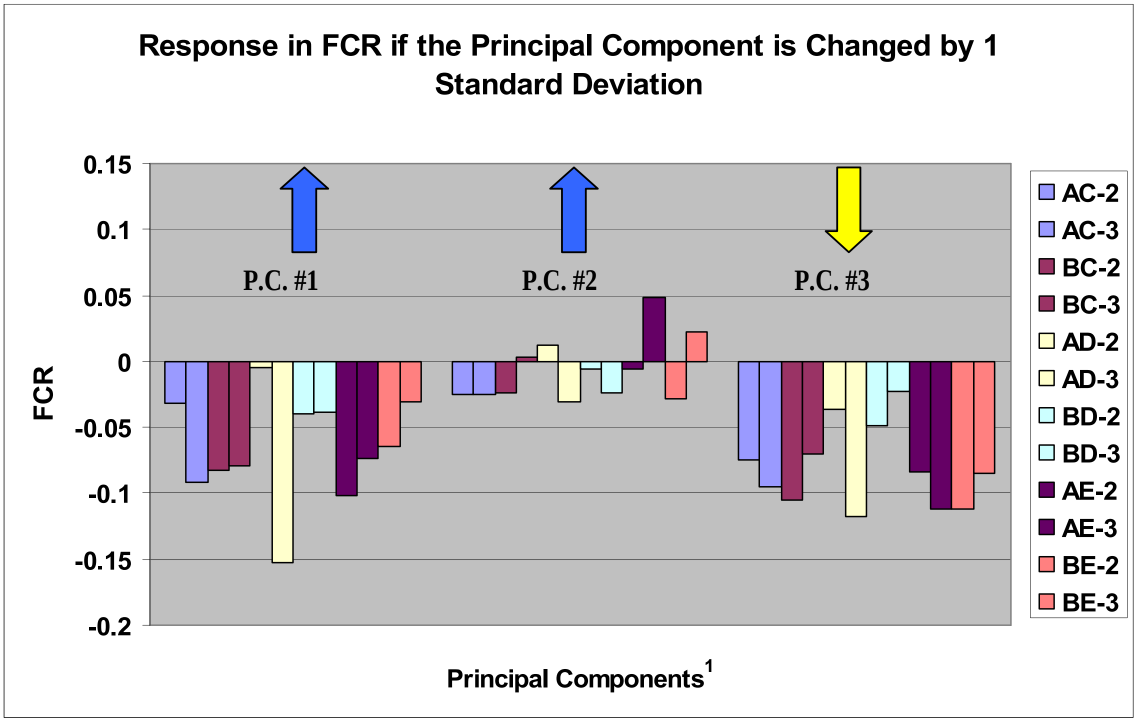


**Figure 11.** Response in FCR if the principal component is changed by one standard deviation

[1]The main effect of principal components was significant at 0.01.

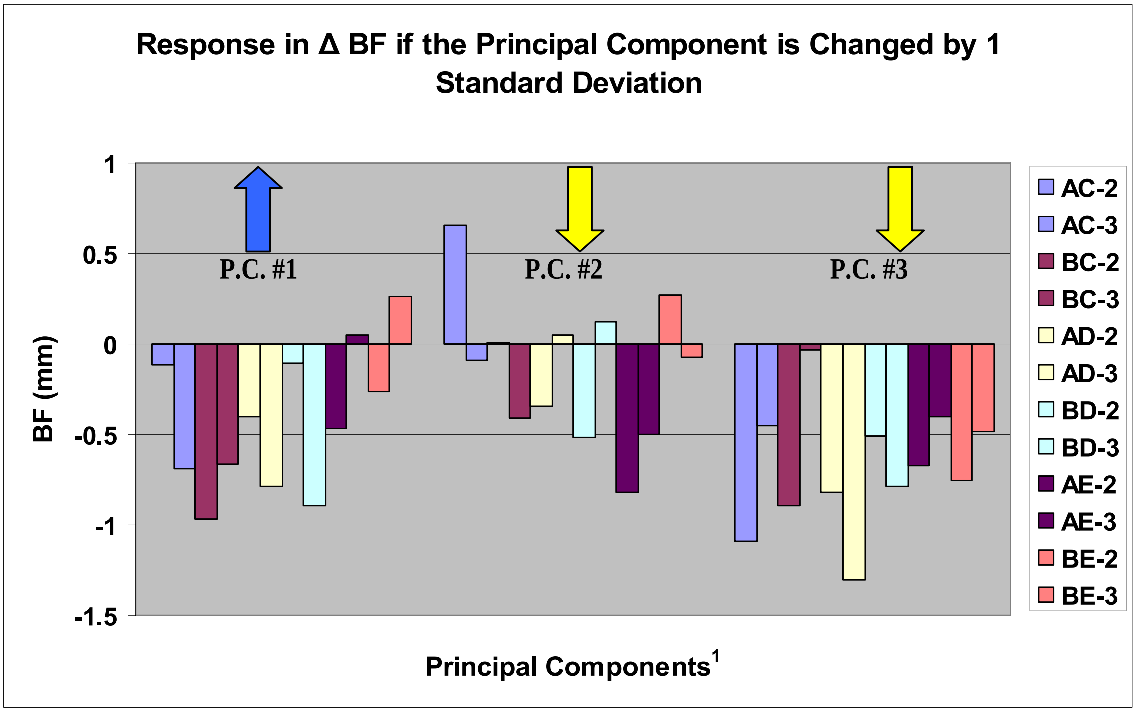


**Figure 12.** Response in Δ BF if the principal component is changed by one standard deviation

[1]The main effect of principal components was significant at 0.01.

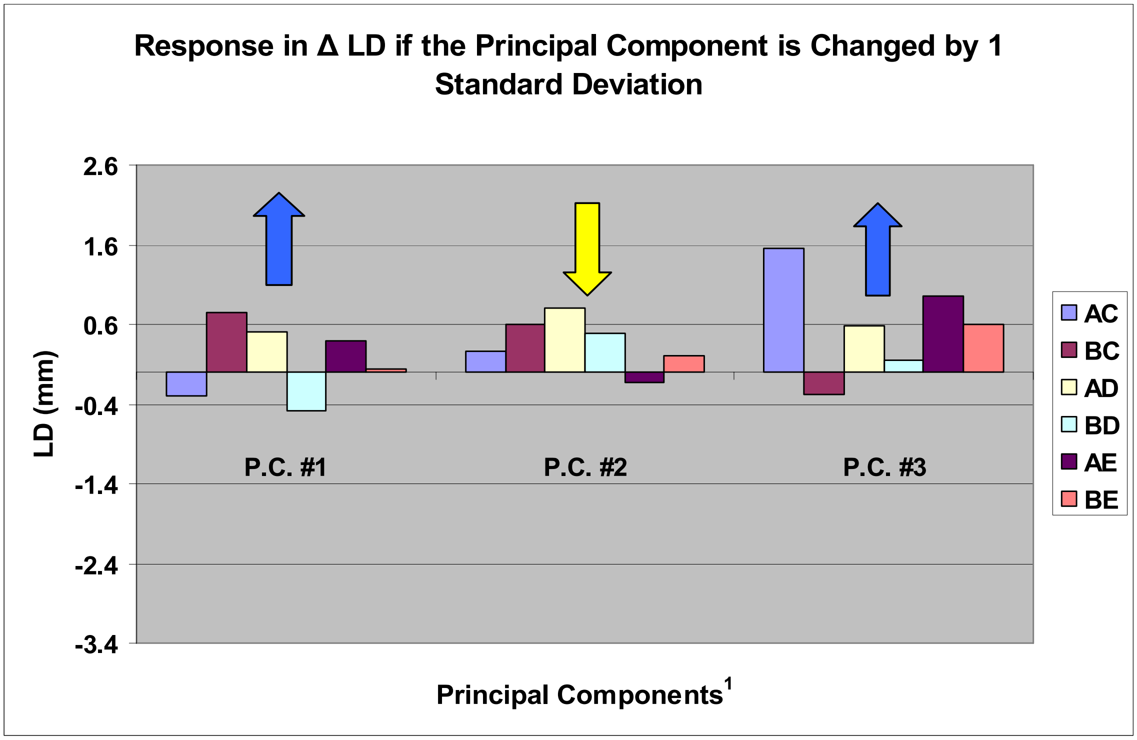


**Figure 13.** Response in Δ LD if the principal component is changed by one standard deviation

[1]The main effect of principal components was significant at 0.01.

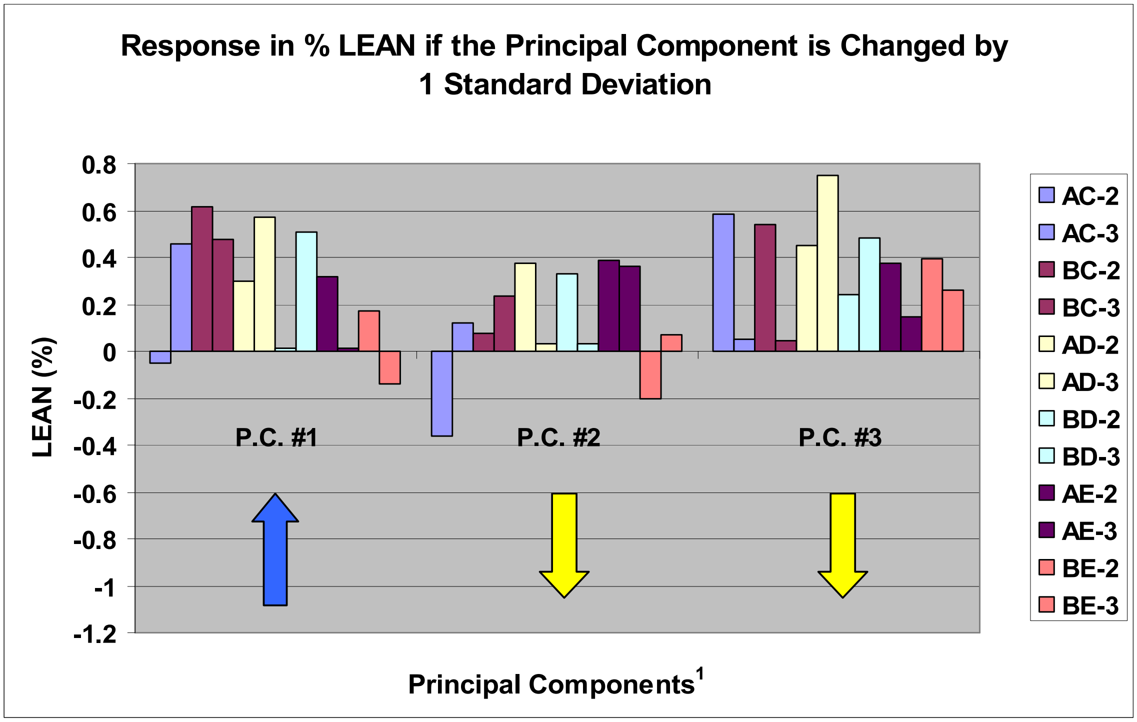


**Figure 14.** Response in % LEAN if the principal component is changed by one standard deviation

[1]The main effect of principal components was significant at 0.01.

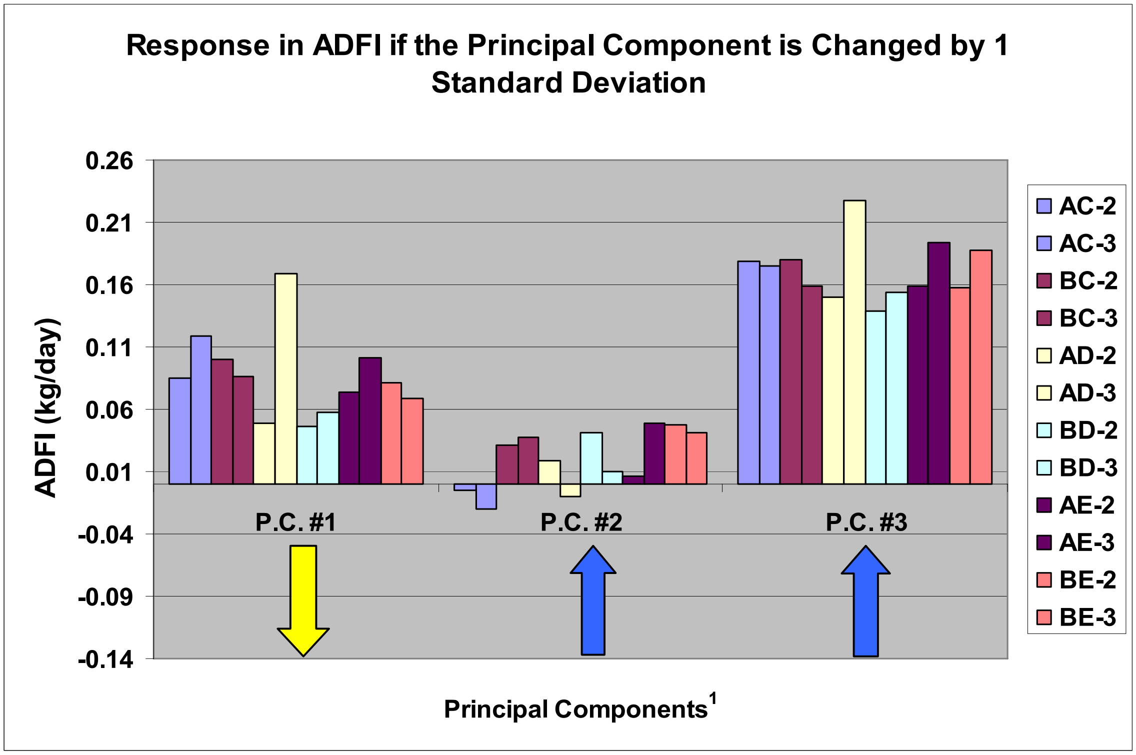


**Figure 15.** Response in ADFI if the principal component is changed by one standard deviation

[1]The main effect of principal components was significant at 0.01.

# APPENDIX I.

**Table 20.** Summary of average daily feed intake statistics in kg

| Line | Sex | n[1] | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|---|
| CA | Gilt | 98 | 2.13 | 0.20 | 1.70 | 2.71 |
| CA | Barrow | 99 | 2.24 | 0.25 | 1.64 | 2.89 |
| CB | Gilt | 152 | 2.15 | 0.22 | 1.47 | 2.68 |
| CB | Barrow | 139 | 2.27 | 0.20 | 1.77 | 2.75 |
| DA | Gilt | 114 | 2.13 | 0.211 | 1.44 | 2.55 |
| DA | Barrow | 102 | 2.30 | 0.26 | 1.46 | 2.86 |
| DB | Gilt | 151 | 2.16 | 0.18 | 1.61 | 2.69 |
| DB | Barrow | 132 | 2.29 | 0.22 | 1.60 | 2.93 |
| EA | Gilt | 126 | 2.07 | 0.21 | 1.46 | 2.66 |
| EA | Barrow | 113 | 2.24 | 0.25 | 1.16 | 2.72 |
| EB | Gilt | 167 | 2.11 | 0.21 | 1.54 | 2.86 |
| EB | Barrow | 163 | 2.35 | 0.23 | 1.78 | 2.96 |
| | Total | 1556 | | | | |

[1]n differs from N in Table 1 because 8 pigs were identified as outliers.

**Table 21.** Summary of average occupation time per day in s

| Line | Sex | n[1] | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|---|
| CA | Gilt | 98 | 4103.48 | 768.23 | 2637.52 | 6378.45 |
| CA | Barrow | 96 | 3956.26 | 741.55 | 2212.49 | 5908.33 |
| CB | Gilt | 152 | 4229.64 | 816.14 | 2754.42 | 6828.30 |
| CB | Barrow | 139 | 4065.39 | 792.62 | 2299.80 | 6286.71 |
| DA | Gilt | 114 | 4229.13 | 773.45 | 2580.74 | 6320.52 |
| DA | Barrow | 101 | 4344.02 | 927.75 | 1836.58 | 6668.36 |
| DB | Gilt | 152 | 4319.07 | 780.02 | 2401.26 | 6598.97 |
| DB | Barrow | 133 | 4225.34 | 890.17 | 1722.82 | 6406.70 |
| EA | Gilt | 126 | 3918.75 | 756.66 | 2037.75 | 5737.49 |
| EA | Barrow | 114 | 4013.41 | 891.62 | 1658.39 | 6498.75 |
| EB | Gilt | 166 | 4126.85 | 844.83 | 2211.96 | 6958.54 |
| EB | Barrow | 163 | 4305.20 | 903.65 | 2178.34 | 6540.23 |
| | Total | 1554 | | | | |

[1]n differs from N in Table 1 because 10 pigs were identified as outliers.

**Table 22.** Summary of statistics for average number of visits / day

| Line | Sex | n[1] | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|---|
| CA | Gilt | 98 | 6.59 | 1.15 | 4.16 | 10.34 |
| CA | Barrow | 99 | 6.49 | 1.29 | 3.43 | 9.68 |
| CB | Gilt | 150 | 6.94 | 1.26 | 3.29 | 11.28 |
| CB | Barrow | 139 | 6.60 | 1.21 | 3.70 | 10.21 |
| DA | Gilt | 113 | 6.91 | 1.24 | 3.86 | 11.05 |
| DA | Barrow | 102 | 7.22 | 1.37 | 4.72 | 10.87 |
| DB | Gilt | 148 | 7.25 | 1.33 | 4.23 | 11.69 |
| DB | Barrow | 130 | 7.26 | 1.61 | 4.10 | 11.58 |
| EA | Gilt | 125 | 6.69 | 1.19 | 3.86 | 10.22 |
| EA | Barrow | 114 | 6.64 | 1.28 | 3.67 | 10.66 |
| EB | Gilt | 167 | 6.88 | 1.15 | 4.42 | 11.10 |
| EB | Barrow | 163 | 7.12 | 1.34 | 4.09 | 12.69 |
| | Total | 1548 | | | | |

[1]n differs from N in Table 1 because 16 pigs were identified as outliers.

**Table 23.** Summary of statistics for average feed intake / visit in g / visit

| Line | Sex | n[1] | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|---|
| CA | Gilt | 114 | 362.97 | 108.29 | 94.91 | 631.71 |
| CA | Barrow | 102 | 349.61 | 101.24 | 102.32 | 615.36 |
| CB | Gilt | 152 | 348.86 | 107.14 | 100.70 | 692.31 |
| CB | Barrow | 135 | 338.87 | 111.18 | 55.45 | 595.68 |
| DA | Gilt | 126 | 384.07 | 109.98 | 134.67 | 727.01 |
| DA | Barrow | 113 | 382.76 | 96.95 | 189.18 | 628.86 |
| DB | Gilt | 166 | 370.73 | 106.59 | 125.74 | 652.43 |
| DB | Barrow | 162 | 365.61 | 100.50 | 58.04 | 641.63 |
| EA | Gilt | 97 | 671.51 | 205.57 | 126.58 | 1239.79 |
| EA | Barrow | 96 | 666.71 | 200.93 | 318.02 | 1314.89 |
| EB | Gilt | 152 | 634.35 | 203.17 | 248.73 | 1326.70 |
| EB | Barrow | 135 | 635.94 | 180.46 | 240.35 | 1138.03 |
| | Total | 1550 | | | | |

[1]n differs from N in Table 1 because 14 pigs were identified as outliers.

**Table 24.** Summary of statistics for average occupation time / visit in s / visit

| Line | Sex | n[1] | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|---|
| CA | Gilt | 97 | 671.51 | 205.57 | 126.58 | 1239.79 |
| CA | Barrow | 96 | 666.71 | 200.93 | 318.02 | 1314.89 |
| CB | Gilt | 152 | 634.35 | 203.17 | 248.73 | 1326.70 |
| CB | Barrow | 135 | 635.94 | 180.46 | 240.35 | 1138.03 |
| DA | Gilt | 114 | 633.60 | 199.12 | 211.88 | 1235.72 |
| DA | Barrow | 101 | 626.53 | 185.67 | 44.74 | 1145.52 |
| DB | Gilt | 150 | 594.36 | 202.38 | 163.35 | 1179.86 |
| DB | Barrow | 135 | 586.57 | 219.26 | 57.00 | 1296.08 |
| EA | Gilt | 125 | 622.07 | 199.45 | 218.24 | 1280.42 |
| EA | Barrow | 112 | 624.74 | 198.74 | 178.27 | 1144.65 |
| EB | Gilt | 163 | 616.18 | 191.87 | 206.35 | 1096.60 |
| EB | Barrow | 164 | 625.00 | 211.89 | 22.55 | 1390.51 |
| | Total | 1544 | | | | |

[1]n differs from N in Table 1 because 20 pigs were identified as outliers.

**Table 25.** Summary of statistics for average feeding rate / visit in g per s per visit

| Line | Sex | n[1] | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|---|
| CA | Gilt | 98 | 38.65 | 6.10 | 24.40 | 57.29 |
| CA | Barrow | 96 | 37.76 | 6.41 | 22.06 | 55.04 |
| CB | Gilt | 152 | 37.68 | 5.52 | 26.05 | 53.67 |
| CB | Barrow | 138 | 39.16 | 7.06 | 24.48 | 60.24 |
| DA | Gilt | 114 | 37.64 | 6.57 | 21.49 | 59.11 |
| DA | Barrow | 103 | 37.11 | 7.61 | 17.27 | 58.04 |
| DB | Gilt | 152 | 37.64 | 6.52 | 22.90 | 56.51 |
| DB | Barrow | 132 | 37.65 | 7.07 | 21.72 | 58.95 |
| EA | Gilt | 125 | 39.56 | 6.64 | 21.89 | 57.84 |
| EA | Barrow | 113 | 39.25 | 7.03 | 25.68 | 58.09 |
| EB | Gilt | 165 | 39.00 | 6.59 | 23.40 | 60.29 |
| EB | Barrow | 162 | 38.70 | 7.66 | 23.45 | 60.64 |
| | Total | 1550 | | | | |

[1]n differs from N in Table 1 because 14 pigs were identified as outliers.

**Table 26.** Summary of statistics for daily consistency (%)

| Line | Sex | n[1] | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|---|
| CA | Gilt | 97 | 0.15 | 0.05 | 0.05 | 0.25 |
| CA | Barrow | 98 | 0.16 | 0.05 | 0.06 | 0.33 |
| CB | Gilt | 151 | 0.15 | 0.05 | 0.05 | 0.26 |
| CB | Barrow | 138 | 0.15 | 0.05 | 0.05 | 0.27 |
| DA | Gilt | 113 | 0.14 | 0.05 | 0.06 | 0.28 |
| DA | Barrow | 102 | 0.15 | 0.05 | 0.03 | 0.33 |
| DB | Gilt | 152 | 0.14 | 0.05 | 0.04 | 0.29 |
| DB | Barrow | 133 | 0.14 | 0.05 | 0.06 | 0.29 |
| EA | Gilt | 123 | 0.16 | 0.05 | 0.08 | 0.31 |
| EA | Barrow | 112 | 0.16 | 0.05 | 0.07 | 0.30 |
| EB | Gilt | 166 | 0.16 | 0.05 | 0.05 | 0.34 |
| EB | Barrow | 164 | 0.15 | 0.05 | 0.04 | 0.32 |
| | Total | 1549 | | | | |

[1]n differs from N in Table 1 because 15 pigs were identified as outliers.

**Table 27.** Summary of statistics for production traits

| Trait | n[1] | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| ADG[2] | 1558 | 0.88 | 0.10 | 0.59 | 1.16 |
| FCR[3] | 1544 | 2.43 | 0.31 | 1.53 | 3.41 |
| Δ BF[4] | 1544 | 8.70 | 3.98 | -1.32 | 21.08 |
| Δ LD[5] | 1548 | 21.39 | 6.75 | 0.99 | 41.28 |
| Lean[6] | 1540 | 56.00 | 2.44 | 48.34 | 63.49 |
| ADFI[7] | 1556 | 2.13 | 0.29 | 1.25 | 2.99 |

[1]n differs from N in Table 1 due to outliers.

[2]ADG = average daily gain in kg.

[3]FCR = feed conversion ratio.

[4]Δ BF = change in backfat in mm.

[5]Δ LD = change in loin depth in mm.

[6]Lean = percentage lean in %.

[7]ADFI = average daily feed intake in kg.