ENVIRONMENTAL ENRICHMENT INFLUENCES ON PIG BEHAVIOR,
PERFORMANCE, AND MEAT QUALITY

by

JEFFERY DARRELL HILL, B.S.

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ABSTRACT

The influence of five treatments varying in environmental enrichment level were evaluated for effects on performance, behavior and carcass characteristics in 320 pigs from weaning to slaughter. Eight replications were evaluated, four replications were PIC C15 X 405 cross which is a commonly employed commercial hybrid in the US swine industry and four replications were of a PIC EXP-94 X 405 cross (one-eighth Meishan). The EXP-94 is an experimental line developed to determine the efficacy of introducing the Meishan breed into the US swine industry. Animals were randomly allotted at weaning (28 days) and were housed in groups of eight pigs per pen. Pigs remained in the nursery four weeks, then were moved to the grower-finisher facility. The live animal evaluation was completed when the replicate average weight reached 113 kgs.

The five environmental treatments were isolation (NEG), weekly normal handling (NOR), daily normal handling plus the addition of environmental enrichment devices (TOYS), daily normal handling plus two minute pleasant handling bouts with humans five days per week (HUM), and daily normal handling with maximum environmental enrichment including environmental enrichment devices plus the two minute pleasant handling bouts with humans five days per week (T+H).

Analysis of pig growth and performance included average daily gain, feed intake, feed:gain ratio and mortality. Behavioral analysis was accomplished through a 24 hour video analysis of home pen behavior (lying, feeding, drinking, hose interaction, and chain interaction) at 50 and 165 days of age. A two minute standardized human-interaction test

was conducted immediately prior to the moving of animals from the nursery facility and immediately prior to the final weigh session. During the final weigh session animals were evaluated for movement and loading scores, and rated for evidence of deviant social behaviors including ear and tail biting.

Four animals per pen were selected for carcass evaluation at a commercial slaughter facility. Animals were subjected to the standard quality assurance program, including carcass weight and Fat-O-Meat'er analysis. Sixteen hours after slaughter, shoulder pH was determined, carcasses were scored for muscling, and measured for carcass length and backfat thickness opposite the first rib, last rib and last lumbar vertebrae. A 10 cm section was collected from the midline of the right loin and analyzed for ultimate pH and coloring (Hunter L*,a*,b*) 48 hours after slaughter. After samples were aged, sliced and frozen, Warner-Bratzler shear value was determined and a trained taste panel evaluation was conducted.

Averaged over genotypes, growth and efficiency measures were not effected by the range of environmental treatments performed. In the finishing stage ADG and F:G ratio for the EXP-94 animals did show performance differences among treatments. EXP-94 pigs exposed to the TOYS treatments had improved ADG and F:G ratio ($P<.05$) compared to the HUM, T+H and NEG treatments.

Environmental treatments significantly altered measured backfat thickness. Isolation (NEG) produced less backfat opposite the last rib and last lumbar vertebrae ($P<.05$). Pork quality measures were not affected by the range of rearing conditions studied during this experiment.

The environmental treatments had no significant effect on the overall duration of the basic behaviors conducted during a 24 hour period, although both treatment and genotype had an effect on behavior patterns in the nursery stage of production.

Animals in isolation (NEG) took longer to make contact and spent less time in contact with the experimenter during both human-interaction testing periods ($P < .001$). The response shown by pigs towards humans did not affect the ability to move or weigh these pigs effectively.

Genetics appeared a greater factor in determining performance, carcass characteristics, and pork quality than the range of rearing conditions studied in this experiment. In the US swine industry there appears to be no benefit to the pig, the producer or the consumer with increased environmental enrichment or extensive human handling.

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CHAPTER I

INTRODUCTION

Pigs are housed in a variety of production systems around the world, from barren indoor confinement systems to natural outdoor systems. A great deal of scientific research has been done (Hemsworth et al., 1981, 1986a, 1987, 1991, 1996a, 1996b; Gonyou et al., 1986; Pearce et al., 1989; Pearce and Paterson, 1993; Paterson and Pearce, 1992; Grandin 1988; Pederson, 1992; Schaefer et al., 1990) to determine how this range of rearing environments impacts the physical and psychological development of the animal. The majority of these studies have focused on a small number of animals handled in intensive enrichment schemes for a short period.

Conflicting data are found in the literature on the improvement of performance with various environmental enrichment schemes. In the past, enrichment schemes have focused on two distinct types; human interaction or novel objects. This study incorporated both categories of environmental enrichment. Environmental enrichment included novel objects, human interaction and various combination schemes, allowing comparison of the effectiveness of humans versus novel objects as enrichment devices. Two distinct genetic lines were analyzed to determine the interaction between genetics and environmental enrichment on performance, behavior, carcass characteristics and meat quality. This work will ultimately allow swine producers to develop better management and housing systems.

CHAPTER II

LITERATURE REVIEW

The development of intensive production techniques in the swine industry has received increasing criticism for limited space allocation, barren environments and the effects of this environment on the physiological and psychological development of the animal.

Indications of animal welfare are believed to be complex in nature and must include an integration of various indicators including physiologic, ethological, pathologic, and performance to obtain an accurate and total evaluation of animal welfare (Duncan, 1981; Smidt, 1983; Barnett et al., 1984). Researchers have studied the effect of increasing space allocation and recently have begun to examine the quality of the animals environment, including environmental enrichment devices and increased human interaction.

2.1 Environmental Enrichment Schemes

Environmental enrichment schemes have ranged from adding a single chain or hose to artificially replicating the “natural” environment (Newberry, 1995). Many environmental enrichment devices and schemes have been investigated to determine their effect on animal well-being (Table 2.1). Pigs preferred a material that was easily manipulated (Grandin and Curtis 1984; Pedersen 1992), and preferences changed as animals developed (Grandin and Curtis 1984). Feddes and Fraser (1994) suggested that

easily damaged materials attract much more chewing than less destructible ones, and the presence of an exposed end increases the amount of chewing.

Natural resources normally found in the pigs' environment have been adopted by many as enrichment devices. These include sterilized earth, straw, branches, peat, and forest bark. Recent interest has developed in combining natural with artificial stimuli in multi-activity pens. Enrichment devices have included straw, bark covered logs hung in chains and timed water showers.

Artificial enrichment devices are often dictated in US modern swine production, due to biosecurity, manure handling, facility and labor concerns. These range from simple cloth strips, chains and hoses to elaborate combinations of devices such as demonstrated by the thesis work of Pedersen (1992) conducted at the University of Illinois. This scheme incorporated a mezzanine, hide areas, hose mobile, wheelbarrow wheel, and a lifter ring/suspended wheel combination. Others have tried incorporating increased human interaction with various environmental enrichment schemes to improve animal welfare.

Day et al. (1995) recently demonstrated that pigs gather information about their environment and modify their explorative and chewing behavior due to the nutritional feedback. Therefore production advantages with increasing enrichment must be carefully scrutinized, since many of the natural enrichment resources and some of the artificial enrichment devices (Schaefer et al., 1990; pig pacifier) provide a nutritional supplement, the pigs may be gaining a dietary advantage over the control animals in the study.

2.2 Effects of Environmental Enrichment on Production Performance

Much of the research done with increasing environmental enrichment has been done to analyze for behavior duration and frequencies, therefore surprisingly little production data are available. The data have shown varying degrees of success in improving growth performance and feed efficiency.

Schaefer et al. (1990) improved pig body weight gain by 4% with the addition of a simple tire and chain device compared with a barren environment. In a second experiment, pigs in a more complex environment with the addition of a teeter-totter device or a pig pacifier (sugar-mineral block), had improved growth rate by 5% for the pacifier group and 8% for the animals with the teeter-totter device compared to barren environments. All pens in this study were bedded with wood shavings, therefore even the barren pen provided a small extent of enrichment. Beattie et al. (1996) showed that the feed conversion ratio for the barren environment was significantly worse than the other four treatments, which all had enrichment (peat and straw) but varied for floor space allocation (0.5, 1.1, 1.7 and 2.3 m²). The pens with the highest amount of allocated space (2.3 m² per pig), showed poorer production performance, but no difference was observed for the barren compared to the enriched pen at this space allocation. Pearce and Paterson (1993) found decreased growth and productivity by reducing the space allocation. Environmental enrichment devices in crowded environments did not improve performance compared to barren environments. Pedersen (1992) showed no significant difference in growth or feed efficiency in the extensive enrichment pens compared to pigs in the barren environment. Grandin (1988) also showed no difference in animal weight gain or

efficiency with the various environmental enrichment schemes. Pearce et al. (1989) showed no significant difference in growth rate with the addition of environmental enrichment devices to pens that were being handled in a pleasant or unpleasant manner three times per week.

2.3 Effects of Environmental Enrichment on Behavior

Many methods have been used to determine the effects of environmental enrichment on animal behavior, ranging from short period scan techniques to elaborate video sequencing programs. Comparing the effectiveness of a particular environmental enrichment scheme by analyzing the general animal behavior is a very common practice. Duration, frequency and sequence of behavior patterns included lying, feeding, drinking, and moving as basic behaviors, and interactive behaviors such as chain play, hose play and aggressive behaviors. Differences in some of these activities may be taken as evidence for restrictions imposed by the environment.

2.3.1 Aggression

Grandin (1988) showed reduced excitability and fighting behavior with the addition of environmental enrichment during mixing of pigs. Beattie et al. (1996) demonstrated that pigs in the barren pen nosed/headthrusted their penmates and were nosed/headthrusted by their penmates for longer periods and more frequently than any of the enriched treatments. This treatment also had a higher frequency of animals biting their penmates than the enriched treatments. This agrees with data from Schaefer et al. (1990)

that the inclusion of the environmental enrichment devices reduced the frequency of total aggressive acts, even though in experiment 2 the pig pacifier and the teeter-totter altered the behavior pattern in different ways. Pedersen (1992) found no significant difference in animal aggression between enriched and barren environments. Although pigs in this study housed in the enriched environment did have higher injury score than pigs in the barren environment.

2.3.2 Basic Behaviors

Wood-Gush and Beilharz (1983) decreased the lying and cage biting while increasing the feeding and rooting behaviors through the addition of sterilized earth. Beattie et al. (1996) showed no difference in basic pig behaviors (feeding, drinking, eliminative, and locomatory) when comparing enriched and barren environments, but there was a significant increase in the frequency of standing in the barren environment. Comparing the crowded barren and crowded enriched environments, Pearce and Paterson (1993) found a reduction in frequency of the inactive behaviors of sitting and standing among enriched pigs. The type of lying behavior was influenced by enrichment devices. Pedersen (1992) found that enrichment increased the frequency of drinking compared to the barren environments. Enrichment also increased the frequency and duration of the standing behavior compared to the barren environments. Pearce et al. (1989) increased exploratory behavior while decreasing resting and drinking behaviors for pigs housed in enriched environments with pleasant human interaction experience.

2.4 Response variation to novel objects/humans

Pedersen (1992) showed that pigs in enriched environments were less fearful than pigs from barren pens during movement through a chute designed to simulate a slaughter facility. Pigs required less stimulation to enter and walk through the chute compared to pigs reared in the barren environment. These results are similar to findings of Grandin (1988) during the same chute test procedure. During the standardized human interaction session Pearce et al. (1989) decreased the amount of time for pigs to enter a 0.5 m area of the experimenter with environmental enrichment devices for both pleasantly and unpleasantly handled animals. Pearce and Paterson (1993) reduced the pig reactivity to a novel stimuli test through environmental enrichment. They showed an increase in the time required to approach and interact with the novel object. Pigs decreased the total amount of time of interaction with the experimenter when they had environmental enrichment.

2.5 Human Interaction

The effect of human handling has been studied extensively over the past 15 years. Handling has ranged from gently petting and stroking pigs, to approaching animals in an upright position, to electrical shocks each time pigs were near a human. Most studies have focused on a small number of animals handled intensively for a short period, due to the high maintenance and labor cost of such experiments. Terms used to describe various handling techniques have been used interchangeably between research groups, so the investigation of results must also include detailed analysis of the handling treatments

performed, and detailed description of the animals' environmental surroundings.

Hemsworth et al. (1986b) measured the response of pigs to various signals (posture, aggression, etc.) that an individual might convey to an animal during handling. This study showed that an individual in a squatting position (which allowed the animal to be the aggressor) was less threatening to the pig. This information has been the basis for the development of many patterns of handling for scientific study.

Indicators for animal well-being studied in this type of research include performance data, physiological development, corticosteroid levels, behavior analysis, and approach patterns towards novel stimuli or humans. The techniques developed in studying animal-human interactions have recently been adopted to determine the amount of stress caused by the adoption of new equipment and ideas into swine industry (Hemsworth et al., 1996a).

Extensive work has been conducted in the area of human handling of animals including work with pigs, chickens, and cattle. The first work was conducted in 1981 by Hemsworth et al. and included only pleasant and unpleasant handling techniques. The pleasant treatment consisted of gently stroking and petting any animal which approached, compared to the unpleasant treatment which consisted of slapping, electrically shocking, or placing a snout noose on any animal which approached.

This work has expanded to include variations in the number of interactions sessions per week and the times in each session. Variations in the size of pig, type of housing facility and groups, individual versus group situations were employed to more closely simulate production styles.

Differing types of handling techniques were developed, including passive interaction, active interaction and animal movement techniques. Active interaction is described as, the person being the aggressor where every pig was contacted, whereas in the passive interaction only pigs which approached were interacted with (Grandin 1988). Inconsistent handling methods were employed to examine the effects of variation in handling between and within stockpersons as found in commercial production units.

2.6 Effects of Human Interaction on Production Performance

Hemsworth et al. (1981) showed a significant increase in growth rate for the pleasantly handled pigs compared to animals in the unpleasant treatment. A trend towards improved feed conversion rates was documented but it was not statistically significant. Growth rate for later studies again showed an improved growth rate for pleasantly handled animals compared to those in unpleasant treatments, but the growth rate for minimally handled pigs showed the same improvement with inconsistently handled pigs being not significantly different (Hemsworth et al., 1987). The results from Gonyou et al. (1986) agree with the early Hemsworth work, where the weight gain and feed efficiency of the positive and minimal treatments were identical and showed a significant improvement in gain compared to the negative and aversive treatments. Grandin (1988) showed no difference in body weight gain or feed efficiency between animals which were minimally handled, actively handled, passively handled, or those which were driven down the alleyway once per week. The most recent Hemsworth et al. study (1996a) had differing results than past work. Pigs in the control (routine husbandry), and the injection

treatments (daily IM injections) showed better growth rates than the negative (electrical shocks) and the positive treatments (gentle petting and stroking of pigs). Recently, controversy has developed regarding the depression in growth rates documented in earlier work Paterson and Pearce (1989 and 1992; Pearce and Paterson, 1989) reported no difference in growth rates between the handling treatments (pleasant, unpleasant and minimal handling), and Hemsworth and Barnett (1991) when studying the interaction of group size and handling treatment showed no differences in pig performance among treatments over the entire ten week study, but did show significant improvement in the first 5 weeks of the trial. Pearce et al. (1989) suggested that increased group size allowed some protection from the effects of handling treatments, based on the work of Arnone and Dantzer (1980) who showed that social interactions between members of a group enabled pigs to resist the effects of stressors.

2.7 The Effects of Human Interaction on Behavior Patterns

The effects of human interaction have been studied by two basic models: (1) behavior in the home pen and (2) interaction studies with a human experimenter or a novel object. Few studies have included analysis of home pen behavior. The human interaction procedure was more common and standardized. This is due to development of a testing procedure for short interval interaction sessions by Hemsworth et al. (1981), which has been adopted as a basis for analyzing animal-human interactions. This procedure is based on four basic premises: (1) time for the animal to enter an area within 0.5 m of the experimenter (2) the total time spent within this area (3) the number of physical

interactions with the experimenter and (4) the time to the first physical interaction with the experimenter. The exception is the work of Grandin (1988) whom used an excitability scoring system (1 calm around a person, 4 active avoidance of a person) and a slaughter chute simulation.

2.7.1 Human Interaction

The standardized human interaction test developed by Hemsworth et al. (1981) has been used extensively (Hemsworth et al., 1981, 1986a, 1987, 1996a; Hemsworth and Barnett, 1991; Gonyou et al., 1986; Paterson and Pearce, 1989, 1992; Pearce et al., 1989). During a human interaction test closely following the completion of the human handling sessions, gilts unpleasantly handled demonstrated avoidance and fear of the experimenter (Hemsworth et al., 1981). Gilts in the pleasant handling treatment spent more time within 0.5 m of the experimenter and had a higher number of interactions with the experimenter, than gilts in the unpleasant treatment. In a test 15 weeks later, no significant differences were observed between the two treatments.

This avoidance reaction has been routinely demonstrated in severely unpleasantly handled animals compared to pleasantly handled animals, in various types of groupings, housing and environmental situations (Hemsworth et al., 1986, 1987, 1996a, 1996b; Hemsworth and Barnett, 1991; Gonyou et al., 1986; Paterson and Pearce, 1989, 1992; Pearce et al., 1989). Slight variations have occurred in individual testing parameters but the final results have been consistently significant. Animals that were inconsistently

handled (Hemsworth et al., 1987) demonstrated the same behaviors as those which were negatively handled.

A slightly unpleasant handling treatment such as the negative treatment imposed by Gonyou et al. (1986), in which the experimenter approached the animal in an upright position, resulted in behavior comparable to the positively and minimally handled pigs in a group test. During an individual test, the time to contact was significantly longer for the slightly negative treatment compared to the positively handled pigs. The injection treatment studied by Hemsworth et al. (1996a) caused similar pig behavior compared to the control treatment, the only significant difference in the standardized human interaction test was that the pigs in the injection treatment were slower to physically interact with the experimenter than pigs in the control treatment.

The minimally handled treatments have led to greater variation in results for the human interaction test. This may be due to the amount of interaction required for daily maintenance and operation, and the amount of interaction required for weighing and the number of weigh sessions of the animals as dictated by the protocol.

Gonyou et al. (1986) found in the group interaction test that minimally handled pigs reacted the same as the positively and negatively handled pigs for time to approach, time within 0.5 m, and number of interactions, but they were significantly different than the aversive treatment. The time to interact parameter was intermediate for the minimal treatment. In the individual test, the minimally handled pigs reacted the same as the positively and negatively handled pigs for time within 0.5 m of the experimenter. For the time to interact and the number of interactions, the minimal treatment was not

significantly different than the other treatments. The human interaction test conducted by Paterson and Pearce (1992) revealed that the time taken to enter within 0.5 m and the time spent in this area were not significantly different than either the pleasantly or unpleasantly handled pigs. However, the minimally handled animals were quicker to interact with the experimenter than the unpleasantly handled pigs.

Hemsworth et al. (1986a) found slight variations in behavior of minimally handled animals when tested at two different times (14 and 18 weeks) in a standardized human interaction test. Pigs in the pleasant treatment were quicker to enter the area near the experimenter at 18 weeks of age, were quicker to interact with the experimenter at 14 and 18 weeks of age, and had a greater number of interactions with the experimenter at 18 weeks of age than pigs in the minimal treatment. Other parameters were not significantly different among treatments. Hemsworth et al. (1987) showed that the minimally handled pigs were quicker to enter the area within 0.5 m of the experimenter, and to interact with the experimenter, spent more time within 0.5 m of the experimenter, and had more interactions with the experimenter than gilts in the unpleasant or inconsistent treatments. Pleasantly-handled animals demonstrated an increased number of interactions, and reduced time to interact with experimenter compared to the minimally handled animals ($P < .01$). The minimally handled treatment adopted by Hemsworth et al. (1996a) was intermediate between the positive and negative control, but was not significantly different than the injection treatment for time to enter an area within 0.5 m of the experimenter. The time spent within 0.5 m for the control treatment was significantly higher compared to the negative treatment, and time to interact was intermediate between the other treatments.

The number of interactions was significantly higher for the control treatment than the negative treatment. In 1996 Hemsworth et al. (1996b) added novel objects to the interaction test, the pigs in the minimal treatment took significantly longer to interact with the experimenter than the positive human treatment. The minimal treatment required significantly longer to approach within 0.5 m of a novel object compared with the other treatments.

Grandin (1988) rated animals on an excitability score and found that pigs that were handled, driven or housed in enriched environments were less excitable than those in control groups. The assertive mingling was more effective in reducing excitability than the passive mingling technique.

Grandin (1988) compared three types of handling techniques: (1) mingling, (2) driving, and (3) control treatments. Human-animal interaction sessions were conducted once per week in the mingling treatment. The driving treatment consisted of an experimenter opening the pen gate, and driving the animals into the alleyway. The chute simulation (Grandin, 1988) procedure produced different results between the two replications; in trial 1 mingling reduced the force required to drive pigs through a chute. A higher percentage of pigs in the control and drive groups had to be prodded through the chute test. In Trial 2, no significant differences were found between the handling treatments.

2.7.2 Basic Behaviors

Few studies have included home pen behavior. Pearce et al. (1989) used a 1 minute scan technique to evaluate animal behavior around the time (40 minutes) of the human handling sessions. The pigs handled unpleasantly spent more time sitting and standing inactive than the pigs handled pleasantly. Unpleasantly handled pigs moved more, but conducted fewer social interactions than the pleasantly handled pigs.

Hemsworth et al. (1996a) developed a procedure to determine the escape-avoidance behavior to handling treatments. Pigs in the negative treatment withdrew to a greater distance and oriented less towards the experimenter than pigs in the other treatments. Pigs in the injection treatment withdrew further and oriented less towards the experimenter compared to the control treatment, but there was no significant difference in withdrawal distance or proportion of animals orienting towards the experimenter between the control and positively handled animals. There was a large difference in the amount of physical contact with the experimenter in the 30 seconds following the treatment procedures.

2.8 Carcass Characteristics and Meat Quality

2.8.1 Genetic Influence on Meat Quality

In recent times, pigs have been bred to increase lean muscle while maintaining acceptable meat quality without sacrificing other production characteristics. Carcass characteristics and meat quality attributes are considered moderately heritable, ranging from .19 for water holding capacity to .48 for loin muscle area as determined by the

National Pork Producers Council genetic evaluation program (1995). Drastic variations in carcass characteristics and meat quality exist between pigs used in the US swine industry (Jensen et al., 1967; Zhang et al, 1992). This variation is strongly influenced by the effect of the halothane gene (Zhang, 1992; De Smet et al., 1996; Leach et al., 1996).

2.8.2 The Effects of Rearing Conditions on Meat Quality

Warriss et al. (1983) examined the effects of rearing conditions on meat quality in two trials. Three genotype combinations were housed in either an intensive confinement system with limited human interaction, or an outdoor facility with an open paddock enriched with tires and tree stumps, housed in a deep bedded facility and excessive human interaction. The pigs reared outside had less backfat, and intensively reared animals produced a paler pork (although the amount of difference was altered by stress susceptibility). Forty-five minutes after slaughter pH₁ and ultimate pH were not significantly altered by rearing conditions, neither was percent drip loss or muscle haem pigment concentrations. The changes were deemed small and not economically significant by the authors. Pearce et al. (1989) whom evaluated the effect of handling (pleasant versus unpleasant) in differing environments (barren versus enriched confinement pens), which were more closely controlled than the previous study. Rearing conditions had no effect on carcass characteristics, as determined by last rib fat (measured by optical probe), and eye muscle area measured between the 1st and 2nd lumbar vertebrae.

2.9 Pig Behavior in the Slaughter Plant

There is variation among packing plants in the amount of time and the physical environments animals are held in prior to slaughter. Recently work done by Geverink et al. (1996) evaluated the behavior of animals during the holding periods at slaughter facilities, concluding that for animal welfare reasons pigs should be slaughtered in the first 10 minutes after arrival. This was because the level of agonistic behavior was significantly lower in the first ten minutes. This finding was in contradiction with Moss (1978) and Warriss et al. (1992). Moss (1978) suggested that 1 to 2 hours is adequate time for pigs to settle down and rest, whereas Warriss et al. (1992) suggested a 2-3 hour resting period which significantly reduced cortisol levels, therefore indicating improved animal welfare.

Meat quality must be carefully analyzed when recommending holding times in the slaughter facility. Very short holding times have been shown to dramatically increase the incidence of PSE and decrease meat quality attributes (Fortin, 1988; Grandin, 1989; Zhang 1992; Owen, 1995; De Smet, 1996). Resting pigs before slaughter offsets the production of lactic acid and elevated temperature in pigs before slaughter. Owen (1995) reported pigs rested 1 hour before slaughter had the lowest occurrence of PSE muscle (17%) while pigs not rested or rested for 3 hours had the highest incidence of PSE muscle (26 and 27 %), with pigs resting for 2 hours intermediate in the occurrence of PSE (19%). De Smet et al. (1996) demonstrated improved meat quality with a rest period of 2 to 3 hours compared to immediate slaughter times, with very little added benefit for additional holding time. Grandin (1989) reduced extreme PSE from 18% in unrested pigs to 1.3% pigs rested 2.5 hours. Fortin (1988) reported that resting pigs 3 hours before slaughter

resulted in a 27 % reduction in PSE. Moss and Robb (1978) reported that a 2 hour holding period before slaughter resulted in a greater incidence of PSE compared to a 24 hour holding period, however the longer holding times resulted in increased incidence of DFD.

2.10 Deviant Social Behaviors

Deviant social behaviors (ear and tail biting, belly nosing and nose thrusting) can develop into serious production and animal welfare problems. Blackshaw (1981) described ear biting as starting during or after feeding, the biter first nuzzled or sucked the ears, eventually the skin on the ear became damaged and sore, when this happened the bitten pig squealed and attempted to escape. This was in comparison to the development of tail biting, which usually begins with one pig but quickly develops where other pigs chase the bitten animal and damage the tail badly which could lead to hind quarter damage and occasionally fuel cannibalism.

Van Patten (1969) suggested that ear biting was associated as an act of aggression since the ears are more sensitive. Tail biting often began from restlessness in a barren environment. This idea that ear biting is an act of aggression is further supported by the determination that most damage occurs to the head and shoulder region during animal fighting (McGlone and Curtis, 1985).

Van Putten (1969) described three phases of damage caused by tail biting, these include (1) restlessness and consequently decreased performance, (2) paralysis and death

through advanced infection and (3) rejection or partial rejection of infected animals at the slaughterhouse.

Theories for the development and manifestation of deviant social behavior vary greatly, from simple boredom to complex nutritional-disease-environmental interactions. The great difficulty in researching these manifestations is instigating the behavior without drastically altering the animals normal environment. Fraser (1978) described a belly nosing behavior in young pigs, which seemed to be instigated by the sounds and behaviors of suckling. Blackshaw (1981) described a more powerful nosing, directed at the inguinal area of the animal. She determined this behavior was a dominance display of the high ranking animals. The incidence of one deviant social behavior did not effect other behaviors from occurring. Van Putten (1969) hypothesized that pigs in an unsatisfactory environment will become active and “restlessness” therefore explorative behavior will increase and may be directed towards penmates in a barren environment. Tail biting was then induced by creating an uncomfortable state which was achieved by increasing CO₂ and NH₃, and decreasing air temperature. Temperature extremes (Penny et al., 1981) and other environmental factor, such as humidity, noise, etc. may increase the problem (Gadd 1967). The effect of social groupings has been shown as a factor in deviant social behavior, with overcrowding and large group size increasing the abnormality (Colyer, 1970; Frischen, 1976; Plumlee et al., 1976; Penny et al., 1981;). However, Arey (1991) found no incidences of tail biting in the smaller of pen sizes with tail biting occurring immediately after increasing the space allocation per pig.

Penny et al. (1972) and Penny and Hill (1974) showed a significant increase in tail biting in male pigs compared to female pigs, whereas this trend was not seen with regard to ear biting (Penny and Hill, 1974). Breed differences (Brent 1975; Fraser and Broom, 1990) appear to be strongly associated with tail biting.

Dietary factors have also been cited as causes of deviant behaviors, these include low dietary fiber, low or poor quality protein, excessive dietary energy and deficiencies or imbalances of various minerals (Gadd, 1967; Ewbank, 1973; Fraser, 1987). Fraser showed an increase in chewing on a blood covered model compared to a plain model, with pigs fed a nutritionally balanced diet. When minerals were removed from the diet, chewing on the plain model remained stable whereas chewing on the blood covered model significantly increased. A salt-deficient diet was shown to elicit an increased chewing response to the blood covered model compared to a diet deficient in all minerals except sodium chloride.

Environmental enrichment has had varying degrees of success in controlling deviant behaviors. Straw has been shown to help control and reduce the occurrence once tail biting has begun (Van Putten, 1969; Hansen and Hagelso, 1980; Madsen, 1980). Artificial enrichment devices (tires, chains, etc.) appear to have limited success in controlling this behavior (Madsen, 1980).

Human-animal interactions which are abusive to the animal have been shown to increase stress levels and jeopardize animal welfare. The animal-animal bond developed in group housing situations may help alleviate part of this stress, but animals under constant stress are more susceptible to performance problems, disease, and deviant behaviors. The

controversy develops concerning identifying the level of environmental complexity and human interaction that causes the animal to suffer. The minimum handling studied in recent years has indicated little or no advantages compared to extensive pleasant handling treatments. With advancements in technology (computerized feeding systems, automated ventilation, manure handling systems, etc.), the need for the producers to extensively interact with livestock no longer exists. This further reduces the complexity of the animals environment and may lead to handling problems, and unacceptable pork quality delivered to the consumer.

The objectives of this thesis are to examine the effects of human interaction and/or physical enrichment devices on pig growth, behavior, body composition and meat quality.

**Table 2.1. Enrichment devices used to alter animal environments' physical complexity
(Mod. after Pedersen, 1992)**

Category of Enrichment	Reference
<u>Macroenvironmental design features</u>	
Exercise facilities and devices	Beaver (1989)
Hiding areas	McGlone and Curtis (1985); Gray (1988) Pederson (1992)
Ledges and Perches	O'Neil (1988); Beaver (1989)
Mazes	Nehring (1981); Simonsen (1990)
Mezzanines	Fraser et al. (1986); Pedersen (1992)
Nest boxes	Snowdon et al. (1985)
Ramps	Phillips et al. (1988); Pedersen (1992)
Ropes and branches	Reinhardt (1989a); Wood-Gush et al. (1990)
Visual Screens	Reinhardt (1989b)
<u>Maintenance activity enhancers</u>	
Branches	Reinhardt (1989a); Wood-Gush et al. (1990); Haskell (1996); Petersen et al. (1995)
Clawscratcher	Tauson (1981)
Dust baths	Wegner (1980)
Manipulable objects	Geenough and Juraska (1979); Eterovic and Ferchmin (1985); Westergaard and Fragasky (1985); Widowski (1988); Beaver (1989); Grandin (1988); Pearce et al. (1989); Schaefer et al. (1990); Pedersen (1992)
Nesting material	Wiowski (1988); Haskell et al. (1996)
Rooting areas	Stolba (1981); Stolba and Wood-Gush (1984)
Rubbing Posts	Stolba (1981)
Showers	Simonsen (1990)
Sticks	Champoux et al. (1987)
Substrate	Chamove et al. (1982); McKenzie et al. (1986)
<u>Foraging activity enhancers</u>	
Alternative feeding devices	McGrew et al. (1986)
Food puzzle boxes	Bloomstrand et al. (1986)
<u>Technological devices</u>	
Joystick video tasks	Rumbaugh et al. (1989)
Television	Rumbaugh et al. (1989)

CHAPTER III

MATERIALS AND METHODS

3.1 Animals

A total of four blocks and 160 pigs of each genotype were examined (320 pigs total). Each block was initiated using PIC Camborough-15 X 405 (C-15) or EXP 94 X 405 (EXP-94) pigs. The C-15 is a commercially available prolific maternal line developed from a Yorkshire, Landrace and Duroc cross. The EXP-94 is an experimental line developed from a standard C-15 crossed with Meishan. The offspring used in this study were 12.5 % Meishan. PIC 405 line was used as the sire line for all offspring, the 405 is a composite line based on the Hampshire, Pietran and other breeds.

Pigs were housed in pens containing 8 pigs each with each block containing five treatment pens of a given genotype. Treatments had varying degrees of human interaction and environmental enrichment, which are described in detail below.

3.2 Allotment and treatments

Pigs were weighed one day prior to weaning, and were randomly allotted to one of five treatment pens. Treatments were as follows.

3.2.1 Treatment 1 -- Weekly Normal Management (CON)

Pigs were treated as they normally are on many commercial farms. Pigs were handled at litter processing, weaning, moving from nursery to growing-finishing and at

market weight. In addition, while in the nursery and grower-finisher, pigs were viewed from the aisle each day and once per week from within the pen to ensure the proper operation of the feeder and waterer. No other handling (body weights, bleeding, etc.) treatments were performed to more closely simulate the experiences of pigs in some commercial settings.

3.2.2 Treatment 2 -- Daily Normal Management, Plus Enrichment (TOYS)

Handling in this treatment consisted of entering the pen daily to check feeder and waterer for proper operation, environmental enrichment devices were also provided. Each pen in this treatment had a combination of 2 chains and 2 rubber hoses hanging from above during all of nursery and growing-finishing. The environmental enrichment devices were spring loaded, with a 17.78 cm high tensile extension spring. The chains were 0.79 cm galvanized chain, they were attached to the spring with quicklinks. The hose devices were developed by attaching a 45.72 cm long piece of 5.08 cm diameter nylon reinforced anhydrous ammonia hose to the chain device with a 0.95 cm diameter bolt. The bolt was placed 5.08 cm from the top of the hose, 4 links (15.24 cm) of the chain extended into the the hose. Hoses were replaced, if damaged to the point where chain appeared from the bottom of the hose.

3.2.3 Treatment 3 -- Negative Control (NEG)

Pigs were housed in pens containing solid walls 1.22 m high to limit the pigs' outside distractions. These pigs had no contact with humans except at litter processing,

moving from farrowing to nursery, moving from nursery to grow-finish and during the final behavioral tests. Humans observed the pen, from the aisle, once per day, but they did not enter the pens.

3.2.4 Treatment 4 -- Positive Control Plus Enrichment (T+H)

This positive control represents a farm with maximum environmental enrichment. Pigs had the same experiences as pigs in treatment 2 (toys plus daily contact) but in addition the “pleasant” experiences described by Hemsworth et al. (1986) were applied as well. In the “pleasant” experience, the human subject squatted in the pen for 2 minutes and when pigs approach, they gently talked to and petted the pigs.

3.2.5 Treatment 5 --Positive Control (HUM)

This positive control represents a farm with frequent human-pig contact. Pigs had the same handling experiences as pigs in treatment 4 (daily contact and pleasant experiences) but no environmental enrichment devices (chains and/or rubber hoses) were provided.

3.3 Housing and Common Features

Weanling pigs were placed in one of two nursery facilities at the Texas Tech swine facility. Each nursery was divided in half by building a dividing wall. The back or isolated half of each nursery was used for this experiment, providing a quiet undisturbed environment free from distractions or human interaction not required by the experimental

protocol. The east nursery layout consisted of two rows of pens, one pen on either side of a 1.22 m alleyway. Each pen measured 2.23*1.52 m and was on woven wire flooring above a shallow pit which was cleaned with a gravity flow flush system 5 times per day. The west nursery consisted of 3 rows of pens. One against the west wall separated from the other two by a 1.22 m alleyway. The two were butted together in parallel fashion. The pens in the west nursery measured 1.68*1.52 m, on woven wire above a shallow pit which was cleaned with a gravity flow flush system 5 times per day. Each nursery pen contained a 5-hole steel nursery feeder butted along the alley gate and a nipple waterer placed 25.4 cm above the woven wire on a 45° angle. Pens were separated with a 76.2 cm high gating system, except for the negative treatment which had 1.91 cm thick plywood attached to the gates making a 1.98 m high solid pen divider. All pigs were subjected to 16 hours of light and 8 hours of darkness per day. Nursery pens were randomly selected for location within each room and prepared with the necessary manipulations for each treatment.

At weaning each pig was administered 1cc of Tylan (Elanco), this treatment was followed by five days of water medication with Aparalan (Elanco) antibiotic beginning three days after the allotment. Handling treatments began after a three day environmental adaptation period after weaning (28 days of age). The pigs were provided free access to a 18% crude protein feed. Feed was weighed prior to the addition to the feeder. Feed was added every other day to maintain freshness and quality. Standard operating procedure for environmental control for Texas Tech nursery facility was followed, including beginning optimal air temperature of 30°C and lowering the temperature 1.11°C per week. Air temperature extremes, and observations were recorded about each pig's

health, performance, and behavioral characteristics on a daily basis. This procedure allowed precise control of the environmental systems and detailed records about overall performance.

Following the weighing procedure, animals were placed in a holding pen (0.91*1.22 m). Once the entire treatment pen was weighed, animals were driven with panels, in a quiet and gentle method and loaded onto a hydraulic livestock trailer. The alley measured 4.88 m long from the holding pen to the outside doorway, and the livestock trailer was placed on the ground at the end of a 1.52 m concrete platform. Two pens of animals were moved in the livestock trailer, separated by a sliding gate, with the exception of the isolated pigs which were always moved in a single group to eliminate any contact with other pigs. The animals were then moved to the finishing barn, unloaded and driven down the alleyway to their finishing pen. Finishing pens were randomly selected for location, and prepared with the necessary adaptations for each treatment prior to the moving procedure. The environmental enrichment devices (chains and hoses) were recovered from the nursery setting, and placed in the corresponding finishing pen.

The finishing facility consisted of 30 finishing pens measuring 3.71*2.13 m. Pens were arranged on each side of a 1.32 m alleyway. Pens were separated with a 91.44 cm high gating system, except for the Negative treatment which had 1.91 cm thick plywood attached to the gates making a 1.22 m high solid pen divider. Pigs were subjected to 16 hours of light and 8 hours of darkness per day. Each pen was equipped with a three-hole feeder located along the alleyway side of the pen which was weighed prior to placement into the pen, a nipple water, 40.64 cm in height on a 90° angle, was located in the middle

of the pen along the back wall. Since the animals were moved from the nursery one week earlier than normal operating procedure, a concrete block was placed under each nipple waterer to increase access for the pigs for one week. The concrete blocks were retrieved, after seven days, during daily routine treatments for the handled treatments, for the less handled pens the concrete blocks were retrieved by snagging them from outside the pen using an 2.44 m long hook.

The feeding schedule consisted of three feed types: an 18 % crude protein nursery feed, an 16% crude protein grower feed and a 14% crude protein finisher feed. The grower feed was fed for the first 100 days of the grower-finishing stage, prior to switching to the finisher feed for the completion of the trial. Feed was added to the feeder approximately 3 times per week. All feed was weighed prior to the addition to the feeder. Feeders were checked once per week for adjustment and proper operation, feeders in the isolated treatment pens were checked by raising the feeders lids with a long hook and making the necessary adjustments from outside the pen area.

Standard operating procedures for environmental control facility were followed, including maintaining an optimal air temperature of 21°C and the use of an above pen sprinkler system when temperatures reached 26°C. Air temperature extremes and observations about each pens health, performance, and behavioral characteristics were recorded on a daily basis. This procedure allowed precise control of the environmental systems and detailed records about overall performance.

Following the weighing and animal evaluation procedure, 20 pigs were selected from each replication (4 per treatment) which most approximately represented the 113 kg

slaughter weight (110.7-136.5 kg). An even sex ratio was maintained as closely as possible while still meeting the packers (Seaboard Farms Inc., Guymon OK) selection criteria. Animals were individually marked with livestock marking pens according to their handling treatments 24 hours prior to shipment. Pigs were loaded by treatment, in a randomized fashion, in early morning (0200) from the Texas Tech Swine facility, in a quiet and gentle manner to avoid additional stress. Early morning transport was adopted to avoid temperature extremes during the hot Texas summer. No bedding material was used to avoid any changes in enrichment over the seasons.

3.4 Behavioral Measures

Twenty-four hour red lighting was implemented above each treatment pen in the nursery, in addition to normal lighting, five days prior to the beginning of a video taping session. Videotaping began 24 (18 to 26) days after movement into the nursery facility. Treatments were taped in a random pattern. Each pen was taped for a 24-hour period. Tapes were recorded at 0.83 frames per second and were analyzed at 5 or 30 frames per second depending on the behavior being examined. Tapes were examined for duration of lying, eating, and drinking for all treatments. Treatments of TOYS and T+H were also examined for duration of chain and hose interaction.

Upon the completion of 28 (27 to 29) days in the nursery facility, a 2 minute human interaction test was performed in each pen in a randomized order within each replication. The human interaction test consisted of an experimenter entering the home nursery pen, squatting against the wall with hands on knees remaining still and allowing

the pigs to approach. The time to first contact of a pig with the experimenter was recorded, along with notes about the animal environment. The interaction test was videotaped at 30 frames per second to allow further investigation into the frequency and duration of human-pig interactions.

Twenty-four hour red lighting was implemented above each treatment finishing pen within the replication, in addition to normal lighting one week prior to the beginning of a video taping session. Videotaping began 115 (110 to 125) days after movement into the finishing facility. Treatments were taped in a random pattern. Each pen was taped for a 24-hr period. Tapes were recorded at 0.83 frames per second and were analyzed at 5 or 30 frames per second depending on the behavior being examined. Tapes were examined for duration of lying, eating, and drinking for all treatments. Treatments of TOYS and T+H were also examined for duration chain and hose interaction.

When average pig weights in a replication approached 113 kg, a second 2 minute human interaction test was performed. As with the human interaction test at the conclusion of the nursery stage, an experimenter entered the pen and squatted against the wall. The experimenter remained still with hands on knees and allowed the pigs to approach. Time to first contact by a pig with the experimenter was measured, the interaction test was videotaped at 30 frames per second allowing further investigation of the frequency and duration of human-pig interactions.

During the final weighing and evaluation session, the time required for the animals to move from their home pen to the holding area was recorded. Time required to weigh the pen of animals was recorded as was return time to their home pen. Distances from

each home pen to the prescale holding area and the return distance from the post-scale holding area were measured. Movement times were expressed as a speed in m/minute.

Following the unloading procedure at the Seaboard Pork Processing Facility in Guymon OK, animals were driven to a resting pen and then observed at 5 minute intervals from an overhead catwalk by Texas Tech personnel. The number of animals engaged in identified behaviors were recorded along with notes about the surrounding environment. Behaviors were broken down into five basic categories; lying, standing, locomotion, drinking and fighting. The animals engaged in aggressive activity were identified by treatments from color-coded markings along their back.

3.5 Performance Measures

Following the completion of the human interaction test at the end of the nursery stage, animals were weighed individually on a platform scale and placed in a holding pen (0.91*1.22 m). All feeders were weighed following the completion of the moving procedure of the animals.

Once the final human interaction test was completed for all treatments in the replication, animals were moved by pen to the scale area located in the middle of the finishing facility. Animals were moved in a quiet and gentle fashion using moving panels. Animals were then individually weighed, scored for ease of movement onto the scale (1 to 5, 1=no assistance required), scored for ear and tail damage (0 to 3, 0=no signs of physical damage), and tattooed in the shoulder and hams with a two digit treatment identification

number. While the animals were being tattooed and the home pen was empty, a portable scale was used to weigh the feeder.

3.6 Slaughter Plant Procedure

Pigs arrived at the Seaboard Farms pork processing facility in Guymon, OK between 0900 and 1000 hours. Pigs were unloaded by Texas Tech personnel according to plant animal flow. Animals were unloaded in as quiet and gentle method as possible to avoid additional stress prior to slaughter. Paddle-stix (plastic paddles filled with beads) were used to move pigs from the trailer and through the slaughter facility. Animals were group weighed and tattooed with a plant lot identification number prior to being moved to their resting pen. Animals had access to water and when the temperature required fenceline water misters were activated for 1 minute on a 15 minute cycle. Animals remained in their resting pen for approximately 2.5 hours (1.75 to 4.5 hours) prior to slaughter. Standard plant slaughtering procedures were followed. All animals were identified by treatment code and carcass number immediately upon exiting the scalding tank with an edible Meatmark Crayon (Auckland, New Zealand). Once carcasses were identified, they were grouped to insure equal time from slaughter to freezer. All identification numbers were checked three times to ensure accuracy prior to the carcasses entering the blast cooler.

Carcasses were processed 20 hours after slaughter. A 10 cm sample was collected from the midline of the trimmed Longissimus muscle during the processing procedure. Samples were immediately vacuum packaged and boxed. The samples were transported

to the Texas Tech University Meats Lab. Loin samples were aged 14 days in a 2°C cooler prior to slicing into 2.5 cm chops which were labeled and vacuum packed for placement in a -29°C freezer. Chops remained frozen until all replications were completed.

3.7 Meat Evaluation

Following standard slaughtering procedures at the Seaboard Farms pork processing facility, carcasses were probed at the tenth rib with a Fat-O-Meat'er (SFK Technology, Soborg Denmark) and hot carcass weight was determined prior to entering the blast cooler. This procedure provided hot carcass weight, percent lean, loin depth, backfat thickness, and reflectance. In addition to standard information provided the customer for pricing and quality comparisons, individual carcass Fat-O-Meat'er data was provided by Seaboard Farms pork processing facility to allow comparisons with data recorded by Texas Tech personnel as the Fat-O-Meat'er procedure was completed to insure accuracy.

Carcasses were evaluated 16 hours after slaughter, evaluation included measurement for backfat thickness opposite the first rib, last rib and last lumbar vertebrae. USDA carcass muscle scores were subjectively determined by trained Texas Tech University personnel, and carcass lengths were measured from the anterior edge of the first rib to the anterior edge of the aitch bone. Seaboard Farms Quality Assurance personnel measured pH with a Unifet Microprocessor model UF100-01 pH probe (IQ Scientific Instruments Inc., San Diego, CA) in the shoulder as prescribed by their testing procedures for export product.

Forty-eight hours after slaughter, loin samples were removed from the cooler and ultimate pH was measured on each sample with an Orion Model 230A pH meter (Orion Research Inc., Boston, MA) fitted with a glass probe. Hunter L*, a*, and b* measurements (Owen, 1995; Milligan 1996) were taken with a Minolta Chroma Meter (portable CR-200b 212410390 Colorimeter, Osaka, Japan). Samples were immediately vacuum packaged and returned to the cooler for aging.

Two loin chops were removed for each sample and thawed for 24 hours at 2°C. Initial weight was determined for each pair of chops prior to placement on a foil lined Faberware open hearth grill. All chops were cooked to an internal temperature of 40°C prior to being turned. Chops were removed when the internal temperature reached 70°C. Cooked chops were then weighed to allow determination of percent cooking loss. Time of placement of chops onto the grill and removal were recorded. External fat, connective tissue and cooked edges were removed prior to cutting into 1.0 cm³ cubes. Samples were placed in pans over warmed sand. A 6-member taste panel trained by procedures of Cross et al. (1978) evaluated samples on an eight point scale for initial and sustained juiciness, initial and sustained tenderness, flavor intensity, pork flavor and overall mouth feel. The panel was conducted in a randomized fashion in individual booths under red lighting conditions to mask color differences. Each booth contained water and apple juice for the panelist to rinse their palates between samples, a cup for expectoration, a plate with two toothpicks, and a napkin. Each panelists was provided a pencil and sensory data form to record their responses.

A third loin chop was removed from each sample and thawed for 24 hours in a 2°C cooler. Initial weight was determined for each chop prior to placement on a foil lined Faberware open hearth grill. All chops were cooked to an internal temperature of 40°C prior to being turned, chops were removed when the internal temperature reached 70°C. Cooked chops were then weighed to allow determination of percent cooking loss, time of placement of chops onto the grill and removal were recorded. Chops were placed in a 2°C cooler for 24 hours on a tray overwrapped with polyvinylchlorid wrap. Six 1.3 cm diameter core samples were obtained from each chop. Samples were taken from the chop parallel to the muscle fiber orientation. Each sample was sheared once with a Salter Warner-Bratzler shear device (model 9406482, Manhattan KS) as previously described (Owen, 1995; Milligan, 1996).

3.8 Statistical analysis

The experimental design was a randomized complete block with five treatments and two genotypes. The pen was the experimental unit. A total of 40 experimental units (8 pigs each) were evaluated (5 treatments X 2 genotypes X 4 blocks each). Complete blocks were started at weaning and treatments continued until a slaughter weight averaged 113 kg. A total of four blocks and 160 pigs of each genotype were evaluated (320 pigs total). Each block was initiated using C-15 or EXP 94 pigs. Data were analyzed using the analysis of variance and GLM procedure of SAS (SAS, 1990). The main plot effects were Treatment, Genotype, and Treatment by Genotype interaction. The 24-hr behavior duration data were analyzed using a split-plot design with 12 time periods over the 24

hour day. Percent mortality were analyzed by chi-square analysis. Separate analysis were calculated for the nursery and finishing stages.

CHAPTER IV

RESULTS

4.1 Production Performance

Pig growth and feed efficiency were consistent among treatments in the nursery stage of production ($P>.05$). Pig growth and feed efficiency were not significantly influenced by the environmental treatments in finishing ($P>.05$). Performance was generally better for the C-15 compared with the EXP-94 genotype (Table 4.1). The genotype effect was significant for final body weight (118.3 and 106.5 ± 3.92 ; C-15 vs EXP-94, respectively), F:G ratio (3.02 and 3.29 ± 0.07) and ADFI (1.95 and 2.10 ± 0.04) in finishing ($P<.05$).

In finishing the genotype by treatment interaction was nearly significant ($P = .07$) for ADG (Fig 4.1) and F:G ratio (Fig 4.2). Within the C-15 genotype, no treatment effect was observed for either measure. Whereas within the EXP-94 genotype, ADG for pigs in the TOYS treatment was significantly greater ($P<0.05$) than for the HUM, T+H, and NEG treatments. The F:G ratio for pig in the TOYS treatment was improved ($P<0.05$) compared to the HUM, T+H, and NEG treatments.

Treatment, genotype and treatment by genotype interaction were not significant for weaning weight, weight at the end of the nursery period, ADG in the nursery, ADFI in the nursery, F:G ratio in the nursery and days to 113 kg.

4.2 Carcass Characteristics and Pork Quality

Enrichment treatments significantly altered measured backfat thickness (Table 4.2). There were no treatment effects for backfat opposite the first rib, but the NEG treatment showed a reduction ($P < 0.05$) in backfat opposite the last rib compared to the other treatments. Pigs in the CON and T+H treatments were lower than the HUM treatment ($P < .01$). For backfat measured opposite the last lumbar vertebrae, NEG treatment pigs were leaner than the other treatments ($P < .05$). When averaged, these measures showed the pigs in the NEG treatment were leaner ($P < 0.05$) than the CON, TOYS, and HUM treatments. Pigs in the T+H treatment were neither fatter than the NEG nor leaner than the CON and TOYS pigs, but they were leaner than the HUM treatment pigs ($P < .05$). Pork quality measures (Table 4.2) were not affected by the range of rearing conditions studied in this experiment ($P > .05$).

Genetics had a much greater effect on carcass characteristics and meat quality than did the environmental treatments (Table 4.3). The genotype effect was significant for carcass weight (which was subsequently used to correct other measures), muscle score, backfat, loin depth, percent lean, pH, L^* , a^* , b^* , cooking time, sustained juiciness, and pork flavor ($P < .05$).

Treatment, genotype and treatment by genotype interactions were not significant for loin pH, first rib backfat, reflectance, carcass length, doneness score, initial juiciness, initial tenderness, sustained tenderness, flavor intensity, mouthfeel and shear value.

4.3 Mortality

Nursery mortality was not significantly altered by treatments, genotype or their interaction (Fig 4.3; range from zero to 6.3 percent). Finishing mortality (Fig 4.4) was significantly different between genotypes and environments. When comparing treatments within a genotype, the C-15 genotype (chi-square=17.65, $P<.01$) had a percent mortality range of 3.1 for the NEG treatment to 37.5 for the T+H. The EXP-94 (chi-square=1.63, $P<.01$) had a much narrower range, with a percent mortality for the NEG treatment of 6.3 to a high of 15.6 for the TOYS treatment. When mortality data were summed for nursery and finishing stages, the analysis showed a genotype by environment effect (Chi-Square=7.95, $P<.01$). Overall mortality is illustrated in Figure 4.5, with detailed analysis and comparisons illustrated in Appendix D.

4.4 Animal Behavior During Human Interaction

Treatments altered the time to first contact and duration of contact with the experimenter during the two minute human interaction tests (Fig 4.6). For both tests, it took longer for the pigs in the NEG treatment to make first contact and they spent less time in contact with the experimenter (Fig 4.7) than the other four treatments ($P<.01$). For the final human interaction tests, time spent in contact with the experimenter was reduced ($P<.01$) for the TOYS, HUM and T+H treatments compared to the nursery test (Fig 4.8). During the final human interaction test, frequency of animal contact was also decreased ($P<.05$) for the CON, TOYS, HUM and T+H compared to the nursery test, which showed a higher frequency of interactions with the experimenter for the HUM

compared to the NEG, CON, and TOYS ($P < .05$). The response shown by pigs towards humans did not effect the ability to move or weigh these pigs effectively (Table 4.4) ($P > .10$), although the genetic makeup did have a significant effect (Table 4.5) on the speed of pig movement (8.77 and 6.63 ± 0.71 m/min for C-15 and EXP-94, respectively) and the time required to weigh each pen (6.73 and 8.00 ± 0.49 minutes; Table 4.4).

4.5 Animal Behavior in Home Pens

Overall duration of the basic behaviors (Table 4.6 and Table 4.7) studied (lying, feeding, drinking) were not effected by rearing environment ($P > .05$). Enviromental enrichment devices were interacted with for 12.96 minutes per day on average. Pigs in the nursery stage interacted with the devices 11.49 minutes per day, this interaction time increased to 14.43 minutes per day in the grower-finisher facility. The pigs in finishing interacted with the hose device more than the chains (19.08 versus 9.78 minutes), whereas in the nursery time was split equally between the different types of devices (11.64 versus 11.34 minutes). Treatment by time interaction was very significant for lying (Fig 4.9) and feeding (Fig 4.10) behavior ($P < .01$) in the nursery facility, the NEG treatment had a more stable behavior pattern for lying and feeding behavior.

Genotype had an influence when comparing the pattern of basic behaviors over a 24 hour period. The genotype by time interaction was significant for lying (Fig 4.11) and feeding (Fig 4.12) behaviors ($P < .01$) in the nursery. The C-15 genotype demonstrated a greater range of fluctuation in their behavior patterns.

When broken down by two hour periods, time of day had a large effect on determining the amount of time spent engaged in each behavior in both stages of production, except for hose interaction while in the nursery stage. Significant time of day effects are outlined in graphical form in Appendix C.

Table 4.1. Least squares means for pig performance

Measure	Control	Toys	Human	T + H	Negative	SE
C-15 genotype						
Number of blocks	4	4	4	4	4	
Weaning Weight (kg)	7.23	7.63	7.61	7.32	7.29	0.4309
End-of Nursery (28d)(kg)	27.85	29.58	29.00	28.53	28.63	1.58
Finishing weight, kg	118.24	117.21	121.33	112.63	122.24	8.76
ADG, kg/d--NUR (kg)	0.20	0.21	0.20	0.21	0.21	0.02
ADG, kg/d--FIN(kg)	0.68	0.61	0.64	0.70	0.64	0.05
ADFI, kg/d--NUR(kg)	0.39	0.38	0.38	0.38	0.37	0.03
ADFI, kg/d--FIN(kg)	1.91	1.99	1.88	1.94	2.04	0.09
F:G ratio--NUR(kg)	1.93	1.83	1.93	1.87	1.75	0.10
F:G ratio--FIN	2.86	3.25	2.96	2.82	3.22	0.17
Days to 113 kg	206.83	219.52	214.96	205.64	214.87	10.36
EXP-94 genotype						
Number of Block	4	4	4	4	4	
Weaning Weight (kg)	7.63	7.25	7.46	7.57	7.20	0.43
End-of Nursery (28d) (kg)	13.24	12.81	13.08	12.75	13.31	0.72
Finishing weight, kg	114.28	109.91	100.29	100.29	107.79	8.76
ADG, kg/d--NUR (kg)	0.21	0.21	0.20	0.19	0.22	0.02
ADG, kg/d--FIN (kg)	0.68 ^{ab}	0.76 ^a	0.61 ^b	0.57 ^b	0.61 ^b	0.05
ADFI, kg/d--NUR (kg)	0.38	0.38	0.35	0.34	0.38	0.03
ADFI, kg/d--FIN (kg)	2.11	2.21	2.08	1.99	2.11	0.09
F:G ratio--NUR	1.83	1.81	1.79	1.94	1.74	0.10
F:G ratio--FIN	3.06 ^{ab}	2.96 ^b	3.49 ^a	3.48 ^a	3.48 ^a	0.17
Days to 113 kg	204.72	191.35	224.45	232.45	221.28	10.36

^{a, b} Means within a row with uncommon superscripts differ $P < 0.05$

NUR=in the nursery stage

FIN=in the finishing stage

Table 4.2. Treatment effects on carcass characteristic

Measure	Control	Toys	Human	T + H	Negative	SE
Number of blocks	8	8	8	8	8	
First Rib (cm)	4.32	4.47	4.47	4.01	4.11	0.16
Last Rib (cm)	2.90 ^b	3.00 ^{ab}	3.12 ^a	2.90 ^b	2.64 ^c	0.08
Last Lumbar (cm)	2.64 ^a	2.72 ^a	2.79 ^a	2.64 ^a	2.29 ^b	0.10
Avg Backfat (cm)	3.28 ^{ab}	3.40 ^{ab}	3.45 ^a	3.18 ^{bc}	3.00 ^c	0.09
Muscle Score	2.1	2.09	2.08	2.00	2.03	0.08
Carcass Length (cm)	83.10	83.10	83.39	82.93	83.72	0.61
Backfat (cm)	2.77	2.51	2.69	2.79	2.34	0.38
Loin Depth (cm)	5.13	5.59	5.54	5.56	5.69	0.17
% Lean	49.47	49.86	49.70	50.74	51.05	0.56
Sensory Evaluation Data						
% cook loss	29.02	28.46	27.61	29.69	29.76	1.95
Doneness score	4.03	4.00	4.00	4.06	4.00	0.03
Cooking time	38.56	37.60	37.37	38.54	40.32	1.63
Initial juiciness	5.36	5.25	5.14	4.98	5.06	0.25
Sustained juiciness	5.49	5.27	5.16	4.90	5.05	0.28
Initial tenderness	6.18	5.90	5.88	5.95	6.00	0.20
Sustained tenderness	6.47	6.08	6.15	6.20	6.18	0.19
Flavor intensity	6.09	6.02	5.86	5.87	5.95	0.12
Pork flavor	6.31	6.22	6.18	6.14	6.14	0.10
Mouthfeel	5.91	5.62	5.56	5.42	5.53	0.23
Shear value--kgs	1.34	1.35	1.34	1.32	1.37	0.05

^{a, b, c} Means within a row with uncommon superscripts differ $P < 0.05$

Table values are least squares means

Table 4.3. Genotype effects on meat quality measures

Measure	C-15		EXP-94	SE
Number of blocks	20		20	
Carcass wt (kg)	95.52	*	86.96	1.64
First Rib (cm)	4.39		4.14	0.11
Last Rib (cm)	2.84		3.00	0.06
Last Lumbar (cm)	2.54		2.69	0.07
Avg Backfat (cm)	3.25		3.28	0.06
Muscle Score	2.16	*	1.96	0.05
Carcass Length	83.72		82.75	0.43
Plant pH	6.10	*	6.52	0.09
TTU pH	5.45		5.39	0.03
Minolta L*	52.46	*	55.38	0.84
Minolta a*	7.95	*	8.78	0.21
Minolta b*	3.58	*	4.71	0.28
Backfat (cm)	1.80	*	3.43	0.28
Loin Depth (cm)	5.74	*	5.26	0.12
% Lean	51.58	*	48.75	0.39
Reflectance	50.18		46.50	2.54

* P < 0.05

Table values are least squares means

Table 4.4. Least squares means for animal movement measures

Measure	Control	Toys	Human	T + H	Negative	SE
Number of blocks	8.00	8.00	8.00	8.00	8.00	
Time to hold	2.74	2.91	2.98	2.58	3.11	0.28
Distance to hold (m)	22.8	22.68	21.08	21.08	24.55	3.16
Meters per min--hold	7.71	7.75	7.14	7.79	8.08	1.12
Time to weigh	7.68	7.40	7.30	6.49	7.95	0.77
Return time to pen	2.00	2.16	2.41	1.84	2.40	0.27
Distance to home pen (m)	32.40	34.27	32.40	32.67	36.13	3.18
Meters per min--home	12.29	13.16	13.43	12.37	13.51	2.15
Total time	40.32	43.18	44.05	40.59	44.33	21.32
Weigh score	2.74	2.59	2.58	2.64	2.85	0.17

Table 4.5. Genotype effects on animal movement

Measure	C-15		EXP	SE
Number of blocks	20.00		20.00	
Time to hold	3.01		2.72	0.18
Distance to hold (m)	26.31	*	17.78	2.01
Meters per min--hold	8.77	*	6.63	0.71
Time to weigh	6.73		8.00	0.49
Return time to pen	2.33		2.00	0.17
Distance to home pen (m)	37.89	*	29.25	2.01
Meters per min--home	18.08		15.45	1.36
Total time	46.03		38.96	13.49
Weigh score	2.61		2.75	0.11

* P < 0.05

Table values are least squares means

Table 4.6. Basic behavior measures for pigs during the nursery stage of production

Measure	Control	Toys	Human	T + H	Negative
Lying	74.45	74.05	75.38	73.97	75.42
Feeding	13.46	15.07	13.01	14.93	14.32
Drinking	1.17	1.48	0.96	1.11	1.25
Hose Interaction	--	1.34	--	0.60	--
Chain Interaction	--	1.02	--	0.87	--

Table 4.7. Basic behavior measures for pigs during finishing stage of production

Measure	Control	Toys	Human	T + H	Negative
Lying	82.23	86.32	82.03	82.67	81.31
Feeding	8.20	8.71	8.09	5.59	6.36
Drinking	1.37	1.05	0.83	1.24	0.92
Hose Interaction	--	1.69	--	1.49	--
Chain Interaction	--	0.77	--	0.86	--

No significant treatment effects

Table values are least squares means for a 2 hour period

Figure 4.1. Average daily gain in finishing stage (kg/d)
 Treatment by genotype interaction ($P = 0.07$) $N = 320$ total animals
 Means with differing superscripts differ between treatments ($P < 0.05$)

Figure 4.2. Feed : Gain ratio in finishing
 Treatment by genotype interaction ($P = 0.07$) $N = 320$ total animals
 Means with differing superscripts differ between treatments ($P < 0.05$)

Figure 4.3. Nursery mortality (Chi-Square, $P > .01$)
N=320 total animals

Figure 4.4. Finisher mortality (Chi-Square $P < 0.01$)
N = 320 total animals

Figure 4.5. Wean to market mortality (Chi-Square, $P < 0.01$)
N=320 total animals

Figure 4.6. Time to contact of the pigs with the experimenter (Treatment effect, $P = 0.001$)

N = 320 total animals

Means with differing superscripts differ between treatments ($P < 0.05$)

Figure 4.7. Percent of time in contact of the pigs with the experimenter ($P = 0.001$)

$N = 320$ total animals

Means with differing superscripts differ between treatments ($P < 0.05$)

Means with * differ in finishing (within one week of slaughter) from the same treatment mean during the nursery phase (8 weeks of age)

Figure 4.8. Frequency of animal contact with the experimenter ($P = 0.002$)

N = 320 total animals

Means with differing superscripts differ between treatment ($P < 0.05$)

Means with * differ in finishing (within one week of slaughter) from the same treatment mean during the nursery phase (8 weeks of age)

Figure 4.9. Lying in nursery (Time of day * treatment effect, $P < 0.05$, $SE = 6.45$)
($N = 4$ pens/point) $N = 160$ total animals

Figure 4.10. Feeding in nursery (Time of day * treatment effect, $P < 0.05$, $SE = 3.17$)
($N = 4$ pens/point) $N = 160$ total animals

Figure 4.11 . Lying in nursery (Time of day * genotype effect, $P < 0.01$, $SE = 3.6$)
($N = 9 - 10$ pens/point) $N = 160$ total animals

Figure 4.12. Feeding in nursery (Time of day * genotype effect, $P < 0.01$, $SE = 2.0$)
($N = 10$ pens/point) $N = 160$ total animals

CHAPTER V

DISCUSSION

5.1 Effects of Environmental Treatments on Performance Characteristics

Averaged over genotypes, growth and efficiency measures were not effected by the range of environmental treatments performed. This agrees with many of the environmental enrichment and human handling studies performed in the past (Grandin, 1988; Pearce et al., 1989; Paterson and Pearce, 1989; Pedersen, 1992; Pearce and Paterson, 1993;), although in the finishing stage average daily gain (ADG) and Feed to Gain ratio (F:G) for the EXP 94 animals did show performance differences among treatments. EXP-94 pigs exposed to the TOYS treatment had improved ADG and F:G ratio compared to the HUM, T+H and NEG treatment.

The genetic by environment interaction may help to explain in part some of the difference in results of the recent environmental and human handling studies. Pearce et al., (1989) suggested that the larger group housing size provides some protection from the effects of handling treatments. The pen size in our study (8 animals) appeared adequate to alleviate the stress imposed, by the environment, for the C-15 genotype. The EXP-94 genotype may be more sensitive to stress, therefore group size and housing conditions may have to be altered to achieve maximum performance from this genotype.

5.2 Carcass Characteristics and Pork Quality

Isolation (NEG treatment) produced a leaner carcass at slaughter than the other treatments. These data disagrees with Warriss et al. (1983) whom reported a slight decrease in backfat for animals in an enriched environment housed in outside pens. This disagreement may be due to the lack of control of environmental enrichment and human interaction during the Warriss et al. (1983) study. Nutrition may also account for some differences obtained by the animals housed in lots with medium for rooting and chewing. The results of our study agree with Pearce et al. (1989), no difference was found in backfat as measured with a backfat probe, but no further analysis was conducted in the Pearce et al. (1989) study.

Genetics did affect the overall pattern of backfat thickness deposition between the treatments. The EXP-94 genotype had a greater amount of backfat opposite the last rib and at the 10th rib, as measured with the Fat-O-Meat'er probe ($P < 0.05$). There was a trend for more backfat in the EXP-94 genotype for all the measures taken, in weight matched animals. This is consistent with the literature regarding the carcass qualities of the Meishan breed (Young, 1992; Lan et al., 1993; White et al., 1993).

When animals were properly handled during loading, transport and slaughter procedures pork quality was not affected by any of the treatments, this disagrees with Warriss et al. (1983) whom found a paler pork product with animals produced in intensively housed indoor environments compared with outdoor reared animals in enriched environments. This may again be explained by the nutritional factors gained during

rooting and exploration of an outside environment, and the lack of control of the environmental enrichment and human handling scheme employed by Warriss et al. (1983).

Both genotypes provided consumer acceptable pork quality, even though there was a slight effect of the animal's genetic makeup on pork quality measures. These included a higher percent cooking loss, with decreased sustained juiciness and pork flavor for the EXP-94 genotype.

5.3 Effect of Environmental Treatment on Human Interaction

Behavior towards humans was significantly altered by the rearing conditions. Isolation (Neg treatment) increased the time to approach and reduced the duration of time the pigs spent in contact with the experimenter. This treatment was an extreme form of the minimal treatments employed during other handling experiments, since the only human contact was during weighing and animals were housed in completely slatted facilities so no washing or pen maintenance occurred. This may explain why the animals reacted much like the behavior normally seen with the negative treatments. Therefore, isolation may be considered a negative treatment as determined by a human interaction session.

The altered behavior pattern of the isolated animals did not increase the difficulty in handling the animal for common production practices. Our findings disagree with the results from Pedersen (1992) and Grandin's (1988) slaughter chute simulation. This may be due to the method of handling techniques during the testing procedure. Pedersen (1992) and Grandin (1988) allowed the animals to dictate the rate and method of movement, whereas in this experiment, animals were handled as recommended by the

National Pork Producers Council for a production facility. This method included the use of solid panels, group movement and incorporation of the animals flight zone.

5.4 The Effect of Environmental Treatments on Animal Behavior

The duration of basic behaviors in the home pen were not significantly altered by the addition of environmental enrichment devices or the incorporation of frequent human handling, nor were they effective in preventing or stopping various deviant social behaviors. Environmental enrichment devices were interacted with for 12.96 minutes per day. Pigs in the nursery stage interacted with the devices 11.49 minutes per day, this interaction time increased to 14.43 minutes per day in the grower-finisher facility. The pigs in finishing interacted with the hose device more than the chains (19.08 versus 9.78 minutes), whereas in the nursery time was split equally between the different types of devices (11.64 versus 11.34 minutes). This difference supports the work of Grandin and Curtis (1984), who suggested that pig preferences change as the animals develops. This development may have allowed the pig the ability to grasp and manipulate the large diameter hose provided during this experiment. This conclusion supports the work of Pedersen (1992) and Grandin and Curtis (1984) that pigs prefer materials which are easily manipulated.

A time of day effect was observed when comparing basic behavior patterns throughout a 24-hr period, isolation (Neg treatment) was shown to alter the pattern of behaviors in the nursery (lying and feeding) over a 24-hr period. The NEG treatment showed less variation in the duration of behaviors during each day. This may be due to

the lack of a significant influence (the presence of a human in or around the pen) in which to base their daily activity patterns, since in the other treatments the first peak of activity was recorded around the time of the handling sessions.

5.5 The Effects of Environmental Treatments on Animal Well-being

The increase in the complexity of the environmental treatments (toys and human interaction) did not appear to improve animal welfare, as indicated by animal performance and behavior. In the case of the C-15 genotype, animal well-being may have been decreased as indicated by the increased mortality in the treatment with the maximum complexity (toys and human interaction), this agrees with the Pedersen (1992) who found a higher injury score for animals in enriched environments.

5.6 Future Research and Discussion

Genetics appeared a greater factor in determining performance, carcass characteristics and pork quality than the range of rearing conditions studied in this experiment.

In summary, based on the results of this study there appears to be no benefit to the pig, the producer or the consumer with increased environmental enrichment or extensive human handling for the genetics commonly employed in the US swine industry. On the contrary, animal well-being may have been jeopardized by the maximum environmental treatment (T+H) as indicated by the increase in pig mortality. The demand for leaner pork

by the consumer may indicate that decreasing the complexity of the pigs environment may be in order.

The lack of drastic changes in the pig's behavior and productivity between the environmental treatments could be interpreted as indicating the pig's ability to adapt to differing environments, and the various levels of stimuli encountered in these environments.

The incorporation of this style of production techniques would allow better utilization of the personnel employed in the swine industry. The number of positions required could be reduced, and more resources dedicated to finding, training and rewarding employees.

The introduction of more exotic breeds to the US swine industry, may reveal the need for alternative methods of handling and housing of these type of animals to maximize their performance and guarantee their well-being.

This study indicates that future research is needed to determine how we can best manage and house differing genetic lines to maximize performance and pork quality while guaranteeing we meet the animals basic welfare needs.

LITERATURE CITED

- Arey, D. S., 1991. Tail-biting in pigs. *Farm Building Progress*, 105:20-23.
- Arnone, M., and Dantzer, R., 1980. Does frustration induce aggression in pigs? *Appl. Anim. Ethol.*, 6:351-362.
- Barnett, J. L., Cronin, G. M., Hemsworth, P. H., and Winfield, C. G., 1984. The welfare of adult pigs: the effects of five housing treatments on behaviour, plasma corticosteroids and injuries. *Appl. Anim. Behav. Sci.*, 12:209-232.
- Barnett, J. L., and Hemsworth, P. H., 1990. The validity of physiological and behavioral measures of animal welfare. *Appl. Anim. Behav. Sci.*, 25:177-187.
- Beattie, V. E., Walker, N., and Sneddon, I. A., 1996. An investigation of the effect of environmental and space allowance on the behaviour and production of growing pigs. *Appl. Anim. Behav. Sci.*, 48:151-158.
- Blackshaw, J. K., 1981. Some behavioural deviations in weaned domestic pigs: persistent inguinal nose thrusting, and tail and ear biting. *Animal Production*, 33:325-332.
- Brent, G., 1975. How to tackle tail-biting. *Pig Farming*. February.:87.
- Cross, H. R., Moen, R., and Stanfield, M., 1978. Training and testing of judges for sensory analysis of meat quality. *Food Technol.*, 32:48-54.
- Colyer, R. J., 1970. Tail biting in pigs. *Agric. Lond.*, 77:215-218.
- Day, J. E. L., Kyriazakis, I., and Lawrence, A. B., 1995. An investigation into the causation of chewing in growing pigs: the role of exploration and feeding motivation. *Appl. Anim. Behav. Sci.*, 48:47-59.
- De Smet, S. M., Pauwels, H., De Bie, S., Demeyer, D. I., Callewier, J., and Eeckhout, W., 1996. Effect of halothane genotype, breed, feed withdrawal, and lairage on pork quality of Belgian slaughter pigs. *J. Anim. Sci.*, 74:1854-1863.
- Duncan, I. J. H., 1981. Animal rights--animal welfare: a scientist's assessment. *Poult. Sci.*, 60:489.
- Ewbank, R., 1973. Abnormal behaviour and pig nutrition. An unsuccessful attempt to induce tail biting by feeding a high energy, low fiber vegetable protein diet. *Br. Vet. J.*, 129:366-369.

- Feddes, J. J. R., and Fraser, D., 1994. Non-nutritive chewing by pigs: implications for tail-biting and behavioral enrichment. *Transactions of the ASAE*. 37:947-950.
- Fortin, A., 1988. The effect of resting time on PSE in pork loins from hogs transported for two hours. *Anim. Res. Inst. Agric.*, Ottawa, Canada.
- Fraser, D., 1978. Behaviour of suckling and early-weaned piglets. *Anim. Behav.*, 26:22-30.
- Fraser, D., 1987. Mineral-deficient diets and the pig's attraction to blood: implications for tail-biting. *Can. J. Anim. Sci.*, 67:909-918.
- Fraser, A. F., and Broom, D. M., 1990. *Farm animal behaviour and welfare*. Balliere Tindall, London.
- Frischen, R. D., 1976. Effect of building arrangement and management on performance and behaviour of G-F pigs. *J. Anim. Sci.*, 42:1339-1340 (Abstract).
- Gadd, J., 1967. Tail-biting. *Pig farming*, July:58-59..
- Geverink, N. A., Engel, B., Lambooij, E., and Weigant, V. M., 1996. Observations on behaviour and skin damage of slaughter pigs and treatment during lairage. *Appl. Anim. Behav. Sci.*, 50:1-13.
- Gonyou, H. W., Hemsworth, P. H., and Barnett, J. L., 1986. Effects of frequent interactions with humans on growing pigs. *Appl. Anim. Behav. Sci.*, 16:269-278.
- Grandin, T., and Curtis, S. E., 1984. Toy preferences in young pigs. *J. Anim. Sci.*, 59(Supp. 1):85 (Abstract).
- Grandin, T. 1988. Effects of rearing environment on behavior and neural development in young pigs. Ph.D. Dissertation, University of Illinois, Urbana-Champaign, Illinois.
- Grandin, T., 1989. The effect of rest time on PSE in pork carcasses. Final Report to Monfort, Inc. Greeley, Colorado.
- Hansen, L. L., and Hagelso, A. M., 1980. A general survey of environmental influence on the social heirachy function in pigs. *Acta Agriculturae Scandanavia*, 30:388-392.
- Hemsworth, P. H., Barnett, J. L., and Hansen, C., 1981. The influence of handling by humans on the behavior, growth, and corticosteroids in the juvenile female pig. *Horm. Behav.*, 15:396-403.

- Hemsworth, P. H., Barnett, J. L., and Hansen, C., 1986a. The influence of handling by humans on the behavior, reproduction and corticosteroids of male and female pigs. *Appl. Anim. Behav. Sci.*, 15:303-314.
- Hemsworth, P. H., Gonyou, H. W., and Dziuk, P. J., 1986b. Human communication with pigs: The behavioural response of pigs to specific human signals. *Appl. Anim. Behav. Sci.*, 15:45-54.
- Hemsworth, P. H., Barnett, J. L., and Hansen, C., 1987. The influence of inconsistent handling by humans on the behavior, growth and corticosteroids of young pigs. *Appl. Anim. Behav. Sci.*, 17:245-252.
- Hemsworth, P. H., and Barnett, J. L., 1991. The effects of aversively handling pigs, either individually or in groups, on their behaviour, growth and corticosteroids. *Appl. Anim. Behav. Sci.*, 30:61-72.
- Hemsworth, P. H., Barnett, J. L., and Campbell, R. G., 1996a. A study of the relative aversiveness of a new daily injection procedure for pigs. *Appl. Anim. Behav. Sci.*, 49:389-401.
- Hemsworth, P. H., Barnett, J. L., and Borgwardt, R., 1996b. Behavioural responses of domestic pigs and cattle to humans and novel stimuli. *Appl. Anim. Behav. Sci.*, 50:43-56.
- Jensen, P., Craig, H. B., and Robinson, O. W., 1967. Phenotypic and genetic associations among traits of swine. *J. Anim. Sci.*, 26:1252-1260.
- Leach, L. M., Ellis, M., Sutton, D.S., McKeith, F. K., and Wilson, E. R., 1996. The growth performance, carcass characteristics, and meat quality of halothane carrier and negative pigs. *J. Anim. Sci.*, 74:934-943.
- Lan, Y. H., McKeith, F. K., Novakofski, J., and Carr, T. R., 1993. Carcass and muscle characteristics of Yorkshire, Meishan, Yorkshire X Meishan, Meishan X Yorkshire, Fengjing X Yorkshire, and Minzhu X Yorkshire pigs. *J. Anim. Sci.*, 71:3344-3349.
- Madsen, A. 1980. Environmental influences on health of bacon pigs. France-Denmark Scientific Cooperation Minisymposium. 181-196.
- McGlone, J. J., and Curtis S. E., 1985. Behavior and performance of weanling pigs in pens equipped with hide areas. *J. Anim. Sci.*, 60:20-24.

- Milligan, S. D., 1996. Improving pork quality by use of resting, hot fat trimming, and tunnel freeze chilling. Master of Science Thesis, Texas Tech University, Lubbock, Texas.
- Moss, B. W., 1978. Some observations on the activity and aggressive behaviour of pigs when penned prior to slaughter. *Appl. Anim. Ethol.*, 4:323-339.
- Moss, B. W., and Robb, J.D., 1978. The effect of preslaughter and lairage on serum, thyroxine, and cortisol levels at slaughter and meat quality of boars, hogs and gilts. *J. Sci. Food. Agric.*, 29:689
- National Pork Producers Council, 1995. Genetic evaluation program. Des Moines, Iowa.
- Newberry, R. C., 1995. Enviromental enrichment: increasing the biological relevance of captive enviroments. *Appl. Anim. Behav. Sci.*, 44:229-243.
- NRC., 1988. Nutrient Requirements of Swine (9th Ed). National Academy Press, Washington, DC.
- Owen, B. L., 1995. Improving pork quality by reducing the incidence of PSE pork. Master of Science Thesis, Texas Tech University, Lubbock, Texas.
- Paterson, A. M., and Pearce, G. P., 1989. Boar-induced puberty in gilts handled pleasantly or unpleasantly during rearing. *Appl. Anim. Behav. Sci.*, 22:225-233.
- Paterson, A. M., and Pearce, G. P., 1992 Growth, response to humans and corticosteroids in male pigs housed individually and subjected to pleasant, unpleasant or minimal handling during rearing. *Appl. Anim. Behav. Sci.*, 34:315-328.
- Pearce, G. P., Paterson, A. M., and Pearce, A. N., 1989. The influence of pleasant and unpleasant handling and the provision of toys on the growth and behaviour of male pigs. *Appl. Anim. Behav. Sci.*, 23:27-37.
- Pearce, G. P., and Paterson, A. M., 1993. The effect of space restriction and provision of toys during rearing on the behaviour, productivity and physiology of male pigs. *Appl. Anim. Behav. Sci.*, 36:11-28.
- Pedersen, B. K., 1992. Comprehensive evaluation of well-being in pigs: environmental enrichment and pen space allowance. Ph.D. Dissertation, Univesity of Illinois, Urbana-Champaign, Illinois.

- Penny, R. H. C., and Hill, F. W. G., 1974. Observations of some conditions seen in pigs at the abattoir with particular reference to tail-biting. *Vet. Rec.*, 94:174-180.
- Penny, R. H. C., Walters, J. R., and Tredget, S. J., 1981. Tail-biting in pigs: a sex frequency between boars and gilts. *Vet. Rec.*, 108:35
- Plumlee, M.P., Cline, T. R., Krider, J. L., and Underwood, L., 1976. Space, protein, and feeder type effects on finishing swine. *J. Anim. Sci.*, 42:1339 (Abstract).
- SAS Institute. 1990. Statistical analysis systems. Cary, NC.
- Schaefer, A. L., Salomons, M. O., Tong, A. K. W., Sather, A. P., and Leauge, P., 1990. The effect of environment enrichment on aggression in newly weaned pigs. *Appl. Anim. Behav. Sci.*, 27:41-52.
- Simonsen, H. B. 1990. Behavior and distrubution of fattening pigs in the multi-activity pen. *Appl. Anim. Behav. Sci.*, 27:311-324.
- Smidt, D. 1983. Advances and problems of using integrated systems of indicators as compared to single traits. In: D. Smidt (Ed.) *Indicators Relevant to Farm Animal Welfare*. Martinus Nijhoff Publishers, Boston, Mass.
- Van Putten, G., 1969. An investigation into tail-biting among fattening pigs. *Br. Vet J.*, 125:511-517.
- Warriss, P. D., Kestin, S. C., and Robinon, J.M., 1983. A note on the influence of rearing environment on meat quality in pigs. *Meat Sci.*, 9:271-279.
- Warris, P.D., Brown, S. N., Edwards, J. E., Anil, M. H., and Fordham, D. P., 1992. Time in lairage needed by pigs to recover from the stress of transport. *Vet Rec.*, 131:194-196.
- White, B. R., Lan, Y. H., McKeith, F. K., McLaren, D. G., Novakofski, J., Wheeler, M. B., and Kasser, T. R., 1993. Effects of Porcine Somatotropin on growth and carcass composition of Meishan and Yorkshire barrows. *J. Anim. Sci.*, 71:3226-3238.
- Wood-Gush, D. G. M., and Beilharz, R. G., 1983. The enrichment of a bare environment for animals in confined conditions. *Appl. Anim. Ethol.*, 10:209-217.
- Young, L. D., 1992. Effects of Duroc, Meishan, Fengjing, and Minzhu boars on carcass traits of first-cross barrows. *J. Anim. Sci.*, 70:2030-2037.
- Zhang, W., Kulers, D. L., and Rempel, W. E., 1992. Halothane gene and swine performance. *J. Anim. Sci.*, 70:1307-1313.

APPENDIX A
DEVIANT SOCIAL BEHAVIOR

A.1 Introduction

A.1.1 Deviant Social Behavior

The outbreak of several deviant social behaviors including nasal thrusting, belly rubbing, tail biting and severe ear biting allowed us the opportunity to study the factors that influence these behaviors. The outbreaks of ear and tail biting followed a cyclic pattern with several weeks of increased activity followed by a short period of very little or no activity.

A.2 Materials and Methods

Several procedures were used to try to determine the causes or eliminate certain widely held beliefs about these deviant social behaviors. These procedures included in-depth dietary analysis, tissue and blood analysis, and environmental investigation. All signs of deviant social behaviors were recorded on a daily basis for each pig involved, including severity of the wounds, related illness, behavioral adaptations, and overall performance. All animals were scored on a (range of 0-3) for physical evidence of tail and ear biting during their final weigh session, scores were then combined for a pen total.

A.2.1 Dietary analysis

Twelve samples of each feed type (SS1, SG2, SF3) were taken with a 1.3 cm core sampler, 6 samples were taken from various feeders and 6 samples were taken from packaged feed prior to delivery to a feeder. Samples were mixed and ground with a Wiley Mill equipped with a 1mm screen to ensure the accuracy of the testing procedures. After

Mill equipped with a 1mm screen to ensure the accuracy of the testing procedures. After grinding samples were divided into 3 packages of each diet. One package was analyzed for crude protein, moisture, crude fat, ash and various mineral content (Calcium, Sodium, Potassium, Phosphorus, Iron, Zinc, Copper and Manganese) at the Texas Tech Feed Laboratory. One sample package was sent to the Texas Veterinary Medical Diagnostic Laboratory and analyzed for Aflatoxin B1, Sterigmatocystin, Zearalenone, Zearalenol, Ochratoxin A, T-2 Toxin, HT-Toxin, Diacetoxyscirpenol, Neosolaniol, Deoxynivalenol, Fusarenon-X, and Citrinin. The third sample package was placed in a -28.89 freezer, in case further test were deemed necessary.

A.2.2 Tissue and blood analysis

Two nonexperimental pigs from the same facility were sent to the Texas Veterinary Medical Diagnostic Laboratory for necropsy and tissue analysis. One animal was suffering from severe ear and tail bite damage, the other showed only signs of ear biting. Blood was collected from the external jugular from ten nonexperimental pigs and sent to the Texas Veterinary Medical Diagnostic Laboratory. Six of the pigs which were sampled were suffering from visible signs of ear/tail biting of differing stages of severity, the other four showed no apparent signs of tissue damage.

A complete histopath work-up was conducted on the two pigs submitted for necropsy including external observations, heart, lung, stomach, small and large intestine, liver, pancreas, spleen, lymph nodes, kidney, reproductive system, urinary bladder, skeletal muscles, and brain.

All twelve samples (2 necropsy and 10 blood samples) were submitted for a complete virology and serology examination consisting of TGE, Bordatella, Hemophilus, and PRRS.

A complete blood biochemistry analysis, was conducted on the 10 samples submitted, including Total Serum Protein, Albumen, Globulins, Albumen/Globulin Ratio, Calcium, Phosphorus, Glucose, Blood Urea Nitrogen, Creatinine, Total Bilirubin, Serum Alkaline Phosphatase, Creatinine Phosphokinase, SGPT, and SGOT. The samples were also evaluated for cholesterol, Magnesium, Sodium, Potassium, Chloride, NA/K, and hemolysis level.

A.2.3 Environmental Investigations

Temperatures were monitored on a daily basis, recording high and low temperature. Due to the increase in deviant behaviors air velocity rate was determined for each ventilation fan with a Omega Engineering, Inc. HH-F10 meter to determine air turnover rate in the facility.

Ammonia levels were monitored over a several week period in the finishing and nursery facilities using a single point monitor (MDA Scientific), with a minimum threshold of 2.6 PPM. The spm was mounted at 30.5 cm above the flooring, it was relocated to another monitoring location half way through the study. Readings were taken at one hour intervals, several days during the testing period. Since the deviant behaviors began to flourish following the move to the finishing facility, testing was concentrated in this area. A Drager hand bellows gas metering pump (model TUV12RgG017) was used

as a verification tool, ensuring the accuracy of the spm. Ammonia detector tubes used in the Drager pump for this analysis had a range of 2 to 30 PPM. The Drager pump was also used to measure ammonia levels in the shallow pit area below the flooring, and in the farrowing and gestation facilities.

A.3 Results

Treatment had no effect on the amount or severity of ear and tail biting as evaluated during the final weigh session, ear biting scores ranged from 3.13 for the NEG treatment to 6.00 for the CON pigs. Tail bite scores much less severe, but more consistent ranging from 1.13 for the CON pigs to 1.75 for the TOYS treatment (Table A.1).

The dietary analysis is shown in Table A.2 with corresponding NRC requirements for each stage of production. No aflatoxins were detected in any of the feed samples.

The clinical analysis demonstrated no symptoms which are specifically related to ear or tail biting. The histopath revealed significant lung damage characterized by diffuse pneumonia and discoloration of both lobes. The lymph nodes were characterized as enlarged, reactive and congested. The digestive system displayed scattered heavy infiltration of lymphocytes and plasma cells. There were no viruses isolated in the twelve serum samples, nor the two tonsil or lung samples. The serology examination revealed negative results for the Bordetella, TGE, and Hemophilus. The results for all twelve samples did show significant amounts of PRRS antibodies, values ranged from 0.79 to 1.96 with a value of 0.4 being positive for PRRS antibody. The SMA results are shown in Table A.3 for the 10 samples along with the normal range values. The blood

biochemistry results are shown in Table A.4, there was significant amount of hemolysis which may have altered some of the data. All ten samples do show a significantly low level of blood magnesium, four samples which had no visible signs of ear or tail biting did have elevated chloride levels, whereas only 1 sample with visible signs of damage was elevated.

Temperature ranged 1.11°C from the set point which was adjusted according to pig size and age as prescribed in the materials and methods. Ventilation was determined to be well within acceptable levels for the 250 animals in the facility. The ammonia concentration in the nursery facility level was lower than the minimum threshold (2.6 ppm) for the majority of samples taken so no values are reported. The finishing facility had a range of none detectable to 26.6 ppm. The average value was 4.12 throughout the facility, 85 readings were recorded over a several week period. Ammonia readings did correspond directly to animal activity levels in the facility. There was a wide range of ammonia readings when location in the facility was tested with the drager pump, from non-detectable to above 30 ppm(tube maximum) directly over the waste outlet in the shallow pit area.

A.4 Discussion

This experiment was begun with no intent on studying the cause and effects of deviant social behaviors, but once these behaviors occurred the opportunity was too great to ignore. Ear or tail biting normally began soon after the move from the nursery facility, and reached the peak midway through the finishing stage. The range of environmental

treatments performed during this experiment had no effect on the number or severity of ear or tail biting performed, even though ear biting was much more common and severe during this experiment. These behaviors ranged from infecting one pig in a pen with only one animal causing the damage, to every animal in the pen being both chewed upon and chewing on others.

The in-depth analysis undertaken during this trial, did not provide results implicated in past literature for contributing to such an outbreak. Animals were neither crowded, nor environmentally or nutritionally challenged. The low blood magnesium level may be a factor, but more than sufficient magnesium was provided in the diet, and the accuracy of blood magnesium as an indicator of body stores is questionable. The effect of the PRRS virus on behavior is unknown and the stress it causes upon the body may be adequate to initiate such a behavioral response.

The human interaction sessions and environmental enrichment devices proved ineffective in preventing or controlling these behaviors, which is supported by the work of Madsen (1980).

The spread of this outbreak included those animals in the negative treatment, which were housed in a solid plywood enclosure with no visual contact of adjoining pens, therefore visual communication seems unlikely as proposed by Blackshaw (1981).

A.5 Future Research

Results from this study indicate that isolating an individual cause of these behaviors may not be feasible in a production style facility. Even though the effect of visual communication appears very unlikely in the spread of an outbreak, research is still required to determine the role of the physical senses in such behavior.

As identification and treatment of diseases and infections improves, the effect of certain ailments on behavior needs to be investigated. This would help identify how these stressors effect the welfare of the animal, and if certain behaviors could be associated with specific ailments it would provide producers with another tool towards improving production while guaranteeing the welfare of the animals.

Table A.1. Deviant social behavior evaluation

	Control	Toys	Human	T+H	Negative	SE
			C-15			
Ear Bite Score	5.00	5.00	6.75	5.00	1.25	1.84
Tail Bite Score	1.25	2.00	1.25	2.00	1.75	0.78
			EXP-94			
	7.00	4.75	4.25	5.50	5.00	1.84
	1.00	1.50	1.25	1.00	0.75	0.78
			Genotypes Combined			
Ear Bite Score	6.00	4.88	5.50	4.50	3.13	1.30
Tail Bite Score	1.13	1.75	1.25	1.50	1.25	0.55
			Genotype Effects			
	C-15		EXP-94	SE		
Ear Bite Score	4.30		5.30	0.82		
Tail Bite Score	1.65		1.10	0.35		
No significant treatment effects						

Table A.2. Comparison of Texas Tech University swine diets To NRC requirement

Ingredient	SS-1 Nursery	NRC	SG-2 Grower	NRC	SF-3 Finishing	NRC
	Feed		Feed		Feed	
% Crude protein	18.03	18	18.3	15	15.87	13
% Moisture	10.51	--	10.16	--	10.21	--
% Crude Fat	1.78	--	1.89	--	2.05	--
% Ash	5.55	--	4.24	--	3.52	--
% Calcium	1.05	0.7	0.94	0.6	0.59	0.5
% Sodium	0.36	0.1	0.27	0.27	0.32	0.1
% Potassium	0.67	0.26	0.14	0.23	0.54	0.17
% Magnesium	0.17	0.04	0.14	0.04	0.17	0.04
% Phosphorus	0.53	0.6	0.59	0.5	0.58	0.4
Iron (Mg)	300	80	200	60	200	40
Zinc (Mg)	200	80	100	60	100	50
Copper (Mg)	20	5	10	4	10	3
Manganese (Mg)	55	3	40	2	40	2

*NRC requirements based on 90% dry matter

Table A.3. Analysis of clinical pathology—SMA results

	Animal Identification Number										Normal Range	
	1	2	3	4	5	6	7	8	9	10	Low	High
Total Serum Proteins (g%)	6.7	5.3	5.9	6.7	7.2	6.9	7.3	6.4	6.3	5.4	6	8
Albumen (g%)	3.7	2.2	2.8	3.9	3	3	2.4	2	2.4	1.7	2.8	4.2
Globulins (g%)	3	3.1	3.1	2.8	4.2	3.9	4.9	4.4	3.9	3.7		
Albumen/Globulin Ratio	1.2	0.7	0.9	1.4	0.7	0.8	0.5	0.5	0.6	0.5		
Calcium (mg%)	9.6	9.3	9.6	9.3	9.5	9	11.1	9	9.1	9.2	9	12
Phosphorus (mg%)	8.2	9.3	8.7	8.7	8.2	7.9	6.8	7.6	8.4	8.1	3.8	9.1
Glucose (mg%)	89	98	99	87	117	85	87	79	87	99	55	179
Blood Urea Nitrogen (mg%)	14	15	21	14	9	11	12	14	12	16	4	30
Creatinine (mg%)	1.3	1.2	1.3	1.5	1.4	1.3	1.3	1.5	1.4	1.8	1	2.6
Total Bilirubin (mg%)	0.2	0.2	0.3	0.2	0.1	0.2	1.3	0.1	0.2	0.2	0	1
Serum Alkaline Phosphatase (IU/1)	165	106	163	122	78	77	107	117	150	233	118	395
Creatine Phosphokinase (IU/1)	454	206	2067	1912	996	3841	4893	234	1928	298	100	200
SGPT (IU/1)	30	30	50	56	32	28	43	29	32	57	20	68
Sgot (IU/1)	23	52	68	28	71	108	111	31	58	31	15	84
Bold = Outside Normal Range												

Table A.4. Analysis of blood chemistry

	Animal Identification number										Normal	Range
	1	2	3	4	5	6	7	8	9	10		
Cholesterol (MG/DL)	1	2	3	4	5	6	7	8	9	10	Low	High
Magnesium (MEQ/L)	84	74	104	99	86	61	81	82	93	91	85	166
Sodium (MEQ/L)	1.4	1.4	1.7	1.9	1.3	1.7	1.7	1.4	1.6	1.6	2.2	3
Potassium (MEQ/L)	145	141	144	143	140	140	141	141	141	145	135	150
Chloride (MEQ/L)	4.9	6.1	7.3	4.7	6.1	7.2	7	4.8	5.5	6.6	3.5	6.7
NA/K (MEQ/L)	107	107	107	107	106	105	106	106	105	109	94	106
Hemolysis (MG/DL)	29.6	23.2	19.7	30.7	22.8	19.3	20.3	29.5	25.7	22.2		
	37	47	65	43	36	58	359	0	63	51	0	50

Bold = Outside Normal Range

APPENDIX B
SLAUGHTER PLANT BEHAVIOR

B.1 Introduction

B.1.1 Slaughter Plant Behavior

There is great variation among packing plants in the amount of time and the physical environments animals are held prior to slaughter. Recently, public concern has developed over the well-being of these animals during this period, with very little scientific data to base decisions upon. This aspect of the study was developed to provide an ethogram of the basic pig behavior prior to slaughter in a modern high speed slaughter facility. The effect of preslaughter holding times on meat quality have been well documented (Fortin, 1988; Grandin, 1989; Owens, 1995; De Smet et al., 1996), with 1 hour most recently being recommended (Owens, 1995).

B.2 Materials and Methods

After the animals were unloaded, weighed, tattooed and moved into the holding pen a 5 minute scan technique for recording the animals behavior was implemented for the 2.5 (range 1.75-4.5) hours animals remained in the pen. Observations were recorded from an overhead catwalk, in as quiet manner as possible to limit the effect of the observer on animal behavior. The number of animals engaged in the five identified behaviors were recorded, these behaviors included lying, standing, locomotion, drinking, and fighting.

Slaughter plant behavior was analyzed by replication, not treatment, since the color scheme used for identification faded during the transportation procedure (especially the

yellow color), and under the water misters provided in the holding pens at Seaboard Farms Pork Processing facility in Guymon, Oklahoma.

This procedure allowed the opportunity to plot the average behavior of animals following a standardized transportation scheme to the processing facility. The information was analyzed for the number of animals engaged in each behavior, and how this behavior pattern was correlated to carcass characteristics and meat quality. The time spent fighting was so small that comparing animals to rearing treatments was not feasible.

B.3 Results

Lying was the most frequently performed behavior, an average of 72% of the animals were lying during each observation session. The percent of animals engaged in each behavior is demonstrated in Figure B.1. It took approximately 30 minutes from the time the pigs entered the holding pen until a majority of the animals were settled and lying down, a tabular listing of the thirty observation periods is described in Table B.1 with a graphical illustration of the 2.5 hour holding period in relation to animal behavior is shown in Figure B.2. Fighting was a very insignificant behavior, on average only 7 of the 30 observation periods resulted in fighting behavior, with a maximum of 3.75 percent of the animals engaged.

B.4 Discussion

The excellent design of the Seaboard Processing Facility including one-way driving of animals, water misting, and the absence of electrical prods in the holding facility

resulted in very calm animals during the rest period. This system resulted in 72 % of the animals engaged in lying behavior over the 2.5 hour rest period, with many scan periods resulting in 100% lying behavior. This is supported by the work of Moss (1978), which showed by the end of the first hour that 80% of the animals were resting quietly and saw little change for the remainder of the holding period. This average is twice the average percent lying after 1.5 hours found by Geverink et al. (1996) in Dutch slaughterhouses and is still considerably higher than in the Belgian slaughterhouses (45% lying after 1.5 hours), where pigs were still under the effects of the tranquilizer given prior to transport.

The difference in the time spent resting may be attributable to handling procedures and the use of electric prods during unloading. Geverink et al. (1996) described most unloading of transports being done with electric prods and some use within the facility, Moss (1978) did not describe handling techniques, or the use of electrical prods. This handling study included strict protocols to ensure quiet and gentle moving of animals during transport, including no use of electrical prods.

The transport time in this study was significantly longer than either the Geverink et al. (1996) or the Moss (1978) study, therefore transport time appears to have little effect on preslaughter behavior.

Table B.1. Percent of animals engaged in specified behavior behaviors

	Behaviors				
	Lying	Standing	Locomotion	Fighting	Drinking
Average	72.00	17.73	7.14	0.41	2.62
Period 1	6.25	55.63	30.00	3.75	4.38
Period 2	8.75	54.38	30.63	0.00	6.25
Period 3	21.88	44.38	23.75	0.00	10.00
Period 4	26.25	45.00	18.75	0.00	10.00
Period 5	36.88	33.13	21.88	1.25	6.88
Period 6	49.38	36.25	6.25	0.00	8.13
Period 7	57.50	31.88	6.88	0.00	3.75
Period 8	65.00	20.63	7.50	0.00	6.88
Period 9	74.38	17.50	7.50	0.00	0.63
Period 10	76.88	15.63	4.38	0.00	3.13
Period 11	77.50	15.00	5.00	0.00	2.50
Period 12	79.38	14.38	2.50	1.25	2.50
Period 13	77.50	16.88	1.88	0.00	3.75
Period 14	81.25	16.25	1.88	0.00	0.63
Period 15	90.63	5.63	0.63	0.00	3.13
Period 16	90.63	8.13	0.63	0.00	0.63
Period 17	90.63	8.13	1.25	0.00	0.00
Period 18	90.63	8.75	0.63	0.00	0.00
Period 19	87.50	6.25	5.00	1.25	0.00
Period 20	89.38	9.38	0.00	0.00	1.25
Period 21	87.50	8.13	1.88	1.25	1.25
Period 22	84.29	12.14	0.71	1.43	1.43
Period 23	87.14	9.29	2.86	0.00	0.71
Period 24	92.14	6.43	1.43	0.00	0.00
Period 25	90.71	8.57	0.71	0.00	0.00
Period 26	85.71	6.43	4.29	2.86	0.71
Period 27	79.29	13.57	5.00	0.00	2.14
Period 28	85.71	5.71	7.14	0.00	1.43
Period 29	85.71	8.57	1.43	0.00	4.29
Period 30	85.71	11.43	0.71	0.00	2.14

Figure B.1. Preslaughter behavior pattern

Figure B.2. Percentage of animals engaged in specified behavior prior to slaughter

APPENDIX C
TIME OF DAY EFFECTS ON BASIC BEHAVIOR PATTERNS

Figure C.1. Time of day effect on lying behavior in the nursery stage
 $P < 0.01$ $N = 19$

Figure C.2. Time of day effect on feeding behavior in the nursery stage
 $P < 0.01$ $N = 20$

Figure C.3. Time of day effect on drinking behavior in the nursery stage
 $P < 0.01$ $N = 20$

Figure C.4. Time of day effect on chain interaction in the nursery stage
 $P < 0.01$ $N = 8$

Figure C.5. Time of day effect on lying behavior in the finishing stage

$P < 0.05$ $N = 20$

Figure C.6. Time of day effect on feeding behavior in finishing stage
 $P < 0.01$ $N = 20$

Figure C.7. Time of day effect on drinking behavior in the finishing stage
P < 0.01 N = 20

Figure C.8. Time of day effect on hose interaction in the finishing stage
 $P < 0.05$ $N = 8$

Figure C.9. Time of day effect on chain interaction in the finishing stage
 $P < 0.10$ $N = 8$

APPENDIX D
DEATH LOSS: ANALYSIS AND DESCRIPTION

Table D.1. Death loss by replication

REP	FIN PEN	GENO	TRT	NURMORT	FINMORT	TOTAL MORT	MORT %
1	30	C15	1	0	0	0	0
1	31	C15	2	0	2	2	0.25
1	14	C15	3	1	0	1	0.125
1	16	C15	4	0	4	4	0.5
1	32	C15	5	0	0	0	0
2	9	EXP	1	1	0	1	0.125
2	25	EXP	2	2	1	3	0.375
2	28	EXP	3	0	0	0	0
2	12	EXP	4	0	3	3	0.375
2	11	EXP	5	0	3	3	0.375
3	24	C15	1	1	2	3	0.375
3	8	C15	2	0	1	1	0.125
3	7	C15	3	0	0	0	0
3	23	C15	4	0	2	2	0.25
3	22	C15	5	0	2	2	0.25
4	4	EXP	1	0	1	1	0.125
4	6	EXP	2	0	2	2	0.25
4	21	EXP	3	0	0	0	0
4	20	EXP	4	0	0	0	0
4	5	EXP	5	1	0	1	0.125
5	27	EXP	1	0	1	1	0.125
5	19	EXP	2	0	1	1	0.125
5	15	EXP	3	0	1	1	0.125
5	3	EXP	4	0	0	0	0
5	29	EXP	5	0	0	0	0
6	2	EXP	1	0	2	2	0.25
6	13	EXP	2	0	1	1	0.125
6	10	EXP	3	1	1	2	0.25
6	26	EXP	4	0	0	0	0
6	18	EXP	5	0	1	1	0.125
7	11	C15	1	0	2	2	0.25
7	12	C15	2	1	1	2	0.25
7	28	C15	3	0	1	1	0.125
7	25	C15	4	1	2	3	0.375
7	9	C15	5	0	0	0	0
8	32	C15	1	1	1	2	0.25
8	16	C15	2	0	0	0	0
8	14	C15	3	0	0	0	0
8	31	C15	4	0	4	4	0.5
8	30	C15	5	0	1	1	0.125

Table D.2. Death loss by treatment for the C-15 genotype

REP	FIN PEN	GENO	TRT	NURMORT	FINMORT	TOTAL MORT	MORT %
1	30	C15	1	0	0	0	0
7	11	C15	1	0	2	2	0.25
8	32	C15	1	1	1	2	0.25
3	24	C15	1	1	2	3	0.375
						7	0.21875
8	16	C15	2	0	0	0	0
3	8	C15	2	0	1	1	0.125
1	31	C15	2	0	2	2	0.25
7	12	C15	2	1	0	1	0.125
						4	0.125
3	7	C15	3	0	0	0	0
8	14	C15	3	0	0	0	0
1	14	C15	3	1	0	1	0.125
7	28	C15	3	0	1	1	0.125
						2	0.0625
3	23	C15	4	0	2	2	0.25
7	25	C15	4	1	1	2	0.25
1	16	C15	4	0	4	4	0.5
8	31	C15	4	0	4	4	0.5
						12	0.375
1	32	C15	5	0	0	0	0
7	9	C15	5	0	0	0	0
8	30	C15	5	0	1	1	0.125
3	22	C15	5	0	2	2	0.25
						3	0.09375

Table D.3. Death loss by treatment for the EXP-94 genotype

REP	FIN PEN	GENO	TRT	NURMORT	FINMORT	TOTAL MORT	MORT %
2	9	EXP	1	1	0	1	0.125
4	4	EXP	1	0	1	1	0.125
5	27	EXP	1	0	1	1	0.125
6	2	EXP	1	0	2	2	0.25
						5	0.15625
5	19	EXP	2	0	1	1	0.125
6	13	EXP	2	0	1	1	0.125
4	6	EXP	2	0	2	2	0.25
2	25	EXP	2	2	1	3	0.375
						7	0.21875
2	28	EXP	3	0	0	0	0
4	21	EXP	3	0	0	0	0
5	15	EXP	3	0	1	1	0.125
6	10	EXP	3	1	1	2	0.25
						3	0.09375
4	20	EXP	4	0	0	0	0
5	3	EXP	4	0	0	0	0
6	26	EXP	4	0	0	0	0
2	12	EXP	4	0	3	3	0.375
						3	0.09375
5	29	EXP	5	0	0	0	0
4	5	EXP	5	1	0	1	0.125
6	18	EXP	5	0	1	1	0.125
2	11	EXP	5	0	3	3	0.375
						5	0.15625

Table D.4. Identification of the cause of death loss by replication

Death Loss Treatment					Death loss identification						
REP	FIN	PEN	GENO	TRT	INJURY	EAR/TAIL	GASTRO	RESPIRATORY	WASTING	SUDDEN	OTHER
1	30		C15	1							
1	31		C15	2						2	
1	14		C15	3							1
1	16		C15	4	1	1	2				
1	32		C15	5							
2	9		EXP	1	1						
2	25		EXP	2	1		1				
2	28		EXP	3							
2	12		EXP	4	2					1	
2	11		EXP	5			2		1		
3	24		C15	1	1	1					1
3	8		C15	2	1						
3	7		C15	3							
3	23		C15	4			1				1
3	22		C15	5				1	1		
4	4		EXP	1					1		
4	6		EXP	2							
4	21		EXP	3							
4	20		EXP	4							
4	5		EXP	5					1		
5	27		EXP	1							1
5	19		EXP	2				1			
5	15		EXP	3						1	
5	29		EXP	5							
5	3		EXP	4							

Table D.4. (Continued)

REP	FIN	PEN	GENO	TRT	INJURY	EAR/TAIL	GASTRO	RESPIRATORY	WASTING	SUDDEN	OTHER
6	2		EXP	1			1				1
6	13		EXP	2			1				
6	10		EXP	3					1		1
6	26		EXP	4							
6	18		EXP	5						1	
7	11		C15	1			1				1
7	12		C15	2	1						
7	28		C15	3			1				
7	25		C15	4	1						1
7	9		C15	5							
8	32		C15	1	1						
8	16		C15	2							
8	14		C15	3							
8	31		C15	4	3				1		
8	30		C15	5							1

Table D.5. Identification of the cause of death loss by treatment

Death loss--Treatment		Death loss--Identification									
REP	FINPEN	GENO	TRT	INJURY	EAR/TAIL	GASTRO	RESPIRATORY	WASTING	SUDDEN	DISEASES	OTHER
1	30	C15	Con	0	0	0	0	0	0	0	0
8	32	C15	Con	1	0	0	0	0	0	0	0
7	11	C15	Con	0	0	0	1	0	0	1	1
3	24	C15	Con	1	1	0	0	0	1	1	0
2	9	EXP	Con	1	0	0	0	0	0	0	0
4	4	EXP	Con	0	0	0	0	1	0	1	0
5	27	EXP	Con	0	0	0	0	0	0	0	1
6	2	EXP	Con	0	0	1	0	0	0	1	1
				3	1	1	1	1	1	4	3
				27.27	9.09	9.09	9.09	9.09	9.09	36.36	27.27
				4.69	1.56	1.56	1.56	1.56	1.56	6.25	4.69
8	16	C15	Toys	0	0	0	0	0	0	0	0
3	8	C15	Toys	1	0	0	0	0	0	0	0
1	31	C15	Toys	0	0	0	0	0	0	0	2
7	12	C15	Toys	1	0	0	0	0	0	0	0
5	19	EXP	Toys	0	0	0	1	0	0	1	0
6	13	EXP	Toys	0	0	0	1	0	0	1	0
4	6	EXP	Toys	1	0	1	0	0	0	1	0
2	25	EXP	Toys	1	0	1	0	1	0	2	0
				4	0	2	2	1	0	5	2
				36.36	0.00	18.18	18.18	9.09	0.00	45.45	18.18
				6.25	0.00	3.13	3.13	1.56	0.00	7.81	3.13

Table D.5. (Continued)

REP	FIN	PEN	GENO	TRT	INJURY	EAR/TAIL	GASTRO	RESPIRATORY	WASTING	SUDDEN	DISEASES	OTHER
3	7		C15	Neg	0	0	0	0	0	0	0	0
8	14		C15	Neg	0	0	0	0	0	0	0	0
1	14		C15	Neg	0	0	0	0	0	1	1	0
7	28		C15	Neg	0	0	0	1	0	0	1	0
2	28		EXP	Neg	0	0	0	0	0	0	0	0
4	21		EXP	Neg	0	0	0	0	0	0	0	0
5	15		EXP	Neg	0	0	0	0	1	0	1	0
6	10		EXP	Neg	0	0	0	0	1	0	1	1
					0	0	0	1	2	1	4	1
					0.00	0.00	0.00	20.00	40.00	20.00	80.00	20.00
					0.00	0.00	0.00	1.56	3.13	1.56	6.25	1.56
3	23		C15	T+H	0	0	1	0	0	0	1	1
7	25		C15	T+H	1	0	0	0	0	0	0	1
1	16		C15	T+H	1	1	2	0	0	0	2	0
8	31		C15	T+H	3	0	0	0	1	0	1	0
4	20		EXP	T+H	0	0	0	0	0	0	0	0
5	3		EXP	T+H	0	0	0	0	0	0	0	0
6	26		EXP	T+H	0	0	0	0	0	0	0	0
2	12		EXP	T+H	2	0	0	0	0	1	1	0
					7	1	3	0	1	1	5	2
					46.67	6.67	20.00	0.00	6.67	6.67	33.33	13.33
					10.94	1.56	4.69	0.00	1.56	1.56	7.81	3.13

Table D.5. (Continued)

REP	FIN	PEN	GENO	TRT	INJURY	EAR/TAIL	GASTRO	RESPIRATORY	WASTING	SUDDEN	DISEASES	OTHER
1	32		C15	Hum	0	0	0	0	0	0	0	0
7	9		C15	Hum	0	0	0	0	0	0	0	0
8	30		C15	Hum	0	0	0	0	0	0	0	1
3	22		C15	Hum	0	0	0	1	1	0	2	0
5	29		EXP	Hum	0	0	0	0	0	0	0	0
4	5		EXP	Hum	0	0	0	0	1	0	1	0
6	18		EXP	Hum	0	0	0	0	0	1	1	0
2	11		EXP	Hum	0	0	2	0	1	0	3	0
					0	0	2	1	3	1	7	1
					0.00	0.00	25.00	12.50	37.50	12.50	87.50	12.50
					0.00	0.00	3.13	1.56	4.69	1.56	10.94	1.56

Table D.6. Identification of the cause of death loss by treatment for the C-15 genotype

C-15 Death loss				Death loss identification									
REP	PEN	GENO	TRT	INJURY EAR/TAIL GASTRO RESPIRATORY WASTING SUDDEN DISEASE OTHER									
1	30	C15	Con	0	0	0	0	0	0	0	0	0	0
3	24	C15	Con	1	1	0	0	0	1	1	1	0	0
7	11	C15	Con	0	0	0	1	0	0	1	1	1	1
8	32	C15	Con	1	0	0	0	0	0	0	0	0	0
				2	1	0	1	1	1	2	2	1	1
				% of trt	33.33	16.67	0.00	16.67	0.00	16.67	33.33	16.67	16.67
				deaths									
				% of total	6.25	3.13	0.00	3.13	0.00	3.13	6.25	3.13	3.13
1	31	C15	Toys	0	0	0	0	0	0	0	0	2	2
3	8	C15	Toys	1	0	0	0	0	0	0	0	0	0
7	12	C15	Toys	1	0	0	0	0	0	0	0	0	0
8	16	C15	Toys	0	0	0	0	0	0	0	0	0	0
				2	0	0	0	0	0	0	0	2	2
				% of trt	50	0	0	0	0	0	0	0	50
				deaths									
				% of total	6.25	0	0	0	0	0	0	6.25	6.25
1	14	C15	Neg	0	0	0	0	0	0	1	1	0	0
3	7	C15	Neg	0	0	0	0	0	0	0	0	0	0
7	28	C15	Neg	0	0	0	0	1	0	0	1	0	0
8	14	C15	Neg	0	0	0	0	0	0	0	0	0	0
				0	0	0	0	1	0	1	2	0	0
				% of trt	0	0	0	50	0	50	100	0	0
				deaths									
				% of total	0	0	0	3.13	0.00	3.13	6.25	3.13	0

Table D.6. (Continued)

REP	PEN	GENO	TRT	INJURY	EAR/TAIL	GASTRO	RESPIRATORY	WASTING	SUDDEN	DISEASE	OTHER
1	16	C15	T+H	1	1	2	0	0	0	2	0
3	23	C15	T+H	0	0	1	0	0	0	1	1
7	25	C15	T+H	1	0	0	0	0	0	0	1
8	31	C15	T+H	3	0	0	0	1	0	1	0
				5	1	3	0	1	0	4	2
				41.67	8.33	25.00	0	8.33	0	33.33	16.67
			% of trt								
			deaths								
			% of	15.63	3.13	9.38	0	3.125	0	12.5	6.25
			total								
1	32	C15	Hum	0	0	0	0	0	0	0	0
3	22	C15	Hum	0	0	0	1	1	0	2	0
7	9	C15	Hum	0	0	0	0	0	0	0	0
8	30	C15	Hum	0	0	0	0	0	0	0	1
				0	0	0	1	1	0	2	1
			% of trt	0	0	0	33.33	33.33	0.00	66.67	33.33
			deaths								
			% of	0	0	0	3.13	3.13	0.00	6.25	3.13
			total								

Table D.7. Identification of the cause of death loss by treatment for the EXP-94 genotype

EXP-94 Death loss				Death loss Identification						
REP	PEN	GENO	TRT	INJURY	EAR/TAIL	GASTRO	RESPIRATORY	WASTING	SUDDEN DISEASE	OTHER
2	9	EXP	Con	1	0	0	0	0	0	0
4	4	EXP	Con	0	0	0	0	1	1	0
5	27	EXP	Con	0	0	0	0	0	0	1
6	2	EXP	Con	0	0	1	0	0	1	1
				1	0	1	0	1	2	2
				20.00	0	20	0	20	4	40
				% of trt						
				deaths						
				% of	3.13	0	0	3.13	0	6.25
				total						6.25
2	25	EXP	Toys	1	0	1	0	1	2	0
4	6	EXP	Toys	1	0	1	0	0	1	0
5	19	EXP	Toys	0	0	0	1	0	1	0
6	13	EXP	Toys	0	0	0	1	0	1	0
				2	0	2	2	1	5	0
				28.57	0	28.5	28.57	14.29	71.43	0
				% of trt						
				deaths						
				% of	6.25	0	6.25	3.13	0	15.63
				total						0
2	28	EXP	Neg	0	0	0	0	0	0	0
4	21	EXP	Neg	0	0	0	0	0	0	0
5	15	EXP	Neg	0	0	0	0	1	1	0
6	10	EXP	Neg	0	0	0	0	1	1	1
				0	0	0	0	2	2	1
				0	0	0	0	66.67	66.67	33.33
				% of trt						
				deaths						
				% of	0	0	0	6.25	0	6.25
				total						3.13

Table D.7. (Continued)

REP	PEN	GENO	TRT	INJURY	EAR/TAIL	GASTRO	RESPIRATORY	WASTING	SUDDEN	DISEASE	OTHER
2	12	EXP	T+H	2	0	0	0	0	1	1	0
4	20	EXP	T+H	0	0	0	0	0	0	0	0
5	3	EXP	T+H	0	0	0	0	0	0	0	
6	26	EXP	T+H	0	0	0	0	0	0	0	0
				2	0	0	0	0	1	1	0
				% of trt	66.67	0	0	0	33.33	33.33	0
				deaths							
				% of	6.25	0	0	0	3.13	3.13	0
				total							
2	11	EXP	Hum	0	0	2	0	1	0	3	0
4	5	EXP	Hum	0	0	0	0	1	0	1	0
5	29	EXP	Hum	0	0	0	0	0	0	0	0
6	18	EXP	Hum	0	0	0	0	0	1	1	0
				0	0	2	0	2	1	5	0
				% of trt	0	40	0	40	20	100	0
				deaths							
				% of	0	6.25	0	6.25	3.13	15.63	0
				total							

Table D.8. Mortality summary (% of total deaths by treatment)

TRT	Total Mor #	INJURY	EAR/TAIL	INFECT DISEASE	OTHER	Total % Mortality
Death Summary--C-15						
Con	6	6.25	3.13	6.25	3.13	18.75
Toys	4	6.25	0	0	6.25	12.50
Neg	2	0	0	6.25	0	6.25
T+H	12	15.63	3.13	12.5	6.25	37.50
HUM	3	0.00	0.00	6.25	3.13	9.38
Death Summary--EXP-94						
Con	5	3.13	0	6.25	6.25	15.63
Toys	7	6.25	0	15.63	0	21.88
Neg	3	0	0	6.25	3.13	9.38
T+H	3	6.25	0	3.13	0	9.38
HUM	5	0	0	15.63	0	15.63
Death Summary--Overall						
Con	11	9.38	3.13	12.50	9.38	17.19
Toys	11	12.50	0.00	15.63	6.25	17.19
Neg	5	0.00	0.00	12.50	3.13	7.81
T+H	15	21.88	3.13	15.63	6.25	23.44
HUM	8	0.00	0.00	21.88	3.13	12.50

APPENDIX E
PEN LAYOUT

Figure E.1. East nursery diagram

Figure E.2. West nursery diagram

Figure E.3. Finishing pen diagram

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