EFFECT OF SWINE DIETS SUPPLEMENTED WITH MAGNESIUM SULFATE AND ELECTROLYTES ON PORK QUALITY

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EFFECT OF SWINE DIETS SUPPLEMENTED WITH MAGNESIUM SULFATE AND ELECTROLYTES ON PORK QUALITY

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ABSTRACT

Market hogs (n = 160, BW=114.4 kg) were allotted into four dietary treatments to evaluate the effectiveness of magnesium sulfate and electrolytes on improving pork quality. The experiment was conducted in four seasons to evaluate seasonality (temperature) as an environmental stressor. The temperature variations in the finishing barn for the four trials were: Trial 1, mean 9.4°C (max 17.6, min 3.1°C); Trial 2, mean 11.9°C (max 27.9, min 3.9°C); Trial 3, mean 21.0°C (max 31.5, min 11.7°C); and Trial 4, mean 23.8°C (max 34.2, min 14.6°C). Duroc and Berkshire x Duroc market hogs were grouped by weight, sex and breed into one of four dietary treatments. The dietary treatments were: 1) control (corn/SBM based; 13.5% CP and 0.8% total lysine), 2) control + 3.2g/pig/d of magnesium sulfate ($MgSO_4$) for a minimum of 14 d prior to slaughter, 3) control + 1.5% electrolytes (sodium bicarbonate; $NaHCO_4$) fed for 48 h prior to slaughter, and 4) control + 3.2 g/pig/d $MgSO_4$ + 1.5% $NaHCO_4$. Hogs were transported to the University of Missouri for slaughter. Pigs were given ½ hour to 5 hours of lairage and slaughtered in random order. No differences ($P > 0.05$) in pork quality were found between dietary treatments. Live weight, gain, carcass weight and

dressing percentage did not differ ($P > 0.05$) by trial. Trial 4 had the highest 24 h loin and ham pH ($P < 0.05$) while hogs processed in Trial 2 had the lowest 24 h pH of the four trials. Trial 4 hogs had the lowest L values in the ham and loin while Trial 3 had the highest L values in the loin and Trial 2 had the highest L values in the ham ($P < 0.05$). Trial 4 loins had the lowest drip loss ($P < 0.05$) which corresponded to the highest pH and lowest L values. The highest values for Warner-Bratzler Shear force ($P < 0.05$) were found in Trials 1 and 2 while Trials 3 and 4 both had the lowest values. Overall, dietary treatment had no effect on pork quality. However, seasonal temperature had an impact on pork quality.

CHAPTER 1

INTRODUCTION

Swine production has changed dramatically over the past 35 years. Large livestock conglomerates have vertically integrated pork production systems, controlling production from conception through consumption. From 1970 to 1993 there was a 73% decline in the number of farms with hogs in the U.S. (Lawrence, 1994). The number of hog farmers was cut in half again by 1997 (Honeyman, 1997). Even with this dramatic decline in the number of hog farms, the number of pigs produced in the U.S. over the same amount of time has stayed relatively consistent (Honeyman, 1996).

The purpose of the Pork Checkoff is to contribute to the success of all pork producers by managing issues related to research, education and product promotion and by establishing U.S. Pork as the preferred protein worldwide (NPB, 2007). This purpose has been exemplified through the immensely successful "*Pork, the other white meat*"® campaign which helped to increase domestic consumption through the 1990's, propelling pork to the most widely consumed meat product in the world (NPPC, 2007).

Pork quality is influenced by many pre-harvest and post-harvest factors, which affect pH, drip loss, and color; therefore, prediction of ultimate pork quality is a challenge (Huff-Lonergan, et al. 2002). Kaufman et al. (1992) reported that 26% of carcasses were undesirable, in most cases having one of two quality defects; dark, firm and dry or pale, soft and exudative meat. The National Pork Producer Council (NPPC, 1998) has developed a series of pork quality targets that represent minimums or ranges for producers to aim for in improving overall pork quality. These targets take into consideration six areas where quality can be quantified; they are color, pH, Warner Bratzler shear force, flavor, intramuscular fat, and drip loss.

Consumer selection of pork hinges mainly on the color of the meat in the retail case, this being the only true indicator consumers have of the freshness, wholesomeness, and taste of the product (Seideman, et al., 1984). Color and pH are indirect indicators of juiciness and tenderness in pork and are related to each other (Aberle et al., 2001). Pork with higher pH values is darker in color, due to light absorbance, and preferred by consumers compared to a lighter colored meat, which has lower pH values (Norman et al., 2003). Pre-slaughter stress can negatively alter these meat quality indicators resulting in inferior meat quality. Stress can come from many different sources including transportation, season of the year, genotype, and environmental conditions (Hambrecht et al., 2005; Küchenmeister et al., 2005). The animals' ability to cope with the particular stressor will ultimately affect meat quality. When pigs are stressed, they begin to immobilize energy sources in the body to maintain normal function this in turn affects the decline and ultimate pH of the meat. A normal pH drop is when the pH of the pig goes from 7.4 at the time of slaughter to approximately 5.6 to 5.7 within 6 to 8 hours (Aberle et al., 2001). If the stress is too high, the pig will not be able to recover these energy sources before processing and this will lead to a final pH which is either higher or lower than normal a normal pork carcass pH of 5.4 – 5.6 (Aberle et al., 2001). If all of the energy stores (glycogen) are used prior to processing there are no substrates for normal postmortem metabolism and the final pH will not fall much below the pH of living muscle causing the pork to be dark, firm, and dry in appearance (Aberle et al., 2001). If the body has begun to metabolize the energy stores prior to processing but there are still energy stores left, postmortem metabolism is in high gear and there will be an excess of lactic acid formed causing pH drops to around 5.5 within an hour after slaughter and settle at roughly 5.3 to 5.6, this is commonly referred to as PSE or pale, soft and exudative meat (Aberle et al., 2001).

One way to overcome the effects of pre-slaughter stress is by supplementing swine diets with nutrients that lessen the stressors affect on the body. Pigs, being mono-gastric animals, are able to transfer nutrients and feed additives directly to muscle and tissue which can in turn affect pork quality (Rosenveld and Andersen, 2003).

In addition, there is evidence that various nutritional factors affect pork quality (color, pH and water holding capacity). Some of the documented nutrients and feed management practices that may alter pork quality are Vitamin E, selenium, Vitamin C, chromium, Vitamin D, pre-slaughter feed deprivation, sugar feeding, sodium oxalate, magnesium and electrolytes (Hasty et al., 2002; Pion et al., 2004; Weigand et al., 2002; D’Souza et al., 1998, 1999; Boles et al., 1992; Pettigrew and Esnaola, 2001).

The current research will focus on two dietary supplements, magnesium sulfate and sodium bicarbonate. Magnesium supplementation is believed to slow the release of catecholamines (epinephrine and norepinephrine) which are hormones related to glycogenolysis (D’Souza et al., 1998, 1999). Pigs that are stressed before slaughter have a high rate of glycogenolysis resulting in a high incidence of poor quality pork, caused by rapid pH decline and a low ultimate pH (Beuge, 1998). Therefore, a high dietary intake of magnesium prior to slaughter should improve pork quality of stressed pigs by reducing the rate of postmortem glycoylsis. Pre-slaughter stress of pigs can alter blood concentrations of certain electrolytes that may be attributed to poor pork quality. Oral administration of alkaline salts or electrolytes (sodium bicarbonate) helps replace the lost nutrient needed for dehydration (Boles et al., 1992).

The overall goal of this project was to determine the effect of supplementing magnesium sulfate and sodium bicarbonate on pork quality. Therefore, in the future, swine nutritionists and the global feed industry can provide diets to market pigs that will enhance the eating experience for consumers and improve product demand.

Two major objectives of the project are:

1. To compare effectiveness of dietary supplementation of magnesium sulfate and/or electrolytes (sodium bicarbonate) on improving pork quality.
2. To compare pork quality in different seasons of the year and to see if the dietary supplements can overcome any seasonal variation.

CHAPTER 2

LITERATURE REVIEW

2.1 Pork Quality

Pork quality is a complex subject having varying definitions along the entire pork supply chain from producer to consumer. At the producer level, excellence in pork production is maximized when market hogs excel in production efficiency while also producing a high quality carcass (NPPC, 2000). The slaughter and further processing sector of the meat industry define quality as freshness, wholesomeness, grade, color, eating satisfaction, and processing attributes which may include water holding capacity and anything else related (Cannon et al., 1995). Lammens et al. (2006) stated that the quality of meat produced from an animal will depend on animal and environmental factors. The main attributes of interest to the packer, and ultimately the consumer, are water-holding capacity, color, fat content and composition, oxidative stability, and uniformity (Rosenveld and Andersen, 2003). Factors that affect these attributes are breed, genotype, feeding regimen, pre-slaughter handling, stunning and slaughter method, chilling, and storage conditions (Rosenveld and Andersen, 2003).

2.1.1 Carcass Composition

Consumers have become increasingly health conscious and are focusing more on the nutritional attributes of their diets. This awareness has been heard loud and clear by the pork industry and in turn it has been producing a leaner animal (Cannon et al., 1995). Excess subcutaneous and seam fat is also being removed from pork cuts (Cannon et al., 1995). Lean percentages of carcasses have increased steadily with Orcutt et al., (1990) reporting that the average market hog in 1990 was 51.7% lean compared to 45.4% lean in the mid 1970's (Cross et al., 1975). Carcass weights have shown a steady increase gaining approximately 0.9 kg a year between 1978 and 1988 (Orcutt et al., 1990). Decreasing carcass fat has also reduced intramuscular marbling and given the consumer a perception of a tougher meat that is less moist and lacks flavor (Dunshea et al., 2005). Cannon et al. (1995) predicted that the increase in lean muscle will not have a negative effect on pork palatability where as Devol et al. (1988) suggested a minimum amount of marbling, 2.5% to 3.0%, be present to ensure acceptable tenderness and juiciness of the pork. Fat as a percentage of the carcass has consistently dropped since the 1940's and as of 1980 70% of the hogs in the U.S. had a carcass grade 1 (Speer, 1991). A U.S. No. 1 grade is predicted to have at least 60.4% of the carcass in the four lean cuts of the ham, loin, Boston butt and picnic shoulder (Savell and Smith, 2000). Pork producers are rewarded by producing leaner carcasses and most hogs in the U.S. are purchased on a grade and yield basis that takes into consideration amounts of lean and fat (Savell and Smith, 2000). Dressing percentage is the dressed carcass weight divided by the live animal weight multiplied by 100 (Savell and Smith, 2000). Pigs will have an approximate dressing percentage of 70%, which is higher than cattle and sheep due to the fact they are monogastric animals, fatter than the other animals, and are dressed with the skin and feet left on (Savell and Smith, 2000).

To ensure a pork product of consistent quality even with the changing carcass composition, the National Pork Producers Council (NPPC, 1998) has developed a series of quality targets that represent minimums or ranges to aim for when improving overall pork quality. These targets take into consideration six areas where quality can be quantified. The following list contains these attributes and the target that is to be obtained: color, 3-5 on a six point scale; pH, 5.6 – 5.9; tenderness, < 3.2 kg Warner Bratzler shear force; flavor, robust pork flavor; intramuscular fat, 2 – 4%; and drip loss < 2.5%.

2.1.2 pH and Temperature

The greatest change that occurs immediately postmortem is the accumulation of lactic acid in the muscle of the animal which causes the pH of the animal to drop (Aberle et al., 2001). The rate and extent of this acidification of the muscle will affect meat quality including, color, water holding capacity, and ultimately eating quality and consumer acceptance (Bendall and Swatland, 1988). This drop can vary widely between individual animals of the same species and also individual muscles of that animal (Seideman et al., 1984). Living muscle has an average pH of 7.0 to 7.4 and pigs have a body temperature of approximately 38.5^{o}C immediately postmortem (Aberle et al., 2001). Carcasses are chilled immediately after processing to ensure food safety, maximize shelf life and decrease shrinkage (Savell et al., 2005). The rapid chilling of the carcass slows the metabolic processes and reduces the rate of pH decline (Huff-Lonergan and Page, 2001). Events that occurred pre-mortem and postmortem will have an effect on the eventual pH and temperature drop of the animal and ultimately play a large role in the meat quality of the animal (Seideman et al., 1984).

A normal pH drop is when the pH of the pig goes from 7.4 at the time of slaughter to approximately 5.6 to 5.7 within 6 to 8 hours (Aberle et al., 2001). The ultimate pH will then be reached at 24 hours at a pH of 5.3 to 5.7 (Aberle et al., 2001). Pigs can also display two other types of pH drops soon after slaughter; one in which pH drops very little shortly after slaughter and remains high until an ultimate pH is accomplished at around 6.5 to 6.8, this is referred to as dark, firm, and dry or DFD while a third type of pH drop can occur in which pH drops to around 5.5 within and hour after slaughter and settles at roughly 5.3 to 5.6, this is commonly referred to as pale, soft, and exudative or PSE meat (Aberle et al., 2001).

Once exanguination occurs the animal loses its ability to control its body temperature and dissipate heat (Aberle et al., 2001). With the build up of lactic acid and glycolysis occurring at the same time the body temperature of the animal will rise slightly postmortem (Aberle et al., 2001). Pigs also undergo scalding in many processing facilities which delays temperature decline even more (Aberle et al., 2001). The goal of any processing facility is for the carcass to reach the chill cooler in the quickest time possible to ensure a constant and consistent temperature decline (Huff-Lonergan and Page, 2001). If the heat of the carcass is not removed quickly enough and the pH of the carcass drops far enough fast enough the condition of PSE may occur (Huff-Lonergan and Page, 2001).

2.1.3 Water Holding Capacity

Muscle is composed of 75% water (Huff-Lonergan and Lonergan, 2005). Water exists in three main forms within the muscle; bound, immobilized, and free (Aberle et al., 2001). Bound water constitutes approximately four to five percent of all water found in the muscle. This water remains attached and tightly bound even when extreme physical or mechanical forces are applied to the meat (Aberle et al., 2001). Water becomes increasingly weaker bound as it is located farther away from the protein. Immobilized water is the intermediary layer of water that can be removed during cooking while free water is easily lost during retail display (Aberle et al., 2001).

In muscle water is located in several different places; within the myofybrils, between the myofybrils, between the myofibrils and sarcolemma, between muscle cells and between muscle bundles (Offer and Cousins, 1992). Most of the intracellular water is found in the myofibrils between the thick filaments of myosin and the thin filaments of actin and tropomyosin (Lawrie, 1998). This interfilament space can vary in size which ultimately affects water holding capacity by variations in pH, sarcomere length, ionic strength, osmotic pressure, and rigor state of the meat (Offer and Trinick, 1983).

Water holding capacity will affect appearance of the meat prior to cooking, the meats ability to retain water during cooking, and the mouth feel upon consumption (Lawrie, 1998). Water holding capacity and especially unacceptable water holding capacity is considered by some to be the most important quality characteristics of raw pork (Huff-Lonergan and Longergan 2005). Estimates are that as much as 50% of the pork processed has high drip loss (Kauffman et al., 1992; Stetzer and McKieth, 2003)

2.1.4 Color

Color is the only determining factor consumers have when selecting pork at retail. This color whether it be pale, soft and exudative or a more normal pinkish gray color is important in determining perceived eating quality (Warriss et al., 2006). The unacceptable color of pork was ranked second only to excessive fat in the 1996 pork quality audit as a major concern to processors (Cannon et al., 1995). The color of lean is most likely connected to the ultimate freshness of the meat (Adams and Huffman, 1972). The U.S. consumer prefers pork that is bright reddish-pink (NPPC, 2000). Fresh pork that tends to be excessively pale, too dark, or have a wide variation either in package or in the meat case tends to deter customers from purchasing (NPPC, 2000).

Visual color can be described using three attributes classified as hue, chroma, and value (Aberle et al., 2001). Hue can be referred to as the actual color that is being viewed whether it is green or red in technical terms it is the wavelength of the light radiation (Aberle et al., 2001). Chroma is the intensity of the perceived color while value is the brightness of the color (Aberle et al., 2001). Instrumental color is measured in industry with one of two likely colorimeters, a Hunter Miniscan or a Minolta (NPPC, 2000). These colorimeters produce three values, L*, a* and b*. L*, arguably the most important to pork processors measures color from black to white on a 100 point scale, 0 being perfectly black and 100 being perfectly white the value a* measures color from green to red while b* measures color from blue to green (NPPC, 2000). The L* value is the highest correlated to the visual color of the pork chop (Brewer et al., 2001). Using L* and a* in tandem can account for 69% of the variation in the pink color of most pork chops (Brewer et al., 2001). Brewer et al., (2001) also determined that L* can be the best determinant of PSE and DFD in pork muscle.

There are two main pigments that are being measured when assessing subjective or objective color of a meat product, they are hemoglobin and myoglobin. (Aberle et al., 2001). Hemoglobin is the pigment of blood and myoglobin is the pigment of muscle (Aberle et al., 2001). Myoglobin makes up the largest part of the color of meat consisting of 80-90 percent in a well bled animal (Aberle et al., 2001). Myoglobin content of muscle varies with age, as an animal ages the myoglobin in the body loses the ability to bind oxygen and in turn more myoglobin must be in the muscles to bind the same amount of oxygen (Aberle et al., 2001).

The chemical state of myoglobin will also have an affect on the color of meat (Aberle et al., 2001). When iron is in an oxidized state (ferric state, Fe^{3+}) it can not combine with oxygen or other molecules, in a reduced state (ferrous state, Fe^{2+}) the myoglobin has a high affinity to bind with oxygen and other molecules (Aberle et al., 2001). Deoxymyoglobin occurs in the absence of oxygen and the meat will tend to be a dark, purplish-red (Kropf, 2000). When air is added to the meat deoxymyoglobin is converted to oxymyoglobin and the meat will turn a bright red, the color most consumer associate with meat (Kropf, 2003). Deoxymyoglobin and oxymyoglobin are both in the reduced state (Kropf, 2003). When meat is exposed to air for an extended period it becomes oxidized and is converted to the metmyoglobin state (Aberle et al., 2001). The metmyoglobin state of meat tends to be a dull brown color (Kropf, 2003).

Species also plays a role in meat color with pork having the lowest concentrations of myoglobin compared to beef and lamb which results in the lightest colored meat of the three (Walters, 1975). Dietary supplementation can also play a role in improving meat color, feed additives such as magnesium sulfate and vitamin D_3 improved the visual color of meat (Mancini and Hunt, 2005).

2.1.5 Tenderness

Tenderness, although not a major concern to pork processors due to the focus placed on other pork quality attributes such as undesirable color or insufficient water holding capacity is ranked by consumers as one of the most important meat quality attributes (Lawrei et al., 1998). Within a species, tenderness can be affected by four main factors; amount of connective tissue, contractile state, protein interactions, and fat and moisture content (Lorenzen, 2006). Not only can tenderness be affected by species but also by post-mortem storage length and cooking time (Goll et al., 1997). Wood (1993) stated that juciness and flavor along with tenderness can be increased with an increasing amount of marbling of the pork. Although not commonly done in the industry, Wood et al. (1996) determined that aging pork from 4 to 10 days led to a slight increase in tenderness as determined by a consumer taste panel.

Tenderness can be evaluated through a variety of methods including; Warner Bratzler shear force (**WBS**), trained or consumer sensory panels, or by measuring amount of collagen and sarcomere length (Lorenzen, 2006).

2.2 Nutrition

The digestive tract of the pig resembles that of the human in almost every facet and both species require roughly the same nutrients in order to maintain everyday function (Pond, 1991). Pigs are a monogastric animal, which means their digestion occurs in one stomach. Nutrients of the pig's diet are easily transferred from the digestive tract to the muscle and fat, affecting meat quality (Rosenvold and Andersen, 2003). The genetic make up of the pig will have the highest impact on its ability to grow muscle; however, the nutritional intake of the animal will help to maximize lean growth (Speer, 1991). The animal industry has been aware of the need to maximize lean growth and muscle development (Speer, 1991). A shift in the nutrient requirements of swine has taken place over the past 30 years as most pigs have moved indoors to a confinement setting and the animal can no longer get any of the nutrients from the soil (Mahan and Kim, 1999). An example of this is the selenium that must be added to today's swine diets which prior to 1970 was not included (Mahan and Kim, 1999).

Today in the U.S., pigs are fed diets consisting of two main ingredients, corn and soybean meal. Corn is the main energy source for the growing pig (Seerley, 1991). Soybean meal is supplemented into the diet as the protein source and provides a balance of amino acids (Seerley, 1991). Wheat or sorghum can also be used as sources of energy in the swine diet but in research by Ramsey et al. (1990) pigs fed a diet of corn produced larger loin eyes and the Warner Bratzler values were lower than pigs fed sorghum based diets. A vitamin and mineral premix is also added to the swine diet to guarantee adequate nutrient supplementation (Mahan and Kim, 1999).

Swine diets are currently balanced on a specified amino acid ratio and not just by total protein content (Lewis, 1991). There are 10 essential amino acids that need to be supplemented in a swine diet. Pigs are able to synthesize 10 of the amino acids in there body and do not have to be added to the diet (Lewis, 1991). In a corn and soybean meal swine diet, lysine is the first limiting amino acid, meaning it is in the least amount relative to its necessity (Lewis, 1991).

Various vitamins are added to the diet with each helping to assist the body in a necessary function. The fat soluble vitamins such as K and E are involved in tissue growth and maintenance; in turn the B vitamins and ascorbic acid are metabolic co-factors that help speed up intercellular reactions (Mahan and Kim, 1999). B vitamins need to be adjusted as the animal consumes a greater amount of feed, because there are more nutrients to metabolize, while the fat soluble vitamins are fed on a per body weight basis (Mahan and Kim, 1999). Phosphorus and calcium are two important macro minerals that aid in bone development and reproduction (Mahan and Kim, 1999). Phosphorus also functions in protein metabolism; both of these minerals if inadequate in the diet will result in decreased bone rigidity and decreased growth performance (Mahan and Kim, 1999).

2.2.1 Feed Additives and Effect on Stress

Feeding high concentrations of micro and macro nutrients shortly before transport and slaughter has been researched to determine if there is an improvement in meat quality (Geesink et al., 2004). Some of the documented nutritional ingredients and feed management practices that may alter pork quality are Vitamin E, selenium, Vitamin C, chromium, Vitamin D, sugar, sodium oxalate, magnesium and electrolytes (Hasty et al., 2002; Pion et al., 2004; Weigand et al., 2002; D'Souza et al., 1998, 1999; Boles et al., 1992; Pettigrew and Esnaola, 2001).

Magnesium is an inorganic element and required at approximately 1.2 g/hd/d (Crenshaw, 1991). Magnesium is part of a group of nutrients including sodium, potassium, and chlorine that help balance osmotic pressure, acid-base balance, membrane potential, substrate transport, and enzymatic cofactors (Crenshaw, 1991). Magnesium is a nutrient that must be provided in the diet at all times because there is no storage mechanism in the body for it and a deficiency will almost immediately affect feed intake (Crenshaw, 1991).

Research has shown that feeding dietary additions of magnesium ranging from 25 mg to 3.2 g for less than 5 days prior to slaughter improved pork color (Minolta a*), reduced drip loss, increased water holding capacity and eliminated PSE carcasses (Schaefer et al., 1993; D'Souza et al., 1998; Frederick et al., 2004). The response observed in pork quality of finishing pigs fed magnesium is independent of source (D'Souza et al., 1999). More recent research has shown no improvements in pork quality traits when finishing pigs were fed 2.5% magnesium mica (Apple et al., 2005).

The addition of electrolytes (sodium bicarbonate) to swine diets has also been researched to determine if preslaughter feeding can affect meat quality. Adding electrolytes to the swine diet prior to slaughter causes a metabolic alkalosis in the animal, raising the initial pH and possibly improving meat quality (Boles et al., 1992). Haydon et al. (1990) stated that heat stress can upset the acid-base balance in livestock. Adding electrolytes to finishing swine diets can help increase feed intake and in turn keep rate of gain consistent through hot periods of the year (Haydon et al., 1990). Researchers (Ahn et al., 1992; Boles et al., 1993; 1994) have shown that 1 to 2 % electrolytes fed prior to slaughter increase the initial muscle pH slowing glycogen metabolism and improving pork color (Minolta b*). Other pork quality characteristics such as drip loss, Minolta L* and ultimate pH had varying results when pigs were fed electrolytes. While there have been many researched feed additives that have shown varying results on improving pork quality, overall, Geesink et al. (2004) suggested that some dietary supplements such as, magnesium acetate, tryptophan, Vitamin C and Vitamin E, showed no improvement on pork quality when the animals were under normal processing conditions.

2.3 Environmental Stress

Hogs can experience many different stressors prior to slaughter and their ability to appropriately handle this stress will have an affect on meat quality. Homeostasis, or the ability to maintain body function through a wide array of environmental stressors, is how animals are able to cope with varying conditions (Webster, 1982). This state can be exacerbated when hogs have porcine stress syndrome (PSS) also identified as malignant hypothermia which lessens their ability to cope with stress (Doumit, 2003). Hormones are released during stressful situations that help the animal deal with the stress. Epinephrine and norepinephrine are secreted from the adrenal medulla during a stressful situation (Sherwood et al., 2005). Epinephrine prepares the body for the "flight" or "fight" response and it also begins to mobilize carbohydrate and other energy stores (Sherwood et al., 2005). Blood flow to the muscles also increases in preparation for contraction (Aberle et al., 2001).

Pre-slaughter stress can be categorized as either long term stress which occurs during on farm loading and transport or as short term stress which can happen during lairage up to the point of stunning (Rosenvold and Andersen, 2003). Long term stress will most likely result in DFD while short term stress can cause the meat to be PSE or red soft and exudative (RSE).

The Halothane-1843 gene and the Rendement Napole gene are two other genetic conditions that cause a decreased stress response and an increase in PSE pork (Doumit, 2003). Halothane carriers tend to have better feed efficiency, carcass yield, and are leaner animals than non carriers (Leach et al., 1996). The Halothane gene was first discovered by exposing pigs to halothane gas, but DNA testing can now be used to determine if the animal is homozygous or heterozygous for the condition (Aberle et al., 2001). In halothane susceptible pigs, the animal's calcium channel is defective which causes a greater pH decline postmortem while body temperature remains high (Aberle et al., 2001). This, in turn, causes greater denaturing of the muscle proteins and PSE pork (Aberle et al., 2001). The Rendement Napole gene causes inferior meat quality through a faulty feedback inhibition system that regulates the synthesis of glycogen (Aberle et al., 2001). This, in turn, causes the animal to have increased amounts of muscle glycogen at slaughter, producing more lactic acid and a decreased final pH (Aberle et al., 2001). This condition in swine is referred to as the Hampshire effect due to its frequency in that particular breed (Monin and Sellier, 1985). Grandin (1994) estimates that 10-15% of PSE pork carcasses are a direct cause of improper handling and 20%-40% of PSE pork can be attributed to a delay in proper carcass chilling.

Animals can experience stress when they are moved to an unfamiliar environment, mixed with unfamiliar animals or there is a drastic change in temperature. Stress can come from many different sources including transportation, season of the year, genotype, and environmental conditions (Hambrecht et al., 2005; Küchenmeister et al., 2005). Physiological changes occur within the animal to maintain heart rate, respiration and body temperature in an effort to deal with the stress (Aberle et al., 2001). Transport stress and season of the year are two main stressors that occur in today's pork industry. With most hogs being reared in climate controlled building, Martoccia et al. (1995) stated that transport stress is the most significant cause of poor meat quality antemortem.

2.3.1 Transport and Lairage

Transport stress can be caused by several different factors including: temperature on the day of transport, stocking density of the truck, and length of transport (Berg, 1998). Many different variables are accompanied by transport stress including: velocity of the truck, vibration, mixing of hogs, and unfamiliar people handling the livestock (Berg, 1998). Stocking density in most cases is a matter of economics and not meat quality (Berg, 1998). Tarrant (1989) suggested the stocking density of 0.35 m^2/100 kg pig. Overcrowding on the livestock trailer can cause heat stress, mortality, fatigue, and inferior meat quality; too much space on the other hand can also cause injury from hogs being thrown around and also is not as economically efficient (Tarrant, 1989; Berg, 1998). Space allowance should be adjusted during extreme heat (Berg, 1998).

Length of transit can also play a role in the ultimate meat quality of the animal. Hogs transported for 650 km had a higher pH at 45 minutes and at 24 hours postmortem than hogs transported a shorter distance of only 180 km (Martoccia et al., 1995). Grandin (1994) reported that pigs transported shorter distances tended to resist movement at the slaughterhouse, resulting in the possibility of increased PSE of the meat.

Most processing plants allow the hogs a lairage period or a time to rest from when they are driven from the truck until stunning. This period allows hogs to recover from the stress of loading, transport and unloading (Berg, 1998). The lairage area not only allows pigs to rest prior to slaughter but also gives the processing plant a reservoir of hogs to pull from to maintain line speed (Geesink et al., 2004). If the reservoir of pigs is depleted, pigs will be driven straight from the truck to slaughter (Geesink et al., 2004). Milliagan et al., (1998) found that at least 2 hours of lairage was ideal for preventing PSE and skin temperatures of pigs decreased as the lairage time increased   Santos et al. (1997) also suggested a 2-3 hour lairage time upon unloading but warned that under warmer lairage temperature conditions, then hogs should be driven straight to slaughter an allowed no time to rest.

2.3.2 Seasonality and Temperature Fluctuation

Hogs are able to thermo-regulate their body temperature over a wide array of temperatures but there are limits to this ability (Black et al., 1999). There are numerous ways in which pigs regulate there body temperature including; shivering, modifying feed intake, altering blood flow to the surface of the skin, huddling, seeking out heat sources, and respiration (Black et al., 1999). When environmental temperatures are below the pigs' thermoneutral point they will vasoconstrict blood vessels to minimize heat loss and eventually heat produced from feed intake and other forms of activity will be lost to the environment (Black et al., 1999). If temperature continues to decrease, the animal will be metabolizing dietary energy for heat production and if this condition continues long enough can ultimately become fatigued and die (Black et al., 1999). If ambient temperature becomes higher than the thermoneutral point of the animal, the skin will vasodialate allowing blood to move closer to the surface of the body to aid in cooling (Black et al., 1999). Pigs have only a small amount of sweat glands and must wet their skin, to allow for evaporation, and increase respiration to maintain a normal body temperature (Black et al., 1999). This is why pigs tend to find a mud hole or find another way to wet themselves on a hot summer day. Eventually if the internal temperature of the pig increases, the voluntary feed intake will cease and respiration reaches its maximum (Black et al., 1999). The animal will become fatigued under these conditions and if the hot weather persitsts long enough and the animal is not cooled, death may occur (Black et al., 1999).

Heitman et al. (1958) reported that temperatures above 27° C have a negative affect on average daily gain (ADG) while temperatures below approximately 5° C had a negative affect on ADG. In a study completed by Garcia-Rey et al. (2005), hogs finished in the coldest months of the year produce animals with heavier carcass and ham weights. When pigs were slaughtered in November, ham pH was the highest at 45 minutes while pigs slaughtered during the warmer months had the highest ham pH at 48 hours (Garcia-Rey et al., 2005). Garcia-Rey et al., (2005) concluded seasonality played a key role in meat quality. Researchers have found that the highest incidence of PSE was in pigs grown during the hottest part of the year; conversely pigs grown during cool weather had more desirable meat that was darker in color and possessed more marbling (Judge et al., 1959). Thomas et al. (1966) concluded that fluctuating temperatures are a major cause of the undesirable condition of pale, soft, and exudative meat.

Pork quality is ultimately affected by numerous factors and controlling all of them is virtually impossible. The current goal of the pork industry is to produce a consistent quality product produced from numerous pork producers under varying conditions over a wide range of environmental stressors.

CHAPTER 3

DIETARY SUPPLEMENTATION OF MAGNESIUM SULFATE AND SODIUM BICARBONATE AND ITS EFFECT ON PORK QUALITY

3.1 Introduction

Monogastric animals, such as pigs, are able to transfer nutrients and feed additives directly to muscle and tissue which can positively or negatively affect pork quality (Rosenveld and Andersen, 2003). Numerous dietary supplements have been researched to determine there effectiveness in improving pork quality.

Magnesium helps maintain osmotic pressure, acid-base balance, membrane potential, substrate transport, and enzymatic cofactors and feed intake will almost immediately be affected if it is lacking in the diet (Crenshaw, 1991). Dietary supplementation of magnesium has been a recent research focus in the improvement of pork quality. The most common Mg source for supplementation is $MgSO_4$. D'Souza et al. (2000) reported that pigs fed $MgSO_4$ for five days prior to slaughter had a decrease in the incidence of PSE carcasses. Other research has been less supportive of supplementing diets with magnesium, showing little or no improvement in pork quality (Apple et al., 2000, 2002; and Hamilton et al., 2002).

Pigs can experience many different stressors prior to slaughter, including transportation, genotype, and environmental conditions, and the animals ability to appropriately handle this stress will have an affect on meat quality (Hambrecht et al., 2005; Küchenmeister et al., 2005). Heat stress in particular can upset the acid-base balance of an animal, and adding electrolytes to finishing diets can help increase feed intake and in turn keep rate of gain consistent through hot periods of the year (Haydon et al., 1990). Researchers (Ahn et al., 1992; Boles et al., 1993; 1994) have shown that 1 to 2 % electrolytes fed prior to slaughter increase the initial muscle pH slowing glycogen metabolism and improving pork color (Minolta b*).

The objectives of the research were to determine if dietary supplementation of magnesium sulfate and electrolytes (sodium bicarbonate) improved pork quality and to determine if there was a more beneficial time of year to feed the supplement by using seasonality as a stressor.

3.2 Materials and Methods

One hundred sixty Duroc and Berkshire x Duroc market weight pigs (114 kg ± 7.5 kg) were grouped by sex, beginning weight and breed and allotted into one of four dietary treatments (Table 3.1): 1) control (**C**), 2) control and sodium bicarbonate (**CE**), 3) control and magnesium sulfate (**M**), and 4) control, magnesium sulfate, and sodium bicarbonate (**ME**). Basal diets were formulated using corn and soybean meal to contain 13.5% crude protein and 0.8% total lysine on an as fed basis.

Magnesium sulfate (**$MgSO_4$**) was added to the diet and fed at a rate of 3.2 g/hd/d, for a minimum of 14 days prior to loading for slaughter. Sodium bicarbonate (electrolytes, **$NaHCO_3$**) was supplemented 48 h prior to loading and fed at 1.5% of the diet. Seasonality and temperature were used as a stressor and the experiment was replicated in the four seasons of the year. Temperatures in the finishing barn (Table 3.2) were recorded every hour for the feeding period using two Omega® Nomad™ data loggers (Stamford, CT).

Table 3.1 Composition of Basal Diet

Ingredient	% of diet
Corn	80
Soybean Meal-48%	15.7
Dicalcium Phosphate	2.5
Limestone	.75
Salt	.4
Vitamin Premix[1]	.25
Trace Mineral Premix[2]	.15
L-lysine	.15

[1] Supplied per kilogram of diet: retinyl acetate, 11,000 IU; cholecalciferol, 1,100 IU; DL-α-tocopheryl acetate, 44.1 IU; menadione Na dimethylpyrimidinol bisulfate, 4.0 mg; vitamin B_{12}, 30.3 µg; riboflavin, 8.3 mg; D-Ca-pantothenate, 28.1 mg; nicotinamide, 33.1 mg; choline chloride, 551.3 mg; D-biotin, 0.22 mg; folic acid, 1.65 mg.
[2] Supplied per kilogram of diet: Zn, 165 mg ($ZnSO_4$); Fe, 165 mg ($FeSO_4H_2O$); Cu, 16.5 mg ($CuSO_45H_2O$); Mn, 33 mg ($MnSO_4$); I, 0.3 mg $Ca(IO_3)_2$; Se, 0.3 mg (Na_2SeO_3).

Pigs were transported approximately 320 km from a southwest Missouri pork producer to central Missouri for the two week feeding trial. Animals were housed in a 14.63 m x 9.75 m confinement building with adjustable side wall curtains to regulate indoor temperature as to maximize temperature stress. Five pigs were allotted to each pen allowing 2.08 m^2/hd. Pigs were sorted into dietary treatments to balance treatments by breed, sex, and beginning weight. Pigs were fed *ad libitum* for the two week feeding trial and water was provided through two nipple waters per pen. Twenty pigs, five from each dietary treatment, were weighed and loaded on a livestock trailer approximately 12 h prior to slaughter and housed on the livestock trailer overnight. The pigs were transported 48 km to the University of Missouri-Columbia abattoir the following morning for slaughter. Each pig was allowed 0.89 m^2/hd on the livestock trailer. Pigs were allowed from ½ to 5 h of lairage time and killed in random order. Two days later, the remaining 20 hogs in the building were transported to slaughter using the same procedure.

Table 3.2 Average, Low, and High Barn and Air Temperatures of the Four Trials and High Temperatures for Each Slaughter Day (°C)

Trial (Month)	Avg. Barn Temp	Avg Air Temp[1]	Low Barn Temp	Low Air Temp[1]	High Barn Temp	High Air Temp[1]	Slaughter Day 1 Air Temp[1]	Slaughter Day 2 Air Temp[1]
1 (Dec)	9.4	-3.8	3.1	-15.5	17.6	6.4	4.0	.5
2 (Feb)	11.9	.8	3.9	-9.5	27.9	15.5	1.4	7.0
3 (May)	21.0	23.1	11.7	11.6	31.5	33.6	23.8	20.2
4 (July)	23.8	24.8	14.6	14.5	34.2	35.2	30.3	31.2

[1]Air temperatures were recorded at Sanborn Field at the University of Missouri-Columbia Experiment Station

Pigs were rendered unconscious with electrical stunning following standards set forth by the Humane Methods of Slaughter Act and exsanguination occurred immediately after shackling. Temperature and pH of the carcass was obtained from the side of the carcass that was shackled using a HH-21 calibrated thermometer (Omega Engineering, Inc., Stanford, CT) for recording the temperature and a SevenGo™ SG2 pH meter (Mettler Toledo, Columbus, OH) for recording the pH. Temperature and pH were recorded at 0, 15, 30, 60, and 1440 min and taken at the 10th rib of the *Longissimus dorsi* (**LD**) and the inside of the back leg for the *Semimembranosus* (**SM**). Hot carcass weight was taken before the animals entered the cooler. Carcasses were chilled at ~ 2° C for 24 h prior to fabrication.

Hams were removed between the 2nd and 3rd sacral vertebrae exposing the SM and leaving a fresh pork leg similar to IMPS #401 (NAMP, 1997; USDA, 1997). Loins were split from the shoulder between the 2nd and 3rd rib and the belly, sirloin, and tenderloin were removed along with the back ribs leaving a boneless loin similar to IMPS #412 (NAMP, 1997; USDA, 1997). The boneless loins were cut in half at approximately the 10th rib. The SM and LM were both allowed 10 min to bloom before color and marbling scores were determined. Visual color and marbling was taken at the 10th rib of the LM using the NPPC (1999) color and marbling scales. L, a, and b values were recorded using a Minolta Chroma Meter CR-400/410 (Konica Minolta, Japan). The 24 h pH was taken again on the LM at the 10th rib interface and the SM. Three 2.54 cm chops were removed at the 10th rib, two were vacuum packaged and frozen for Warner Bratzler shear force measurement and one was to determine drip loss.

Drip loss was measured using the NPPC (2000) 48 h drip loss test. Briefly two 50 g samples of LM were trimmed of external fat and weighed. Each piece of meat was suspended from a #8 fish hook in a 200 ml plastic container. The containers were kept at 4° C for 48 h and each sample was reweighed. The two samples were averaged to determine an ultimate drip loss.

Two LM chops were thawed at ~ 4° C for 24 h prior to cooking and determination of Warner Bratzler shear force (WBSF) (AMSA, 1995). A thermocouple (Omega Engineering, Inc., Stanford, CT) was place in the geometric center copper constantan of each chop and then attached to an HH-21 calibrated thermometer. Chops were placed on a preheated Hamilton Beach® Indoor/Outdoor grill (Hamilton Beach, Southern Pines, NC) cooked to an internal temperature of 35° C turned over and cooked to a final internal temperature of 71° C. Chops were removed from the grill and wrapped in Glad® ClingWrap (Oakland, CA) and cooled at ~ 4° C for 24 h. After cooling, six 1.27 cm cores were removed from the chops parallel to the muscle fibers (AMSA, 1995) to determine an average shear force value for the loin. Cores were sheared perpendicular to the muscle fibers using a United STM Smart-1 Test System SSTM-500 (United Calibration Corp., Huntington Beach, CA.). Settings for the United Test System were: force units – kg, linear units – mm, cycling 1 x 70 mm, test speed -250 mm/min, return speed – 500 mm/min, setup scales – CAP = 226.8.

3.3 Statistics

Data was analyzed as a randomized complete block design using the using the GLM procedure of SAS (SAS Inst., Cary, NC). The pig was analyzed as the experimental unit and treatment, trial, day, breed, sex, and lairage were the main effects. Interactions were observed between treatment, trial, and day. Least squares means were calculated and all main effects and interactions were considered significant at $P < 0.05$. No interactions with breed or sex were reported due to current literature explaining differences between these two characteristics.

3.4 Results

3.4.1 Performance and Carcass Data

The Berkshire x Duroc pigs had a higher ($P < 0.05$) beginning weight, ending weight and a higher average daily gain over the two week feeding trial than the Duroc sired animals (Table 3.3). Berkshire x Duroc pigs had heavier ($P < 0.05$) carcass weights than Duroc pigs but there was no difference ($P > 0.05$) in dressing percentage between the two breeds.

Table 3.3 Effect of Breed on Pig Carcass and Performance Data (Means ± SE)

	Breed		
	Berkshire x Duroc (n = 69)	Duroc (n = 91)	*P* value
Beginning Weight (kg)	$116.8^{a} \pm 2.6$	$113.0^{b} \pm 1.9$	0.003
Ending Weight (kg)	$124.6^{a} \pm 3.1$	$118.0^{b} \pm 2.3$	0.002
ADG (kg)	$0.52^{a} \pm .06$	$0.38^{b} \pm .04$	0.05
HCWT (kg)	$92.1^{a} \pm 2.2$	$86.9^{b} \pm 1.7$	0.0004
Dressing %	73.8 ± .3	73.7 ± .2	0.32

$^{a,\,b}$Means within a row that do not have a common superscript differ ($P < 0.05$)

Performance and carcass characteristics did not differ ($P > 0.05$) between the sex classes (Table 3.4). There were no differences ($P > 0.05$) in performance or carcass characteristics between the dietary treatments (Table 3.5). There were no trial differences

(*P* > 0.05) for beginning weight or ending weight (Table 3.6). Average daily gain was highest (*P* < 0.05) for Trial 3 while pigs in Trial 2 and 4 had the lowest (*P* < 0.05) average daily gain over the two week feeding trial. There were also no Trial differences (*P* > 0.05) for hot carcass weight or dressing %.

Table 3.4 Effect of Sex Class (barrows, n = 49; gilts, n = 111) on Pig Performance and Carcass Data (Means ± SE)

	Sex Class		
	Barrow (n = 49)	Gilt (n = 111)	*P* value
Beginning Weight (kg)	114.5 ± 2.5	114.5 ± 1.6	0.98
Ending Weight (kg)	121.5 ± 3.0	121.1 ± 1.9	0.44
ADG (kg)	0.46 ± .05	0.44 ± .03	0.74
HCWT (kg)	89.5 ± 2.2	89.5 ± 1.4	0.58
Dressing %	73.9 ± .3	73.6 ± .2	0.44

Table 3.5 Effect of Mg & Sodium Bicarbonate Supplementation on Pig Performance and Carcass Data (Means ± SE)

	Dietary Treatment[1]				
	Control (n = 40)	$MgSO_4$ (n = 40)	Control + E (n = 40)	$MgSO_4$ + E (n = 40)	P value
B. Wt. (kg)	114.9 ± 2.7	114.3 ± 2.7	114.4 ± 2.7	114.2 ± 2.7	0.97
End Wt. (kg)	120.8 ± 3.2	121.1 ± 3.2	121.5 ± 3.2	121.7 ± 3.2	0.90
ADG (kg)	0.39 ± .06	0.46 ± 0.6	0.47 ± 0.6	0.49 ± .06	0.53
HCWT (kg)	89.2 ± 2.3	89.6 ± 2.3	89.4 ± 2.3	89.9 ± 2.3	0.88
Dressing %	73.8 ± .3	73.9 ± .3	73.5 ± .3	73.8 ± .3	0.77

[1] $MgSO_4$ = 3.2 g/hd/d, E = 1.5 % electrolytes, $NaHCO_3$ supplemented 48 hours prior to slaughter

Table 3.6 Effect of Season of the Year on Pig Performance and Carcass Data (Means ± SE)

	Trial				
	1 (n = 40)	2 (n = 40)	3 (n = 40)	4 (n = 40)	P value
B. Wt. (kg)	115.5 ± 3.3	114.3 ± 2.7	114.4 ± 2.7	114.2 ± 2.7	0.19
End Wt.(kg)	120 ± 3.2	121.1 ± 3.2	121.5 ± 3.2	121.7 ± 3.2	0.91
ADG (kg)	0.47^{ab} ± .07	0.42^{b} ± 0.6	0.60^{a} ± 0.6	0.31^{b} ± 0.6	0.009
HCWT (kg)	89.9 ± 2.8	89.7 ± 2.3	89.5 ± 2.3	88.9 ± 2.3	0.92
Dressing %	73.4 ± .3	73.3 ± .3	73.8 ± .3	74.4 ± .4	0.14

[a, b] Means within a row that do not have a common superscript differ (*P* < 0.05)

There were no differences (*P* > 0.05) for beginning weight, ending weight, hot carcass weight or dressing % between the two slaughter days (Table 3.7). Pigs slaughtered on Day 1 had a higher (*P* < 0.05) average daily gain then pigs slaughtered on Day 2. Pigs that were rested for 1-3 h in lairage had the heaviest (*P* < 0.05) carcass weights while pigs given 3 - 5 h had the lightest carcass weights. Pigs given 3-5 h of lairage had the highest (*P* < 0.05) dressing percentage while pigs given less than 1 h and 1-3 h had the lowest dressing percentage.

Table 3.7 Effect of Slaughter Day on Pig Performance and Carcass Data (Means ± SE)

	Slaughter Day		
	Day 1 (n = 80)	Day 2 (n = 80)	*P* value
Beginning Weight (kg)	114.5 ± 2.0	114.4 ± 2.0	0.0025
Ending Weight (kg)	121.8 ± 2.4	120.8 ± 2.4	0.67
ADG (kg)	0.51^{a} ± .39	0.39^{b} ± .04	0.03
HCWT (kg)	89.7 ± 1.7	89.3 ± 1.8	0.77
Dressing %	73.6 ± .2	73.9 ± .2	0.53

[a, b] Means within a row that do not have a common superscript differ (*P* < 0.05)

Table 3.8 Effect of Length of Lairage on Pig Carcass Data (Means ± SE)

	Lairage			
	< 1 h (n = 29)	1 - 3 h (n = 74)	3 - 5 h (n = 57)	*P* value
Ending Weight (kg)	$268.7^{ab} \pm 3.8$	$271.4^{a} \pm 2.3$	$260.8^{b} \pm 2.7$	0.01
HCWT (kg)	$89.4^{ab} \pm 2.7$	$90.9^{a} \pm 1.7$	$88.3^{b} \pm 1.9$	0.05
Dressing %	$73.1^{b} \pm .3$	$73.7^{b} \pm .2$	$74.5^{a} \pm .2$	0.05

$^{a, b}$ Means within a row that do not have a common superscript differ ($P < 0.05$)

3.4.2 Loin Temperature and pH

Berkshire x Duroc pigs had a higher ($P < 0.05$) 1440 min loin temperature than Duroc pigs (Table 3.9). Barrows had a higher ($P < 0.05$) pH at 1440 min than gilts (Table 3.10). There were no other differences ($P > 0.05$) in loin pH or temperature between breed or sex class.

Table 3.9 Effect of Breed on Pork Loin pH and Temperature (Means ± SE)

	Breeds		
	Berkshire x Duroc (n = 69)	Duroc (n = 91)	*P* value
Loin			
0 min	6.61 ± .04	6.62 ± .03	0.57
15 min	6.52 ± .06	6.54 ± .04	0.47
30 min	6.40 ± .05	6.40 ± .03	0.90
60 min	6.26 ± .06	6.29 ± .05	0.58
1440 min	5.74 ± .03	5.74 ± .02	0.91
Temperature			
0 min	39.4 ± .2	39.5 ± .1	0.70
15 min	39.5 ± .1	39.6 ± .1	0.70
30 min	39.3 ± .1	39.4 ± .1	0.95
60 min	37.8 ± .2	38.1 ± .2	0.58
1440 min	$1.9^{a} \pm .1$	$1.7^{b} \pm .1$	0.02

$^{a, b}$ Means within a row that do not have a common superscript differ ($P < 0.05$)

Table 3.10 Effect of Sex Class on Pork Loin pH and Temperature (Means ± SE)

	Sex Class		
	Barrow (n = 49)	Gilt (n = 111)	*P* value
pH			
0 min	6.64 ± .04	6.60 ± .03	0.58
15 min	6.53 ± .06	6.53 ± .03	0.78
30 min	6.38 ± .04	6.41 ± .03	0.85
60 min	6.27 ± .06	6.27 ± .03	0.85
1440 min	5.78^{a} ± .03	5.70^{b} ± .02	0.02
Temperature			
0 min	39.5 ± .2	39.3 ± .1	0.19
15 min	39.6 ± .1	39.5 ± .1	0.37
30 min	39.3 ± .1	39.4 ± .1	0.83
60 min	38.1 ± .2	37.9 ± .1	0.51
1440 min	1.7 ± .1	1.8 ± .1	0.43

$^{a, b}$ Means within a row that do not have a common superscript differ ($P < 0.05$)

Pigs fed the control diet had the highest ($P < 0.05$) 1440 min temperature while pigs fed the CE and ME diet had the lowest ($P < 0.05$) 1440 min temperature (Table 3.11). Trial 4 pigs had a higher ($P < 0.05$) loin pH at 15 and 60 min, while Trial 2 had the lowest pH at 15 and 60 min (Table 3.12). Trial 3 had a higher ($P < 0.05$) loin temperature at 15 min than the other trials. Trial 1 and 3 had a higher ($P < 0.05$) 60 min loin temperature than Trials 2 and 4. Trial 4 had the lowest ($P < 0.05$) initial and 60 min loin temperature, while Trials 1 and 4 had the lowest ($P < 0.05$) 15 min loin temperature.

Pigs slaughtered on d 1 had higher ($P < 0.05$) 60 min loin temperature compared to pigs slaughtered on d 2 (Table 3.13). Pigs given < 1 h of lairage had the highest ($P < 0.05$) pH at 0, 15, and 30 min. Pigs given 3-5 h of lairage had the highest ($P < 0.05$) loin temperatures at 15, 30, and 60 min while pigs given less than 1 h of lairage had the lowest ($P < 0.05$) 15 min temperature and hogs given less than 1 h and 1-3 h had the lowest loin temperature at 30 and 60 min.

Table 3.11 Effect of Mg & Electrolyte Supplementation on Pork Loin pH and Temperature (Means ± SE)

	Dietary Treatments[1]				
	Control (n = 40)	Control + E (n = 40)	$MgSO_4$ (n = 40)	$MgSO_4$ + E (n = 40)	*P* value
pH					
0 min	6.55 ± .05	6.68 ± .05	6.65 ± .05	6.60 ± .05	0.17
15 min	6.54 ± .06	6.53 ± .06	6.55 ±.06	6.51 ± .06	0.99
30 min	6.38 ± .05	6.35 ± .05	6.44 ± .05	6.41 ± .05	0.80
60 min	6.26 ± .06	6.30 ± .06	6.29 ± .06	6.26 ± .06	0.95
1440 min	5.74 ±.03	5.75 ±.03	5.73 ±.03	5.73 ±.03	0.96
Temperature					
0 min	39.5 ± .2	39.5 ± .2	39.2 ± .2	39.5 ± .2	0.40
15 min	39.6 ± .1	39.6 ± .1	39.5 ± .1	39.5 ± .1	0.66
30 min	39.5 ± .2	39.4 ± .2	39.0 ± .2	39.5 ±.2	0.13
60 min	38.2 ± .2	37.7 ± .2	37.9 ± .2	38.1 ± .2	0.39
1440 min	2.0^a ± .1	1.7^b ± .1	1.8^{ab} ± .1	1.7^b ± .1	0.03

[1] $MgSO_4$ = 3.2 g/hd/d, E = 1.5 % electrolytes, $NaHCO_3$ supplemented 48 h prior to slaughter
[a, b] Means within a row that do not have a common superscript differ ($P < 0.05$)

Table 3.12 Effect of Seasonality on Pork Loin pH and Temperature (Means ± SE)

	Trial				
	1 (n = 40)	2 (n = 40)	3 (n = 40)	4 (n = 40)	*P* value
pH					
0 min	6.56 ± .06	6.59 ± .05	6.63 ± .04	6.69 ± .05	0.28
15 min	6.41^b ± .07	6.50^{ab} ± .06	6.58^{ab} ± .05	6.63^a ± .06	0.05
30 min	6.30 ± .06	6.35 ± .05	6.41 ± .05	6.52 ± .05	0.18
60 min	6.17^b ± .07	6.30^{ab} ± .06	6.24^{ab} ± .06	6.39^a ± .07	0.04
1440 min	5.70 ± .04	5.58 ± .03	5.78 ± .03	5.88 ± .04	<0.0001
Temperature					
0 min	39.3^{ab} ± .2	39.7^a ± .2	39.8^a ± .2	39.0^a ± .2	0.001
15 min	39.3^b ± .2	39.7^{ab} ± .1	39.9^a ± .1	39.4^b ± .1	0.005
30 min	38.8 ± .2	39.5 ± .2	39.8 ± .1	39.2 ± .2	0.001
60 min	38.3^a ± .2	37.8^{ab} ± .2	38.4^a ± .2	37.3^b ± .2	0.004
1440 min	1.4 ± .1	2.1 ± .1	2.3 ± .1	1.3 ± .1	<0.0001

[a, b] Means within a row that do not have a common superscript differ ($P < 0.05$)

Table 3.13 Effect of Slaughter Day on Pork Loin pH and Temperature (Means ± SE)

	Slaughter Day		
	Day 1 (n =80)	Day 2 (n = 80)	*P* value
<u>pH</u>			
0 min	6.56 ± .03	6.68 ± .04	0.006
15 min	6.50 ± .04	6.56 ± .04	0.21
30 min	6.41 ± .03	6.38 ± .04	0.88
60 min	6.25 ± .05	6.30 ± .05	0.43
1440 min	5.73 ± .03	5.75 ± .03	0.36
<u>Temperature</u>			
0 min	39.3 ± .1	39.5 ± .1	0.29
15 min	39.6 ± .1	39.5 ± .1	0.01
30 min	39.3 ± .1	39.4 ± .1	0.07
60 min	38.3[a] ± .2	37.6[a] ± .2	0.002
1440 min	1.6 ± .1	1.9 ± .1	<0.0001

[a, b] Means within a row that do not have a common superscript differ ($P < 0.05$)

Table 3.14 Effect of Length of Lairage on Pork Loin pH and Temperature (Means ± SE)

	Lairage			
	< 1 h (n = 29)	1 - 3 h (n = 74)	3 - 5 h (n = 57)	*P* value
<u>pH</u>				
0 min	6.72[a] ± .05	6.56[b] ± .03	6.57[b] ± .04	0.02
15 min	6.65[a] ± .07	6.48[b] ± .04	6.47[b] ± .05	0.03
30 min	6.49[a] ± .06	6.40[ab] ± .03	6.30[b] ± .04	0.02
60 min	6.33 ± .07	6.27 ± .05	6.22 ± .05	0.26
1440 min	5.70 ± .04	5.74 ± .02	5.77 ± .03	0.52
<u>Temperature</u>				
0 min	39.2 ± .2	39.5 ± .1	39.5 ± .1	0.35
15 min	39.3[b] ± .2	39.6[ab] ± .1	39.8[a] ± .1	0.009
30 min	39.1[b] ± .2	39.3[b] ± .1	39.7[a] ± .1	0.05
60 min	37.4[b] ± .3	38.0[b] ± .2	38.6[a] ± .2	0.0002
1440 min	1.8 ± .1	1.8 ± .1	1.8 ± .1	0.67

[a, b] Means within a row that do not have a common superscript differ ($P < 0.05$)

3.4.3 Loin Trial by Day Interaction

Initial loin pH was the highest ($P < 0.05$) for pigs slaughtered d 2 of Trial 2, and lowest ($P < 0.05$) for d 1 Trial 2 (Table 3.15). Day 1 of trial 4 had the highest ($P < 0.05$) 30 min loin pH. The 24 h loin pH was highest ($P < 0.05$) for d 1 Trial 3 pigs and d 2 Trial 4 pigs, while pigs slaughtered on d 1 and 2 of Trial 2 had the lowest 24 h pH. Loin temperature at 30 min was highest ($P < 0.05$) for pigs from d 1 of Trial 4. Day 1 of Trial 1 and d 2 of Trial 4 had the lowest ($P < 0.05$) loin temperature at 30 min. Loin temperature at 24 h was highest ($P < 0.05$) for d 1 and 2 of Trial 3 and d 2 of Trial 2.

Table 3.15 Effect of Seasonal Environment and Slaughter Day on Trial by Day Interactions for Loin pH and Temperature (Means ± SE)

Trial	Day	Loin pH initial	Loin pH 30 min	Loin pH 24 h	Loin Temp 30 min	Loin Temp 24 h
1	1	$6.53^{bc} \pm .07$	$6.24^{b} \pm .10$	$5.67^{bc} \pm .05$	$38.3^{c} \pm .2$	$1.2^{d} \pm .1$
1	2	$6.59^{b} \pm .07$	$6.37^{ab} \pm .10$	$5.74^{b} \pm .05$	$39.4^{b} \pm .2$	$1.6^{c} \pm .1$
2	1	$6.42^{c} \pm .06$	$6.41^{ab} \pm .09$	$5.58^{c} \pm .05$	$39.4^{b} \pm .2$	$1.9^{b} \pm .1$
2	2	$6.77^{a} \pm .06$	$6.28^{b} \pm .09$	$5.58^{c} \pm .05$	$39.6^{ab} \pm .2$	$2.2^{a} \pm .1$
3	1	$6.58^{b} \pm .06$	$6.41^{ab} \pm .09$	$5.90^{a} \pm .05$	$40.0^{a} \pm .2$	$2.3^{a} \pm .1$
3	2	$6.68^{ab} \pm .06$	$6.41^{ab} \pm .09$	$5.67^{bc} \pm .05$	$39.6^{ab} \pm .2$	$2.2^{a} \pm .1$
4	1	$6.71^{ab} \pm .07$	$6.58^{a} \pm .09$	$5.76^{b} \pm .05$	$39.4^{b} \pm .2$	$1.0^{d} \pm .1$
4	2	$6.67^{ab} \pm .07$	$6.46^{ab} \pm .09$	$6.01^{a} \pm .05$	$39.1^{bc} \pm .2$	$1.7^{bc} \pm .1$

[a, b,c, d] Means within a heading that do not have a common superscript differ ($P < 0.05$

3.4.4 Loin Trial by Treatment Interaction

Loin pH at 30 min was higher ($P < 0.05$) for pigs in Trial 4 fed $MgSO_4$ and electrolytes while pigs in Trial 1 fed the control diet had a lower ($P < 0.05$) 30 min pH (Table 3.16). Loin temperature at 30 min was higher ($P < 0.05$) for pigs fed the $MgSO_4$

and electrolytes in Trial 3 while pigs fed the $MgSO_4$ in Trial 1 had the lowest ($P < 0.05$) 30 min loin temperature.

Table 3.16 Effect of Mg & Electrolyte Supplementation and Seasonal Environment on Trial by Treatment Interactions for Pork Loin pH and Temperature (Means ± SE)

Trial	Treatment[1]	Loin pH 30 min	Loin Temp 30 min
1	Control	$6.20^{c} \pm .15$	$38.8^{cd} \pm .3$
1	Control + E	$6.33^{bc} \pm .13$	$39.6^{abcd} \pm .3$
1	$MgSO_4$	$6.45^{abc} \pm .13$	$38.0^{e} \pm .3$
1	$MgSO_4$ + E	$6.24^{bc} \pm .13$	$39.0^{bcd} \pm .3$
2	Control	$6.40^{abc} \pm .12$	$39.7^{ab} \pm .3$
2	Control + E	$6.27^{bc} \pm .12$	$39.0^{bcd} \pm .3$
2	$MgSO_4$	$6.27^{bc} \pm .12$	$39.7^{ab} \pm .3$
2	$MgSO_4$ + E	$6.44^{abc} \pm .12$	$39.6^{abcd} \pm .3$
3	Control	$6.58^{ab} \pm .12$	$40.1^{a} \pm .3$
3	Control + E	$6.30^{bc} \pm .12$	$39.7^{abc} \pm .3$
3	$MgSO_4$	$6.52^{abc} \pm .12$	$39.7^{abc} \pm .3$
3	$MgSO_4$ + E	$6.24^{bc} \pm .12$	$39.8^{a} \pm .3$
4	Control	$6.34^{bc} \pm .13$	$39.3^{abcd} \pm .3$
4	Control + E	$6.52^{abc} \pm .13$	$39.4^{abcd} \pm .3$
4	$MgSO_4$	$6.51^{abc} \pm .13$	$39.7^{de} \pm .3$
4	$MgSO_4$ + E	$6.72^{a} \pm .13$	$39.4^{abcd} \pm .3$

[1] $MgSO_4$ = 3.2 g/hd/d, E = electrolytes, $NaHCO_3$ supplemented 48 h prior to slaughter
[a, b,c,d, e] Means within a heading that do not have a common superscript differ ($P < 0.05$)

3.4.5 Ham pH and Temperature

There were no differences ($P > 0.05$) in ham pH between the two breeds or sex classes. Similar to loin temperatures Berkshire x Duroc pigs had a higher ($P < 0.05$)

1440 min ham temperature than Durocs (Table 3.17). Similar to loin pH, barrows had a higher (P < 0.05) pH at 1440 min than gilts (Table 3.18).

Table 3.17 Effect of Breed on Pork Ham pH and Temperature (Means ± SE)

	Breed		
	Berkshire x Duroc (n = 69)	Duroc (n = 91)	*P* value
pH			
0 min	6.59 ± .06	6.67 ± .04	0.36
15 min	6.40 ± .05	6.51 ± .03	0.10
30 min	6.32 ± .05	6.42 ± .03	0.06
60 min	6.14 ± .06	6.19 ± .04	0.57
1440 min	5.74 ± .03	5.80 ± .02	0.25
Temperature			
0 min	40.2 ± .1	40.1 ± .1	0.42
15 min	40.3 ± .1	40.4 ± .1	0.53
30 min	40.3 ± .1	40.4 ± .1	0.30
60 min	40.1 ± .2	39.9 ± .2	0.57
1440 min	3.3^{a} ± .1	2.9^{b} ± .1	0.006

$^{a,\,b}$Means within a row that do not have a common superscript differ (P < 0.05)

Table 3.18 Effect of Sex Class on Pork Ham pH and Temperature (Means ± SE)

	Sex Class		
	Barrow (n = 49)	Gilt (n = 111)	*P* value
pH			
0 min	6.66 ± .06	6.60 ± .04	0.40
15 min	6.44 ± .05	6.47 ± .03	0.42
30 min	6.37 ± .04	6.36 ± .03	0.78
60 min	6.15 ± .06	6.17 ± .04	0.83
1440 min	5.82^{a} ± .03	5.71^{b} ± .02	0.001
Temperature			
0 min	40.2 ± .1	40.1 ± .1	0.32
15 min	40.3 ± .1	40.3 ± .1	0.91
30 min	40.3 ± .1	40.4 ± .1	0.95
60 min	40.1 ± .2	39.9 ± .1	0.45
1440 min	3.1 ± .1	3.2 ± .1	0.91

$^{a,\,b}$Means within a row that do not have a common superscript differ (P < 0.05)

Ham temperature at 30 min was higher ($P < 0.05$) for pigs fed the ME diet, while pigs fed the M diet had the lowest 30 min ham temperatures (Table 3.19). Trial 4 pigs had a higher ($P < 0.05$) pH at 1440 min (Table 3.20). Trial 1 pigs had a lower ($P < 0.05$) pH at 30 min while Trial 1 and Trial 2 hogs had a lower ($P < 0.05$) pH at 1440 min. Pigs given greater than 3 h of lairage had a higher ($P < 0.05$) 1440 min pH while pigs given less than 1 h of lairage had lower ($P < 0.05$) 1440 min pH. Pigs slaughtered during Trial 1 and 2 had higher ($P < 0.05$) 30 and 60 min ham temperatures then pigs slaughtered during Trial 3 and 4. Trials 2 and 3 had the highest ($P < 0.05$) 1440 min ham temperatures. Pigs slaughtered on d 2 had a higher ($P < 0.05$) 1440 min ham temperature (Table 3.21). Length of lairage had no effect ($P > 0.05$) on ham pH or temperature (Table 3.22)

Table 3.19 Effect of Mg & Electrolyte Supplementation on Pork Ham pH and Temperature (Means ± SE)

	Dietary Treatments[1]				
	Control (n = 40)	Control + E (n = 40)	$MgSO_4$ (n = 40)	$MgSO_4$ + E (n = 40)	*P* value
pH					
0 min	6.63 ± .06	6.63 ± .06	6.56 ± .06	6.71 ± .06	0.35
15 min	6.45 ± .05	6.41 ± .05	6.45 ± .05	6.51 ± .05	0.53
30 min	6.38 ± .05	6.37 ± .05	6.39 ± .05	6.32 ± .05	0.68
60 min	6.12 ±.06	6.21 ± .06	6.19 ± .06	6.13 ± .06	0.68
1440 min	5.79 ± .03	5.79 ± .03	5.75 ± .03	5.75 ± .03	0.60
Temperature					
0 min	40.2 ± .1	40.2 ± .1	40.1 ± .1	40.2 ± .1	0.91
15 min	40.3 ± .1	40.3 ± .1	40.3 ± .1	40.5 ± .1	0.44
30 min	40.3^{ab} ± .1	40.3^{ab} ± .1	40.2^{b} ± .1	40.6^{a} ± .1	0.03
60 min	40.2 ± .2	40.0 ± .2	39.6 ± .2	40.1 ± .2	0.21
1440 min	3.0 ± .1	3.0 ± .1	3.2 ± .1	3.2 ± .1	0.45

[1] $MgSO_4$ = 3.2 g/hd/d, E = 1.5 % electrolytes, $NaHCO_3$ supplemented 48 hours prior to slaughter
[a, b]Means within a row that do not have a common superscript differ ($P < 0.05$)

Table 3.20 Effect of Seasonality on Pork Ham pH and Temperature (Means ± SE)

	Trial				
	1 (n = 40)	2 (n = 40)	3 (n = 40)	4 (n = 40)	*P* value
pH					
0 min	6.54 ± .08	6.62 ± .06	6.72 ± .06	6.65 ± .07	0.31
15 min	6.34 ± .07	6.43 ± .05	6.46 ± .05	6.57 ± .05	0.13
30 min	6.29 ± .06	6.35 ± .05	6.36 ± .05	6.46 ± .05	0.17
60 min	6.14 ±.07	6.14 ± .06	6.14 ± .06	6.23 ± .06	0.70
1440 min	5.67^{c} ± .04	5.63^{c} ± .03	5.78^{b} ± .03	5.99^{a} ± .04	<0.0001
Temperature					
0 min	40.4 ± .1	40.4 ± .1	40.4 ± .1	39.8 ± .1	0.01
15 min	40.6 ± .1	40.8 ± .1	40.0 ± .1	40.0 ± .1	<0.0001
30 min	40.4^{a} ± .1	40.6^{a} ± .1	40.2^{b} ± .1	40.2^{a} ± .1	0.03
60 min	40.6^{a} ± .2	40.6^{a} ± .2	38.9^{c} ± .2	39.9^{b} ± .2	<0.001
1440 min	2.7^{b} ± .1	3.4^{a} ± .1	3.4^{a} ± .1	2.9^{b} ± .1	<0.0001

[a, b,c] Means within a row that do not have a common superscript differ ($P < 0.05$)

Table 3.21 Effect of Slaughter Day on Pork Ham pH and Temperature (Means ± SE)

	Slaughter Day		
	Day 1 (n = 80)	Day 2 (n = 80)	*P* value
pH			
0 min	6.62 ± .05	6.64 ± .05	0.90
15 min	6.41 ± .04	6.50 ± .04	0.72
30 min	6.37 ± .03	6.36 ± .04	0.73
60 min	6.18 ± .04	6.15 ± .04	0.51
1440 min	5.75 ± .02	5.79 ± .02	0.21
Temperature			
0 min	40.2 ± .1	40.2 ± .1	0.95
15 min	40.5 ± .1	40.2 ± .1	<0.0001
30 min	40.4 ± .1	40.3 ± .1	0.61
60 min	40.1 ± .2	39.9 ± .2	0.21
1440 min	3.0^{b} ± .1	3.3^{a} ± .1	0.002

[a, b] Means within a row that do not have a common superscript differ ($P < 0.05$)

Table 3.21 Effect of Length of Lairage on Pork Ham pH and Temperature (Means ± SE)

	Lairage			
	< 1 h (n = 29)	1 - 3 h (n = 74)	3 - 5 h (n = 57)	*P* value
pH				
0 min	6.58 ± .07	6.63 ± .05	6.69 ± .05	0.45
15 min	6.39 ± .06	6.47 ± .04	6.50 ± .05	0.98
30 min	6.35 ± .06	6.39 ± .03	6.37 ± .04	0.56
60 min	6.10 ± .07	6.21 ± .04	6.17 ± .05	0.39
1440 min	5.68 ± .04	5.78 ± .02	5.78 ± .03	0.09
Temperature				
0 min	40.0 ± .1	40.2 ± .1	40.3 ± .1	0.11
15 min	40.4 ± .1	40.3 ± .1	40.4 ± .1	0.44
30 min	40.2 ± .1	40.4 ± .1	40.4 ± .1	0.65
60 min	40.1 ± .3	39.8 ± .2	40.0 ± .2	0.37
1440 min	3.0^{b} ± .1	3.4^{a} ± .1	2.9^{b} ± .1	0.003

[a, b] Means within a row that do not have a common superscript differ (*P* < 0.05)

3.4.6 Ham Trial by Day Interactions

Ham pH at 15 min was highest (*P* < 0.05) for pigs slaughtered on d 2 of Trial 4 while pigs slaughtered on d 1 of Trial 1 had the lowest (*P* < 0.05) ham pH at 15 min (Table 3.23). Initial ham temperature was highest (*P* < 0.05) for pigs slaughtered on the first day of Trials 2 and 3 as well as the second day of Trials 1 and 3. Initial ham temperature was lowest (*P* < 0.05) for d 1 of trial 4. Ham temperature at 15 min was highest (*P* < 0.05) for d 1 of Trial 2 while d 1 of Trial 4 had the lowest (P < 0.05) ham temperature at 15 min.

Table 3.23 Effect of Seasonal Environment and Slaughter Day on Trial by Day Interactions for Pork Ham pH and Temperature (Means ± SE)

Trial	Day	Ham pH 15 min	Ham Temp initial	Ham Temp 15 min
1	1	$6.24^{d} \pm .07$	$40.2^{ab} \pm .2$	$40.4^{bc} \pm .2$
1	2	$6.45^{abc} \pm .09$	$40.5^{a} \pm .2$	$40.7^{b} \pm .2$
2	1	$6.32^{cd} \pm .07$	$40.5^{a} \pm .1$	$41.1^{a} \pm .1$
2	2	$6.55^{ab} \pm .07$	$40.2^{ab} \pm .1$	$40.5^{bc} \pm .1$
3	1	$6.53^{ab} \pm .07$	$40.4^{a} \pm .1$	$40.4^{bc} \pm .1$
3	2	$6.40^{bcd} \pm .07$	$40.3^{a} \pm .1$	$39.5^{d} \pm .1$
4	1	$6.54^{ab} \pm .07$	$39.6^{c} \pm .1$	$39.9^{d} \pm .1$
4	2	$6.61^{a} \pm .08$	$39.8^{bc} \pm .1$	$40.1^{cd} \pm .2$

$^{a, b, c, d}$ Means within a column that do not have a common superscript differ ($P < 0.05$)

3.4.7 Ham Treatment by Day Interactions

Pigs fed the M diet and slaughtered on d 2 had the highest (*P* < 0.05) ham pH at 15 min while pigs that were fed the M diet and slaughtered on d 1 had the lowest (*P* < 0.05) pH at 15 min (Table 3.24).

Table 3.24 Effect of Mg & Electrolyte Supplementation and Slaughter Day on Treatment by Day Interactions for 15 min Ham pH (Means ± SE)

Treatment[1]	Day	Ham pH 15 min
Control	1	$6.41^{bc} \pm .07$
Control	2	$6.49^{ab} \pm .08$
Control + E	1	$6.40^{bc} \pm .07$
Control + E	2	$6.42^{bc} \pm .08$
$MgSO_4$	1	$6.28^{c} \pm .07$
$MgSO_4$	2	$6.63^{a} \pm .07$
$MgSO_4$ + E	1	$6.54^{ab} \pm .07$
$MgSO_4$ + E	2	$6.48^{ab} \pm .07$

[1] $MgSO_4$ = 3.2 g/hd/d, E = electrolytes, $NaHCO_3$ supplemented 48 hours prior to slaughter

[a, b, c] Means within a column that do not have a common superscript differ (*P* < 0.05)

3.4.8 Loin and Ham Face pH, Color, Marbling, Drip Loss, and WBSF

The Berkshire x Duroc pigs had a lower (*P* < 0.05) L value in the ham than the Duroc pigs (Table 3.25). Berkshire x Duroc pigs had more tender meat (*P* < 0.05). Barrows had a higher (*P* < 0.05) ham and loin face pH (Table 3.26). Gilts had a higher (*P* < 0.05) a value than the barrows.

There were no treatment differences (P < 0.05) for ham and loin face pH. Color, marbling, drip loss, and WBSF (Table 3.27). Trials 1, 3, and 4 had a higher (*P* < 0.05) ham pH while Trial 2 had the lowest ham face pH (Table 3.28). Trial 3 had the highest ($P < 0.05$) L values in the loin, while L and b value was lowest ($P < 0.05$) for Trial 4 in the loin. The ham had the lowest ($P < 0.05$) b value in Trial 4 while the other trials showed no differences. Trial 3 had the highest ($P < 0.05$) drip loss while no differences ($P > 0.05$) were found between the other three trials. Trial 1 and 2 had the toughest ($P < 0.05$) meat while Trials 3 and 4 had lower shear force values. Marbling was higher ($P < 0.05$) for hogs slaughtered on d 2 (Table 3.29). Pigs given the greatest amount of lairage had the highest ($P < 0.05$) force values (Table 3.30)

Table 3.25 Effect of Breed on Loin and Ham Face pH, color, marbling, drip loss and WBSF (Means ± SE)

	Breed		
	Berkshire x Duroc (n = 69)	Duroc (n = 91)	*P* value
Loin Face pH	5.62 ± .03	5.67 ± .03	0.09
Ham Face pH	5.84 ± .03	5.67 ± .02	0.19
Loin L	44.55 ± .47	43.73 ± .35	0.15
Loin a	14.65 ± .12	14.37 ± .09	0.09
Loin b	4.34^{a} ± .11	4.08^{b} ± .09	0.02
Ham L	43.00^{b} ± .59	45.95^{a} ± .44	0.01
Ham a	15.52 ± .16	15.22 ± .12	0.25
Ham b	4.41± .14	4.55 ± .10	0.42
NPPC color[1]	3.4 ± .1	3.4 ± .2	0.97
Marbling	2.0 ± .1	2.0 ± .1	0.30
Drip Loss	2.4 ± .3	2.2 ± .2	0.48
WBSF	3.43^{b} ± .11	3.82^{a} ± .08	0.01

[1]NPPC color score: 1= pale pinkish gray, and 6 = dark purplish red (NPPC, 1998)
[a, b] Means within a column that do not have a common superscript differ ($P < 0.05$)

Table 3.26 Effect of Sex Class on Loin and Ham Face pH, color, marbling, drip loss and WBSF (Means ± SE)

	Sex Class		
	Barrow (n = 49)	Gilt (n = 111)	*P* value
Loin Face pH	5.91^{a} ± .04	5.83^{b} ± .02	0.04
Ham Face pH	5.68^{a} ± .03	5.61^{b} ± .02	0.03
Loin L	44.10 ± .47	44.18 ± .29	0.97
Loin a	14.55 ± .12	14.47 ± .08	0.55
Loin b	4.23 ± .11	4.18 ± .07	0.26
Ham L	44.08 ± .58	43.86 ± .36	0.77
Ham a	15.17^{b} ± .17	15.57^{a} ± .10	0.03
Ham b	4.43 ± .14	4.53 ± .09	0.43
NPPC color[1]	3.4 ± .1	3.4 ± .1	0.69
Marbling	2.2 ± .1	2.1 ± .1	0.53
Drip Loss	2.3 ± .3	2.4 ± .2	0.89
WBSF	3.60 ± .11	3.65 ± .07	0.53

[1]NPPC color score: 1= pale pinkish gray, and 6 = dark purplish red (NPPC, 1998)

[a, b] Means within a column that do not have a common superscript differ (*P* < 0.05)

Table 3.27 Effect of Mg & Electrolyte Supplementation on Loin and Ham Face pH, color, marbling, drip loss and WBSF (Means ± SE)

	Dietary Treatments[1]				
	Control (n = 40)	Control + E (n = 40)	$MgSO_4$ (n = 40)	$MgSO_4$ + E (n = 40)	*P* value
Loin Face pH	5.63 ± .03	5.67 ± .03	5.64 ± .03	5.65 ± .03	0.74
Ham Face pH	5.84 ± .04	5.87 ± .04	5.88 ± .04	5.89 ± .04	0.87
Loin L	44.25 ± .49	43.72 ± .49	44.23 ± .50	44.35 ± .49	0.68
Loin a	14.67 ± .13	14.32 ± .13	14.44 ± .13	14.60 ± .07	0.18
Loin b	4.30 ± .12	4.16 ± .12	4.10 ± .12	4.27 ± .12	0.73
Ham L	44.22 ± .61	44.15 ± .61	43.62 ± .61	43.91 ± .61	0.85
Ham a	15.50 ± .17	15.24 ± .17	15.23 ± .17	15.51 ± .17	0.42
Ham b	4.43 ± .15	4.58 ± .14	4.29 ± .15	4.61 ± .14	0.29
NPPC color[2]	3.4 ± .1	3.6 ± .1	3.3 ± .1	3.4 ± .1	0.29
Marbling	2.0 ± .1	2.3 ± .1	2.1 ± .1	2.1 ± .1	0.54
Drip Loss	2.4 ± .3	1.9 ± .3	2.2 ± .3	2.6 ± .3	0.26
WBSF	3.55 ± .11	3.65 ± .11	3.68 ± .12	3.62 ± .11	0.93

[1] $MgSO_4$ = 3.2 g/hd/d, E = 1.5 % electrolytes, $NaHCO_3$ supplemented 48 hours prior to slaughter

[2]NPPC color score: 1= pale pinkish gray, and 6 = dark purplish red (NPPC, 1998)

[a, b] Means within a column that do not have a common superscript differ (*P* < 0.05)

Table 3.28 Effect of Seasonality on Loin and Ham Face pH, color, marbling, drip loss and WBSF (Means ± SE)

	Trial				
	1 (n = 40)	2 (n = 40)	3 (n = 40)	4 (n = 40)	*P* value
Loin Face pH	5.67 ± .03	5.51 ± .03	5.62 ± .03	5.78 ± .03	<0.0001
Ham Face pH	5.92[a] ± .05	5.67[b] ± .04	5.91[a] ± .04	5.97[a] ± .04	<0.0001
Loin L	44.34[b] ± .60	44.32[b] ± .49	45.93[a] ± .48	41.96[c] ± .53	<0.0001
Loin a	14.53 ± .16	14.53 ± .13	14.69 ± .12	14.29 ± .14	0.18
Loin b	4.32 ± .14	4.16 ± .12	4.58 ± .11	3.76 ± .13	0.005
Ham L	42.23 ± .74	46.51 ± .60	44.60 ± .59	42.55 ± .66	<0.0001
Ham a	15.97 ± .21	14.98 ± .17	15.61 ± .16	14.92 ± .18	0.0003
Ham b	4.61[a] ± .18	4.86[a] ± .14	4.63[a] ± .14	3.81[b] ± .16	<0.0001
NPPC color[1]	3.9 ± .1	3.4 ± .1	2.9 ± .1	3.5 ± .1	<0.0001
Marbling	2.1 ± .1	2.0 ± .1	2.0 ± .1	2.3 ± .1	0.36
Drip Loss	1.6[b] ± .3	2.3[b] ± .3	3.4[a] ± .3	1.8[b] ± .3	<0.0001
WBSF	3.96[a] ± .14	3.88[a] ± .11	3.33[b] ± .11	3.34[b] ± .12	<0.0001

[1]NPPC color score: 1= pale pinkish gray, and 6 = dark purplish red (NPPC, 1998)
[a, b] Means within a column that do not have a common superscript differ (*P* < 0.05)

Table 3.29 Effect of Slaughter Day on Loin and Ham Face pH, color, marbling, drip loss and WBSF (Means ± SE)

	Slaughter Day		
	Day 1 (n = 80)	Day 2 (n = 80)	*P* value
Loin Face pH	5.63 ± .02	5.66 ± .02	0.26
Ham Face pH	5.88 ± .03	5.86 ± .03	0.66
Loin L	44.71[a] ± .36	43.56[b] ± .37	0.02
Loin a	14.50 ± .09	14.52 ± .09	0.83
Loin b	4.38 ± .09	4.04 ± .09	0.004
Ham L	43.53 ± .45	44.41 ± .46	0.15
Ham a	15.55 ± .12	15.19 ± .12	0.05
Ham b	4.57 ± .11	4.38 ± .11	0.13
NPPC color[1]	3.5 ± .1	3.3 ± .2	0.05
Marbling	2.0[b] ± .1	2.3[a] ± .1	0.02
Drip Loss	2.4 ± .3	2.1 ± .2	0.29
WBSF	3.63 ± .11	3.62 ± .08	0.67

[1]NPPC color score: 1= pale pinkish gray, and 6 = dark purplish red (NPPC, 1998)
[a, b] Means within a column that do not have a common superscript differ (*P* < 0.05)

Table 3.30 Effect of Length of Lairage on Loin and Ham Face pH, color, marbling, drip loss and WBSF (Means ± SE)

	Lairage			
	< 1 h (n = 29)	1 - 3 h (n = 74)	3 - 5 h (n = 57)	*P* value
Loin Face pH	5.61 ± .03	5.65 ± .02	5.67 ± .02	0.34
Ham Face pH	5.80 ± .05	5.90 ± .03	5.90 ± .03	0.07
Loin L	43.99 ± .58	44.44 ± .36	43.99 ± .41	0.87
Loin a	14.53 ± .15	14.51 ± .09	14.48 ± .11	0.99
Loin b	4.06 ± .14	4.35 ± .09	4.21 ± .10	0.22
Ham L	43.84 ± .71	43.75 ± .71	44.32 ± .51	0.51
Ham a	15.62 ± .21	15.39 ± .13	15.25 ± .15	0.36
Ham b	4.47 ± .17	4.37 ± .10	4.59 ± .12	0.10
NPPC color[1]	3.4 ± .1	3.5 ± .1	3.4 ± .1	0.60
Marbling	2.0 ± .2	2.1 ± .1	2.2 ± .1	0.92
Drip Loss	1.9 ± .3	2.5 ± .2	2.4 ± .1	0.33
WBSF	3.51^{b} ± .13	3.48^{b} ± .08	3.88^{a} ± .10	0.005

[1]NPPC color score: 1= pale pinkish gray, and 6 = dark purplish red (NPPC, 1998)
[a, b] Means within a column that do not have a common superscript differ (*P* < 0.05)

3.4.9 Trial by Day Interaction for Loin pH, Visual and Instrumental Color

Loin face pH was the highest (*P* < 0.05) for pigs on d 1 and 2 of Trial 4 and pigs slaughtered on d 1 and 2 of Trial 2 and d 2 of Trial 3 had the lowest (*P* < 0.05) loin face pH. Ham L value was highest (*P* < 0.05) for pigs slaughtered on d 2 of Trial 2, while pigs slaughtered on d 1 and 2 of Trial 4 and d 1 of Trial 1 had the lowest L values. Pigs slaughtered on d 1 and 2 of Trial 1, d 1 of Trial 2 and d 2 of trial 3 had a higher (*P* < 0.05) a value in the ham while pigs slaughtered on d 2 of Trial 4 had the lowest a values. Loin b was highest (*P* < 0.05) for pigs slaughtered on d 1 of Trials 1 and 2 and also d 1 and 2 of Trial 3. Pigs slaughtered on day 1 of Trial 4 had the lowest (*P* < 0.05) b values. Hogs slaughtered on days 1 and 2 of Trial 1, d 1 of Trial 2 and d 1 of Trial 4 had the highest ($P < 0.05$) NPPC loin color score while d 2 Trial 3 pigs had the lowest ($P < 0.05$) color score.

Table 3.30 Effect of Seasonality and Slaughter Day on Trial by Day Interactions for Loin pH, Visual and Instrumental Color (Means ± SE)

Trial	Day	Loin Face pH	Loin b	Ham L	Ham a	Color[1]
1	1	$5.64^{bc} \pm .04$	$4.64^{a} \pm .18$	$42.17^{d} \pm .94$	$16.16^{a} \pm .26$	$3.7^{ab} \pm .2$
1	2	$5.70^{bc} \pm .04$	$4.01^{bc} \pm .18$	$42.28^{c} \pm .94$	$15.77^{ab} \pm .26$	$4.0^{a} \pm .2$
2	1	$5.50^{d} \pm .04$	$4.46^{ab} \pm .16$	$44.79^{b} \pm .84$	$15.59^{ab} \pm .23$	$3.6^{abc} \pm .2$
2	2	$5.51^{d} \pm .04$	$3.85^{d} \pm .16$	$48.23^{a} \pm .84$	$14.37^{d} \pm .23$	$3.2^{c} \pm .2$
3	1	$5.67^{bc} \pm .04$	$4.46^{ab} \pm .16$	$44.62^{bc} \pm .82$	$15.13^{bc} \pm .23$	$3.2^{c} \pm .2$
3	2	$5.57^{cd} \pm .04$	$4.70^{a} \pm .16$	$44.59^{bc} \pm .83$	$16.09^{a} \pm .23$	$2.5^{d} \pm .2$
4	1	$5.71^{ab} \pm .04$	$3.94^{cd} \pm .17$	$42.53^{bcd} \pm .86$	$15.30^{b} \pm .24$	$3.6^{ab} \pm .2$
4	2	$5.86^{a} \pm .04$	$3.57^{d} \pm .17$	$42.56^{bcd} \pm .90$	$14.54^{cd} \pm .25$	$3.3^{bc} \pm .2$

[1]NPPC color score: 1= pale pinkish gray, and 6 = dark purplish red (NPPC, 1998)
[a, b, c, d] Means within a column that do not have a common superscript differ ($P < 0.05$)

3.5 Discussion

Supplementing swine diets with $MgSO_4$ or sodium bicarbonate had no affect on growth performance, carcass weight or dressing percentage. Previous work by Peeters, et al. (2005) has shown that supplementing swine diets with Mg produces calmer pigs on arrival at the slaughter facility, which could lead to improvements in pork quality due to less aggressive behavior and stress. In the current study, pig supplemented with $MgSO_4$ did not seem less aggressive or calmer than pigs fed the control diet. All pigs were pen mates prior to the feeding trial and no new pigs were introduced which could explain the lack of fighting or aggressive behavior. A tendency towards improved ADG was reported by Utley et al. (1987) when electrolyte balance was maintained at 250 meq/kg while Haydon et al. (1990) stated that 250 meq/kg was the optimal rate of $NaHCO_3$ to be added to the ration to maintain ADG through periods of hot weather. The current study found no such increase.

Loin pH and temperature did not differ by dietary treatment, except for 24 h loin temperature. Ham temperature was slightly higher for the pigs fed the ME diet at 30 min, but ham pH was not different. In previous studies, initial and final pH was not affected by Mg supplementation (D'Souza et al., 1999, 2000; Hamilton et al., 2002, 2003; Frederick et al., 2006). Ahn et al. (1992) observed a decrease in pH decline in the LD when pigs were supplemented with electrolytes immediately prior to slaughter. Pigs supplemented with Mg have shown an increase in ultimate pH (Swigert et al., 2004). Several researchers have reported no affect of Mg supplementation on ultimate pH (D'Souza et al., 1999, 2000; Apple et al., 2000, 2002; Frederick et al., 2004). Boles et al. (1993) found no differences in pH of halothane positive pigs supplemented with electrolytes 4 days prior to slaughter. Pigs supplemented with the ME diet did have a higher pH during Trial 4, suggesting the ME supplementation might improve pH in the hottest times of the year but this did not equate to improved overall pork quality. Apple et al. (2005) found that magnesium supplementation can increase initial and 45 min pH when a short transportation to slaughter is involved but the current study did not report similar findings. Since the pigs were loaded approximately 12 hours prior to slaughter and removed from feed and water the dietary supplements could have been metabolized returning glycogen to basal levels prior to slaughter therefore were not available for raising initial pH and subsequently improving pork quality.

D'Souza et al. (1998) reported a total elimination in PSE carcasses from pigs supplemented with 3.2g/hd/d of $MgSO_4$ for 5 d prior to slaughter. Swigert et al. (2004)

reported that chops from pigs supplemented with Mg at 3.5g/hd/d for 48 h prior to slaughter had lower L* values or darker colored meat than the other diets supplemented with Vitamin E or D_3. Swigert et al. (2004) also concluded that Mg supplemented diets decreased purge but no differences were found in tenderness between supplemented and control animals. Peeters et al. (2006) concluded that pigs supplemented with Mg must be stressed to a greater extent to see improvements in pork quality such as color and drip loss. Geesink et al. (2004) went on to state that under normal processing conditions dietary magnesium showed no improvement on pork quality. Although there were no improvements in pork quality when pigs were supplemented the dietary nutrients the pigs were all in the acceptable pork quality range of a 3 - 5 NPPC color score and a ultimate pH of 5.6 – 5.9.

There were no differences in gain, carcass weight, or dressing percentage between the four Trials. The warmest temperatures were reported during Trial 4 and according to Heitman et al. (1958) temperatures were high enough to cause heat stress lowering ADG in Trial 4. Lopez et al. (1991) stated that high temperatures cause a decrease in feed intake and gain. Pigs tended to gain the most weight in Trial 3 which was closest to the animals' ambient temperature; however ADG was below normal in all four trials. Data in the current study agreed with Gosalvez et al. (2006) who stated that time of year had no affect on carcass yield. During Trials 1 and 2 dressing percentage tended to be lower, which agrees with Lefaucheur et al. (1991) who stated pigs in colder temperatures had decreased dressing percentages. Lefaucher et al. (1991) stated that a lower environmental temperature increased pH decline, and went on to hypothesize that lower environmental temperatures would adversely affect overall pork quality. Lower pH values were observed in the current study during the colder trials as opposed to the warmer trials. Temperatures in Trial 3 fluctuated the greatest between hot and cold resulting in pigs having the lowest values for NPPC color and the highest drip loss of the other 3 trials. Although these animals were not deemed to be PSE, Judge et al., (1966) stated that pigs finished under highly variable temperatures are most likely to have poor pork quality.

Tarrant (1989) concluded that shorter trips to slaughter can be the most detrimental to pork quality since loading and unloading are more stressful activities than the actual transport. Although there were no drastic differences in pork quality between lengths of lairage, the results did vary as in determining what length of lairage is best suited for a short trip to slaughter. Dressing percentage was improved when pigs were rested for greater than 3-5 h in the current study. Aaslyng and Gade (2001) found that initial temperature of the LD was elevated for animals given less than 30 min of lairage, as well as an increase in drip loss from the *Biceps femoris* (**BF**), and lighter colored LD and BF muscles also occurring. A shorter lairage of less than 3 h produced lower shear force values in the LD.

Variation in loin and ham pH between the two breeds was not significant, along with marbling, visual color, and drip loss. Berkshire cross pigs had lower L values in the ham relating to a darker color meat as well as lower shear force values. Barrows had higher ultimate pH values in the ham and the loin which disagrees with Nold et al. (1999) who reported no differences in pH between the sex classes.

Pigs spent less time in lairage on the second slaughter day due to increased efficiency on the kill floor allowing pig carcasses to reach the cooler faster and lowering the 60 min loin temperature on day 2. There were also fewer pigs that spent 3-5 h in lairage on slaughter day 2 of each trial compared to day 1

3.6 Conclusion

In the current study supplementing swine diets with 3.2 g/hd/d $MgSO_4$ and 1.5 % sodium bicarbonate prior to slaughter had no beneficial impact on performance, carcass traits, or ultimate pork quality. The current study reinforced the fact that seasonality and temperature variation in the finishing barn and during transport to slaughter plays a significant role in pork quality. The Duroc and Berkshire x Duroc pigs in the current study were procured from a swine producer with a history of producing exceptional meat quality animals, this coupled with the fact that the pigs were given ample room per head in the finishing barn, allowed time to rest after weighing and loading the night prior to slaughter and transported a very short (48km) distance to the processing facility is the most likely reason the dietary treatments were not beneficial in improving pork quality.

APPENDIX A: Materials and Methods

A.1. Live Animal Handling

1. Hogs were procured from Everett Forkner and the animals were transported from Richards, MO on a livestock trailer to Fulton, MO (approximately 200 miles) where the feeding trial occurred.
2. Hogs were unloaded onto a hydraulic hog trailer at the farm of Jim Humphreys' and transported 1 mile from unloading point to building.
3. Hogs were driven on foot approximately 80 feet from hydraulic trailer to hog building, which was a 14.63m x 9.75m confinement type building with adjustable curtains.
4. Hogs were sorted into pens upon arrival and divided up depending on breed, sex and initial weight.
5. Five hogs were placed into each pen giving an approximate pen space allotment of 2.08 m^2 per pig.
6. Hogs were fed ad lib for the two week feeding period; 20 pigs receiving the control diet were place on one half of the building and the 20 pigs receiving the magnesium diet were placed on the opposite side of the building.
7. Water was provided by two nipple waters located in each pen.
8. Temperature was recorded in the buildings using two Omega® Nomad™ data loggers and the data loggers were place on opposite sides and ends of the building.
9. Electrolytes were added to the diet 48 hours prior to transport to slaughter.

10. After the two week feeding trial 20 hogs were removed from the building, five from each group, and driven back onto the hydraulic trailer and taken to the livestock trailer.
11. Hogs were loaded and weighed on a set of balance type Smidley® hog scales placed on the back of the stock trailer, and weighed and recorded as they entered the trailer.
12. After loading, hogs were transported approximately ½ miles and allowed to sit on the trailer overnight.
13. The following morning the hogs were hauled from Fulton, MO to Columbia, MO (approximately 30 miles) to the University of Missouri abattoir.
14. The pigs were unloaded and given from ½ hour to >3 hours of lairage time prior to stunning.
15. Two days later the same method was used to transport the other 20 hogs to the abattoir.

A.2. Procedures on the Kill Floor

1. Animals were moved from the lairage area to the stunning area.
2. Animals were immediately stunned using electricity and exsanguination occurred once they were shackeled, interval from stun to stick was kept at a minimum.
3. Ear notch number was recorded.
4. Upon approval from the USDA inspector, the back of the animal was cut at approximately the 10^{th} rib and the inside of the back leg was also cut allowing access to the *Longissimus dorsi* and *Semimembranosus*.
5. The side of the animal which had its leg shackled was chosen as the side to take the pH and temperature measurements from.
6. The pH was recorded using a SevenGo™ SG2 pH meter (Mettler Toledo Columbus, OH) and temperature was recorded using an HH-21 thermometer (Omega Engineering, Inc. Stanford, CT).
7. pH and temperature values were recorded postmortem at a previously defined intervals of initial, 15 minutes, 30 minutes, 60 minutes, and 1440 minutes.
8. Animals were scalded, tumbled to remove hair and eviscerated.
9. Carcass weight was recorded and animals were put in the chill cooler at 2° C.
10. After 24 hours the carcass were moved from the abattoir to the meat lab to be analyzed for meat quality characteristics.

A.3. Procedures for Pork Fabrication

1. One side of the carcass from each hog was rolled from the carcass cooler into the fabrication room.
2. The same side that was measured for pH and temperature drop on the kill floor was used for further meat quality analysis.
3. Ten sides were laid on the tables at a time.
4. Hams were removed at no more than 1.5 inches from the aitch bone and cut on a line parallel with the hock.
5. Tenderloins were removed.
6. Loins were removed from the carcass between the 2^{nd} and 3^{rd} rib and the last lumbar vertebrae.
7. The loins were removed from the belly at no more than 3 inches from the vertebral column.
8. Loins were skinned and rolled away from the bone.
9. The loin was then cut at approximately the 10^{th} rib for color evaluation.
10. Loin and hams were given 10 minutes to bloom before visual color, marbling and colorimeter readings were taken.
11. pH was recorded on the face of the ham and loin.
12. Marbling and NPPC color scores were recorded for the *Longissumus dorsi*.
13. Minolta L, a, and b values were taken on the *Longissumus dorsi* and the *Semimebranoseous* muscle.
14. Three one inch chops were removed from the *Longissumus dorsi.*

15. One chop was used for measuring drip loss and the other two chops were used for Warner Bratzler Shear Force.

A.4. Water Holding Capacity

1. A 2.54 cm chop was removed from the *Longissimus dorsi* 24 hours postmortem.
2. All subcutaneous fat was removed from the chop.
3. Two cubed shape portions were removed from the chop each weighing approximately 50 g.
4. Any remaining fat was removed from the chop and a final weight was taken to the one hundredth decimal place.
5. A 1/8th of an inch hole was drilled into the lid of a 200 ml plastic container.
6. A fish hook was suspended in the container using a small paper clip.
7. The meat sample was suspended from the fish hook, making sure it did not touch the sides or bottom.
8. Cups were then placed in 4^{o} C for 48 hours with a constant humidity and air flow.
9. Samples were removed from the cooler, patted dry with a paper towel to remove any surface exudation and reweighed.
10. Percent drip loss was determined by the results.
11. Test was accomplished in duplicate and data was averaged.

A.5. Warner Bratzler Shear Force

1. Two 2.54 cm chops were removed from the *Longissimus dorsi* at the 10^{th} rib, 24 hours postmortem.
2. The chops were labeled and vacuum packaged.
3. They were subsequently frozen until Warner Bratzler could be performed.
4. Chops were removed from the freezer the day before cooking and given a 24 hour thaw at refrigeration temperatures.
5. Hamilton Beach® indoor/outdoor grills were used to cook the pork chops.
6. Grills were preheated for 10 minutes prior to cooking on a temperature setting of 5.
7. All chops were thermocoupled using Omega® brand thermocouples.
8. Thermocouples were placed in the geometric center of the chop.
9. Thermocouples were attached to an Omega® brand model HH21 microprocessor thermometer and temperatures were recorded in Celsius.
10. Chops were placed on the grill and allowed to cook until the temperature reached 35^{o} C at this time they were turned over and cooked to an internal temperature of 71^{o} C.
11. The chops were removed from the grill and wrapped in saran wrap and placed at refrigeration temperature for 24 hours.
12. Chops were removed from the refrigerator the following day and a total of six 1.27 cm cores were removed from the two chops parallel to the muscle fibers.
13. The cores were sheared using a United STM Smart-1 Test System SSTM.
14. The six cores were averaged giving the ultimate shear value in kg.

APENDIX B: Data Collection Sheets

B.1. Trial Allocation and Loading Schedule

Date_________________

MgSO+E   Pen #

Ear notch	Sex	Breed	Begin Wt.	Ending Wt.

MgSO Pen #

Ear notch	Sex	Breed	Begin Wt.	Ending Wt.

Control   Pen #

Ear notch	Sex	Breed	Begin Wt.	Ending Wt.

Control+E   Pen #

Ear notch	Sex	Breed	Begin Wt.	Ending Wt.

B.2. pH and Temperature Collection (slaughter floor) Date___________________

Pig #		Earnotch #		Slaughter time	
		Loin		Ham	
		Temp	pH	Temp	pH
HCW#	initial				
	15 min				
	30 min				
	60 min				
	1440 min				

Pig #		Earnotch #		Slaughter time	
		Loin		Ham	
		Temp	pH	Temp	pH
HCW#	initial				
	15 min				
	30 min				
	60 min				
	1440 min				

Pig #		Earnotch #		Slaughter time	
		Loin		Ham	
		Temp	pH	Temp	pH
HCW#	initial				
	15 min				
	30 min				
	60 min				
	1440 min				

Pig #		Earnotch #		Slaughter time	
		Loin		Ham	
		Temp	pH	Temp	pH
HCW#	initial				
	15 min				
	30 min				
	60 min				
	1440 min				

B.3. 24 h Instrumental Color

Date: ___________________

Pig #		Ham	Loin
	L*		
	a*		
	b*		

Pig #		Ham	Loin
	L*		
	a*		
	b*		

Pig #		Ham	Loin
	L*		
	a*		
	b*		

Pig #		Ham	Loin
	L*		
	a*		
	b*		

Pig #		Ham	Loin
	L*		
	a*		
	b*		

Pig #		Ham	Loin
	L*		
	a*		
	b*		

Pig #		Ham	Loin
	L*		
	a*		
	b*		

Pig #		Ham	Loin
	L*		
	a*		
	b*		

B.4. NPPC Color and Marbling; Ham and Loin Face pH

Date___________________________

Pig #	NPPC color	NPPC marb	Loin Face pH	Ham Face pH

B.5. Water Holding Capacity

Date: ___________________

Pig #	Cup #1			
	A		B	
	Initial	Final	Initial	Final

Pig #	Cup #2			
	A		B	
	Initial	Final	Initial	Final

Pig #	Cup #3			
	A		B	
	Initial	Final	Initial	Final

Pig #	Cup #4			
	A		B	
	Initial	Final	Initial	Final

Pig #	Cup #5			
	A		B	
	Initial	Final	Initial	Final

Pig #	Cup #6			
	A		B	
	Initial	Final	Initial	Final

Pig #	Cup #7			
	A		B	
	Initial	Final	Initial	Final

Pig #	Cup #8			
	A		B	
	Initial	Final	Initial	Final

B.6. Warner Bratzler Shear Force

Date: _______________

Pig #	1	2	3	4	5	6	avg

Pig #	1	2	3	4	5	6	avg

Pig #	1	2	3	4	5	6	avg

Pig #	1	2	3	4	5	6	avg

Pig #	1	2	3	4	5	6	avg

Pig #	1	2	3	4	5	6	avg

Pig #	1	2	3	4	5	6	avg

Pig #	1	2	3	4	5	6	avg

Pig #	1	2	3	4	5	6	avg

Pig #	1	2	3	4	5	6	avg

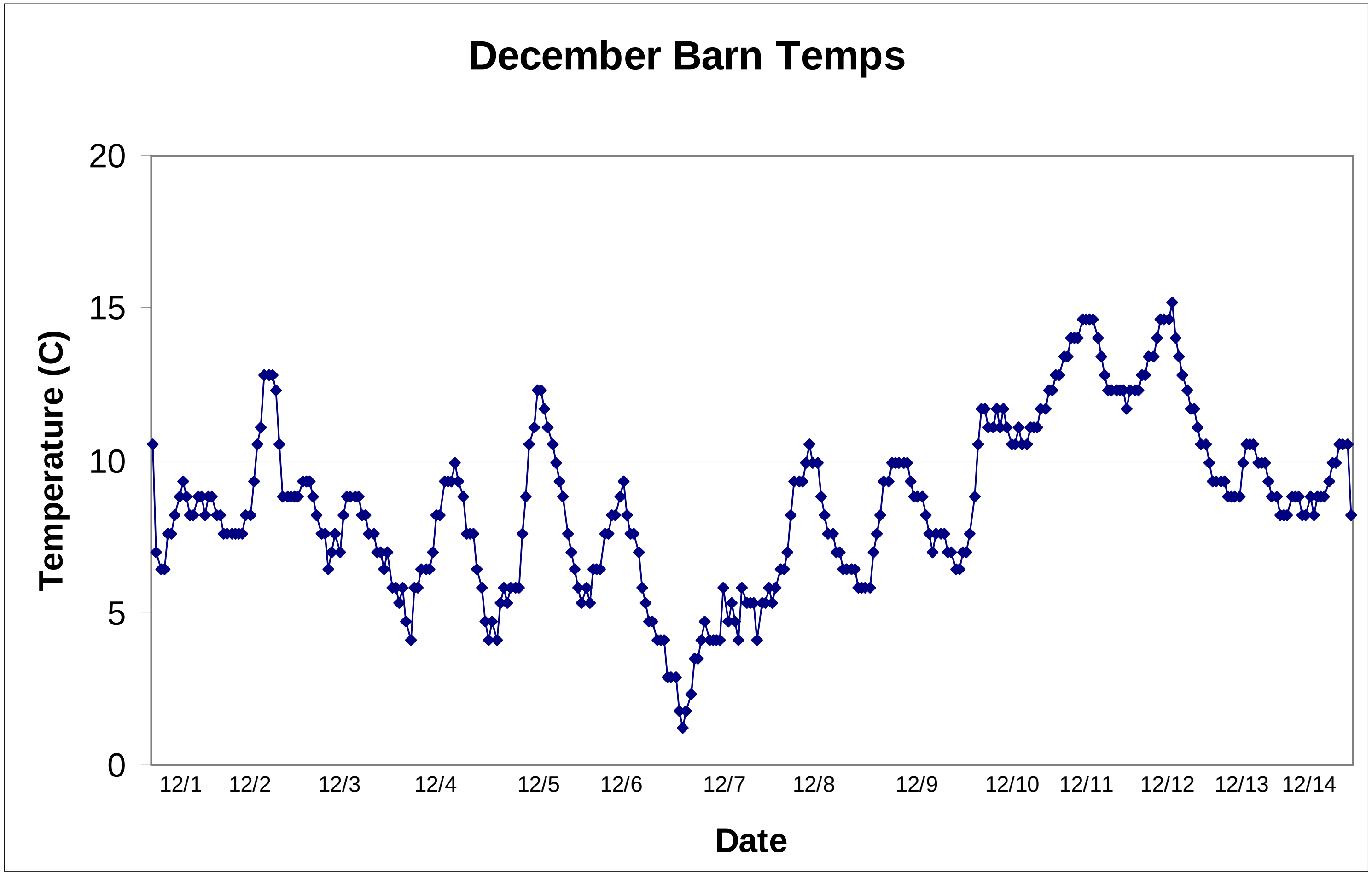
Pig #	1	2	3	4	5	6	avg

Pig #	1	2	3	4	5	6	avg

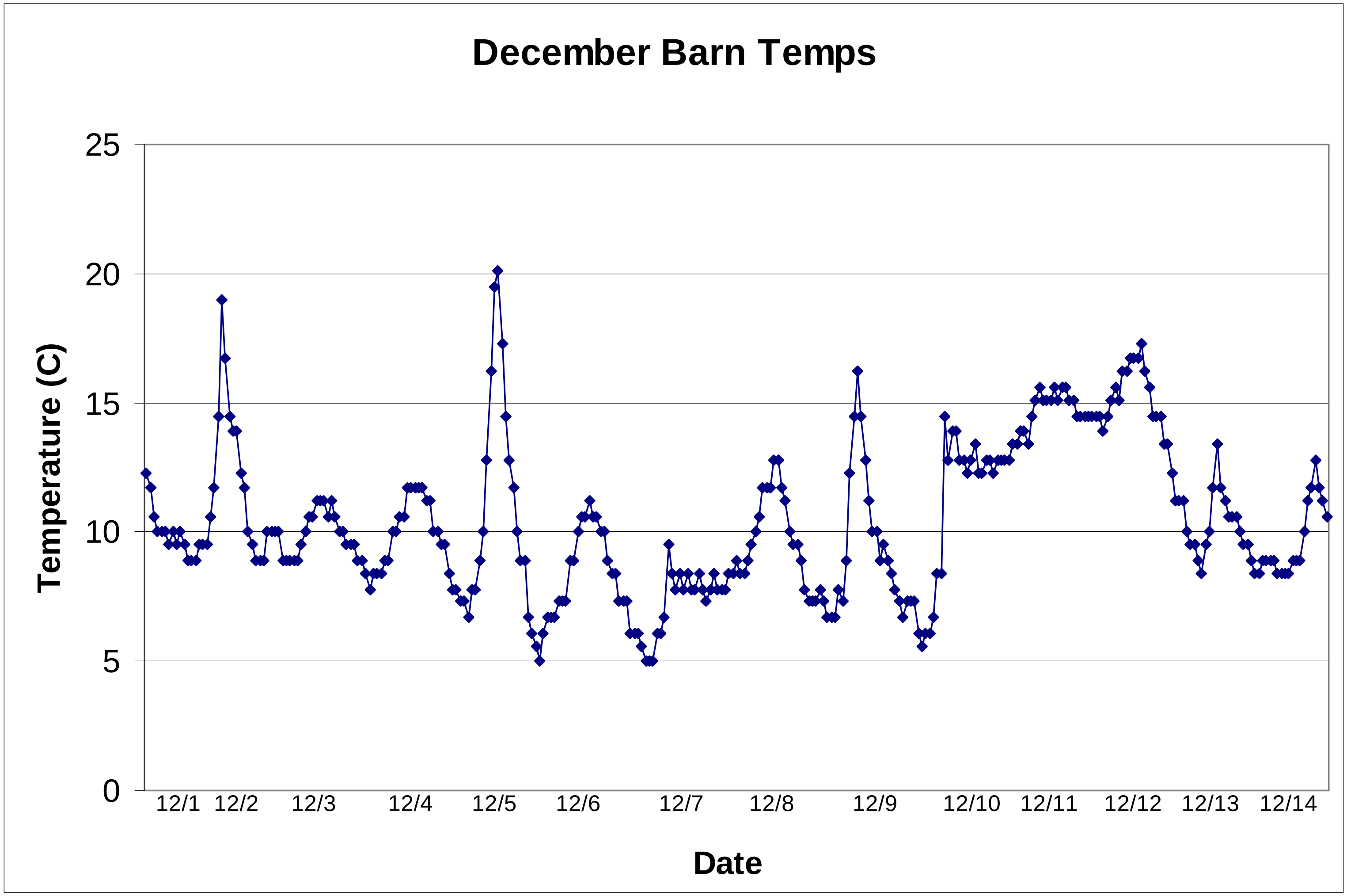
Pig #	1	2	3	4	5	6	avg

Pig #	1	2	3	4	5	6	avg

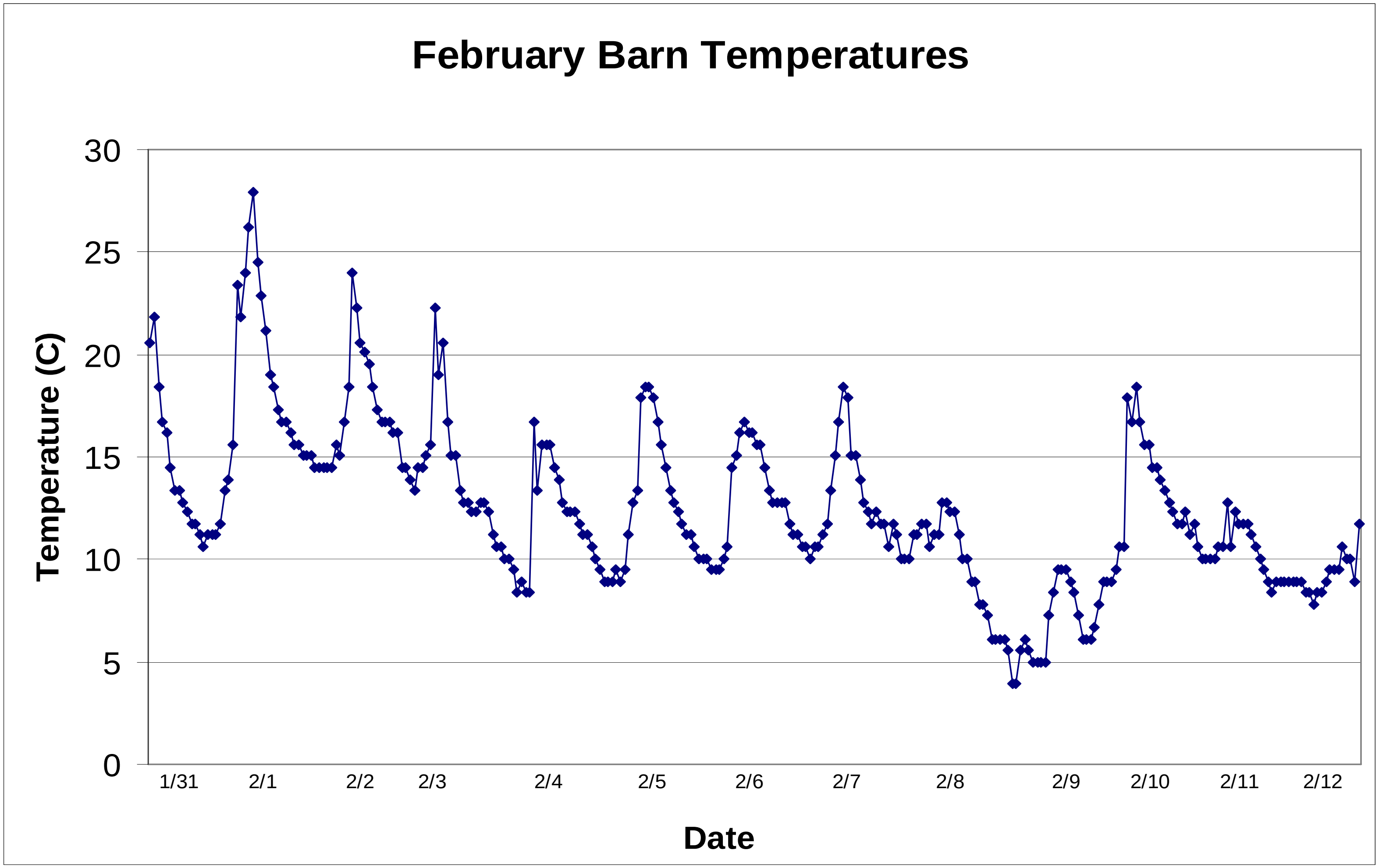
APPENDIX C: Temperatures



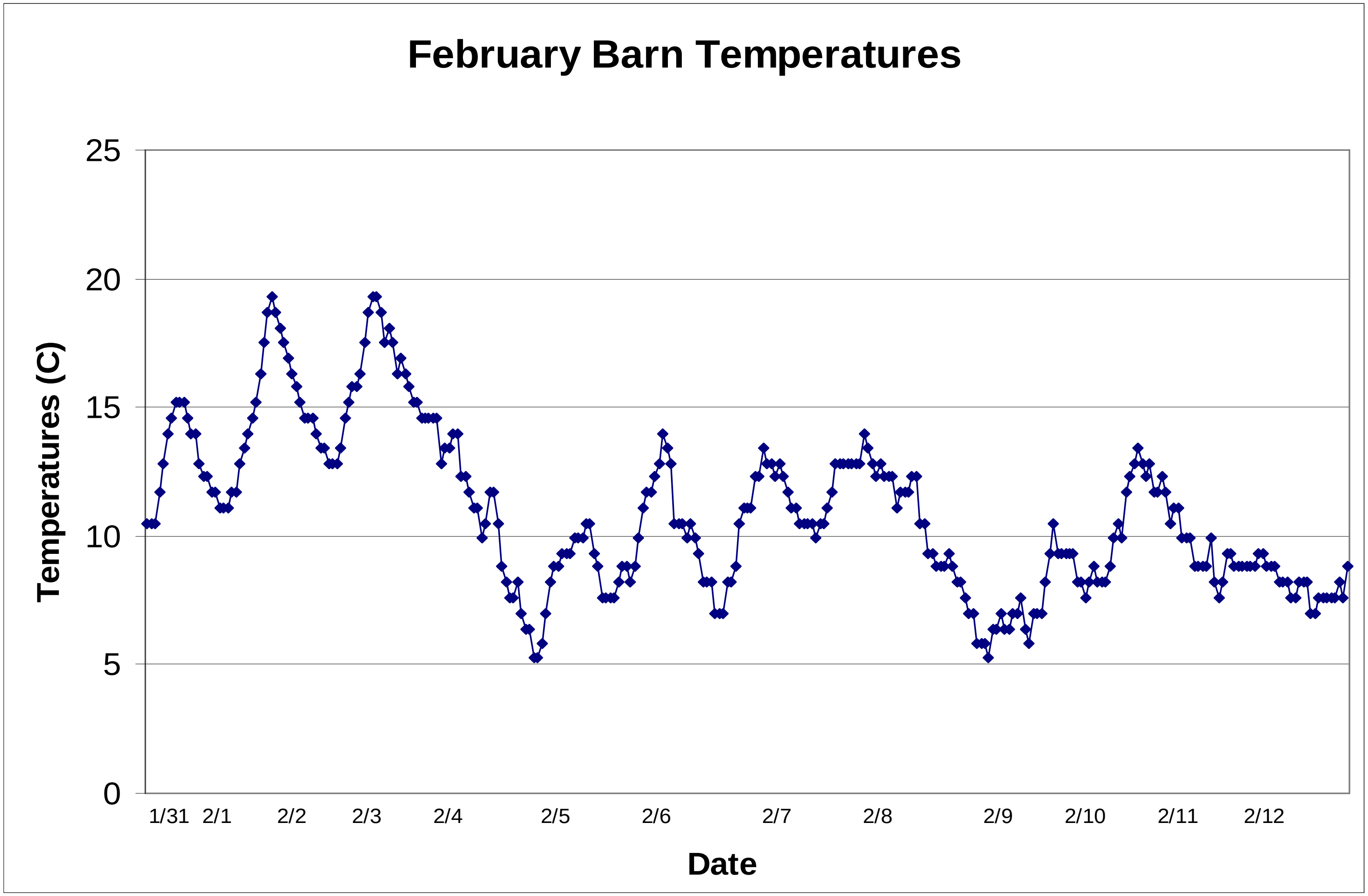
C.1. December Barn Temperature Variation Pen 8



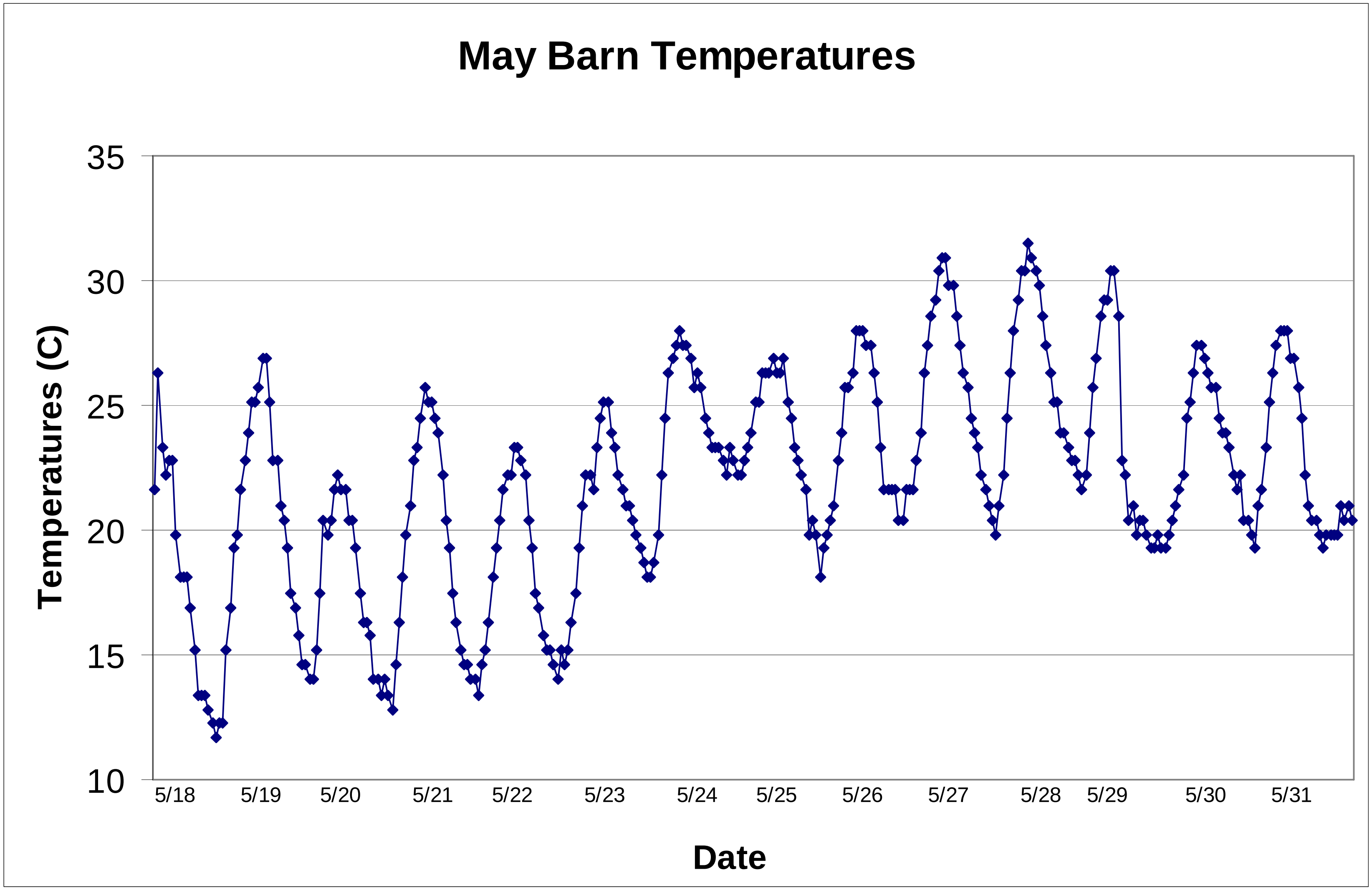
C.2. December Barn Temperature Variation Pen 2



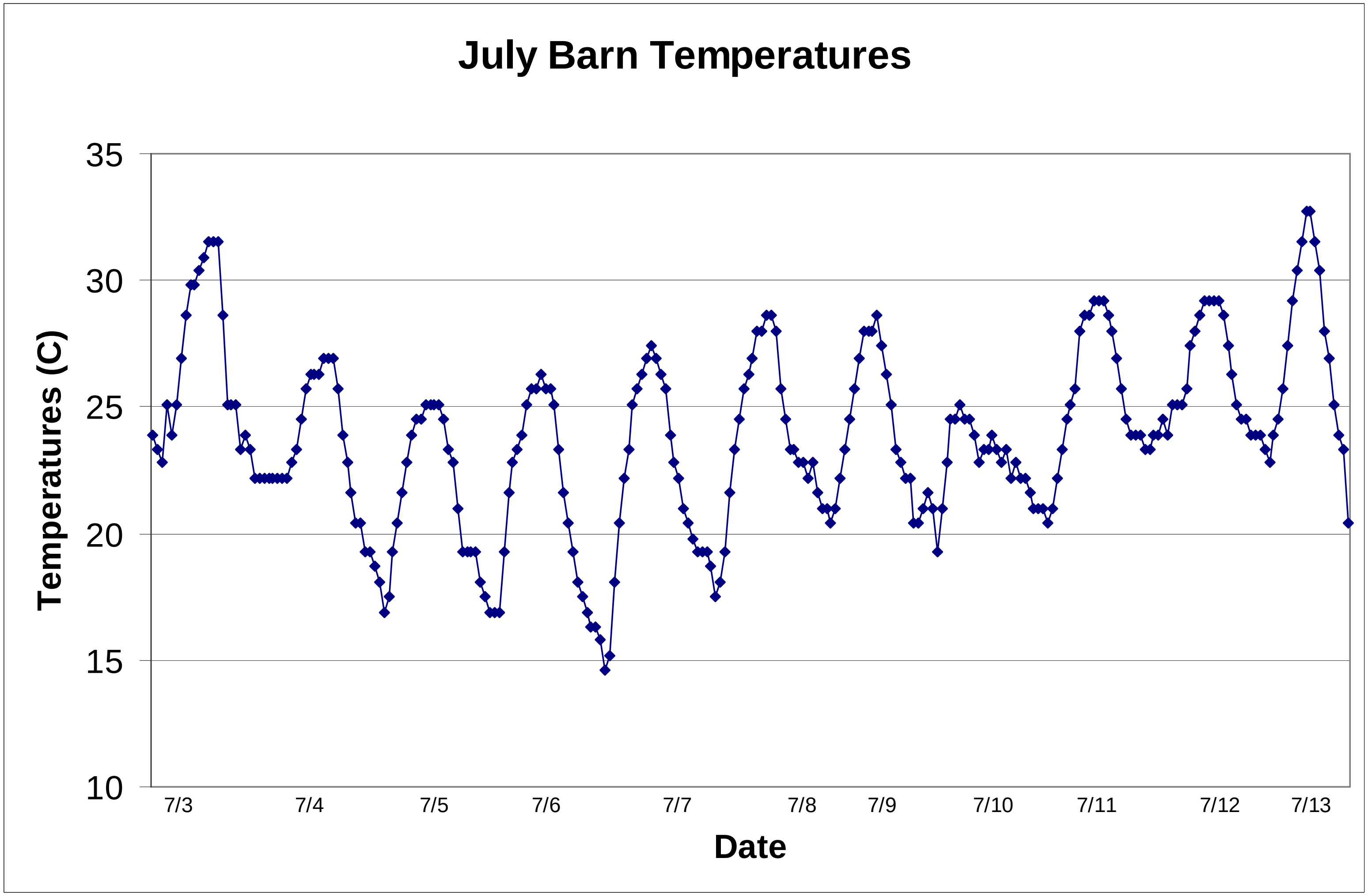
C.3. February Barn Temperature Variation Pen 2



C.4. February Barn Temperature Variation Pen 8



C.5. May Barn Temperature Variation Pen 8



C.6. July Barn Temperature Variation Pen 2

APPENDIX D: SAS Programs

D.1. ANOVA, LS Means, PDIFF and STDERR

```
options ls=100 ps=70;
data one;
infile 'C:\Documents and Settings\jlhqmb\Desktop\pigdata1.csv' dsd
firstobs=2 lrecl=1000;

input trial day trt$ sex$ breed$ lairage
bwt livewt gain carcwt dress haml
hama hamb hamFpH loinL loina loinb loinFpH color marb
Dlavg Lti LT15 LT30 LT60 LT24hr LpHi LpH15 LpH30 LpH60
LpH24hr HTi HT15 HT30 HT60 HT24hr HpHi HpH15 HpH30 HpH60
HpH24hr WBSF;
run;

proc glm; class trial trt sex day breed lairage;
model bwt livewt gain carcwt dress haml
hama hamb hamFpH loinL loina loinb loinFpH color marb
Dlavg Lti LT15 LT30 LT60 LT24hr LpHi LpH15 LpH30 LpH60
LpH24hr HTi HT15 HT30 HT60 HT24hr HpHi HpH15 HpH30 HpH60
HpH24hr WBSF;
=trial trt sex day breed lairage trial*sex trial*day sex*day trial*trt trt*day trial*trt
trial*sex trt*sex;
lsmeans trial trt day sex breed lairage trial*sex trial*day sex*day trial*trt trt*day trial*trt
trial*sex trt*sex/stderr pdiff;
run;
```

LITERATURE CITED

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