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STRATEGIES TO ELIMINATE ATYPICAL AROMAS
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# STRATEGIES TO ELIMINATE ATYPICAL AROMAS AND FLAVORS IN SOW LOINS

By

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ABSTRACT

STRATEGIES TO ELMINATE ATYPICAL AROMAS AND FLAVORS IN SOW LOINS

By

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The objective of this study was to eliminate atypical aromas and flavors in sow loins with marination treatment solutions composed of sodium bicarbonate and sodium tripolyphosphate. Sow loin sections (n=20) with atypical aromas and flavors we termed "sow taint" were treated with a solution of sodium tripolyphosphate (0.25-0.50%) and sodium bicarbonate (0.35-0.70M) and evaluated for flavor and textural attributes by a trained sensory panel. Response surface methodology identified four treatment combinations that reduced ($P<0.05$) metallic aroma, metal and sour aftertastes, and detectable connective tissue while improving ($P<0.05$) muscle fiber tenderness, juiciness, and overall tenderness. Consumer sensory panel ratings determined that sow loin chops injected with a 15% solution of sodium tripolyphosphate (0.50%) and sodium bicarbonate (0.35M) were not different ($P>0.05$) than loin chops from a marinated (0.25% sodium tripolyphosphate, 15% injection level) commodity control loin for flavor, texture, juiciness, and overall acceptability. A solution containing sodium tripolyphosphate and sodium bicarbonate minimized atypical aromas and flavors in selected sow loins and may enhance their utilization for value added whole muscle products.

This thesis is dedicated to those who have stood behind me pushing, beside me helping, and in front encouraging.

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## INTRODUCTION

Value added products serve an important role in the meat industry. The term "value added" is defined as any practice that adds marketability or economic value for the processor while providing convenience, improving eating quality, and increasing food safety for the consumer (Miller 2000). Value added products include fresh meats that have been further processed by such methods as injection/marination, curing, restructuring, tenderization, portion cutting, or packaging. Meat trimmings or subprimal cuts from carcasses that exhibit poor quality (color, texture, firmness), and edible by products are raw materials that may undergo value added processing. Value added principles can be applied to increase the value of meat obtained from older carcasses (i.e. cow, sow, etc.) in an effort to improve its usability and value.

Sow meat is primarily utilized in comminuted products such as prerigor fresh pork sausage. Prerigor or hot-boned meat is removed from the carcass prior to chilling and before the onset of rigor. Prerigor meat possesses a higher water holding capacity resulting in higher yields and a more uniform darker color than cold boned meat that has been chilled and gone through rigor (Van Laack et al., 1989). Industry feedback (Prochaska et al., 2001) indicates occurrences of undesirable flavors in sow carcasses. This off flavor or "taint" combined with decreased tenderness due to more cross linked insoluble collagen normally associated with older animals (Hedrick et al., 1989), darker muscle color from an increased concentration of myglobin, and inconsistent muscle size hinders the use of sow meat for whole muscle meat products. It is well documented that acceptable tenderness in whole muscle products can be achieved by use of mechanical (Cordray et al., 1985; Motycka and Bechtel, 1983), or enzymatic tenderization (Romans et al., 1994), or cooking methods (Simmons et al., 1985; Pearson and Gillett, 1996; Harmon et al., 1989).

Undesirable flavor in sow meat is a more challenging issue to address. Sow meat with undesirable flavors has been observed to possess a combination of bitter, cardboard-like, and astringent off flavors as well as aromas detrimental to its acceptability by consumers (Chen and Ho, 1998). Marination, which utilizes injection or tumbling to disperse a solution of water, salt, and other non meat ingredients has been used by the meat industry to change a products flavor and texture profile. The potential exists to utilize marination to combat the problem of undesirable flavors in sow meat. Research by Kauffman et al. (1998) has indicated an improvement in flavor by injecting a solution of sodium bicarbonate and salt in prerigor loins from gilts. Several studies have shown the potential of phosphates to decrease and mask off flavors in pork. (Boles and Parrish, 1990; Sutton et al., 1997; and Matlock et al., 1984).

The potential exists to utilize the synergistic effects of phosphates, sodium bicarbonate, and salt as an effective intervention strategy to reduce or eliminate undesirable flavors in sow meat. Phosphates increase water holding capacity as well as providing flavor enhancement and controlling pH (Barbut et al., 1988, Matlock et al., 1984, Keeton et al., 1984). Sodium bicarbonate offers an increase in buffering capacity during cooking when flavor volatiles are formed (Mottram, 1998). Salt increases the intensity of flavors (Matlock et al., 1984, Barbut et al., 1988). The hypothesis is marinating off flavored sow meat with a solution of sodium bicarbonate, phosphates, and salt will minimize or eliminate the off flavors and create a consumer acceptable product. Utilizing marination to produce an acceptable whole muscle product from a sow loin would add value to lower valued sow meat and result in new uses for it while creating better marketing opportunities for sow meat.

The first objective of this study was to use a trained sensory panel to identify an optimum concentration of sodium bicarbonate, phosphate, and percent marinade solution that would eliminate or reduce off flavors in sow loins. The second objective was to determine consumer acceptability of enhanced sow loins treated with sodium bicarbonate and tripolyphosphate. Results of this study will be transferred to the pork industry to provide guidelines for using sow meat as a raw material for whole muscle value added pork products.

This thesis is formatted as 3 chapters. Chapter 1 is the review of literature. Chapter 2 covers detailed materials and methods of the preliminary study, study I, and study II. Appendices that explain in detail protocols and procedures of each experiment are referenced throughout Chapter 2. Chapter 3 is formatted in manuscript style according to the Journal of Meat Science. This chapter includes and abstract, introduction, materials and methods, results and discussion, tables, figures, and references inclusive of the preliminary study, study I, and study II.

# CHAPTER 1

## Review of Literature

### I. Problems Associated with Sow Meat

#### Introduction

Meat is defined as intact, manufactured, or processed animal tissues that are suitable for use as food (Hedrick et al., 1994). Nearly all animal species can be used as a source of meat, however cattle, hogs, sheep, poultry, and fish usually prevail as the predominant domestic and aquatic sources. Meat serves an important role in the human diet. It is an excellent source of protein, iron, essential B vitamins, and vitamin A (Romans et al., 1994). Meat animal carcasses can be separated into three specific categories: roasts and steaks, lean trim, and fat and bone. The American Meat Institute (1991) estimates that 41.0% of a beef carcass is composed of boneless roasts, steaks, and chops; another 26.7% is lean trim; and 30.5% is fat and bone. Pork and lamb carcasses have similar percentage categorical composition (Romans et al., 1994).

Primal and subprimal cuts from meat animal carcasses are fabricated into steaks, chops, and roasts primarily from the middle sections (rib/rack, loin) of beef, pork, and lamb because they include a larger percentage of tender muscles (psoas major and longissimus dorsi). Muscle profiling (Jones et al., 2001) has identified these muscles to be more tender than muscles found in the round/leg and chuck/shoulder because they possess a lower amount of cross linked insoluble collagen surrounding muscle fibers. These steaks, chops, and roasts have very acceptable taste, texture, and tenderness attributes and do not require additional manufacturing or processing to make them meet or exceed consumer expectations (Romans et al., 1994).

Primal and subprimal cuts from meat animal carcasses that are 30 months of age or older from the end sections of beef (round and chuck), pork (ham and shoulder), and lamb (leg and shoulder) are found to be less desirable. This is due to greater amounts of connective tissue from increases of collagen cross linkages that occur as animals get older (Hedrick et al., 1989). This meat is characterized as having lower value because it is less tender (Hedrick et al., 1989), juicy, and flavorful. The majority of lower valued meat exists as meat trimmings produced from fabricating primal and subprimal cuts into retail cuts. These meat trimmings are either incorporated into sausage products or fresh ground beef, pork, and lamb which are both lower valued products (Romans et al., 1994).

The definition of lower value meat also includes primal, subprimal, and retail cuts that possess marginal quality (inconsistent color, juiciness, and tenderness) (Miller, 2000). These cuts may be improved using natural aging, blade or enzymatic tenderizing, or marination. Pale, soft, and exudative (PSE) pork and dark, firm, and dry (DFD) beef are two examples of meat with marginal quality. PSE pork has a pale color, a soft texture, and "exudative" or poor water binding properties. The PSE condition results in a cooked product that is dry and tough in texture. DFD beef has a dark color, a firm texture, and a dry surface appearance creating a consumer unacceptable raw meat appearance. Edible by-products, sometimes referred to as "variety meats", are also considered lower valued meat (Romans et al., 1994) since they are used very little in the United States due to an abundance of animal carcass meat and consumer eating preference.

Value added technology is important to the meat industry. There is a need to improve the flavor, tenderness, color, and inconsistent muscle size that may be associated with lower valued meat. Improving these properties of lower valued meat may also improve the marketing opportunities for products manufactured from them.

**Meat Flavor**

Flavor is an important component of meat that dictates the sensory qualities of products (Shahidi, 1998). Flavor, described by Mottram (1998), is comprised of taste and aroma components. Taste is described by attributes that include juiciness, tenderness, mouth feel, and flavor. Aroma is explicated as volatile organic compounds in meat and detected by olfactory organs as a smell (Mottram, 1998). Pork, like all meat, has little flavor or aroma until it undergoes any type of thermal processing. Heating activates aroma compounds and these aromas are then released for olfactory sensing (Shahidi, 1998). Raw, fresh pork is bland, metallic, and slightly salty whereas the characteristic meaty pork type flavors are found after heating. Chen and Ho (1998) discuss the pathways to generating pork flavor as follows:

"The reactions involved in pork flavour development are very complex, and they include the thermal degradation of individual components of pork muscle, thermal oxidation of lipids, reactions between amino acids and carbohydrates, and interactions between these various reactions."

Industry feedback (Prochaska et al., 2001) indicates the presence of undesirable flavors in an estimated 20-30% of sow carcasses. These off flavors have been identified as a combination of bitter, cardboard-like, and astringent (Miller 2000). Although undesirable flavors are not present in all sow carcasses, there are no technologies readily available to successfully identify and sort carcasses based on desirable or undesirable flavors. If sow carcasses could be successfully sorted by desirable and undesirable flavors, more opportunities would then exist to create value added whole muscle products that would be consumer acceptable. As a result of not being able to identify sow carcasses that have undesirable flavors, to provide products that meet consumer acceptability standards, all sow carcasses are handled as if they possess off flavors.

**Tenderness**

According to Hedrick et al. (1989), tenderness in meat products has been investigated more than any other palatability factor. The National Pork Board (1999) defines tenderness as the average of muscle fiber tenderness (ease of fiber fragmentation during mastication) and connective tissue tenderness when connective tissue amount is perceived as low. Hedrick et al. (1989) stated that muscles from young beef, pork, and lamb are more tender than that from older sows, cows, and mutton, mainly due to lower amounts of cross linked insoluble collagen. Additionally, muscles involved with locomotion (i.e. gluteus medius or biceps femoris) are tougher than muscles surrounding the vertrebral column which are used for support (i.e. longissimus dorsi or psoas major) because of the higher amounts of collagen associated with locomotive muscles.

Mechanical or cooking methods can be used to help alleviate tenderness challenges. Research by Corday et al. (1986) investigated the effects of blade tenderization on the tenderness of restructured pork steaks made from sow meat. They concluded that tenderness was improved ($P<0.05$) in restructured pork steaks that were mechanically tenderized. In similar work, Huffman et al. (1981) studied the effectiveness of mechanical tenderization on improving the tenderness of restructured chops manufactured from sow meat. Results indicated mechanically tenderized chops had a lower compression value (479 vs. 559 grams of force) than controls.

Meat cookery can also improve tenderness in sow meat. Cooking time and temperature contribute to the tenderizing and toughening changes in meat (Cross et al., 1986). Romans et al. (1994) suggests cooking one-inch thick pork chops 8 to 11 minutes compared to 20 to 25 minutes per pound for leg roasts to reach an internal temperature of 71°C. The longer cooking time for larger cuts allows for a more complete breakdown of soluble connective tissue present in cuts composed of tougher muscle groups. Simmons et al. (1985) found that tenderness decreased ($P<0.05$) when the final internal temperature of pork chops increased from 60°C to 80°C. This was suggested to be a result of lower cook yields ($P<0.05$) found in 80°C chops compared to the 60° chops.

## Muscle Color

Adams and Huffman (1972) suggested that consumers relate the color of meat to freshness. The National Pork Board (Baas et al., 2000) states that the color of pork has an important impact on consumer decisions. Consumers make meat buying decisions based on their knowledge of what color meat products have historically been and based on that what they believe the ideal meat color should be. Based on this information, the National Pork Producers Council developed guidelines to evaluate and identify the "ideal" color of pork. They established ideal colors ranging from a pale pinkish gray to white color with a Minolta $L^*$ value of 61 to a dark purplish red color with a Minolta $L^*$ value of 31. Consumer acceptable pork has been suggested to posses a reddish pink color with a Minolta $L^*$ value of approximately 49 (Baas et al., 2000).

Kauffman and Marsh (1987) stated that as the chronological age of animals increases, the quantity of myoglobin (a protein pigment) in muscle increases. This results in darker colored meat. Nold et al. (1999) supported this statement with research characterizing the color of muscles from boars, barrows, and gilts. Muscles were found to have a darker color ($P<0.001$) in gilts ($L^*$ 44.54) compared to barrows ($L^*$ 45.61). The darker color found in sow meat is associated with a higher myoglobin content from an older animal resulting in a lower L* color value. This darker color creates a less consumer appealing whole muscle product (Nold et al., 1999).

**Muscle Size**

Because sow meat is currently ground for comminuted sausages such as fresh pork sausage, muscle size has not been a problem. However, this issue will need to be addressed for sow meat to be used for whole muscle value added products. Generally, muscles increase in size (diameter, length, width, depth) as animals increase in weight. Studying the performance, carcass merit, and meat quality of boars, gilts, and barrows, Grandhi and Cliplef (1996) found the loin eye area of gilts to be larger (33 $cm^2$) than that of barrows (31$cm^2$). Sows can be expected to have even larger loin eye areas as they have heavier weight carcasses (120 to 180 kg). However, this is not always found to be true as sows can also have much smaller loin eye areas due to large body weight fluctuations as a result of intensive gestation, farrowing, lactating, and fattening cycles (Taylor, 1995).

Products from carcasses which have inconsistently sized muscles and are used for whole muscle meat products result in non uniform portion sizes of retail products. Consumers can find these products to have greater or fewer servings per package than desired compared to products from other pork carcasses with consistently sized muscles. Portion sizing, which is physically reducing the size of muscle by cutting it into desired portions, or restructuring are two methods to combat this problem. Huffman et al. (1981) and Cordray et al. (1985) used restructuring to combat this problem by manufacturing restructured chops with desirable (smaller) size properties from hot processed sow meat.

## II. Utilizing sow meat

### Overview of Sow Meat

Approximately 98,000,000 hogs were slaughtered in the United States in federally inspected plants in 2001. These hogs had an average hot carcass weight of 87 kg producing nearly 771,107,029 kg of pork (USDA, 2001). Of those hogs slaughtered, 3,000,000 were sows with an average hot carcass weight of 143 kg constituting 3.1 % of the total hogs slaughtered in the United States (USDA, 2002). Carcasses from sows are primarily processed into comminuted products such as pre rigor fresh pork sausage (Huffman et al., 1981). This process makes use of fat and muscle from the entire carcass. However, undesirable flavors (Prochaska et al., 2001), lack of tenderness (Corday et al., 1986), darker muscle color (Nold et al., 1999), and varying muscle size (Huffman et al., 1981) are problems associated with sow meat that hinder its ability to be used in whole muscle value added products.

### Hot-Boning vs. Cold-Boning

*Advantages*

Hot-boning is a technique used primarily in the pork industry where carcasses are fabricated pre-rigor shortly after slaughter with no chilling. In a pre-rigor state, muscles have not yet gone through permanent actin and myosin filament cross-bridging, have a high level of ATP (energy), and have high pH relative to preslaughter conditions (Hedrick et al., 1989). There are a number of advantages and disadvantages to hot-boning. One advantage of hot-boning is the economic savings from eliminating energy costs associated with carcass chilling. Pisula and Tyburcy (1996) stated that hot boning allows for a reduction in cooler space of 50-55% ultimately reducing refrigeration input (energy) by 40-50%. Hot-boned sow, pork, beef, and lamb carcasses have been shown to have an increase in water holding capacity (WHC), cook yield, and color uniformity due to a less severe pH decline resulting in less protein denaturation (Honikel and Reagan, 1987).

Water holding capacity is a measure of a muscle's ability to retain and hold water and is determined by the degree of protein denaturation in the muscle (Hedrick et al., 1989). A high WHC is a desirable characteristic in most processed meats as it results in higher product yields and improved textural properties (juiciness, tenderness). Increased levels of protein denaturation result in a lower WHC. For normal slaughter and fabrication production where carcasses are subjected to chilling, adenosine triphosphate (ATP) and glycogen causes muscle pH to fall from approximately 7.4 to ultimate values in the 5.4-5.8 range (Hedrick et al., 1989). This rapid drop in pH combined with decreasing muscle temperatures during the pH decline, cause denaturation of proteins with a concomitant decrease in WHC.

Drip loss by suspending meat samples using a hook and string apparatus and physically measuring fluid loss is one method to determine water holding capacity. In the fresh state, hot-boned pork has a higher WHC with less drip loss (4.3 vs. 2.8%) than cold boned pork (Reagan, 1983). In constrast, van Laack et al. (1992) investigated the effects of hot-boning on water holding capacity and found that drip loss for hot-boned pork was not statistically different when compared to cold boned pork stored for 1 (2.2 vs. 2.8%), 5 (2.1 vs. 2.0%), or 13 days (0.9 vs. 1.0 %).

Cook yields of meat products with or without the inclusion of non meat ingredients are investigated to measure differences in cooking loss. Products manufactured from hot-boned meat are found to have higher yields than those from cold-boned meat (Pisula and Tyburcy, 1996). Bentley et al. (1988) reported luncheon loaves formulated with hot-boned meat had improved ($P<0.05$) cooking yields (93.0 vs. 90.0%) compared to loaves made with cold-boned meat. Shin et al. (1992) reported improved ($P<0.05$) cook yields from hot-boned pork roasts when comparing the effects of heating rate on palatability and associated properties of pre- and post rigor muscle.

In contrast to cold-boned carcasses, the breakdown of ATP and glycogen in hot-boned carcasses causes muscle pH to fall from 7.4 to ultimate pH values from 6.0 to 6.2 (Honikel and Reagan, 1987). Although the same temperatures may exist in the muscle after slaughter but before rigor, the change in pH is much smaller than in cold-boned muscle resulting in a less severe pH decline, less protein denaturation, and a higher WHC. Since color of fresh meat is affected by the severity of pH decline and ultimately protein denaturation, a less severe pH decline with less protein denaturation will result in a more uniform color of lean in the muscle (Honikel and Reagan, 1987).

*Disadvantages*

Hot-boning pork is currently used in the industry for sausage products and not whole muscle cuts for a number of reasons. Hot-boned pork has been found to have an increased muscle shape distortion and a higher incidence of microbial growth.

*Muscle Distortion*

Removing warm muscles from a carcass during hot-boning allows for them to contract more than intact muscles that remain stretched on the carcass while chilling (Pisula and Tyburcy, 1996). In conventional slaughter, muscles "stiffen" or go through rigor mortis. Rigor mortis begins after exsanguination and is the formation of permanent cross-bridges in muscle between actin and myosin causing stiffening of the muscle (Hedrick et al., 1989). These warm muscles distort in shape and size since they have not gone through rigor mortis while stretched on the carcass.

*Microbial Growth*

Hot-boned pork possesses a higher ultimate pH (6.0-6.2) creating a more ideal environment for bacteria and microbial growth (Smulders and Eikelenboom, 1987). Choi et al. (1987) studied the effects of hot-boning with various levels of salt and phosphates on microbial values of preblended pork. Their research concluded that hot-boned blend treatments had higher mesophilic ($P<0.05$) and psychotrophic ($P<0.05$) counts than cold-boned preblends.

Problems of microbial growth and muscle distortion minimize hot-boning pork production in most commercial settings. The discussed negative quality characteristics and the concern of producing undesirable products for further processors and consumers discourage the implementation of hot-boning for fabrication and use for whole muscle products.

## III. Developing Value added products

### Sources of Raw Materials

As previously discussed, there is an array of different raw materials from edible by-products, meat trimmings and less tender cuts that can be used to develop value added products. Each raw material possesses processing characteristics that determine if it can be used as a raw ingredient for a specific product. Specific value adding technologies are applied to raw ingredients in an effort to develop products that meet or exceed consumer acceptability (appearance and safety) and desirability (tenderness, juiciness, and flavor)

### Value Added Technologies

Processing technologies and non-meat ingredients are used to improve product uniformity (i.e. color, texture), tenderness, and juiciness. The overall goal of value added products is to increase consumer acceptability and create renewed interest to buy meat products.

Swart (2000) defines value added as processing steps or technologies that contribute to the end state of a product which make the improved product valued by customers. Injection, restructuring, mechanical tenderization, tumbling, mixing, and usage of ingredients such as salt, phosphates, gums, and starches can improve a product's value. Products do not have to undergo complex manufacturing or processing steps such as sectioning and forming or restructuring to be classified value added. They can be included in this category by technologies ranging between a slight modification in packaging or creating a new name for an existing product to producing a restructured and reformed product.

*Injection*

Injection technology is used to physically distribute brine (a combination of salt and water; Romans et al., 1994) or a marinade (a solution of salts, phosphates, and spices) into whole muscle meat and poultry through needles that penetrate into the muscle and distribute the brine or marinade under pressure. Injection is used to improve the juiciness, tenderness, and flavor of a meat product. Research has shown that injection is an ideal method to distribute non-meat ingredients such as salt, phosphates, nitrates, cure accelerators, sweeteners, seasonings, non-meat proteins, starches, gums, water, and preservatives in meat products. Vote et al. (2000) revealed that injecting beef strip loins with solutions containing sodium tripolyphosphate, sodium lactate, and sodium chloride improved tenderness ($P<.05$), juiciness ($P<.05$), and cooked beef flavor ($P<.10$). Sheard et al. (1999) and Sutton et al. (1997) investigated injecting pork loins with a marinade consisting of polyphosphates and water to improve sensory characteristics. They found that polyphosphates improved water holding capacity, and generally produced more tender and juicy chops than control chops. The benefits of injecting has enabled the pork industry to inject marinade solutions into fresh pork thus creating the term “enhanced pork”.

*Restructuring*

Restructured products are manufactured from muscle groups that are partially or completely comminuted and reformed into the same or different form. Restructuring uses three basic approaches: chunking and forming, flaking and forming, and tearing and forming (Pearson et al., 1996). Taking muscles apart, physically manipulating them, and reforming them into a specific shape has a number of advantages. Restructured products have a texture that closely resembles intact meat cuts and are more economical to produce from less tender muscles and meat trimmings than boneless intact meat cuts. Restructuring also allows the possibility for specific portion control (Pearson et al., 1996).

From a processors viewpoint, restructuring aids in accurate portion and compositional control, easier slicing and serving, more accurate predictions of yields and servings. (Akamittath et al.,1990). However, problems such as color instability and fat oxidation do exist with this technology. Akamittath et al. (1990) found that lipid oxidation could be inhibited up to four weeks in restructured frozen beef steaks, up to six weeks in frozen turkey steaks, and up to eight weeks in frozen pork steaks with the use of phosphates. Further investigation discovered color stability (the ability for a product to retain its ideal color) and lipid oxidation to be highly correlated. In related studies, Schwartz and Mandigo (1976) further studied the effects of various salt and sodium tripolyphosphate combinations on restructured pork with varying results. Their findings showed that as salt levels increased (0-2.25%), raw color scores decreased ($P<0.05$) and TBA values measuring lipid oxidation increased ($P<0.05$). As phosphate levels increased (0-0.5%), raw color scores and TBA (lipid oxidation) values increased ($P<0.05$). However, salt and phosphates synergistically produced color scores higher ($P<0.05$) than salt or phosphates could alone.

*Mechanical Tenderization*

Mechanical tenderization is a technology used to improve tenderness of meat products by destroying connective tissue and muscle fibers (Hedrick et al., 1989). It is very effective in improving the tenderness of meat from carcasses with high amounts of connective tissue (Pearson and Gillet, 1996). Huffman (1981) and Booren et al. (1981) reported improvements in tenderness measured by compression and Kramer shear respectively by blade tenderizing restructured pork chops, USDA Good (currently called Select) and Choice beef steaks, and restructured beef steaks respectively. The advantages of mechanical tenderization are: improving acceptable tenderness of steaks and chops, creating a more uniformly tender product, and improving cost effectiveness and ease of implementation in a plant setting (Hayward et al., 1980).

The effectiveness of value added technologies can vary from one product to another due to differences in raw ingredient type, the final product desired, and the overall goals of each individual product. Some product goals may be: is the product intended for food service or retail, which economic consumer group (low, middle, or high income) may have interest, and what final destination (restaurant, fast food chain, household, or export market) the product is best suited.

## Developing Marinated / Enhanced Product

Marinated or enhanced products are common processing practices for whole muscle products. Non-meat ingredients including sodium chloride, sodium phosphates, and spices are used for developing these products. These ingredients serve important roles to increase flavor, texture, and shelf life of marinated products (Miller, 2000).

### *Non-Meat Ingredients*

Non-meat ingredients are defined as any type of non-animal based ingredient that is allowed as an additive in meat products by the United States Department of Agriculture (USDA), Food Safety and Inspection Service (FSIS) (Pearson et al., 1996). This list includes water, salt, ascorbates, erythorbates, sugars, phosphates, starches, gums, carrageenans, and spices just to name a few. Non-meat ingredients are added to fresh or processed meat to improve juiciness and/or tenderness, enhance flavor, stabilize or improve color, increase shelf life, control microbial growth, or increase the water holding capacity of a product (Miller 2000). Non-meat ingredients are also used to increase protein content, improve emulsion stability, improve fat binding properties, or improve slicing characteristics (Pearson et al., 1996). These beneficial properties of non-meat ingredients allow for increased success in developing value added products.

*Water / Injection Level %*

Of all the non meat ingredients, water constitutes the largest usage. Water plays a significant role in the development of value added products and serves a number of important functions in meat applications. Water acts as an ideal dispersing medium for non-meat ingredients that are water-soluble or can be suspended for subsequent addition into meat (Romans et al., 1994). These solutions, marinades, or brines can then be added to meat by injection, soaking, tumbling, chopping, or mixing.

Water, in conjunction with other non-meat ingredients, assists in reducing cooking loss and maintaining a final cooked product that is moist and juicy by compensating for moisture lost during thermal processing (Romans et al., 1994). It also reduces product costs by providing opportunities to have products with greater water levels than those naturally present in raw meat (Romans et al., 1994). Water can then be described as a cheap ingredient source ideal for increasing the profitability of fresh meat products for processors.

However, the United States Department of Agriculture (USDA) Food Safety Inspection Service (FSIS) does regulate the amount of water (and other non-meat ingredients) that may be added to products. Specific product labeling must define the amount of solution (including water) added in order for a product to pass FSIS inspection (Miller 2000). Fresh meat products with up to 10% added solution must be labeled deep balasted or marinated. Those fresh products that contain a solution over 10% must be labeled "containing up to" and the actual percentage of solution listed. These regulations protect consumers from false information and false representation of the contents in the meat products they are buying.

Interestingly, water has also been suggested to dilute out meat flavor compounds and provide a decrease in meat flavor. However, the functionality of water is limited without the use of non-meat ingredients or mechanical actions. The addition of water as a single ingredient is suggested to result only in increased package purge (Miller, 2000).

*Sodium Chloride*

The use of sodium chloride (salt) used in meat products has been used since the beginning of meat consumption. Salt was first found beneficial (at very high levels) as a preservative by lowering the water activity in meat and consequently reducing microbial growth and rancidity that contribute to spoilage (Romans et al., 1994). Although the addition of salt is self limiting, it is closely monitored by processors due to concerns of dietary sodium and its relationship to hypertension (Rust 1987). Further investigation of salt found it to have other beneficial properties. Rust (1987) states that salt has three primary functions: preservation, flavor enhancement, and protein extraction for texture and binding purposes. Miller (2000) and Romans et al. (1994) stated that salt improves water holding capacity resulting in decreased purge loss and improved cooking yields.

Salt improves water holding capacity by swelling meat proteins up to twice their normal size. This is accomplished by the chloride ion of salt binding to meat protein filaments. When bound, the chloride ion lowers the isoelectric point while increasing ionic strength of meat proteins. This increases the repulsive forces within the protein structure matrix creating an unfolding of the matrix that subsequently allows for swelling. This swelling provides more protein side chains to be available for binding water (Lindsay, 1985). Research conducted by Matlock et al. (1984), Schwartz and Mandigo (1976), and Vote et al. (2000) report improvements in water holding capacity by using salt in frozen pork sausage (1.0%), restructured pork (0.75%), and beef strip loins (0.5%) respectively. These levels were found desirable to maintain acceptable yield and sensory properties with no bitter, sour, or salty flavors.

*Phosphates*

Phosphates are compounds manufactured from phosphoric acid where the acid has been neutralized with sodium, potassium, or calcium alkali metal ions (Dziezak, 1990). Phosphates can be categorized as orthophosphates with only one phosphorus atom or polyphosphates composed of two or more phosphorus atoms (Sofos, 1986). Phosphates used in meat products are predominately sodium based. The allowable limit for phosphates in meat products is 0.5% of the finished product weight (USDA, FSIS, 2002).

Townsend and Olson (1987) stated that the primary reason for using phosphates in meat products is to increase water holding capacity and reduce purge (amount of released water). This is accomplished by increasing the pH of meat that results in a shifting of the pH away from the isoelectric point. This pH shifting increases repulsive forces resulting in an increased ionic strength, an increased amount of negative charges, and a greater association for water binding (Trout and Schmidt, 1983). Polyphosphates can further bind water by attaching to a positively charged group in a muscle structure while the chain of the polyphosphate attracts water molecules resulting in further increasing the amount of water bound or water holding capacity (Sofos, 1986).

Improved water holding capacity by using phosphates has been well documented (Sheard et al., 1999; Sutton et al., 1997; Smith et al., 1984g; Vote et al., 1999; Boles and Parrish, 1990). Specifically, Sheard et al. (1999) investigated the effect of injecting pork loins with polyphosphates on juiciness and tenderness. Their research found phosphates at 0.3% and 0.5% injection levels to decrease ($P<0.05$) cooking loss compared to no injection. However, no significant differences were found in cooking loss between 0.3% and 0.5% treatments. Interestingly, their research also showed an increase in tenderness by increasing phosphates levels from 0% to 0.5%. An increase in tenderness was hypothesized to be a result of two actions: 1) phosphates weakening the binding of myosin heads to actin, not allowing the association of actomyosin, thus resulting in minor expansion of muscle filaments; 2) the higher water content resulting in a higher water/protein ratio.

Although phosphates have been shown to contribute to higher water holding capacity properties, they have also been associated with changes in meat texture and flavor. Miller (2000) suggests that high levels of phosphates may result in a product that has a soft texture. This soft (mushy) texture could lead to a product considered unacceptable by consumers.

Phosphates used at high levels have been recognized to impart off flavors described as soapy or metallic. Craig et al. (1991) investigating the use of phosphates in turkey discovered off flavors to be greater ($P<0.05$) in samples with 0.5% compared to those with 0% or 0.3%. Vote et al. (2000) and Smith et al. (1984) also recognized that off flavors were present in some pork and beef roasts injected with phosphates. However, Keeton et al. (1984) found no detectable off flavors in pork from phosphates used at 0.5%.

Interestingly, Sheard et al. (1999) found that pork loins injected with 0.3% and 0.5% phosphates had a less intensive pork flavor. Sutton et al. (1997) agreed with this statement suggesting that pork flavor was partially masked by the addition of 0.4% phosphate in pork roasts. Although not well understood, this decrease in pork flavor could be a result of the buffering properties of phosphates controlling the pH of meat proteins proposed by Trout and Schmidt (1983), Miller (2000), and Dziezak (1990).

*Sodium Bicarbonate*

Sodium bicarbonate is classified as an alkaline (base) substance that is used in a variety of applications in foods and food processing. It is the most common leavening salt used for foaming and gas releasing properties. Sodium bicarbonate is also quite soluble in water (619 g per 100 ml) and ionizes completely. It is also known as an excellent buffer and can be used to control pH (Lindsay, 1985). The buffering and pH controlling properties of sodium bicarbonate make it an interesting compound to study for use in meat products.

However, limited research has been done with the use of sodium bicarbonate in meat products. Bechtel et al. (1985) investigated the use of sodium bicarbonate as a substitute for sodium chloride in frankfurters. Their findings discovered that 1% and 2% added sodium bicarbonate linearly increased ($P<0.05$) pH and decreased ($P<0.05$) free water. This was suggested to occur due to the buffering ability of sodium bicarbonate. Their work also found frankfurters with increasing levels (1% and 2%) of sodium bicarbonate to possess a poorer texture, mouthfeel ($P<0.05$), and an increase ($P<0.05$) in off flavors described as metallic and alkali. Large vacuoles or air spaces were found in the surfaces of the samples. This agrees with a statement by Lindsay (1985) proposing that gas released from sodium bicarbonate along with expansion of trapped air and moisture vapor imparts a characteristic porous structure on finished products.

Kauffman et al. (1998) investigated the effects of injecting a solution containing sodium bicarbonate or a combination sodium chloride and sodium bicarbonate into pork loins pre-rigor and post-rigor in an effort to prevent pale, soft, and exudative meat. Their results showed that injecting sodium bicarbonate pre-rigor and post-rigor increased ($P<0.05$) the final (ultimate) pH between 0.1 and 0.6 units and decreased ($P<0.05$) drip loss 5.4% and 4.3% respectively. Interestingly, the sodium bicarbonate + sodium chloride solution had improved ($P<0.05$) flavor and juiciness compared with other treatments suggesting that synergistic effects may have occurred.

**Challenges for Value Added Products**

Processing technologies can increase the utilization of lower valued muscles by improving their quality and consistency. Applying specific processes to increase uniformity of color, texture, and tenderness adds value to products. However, a number of challenges must be addressed when manufacturing value added products.

Technologies such as restructuring, blade tenderization, marination by injection, and vacuum packaging can cause adverse problems with customer acceptance. These technologies may create consumer confusion and concern. The consumer's lack of familiarity with value added terminology printed on labels such as "enhanced" or "injected with a solution containing...", creates confusion as to what has actually been done to the product. This confusion can develop into concern as consumers may inquire if value added products compared to traditional products are still safe and wholesome.

Along with consumer acceptance, the processing industry also faces a number of challenges with value added products. One of these challenges is minimizing microbial growth in products where technologies such as injection or blade tenderization may introduce food borne pathogens. Banks et al. (1998) investigated what effects injecting fresh pork loins with lactate/sodium tripolyphosphate had on aerobic plate counts. Research suggests that the increase in pH from the addition of phosphates in a meat product can increase the susceptibility of microbial growth, consequently decreasing shelf life. Choi et al. (1987) conducted similar research investigating the effects of hot boning and several combinations of salt and phosphate on microbial growth. It was reported that microbial counts in hot boned preblended pork were significantly higher than that of cold blended pork regardless of salt and phosphate levels. However, these differences were not imperative as both hot boned and cold boned microbial counts were within acceptable ranges (less than $10^5$ organisms/g; (Yanai et al., 1976).

Another challenge of producing value added products is controlling and extending the shelf life of value added products (Sutton et al., 1997). Lipid oxidation impacts the shelf life of meat products. Lipid oxidation causes rancidity, which is one of the most serious flavor problems in meat products (Pearson et al., 1996) and is common when mechanical machinery is introduced to product production. Rancidity occurs when fats are oxidized, become free radicals, and react with a number of pre existing reactants. These products readily decompose into acids, aldehydes, alcohols, carbonyls, and ketones. Some of these compounds can then contribute to strong flavors or odors that contribute to the rancidity of a product (Schmidt, 2000). Schwartz and Mandigo (1976) investigated the effects of salt, sodium tripolyphosphate, and storage time on restructured pork concluding that both salt and sodium tripolyphosphates increased thiobarbituric acid (TBA) values. In similar research, Booren et al. (1981) discovered that the addition of salt and the use of blade tenderization when producing section and formed beef steaks also increased TBA values. This work is also in agreement with Choi et al. (1987) who studied the effects of hot boning and levels of salt and phosphates on TBA values of preblended pork during cooler storage. His findings indicated that there were no differences in TBA values between hot boned and cold boned preblends regardless of phosphate levels. However, the addition of salt (1.5% or 3.0%) was shown to increase the TBA values in both cold boned and hot boned preblends.

Controlling the development of off flavors is another challenge associated with value added products. "Fresh" flavor quality or flavors that are recognized as meat type flavors by consumers are necessary for their acceptance. Off flavor development is a result of previously discussed lipid oxidation, cooking and reheating causing warmed over flavor (Craig et al., 1991), and the use of non meat ingredients such as phosphates or non traditional spices. Warmed over flavor describes the rapid development of undesirable flavors in cooked meat during refrigerated storage. Phospholipids present as a result of oxidation of fat into free radicals contribute to the development of this undesirable flavor (Hettiarachchy and Gnanasambandam, 2000). Phosphates, salts, and flavorings are commonly used to combat warmed over flavor and improve palatability characteristics of meat products (Vote et al., 1999).

However, non-meat ingredients can cause off flavor development. Phosphates when used at high levels (0.5% wt/wt) commonly produce flavors identified as soapy or alkaline tasting (Craig et al., 1991). Sutton et al. (1997) investigated the effects of sodium lactate and sodium phosphate on the physical and sensory characteristics of pumped loins. This research indicated that using phosphates and sodium lactate improved tenderness, juiciness, while decreasing purge loss, and cooking loss. However, phosphates were found to partially mask pork flavor and produce a soapy and alkaline type taste. Sodium lactate was found to enhance the soapy and alkaline type taste. Sheard et al. (1999)

investigated injecting polyphosphates into pork after cooking and found similar results of improved juiciness and tenderness but also finding a decrease in normal pork flavor intensity and an increase in abnormal flavor intensity.

Although using phosphates, sodium lactate, salts, sodium chloride and spices in meat products have been shown to improve the palatability and sensory aspects of value added meat products, other challenges still exist. Investigating the effects of salt and sodium trypolyphosphate on restructured pork, Schwartz et al. (1976) recognized that salt and sodium trypolyphosphate greatly reduced ($P<0.01$) cooking yields (difference between the precooked and cooked weights) but salt increased ($P<0.01$) packaging loss (difference between the raw weight at the time of packaging and the frozen weight prior to cooking) as levels increased from 0 to 2.25%. Their work also discovered an increase in product stickiness as salt levels increased from 0 to 2.25% causing meat particles to adhere to the packaging material. Davis et al. (1977) discovered that blade tenderizing boneless beef strip loins resulted in greater weight losses during storage and a decreased overall appearance (a combination of muscle color, freshness of fat, surface discoloration, and peripheral discoloration). Hayward et al. (1980) and Davis et al. (1975) both concluded that blade tenderizing beef longissimus muscles resulted in increased cooking losses. However, Tatum et al. (1977) found no differences in cooking loss between blade tenderized and non-blade tenderized beef roasts.

Food safety, shelf life, off flavor development, cooking loss, and packaging losses are obstacles to overcome when developing value added products.

These challenges require special attention by addressing the problem and developing solutions that will ensure the success of that particular product.

**Benefits of Value Added Products**

Although there appears to be many challenges associated with the development or manufacture of value added products, there are several reasons to continue the effort to develop them. One reason is to utilize lower valued meat, which can be harder to market. Lower valued meat has a lower value because there is currently little demand for its use. If value adding technologies can be applied to lower value meat, the demand for lower valued meat will increase subsequently increasing the value of it. A second reason is to improve the uniformity of existing products. Miller (2000) stated that value added products allow for improvements in quality attributes by having: 1) a more uniform color of cut surface lean and in some cases an improved "ideal" species (beef, pork, lamb, poultry) color or appearance; 2) improved tenderness of a product line (i.e. beef steaks) or improved tenderness uniformity within a product; 3) improved juiciness of a product line (i.e. pork chops) or improved juiciness uniformity within a product; and 4) and extended shelf life of a products.

Value added products increase product variety or choice that consumers can choose from. Isolated soy proteins, gums, and starches can be used to replace expensive animal protein (Keeton et al., 1984) creating the opportunities to produce lower-cost extended products. This can become increasingly important when developing meat products that are economically competitive with other protein sources such as beans.

## IV. Summary

The development of value added products is a continual process that aids in the utilization of under or lower valued meat. The concept of utilizing lower valued sow meat as the primary raw ingredient to develop value added products is a novel yet important area of interest for investigation. Research has been conducted to improve the functionality and textural attributes of raw meat ingredients for use in value added products. This research has shown through an array of technologies (i.e. tenderization, restructuring, marination, etc.) that consumer acceptable value added products can be achieved. These technologies result in products that possess at least the minimal quality attributes of tenderness, juiciness, and flavor to be deemed acceptable by consumers.

The presence of off flavors in lower valued pre-rigor sow meat creates a serious problem (Prochasksa et al., 2001) when trying to attain a consumer acceptable product. The sporadic occurrence of these off flavors and the lack of available technology to detect and sort carcasses that possess off flavors forces processors to grind and heavily season the sow meat. This process successfully masks off flavors but produces a lower value ground product (i.e. fresh ground pork sausage).

With the continual acceptance of enhanced or marinated pork products, marination is theorized to be an excellent technology to distribute salt, water, phosphates, and sodium bicarbonate into sow meat to minimize the presence of off flavors. These ingredients could have the potential to manipulate the biological systems in the meat structure to act as a buffer to control pH, a water binder to create dilution effects, and a flavor enhancer to increase pork type flavors.

If a marinade containing salt, water, phosphates, and sodium bicarbonate could successfully mask off flavors found in sow meat, then higher value whole muscle sow pork products could then be marketed. This technology could create a new avenue of marketing lower value sow meat and allow processors to market sow meat as a value added product with a larger return.

# CHAPTER 2

## Materials and Methods

### I. *Preliminary Study: Identifying sow loins with atypical aromas and flavors with electronic nose technology.*

Principal component analysis (PCA) using an Applied Sensor 3320 was utilized in preliminary research to determine if differentiation could be achieved between sow loin chops with atypical flavors and aromas (n=3) and chops with no atypical flavors and aromas (n=2). A chemical sensor system composed of a relatively limited number of gas sensors with overlapping sensitivity was used to span a large range of volatile compounds thus creating unique response patterns when exposed to different odors. The gas sensors used for this testing were FE102A for amines and esters, FE103A for aldehydes and alcohols, and FE105A, MO102, MO111, MO112 which are proprietary sensors.

Three grams in triplicates of each sample were run under the following conditions: idle 25°C, standby, 60°C for 5 min and incubation, and 60°C for 10 min. PCA was performed using the Applied Sensor 3320 equipped with Senstool Software (version 2.7.5.27). Results of this study showed that it was possible to differentiate between sow loin samples with atypical flavors and aromas from samples with no atypical flavors and aromas by detecting the chemical properties from vapor emitted by the samples.

Based on these results a second preliminary study was conducted to determine if various combinations of a solution containing sodium tripolyphosphate (STP) (0.3 and 0.5%; Brifisol 512; BK Giulini Corporation, Simi Valley, CA), sodium bicarbonate (BICARB) (0.25 and 0.5 M; J.T. Baker, Phillipsburg, NJ) and salt (1%) at 15% addition (wt/wt) would minimize the amount of volatile compounds emitted from tainted loin chops. Chops were analyzed as previously described. Results of this preliminary study indicated that loin chops treated with a 15% solution of STP (0.30%) and 1% salt (Coded sample 223) and loin chops treated with a 15% solution of BICARB (0.5M) and 1% salt were similar to non-tainted control loin chops (Coded sample 15). Based on these results the following parameters were established for the formulation of marinade solutions for further investigation as a $2^3$ central composite design: STP at 0.25 and 0.50%, BICARB at 0.35 and 0.7M concentration, and PUMP (injection level) at 5 and 15% with salt held at a constant of 1.0%.

## II. *Study I – Determination of percent sodium tripolyphosphate, sodium bicarbonate concentration, and injection level to minimize atypical aromas and flavors in sow loins.*

*Experimental Design and Data Analysis*

The experimental design was a $2^3$ central composite rotatable design (Cochran and Cox, 1957). Parameters for the variables were set as follows: sodium tripolyphosphate= 0–0.50% (wt/wt), sodium bicarbonate= 0.35-0.70 *M*, and injection level= 5-15%. Fifteen combination treatments of the three variables were generated from the central composite design with one treatment combination (the center point) replicated six times to derive error degrees of freedom to test for significance (Appendix 1). A second order response surface regression model was used for simultaneous analysis of two non-meat ingredient variables (sodium tripolyphosphate, sodium bicarbonate) and one processing variable (injection level).

For each factor assessed, the variance was separated into linear, quadratic, and cross product components to assess the adequacy of the second-order polynomial function and the relative significance of these components. The significance of the equation parameters for each response variable was assessed by F-test and the level of significance was determined at $P<0.10$.

For all other experiments in Study I, main effects were tested for significance using a mixed-effects model. The significant main effect means were separated using Satterthwaite approximation (Satterthwaite, 1946)

*Plant Procurement*

Boneless sow longissimus dorsi muscles (loins) were removed from hot-boned sow carcasses at Jimmy Dean Foods, Inc., Cordova, TN. These loins were removed approximately 45 minutes after exsanguination. The loins were almost completely defatted during early hot-boning stages. The loins were then conveyored to a skinning area to remove the remaining subcutaneous fat and then conveyored to a spiral freezer (0°C) (10 minute time period). Loins entering the spiral freezer had an average internal temperature of 37.2°C.

The loins remained in the spiral freezer (0°C) for 45 minutes where they were crust frozen to an average internal temperature of 6.3°C. After leaving the spiral freezer, loins were evaluated to determine if they had off flavors or not by trained research personnel. For this evaluation, a 0.64 cm slice was removed from the loin and microwaved and both smelled and tasted to determine if undesirable flavors were present. The loins were then individually wrapped in Saran™ over wrap, and packaged 4 loins per box. This process was completed within 60 minutes. The boxes were placed in a blast freezer (-17.8°C) and spaced so they would not be insulated by each other. The boxes were held in blast freezer for 36 h to reach an internal temperature of –17.8°C then shipped in insulated coolers packed with dry ice by overnight carrier to the Michigan State University meat laboratory.

*Product Procurement*

Sixteen loins with off flavors and 13 loins with no off flavors were sent to the MSU meat laboratory. Upon arrival (n=29), each loin was randomly numbered to identify off flavor loins and non-off flavor loins. The Saran™ over wrap was removed from each loin. A 0.64 cm slice was removed with a band saw from the posterior end of each frozen loin for off flavor / no off flavor verification. This was accomplished by microwaving each 0.64 cm slice for 30 s and smelling or tasting of the sample by a trained research and development personnel. Two additional 0.64 cm slices (10 g total) were removed with a band saw from posterior end of each frozen loin for rigor determination. Each loin was then weighed, vacuum packaged using 30.5 x 40.6 cm bags (Cryovac, Simpsonville, SC), placed on trays, and stored in -10°C freezer. Samples were stored in -20°C freezer.

*Ultimate pH Determination*

Upon arrival, samples (10 g) were removed from each loin and diced with a knife into fine pieces. One gram was weighed and placed into a 50 ml centrifuge plastic tube. Ten ml of distilled, deionized water was added to each centrifuge tube. Samples were homogenized with Polytron mixer (PT-35, Kinematica, AG, Switzerland) on speed setting 2 for 2, 10 s bursts. The pH of each sample was measured using Accumet pH meter (AB 15, Fisher Scientific, Co., Pittsburgh, PA) calibrated with phosphate buffers 4.0 and 7.0. After first pH measurement, samples were allowed to rest in –6.7°C cooler for 10 min. After the 10 min rest, the pH of samples was remeasured (Appendix 2). All samples were done in duplicates.

*R-Value Determination Test*

Ten gram frozen samples were diced with a knife into fine pieces. Two grams of sample placed in a 50 ml plastic centrifuge tube. Ten ml of 38-40°C 0.6 N Perchloric acid (Appendix 3) was added to a 50 ml plastic centrifuge tube containing meat sample. Samples were homogenized using a Polytron mixer (PT-35, Kinematica, AG, Switzerland) on speed setting 4 for 2 bursts of 30 s each while the sample was on ice. Samples were then transferred from 50 ml plastic centrifuge tube to 30 ml glass centrifuge tube. The samples were then centrifuged at 40,000 x *g* for 20 minutes in centrifuge (RC-5 superspeed refrigerated, Sorvall Co., Norwalk, CT). The tubes were removed from the centrifuge and placed in a bucket of ice for chilling. Each tube was mixed using a Vortex mixer (American Scientific Products, McGaw Park, IL) for 15 s to ensure proper mixture. Three aliquots (60 ul each) of supernatant were pipetted into 3 quartz cuvettes. Three ml of 0.1 M phosphate buffer (Appendix 3) was added to each of the 3 cuvettes containing the supernatant. The cuvettes were covered with parafilm and inverted 3 times to mix. Cuvettes were then read on spectrophotometer (Lambda 20, Perkin Elmer, Norwalk, CT) at $A_{250}$ and $A_{260}$ wavelengths.

*pH Determination*

Raw (n=29) and marinated treatment combination (n=15) pH were determined as described in appendix 4.

*Subjective / Objective Quality Analysis*

The loins were tempered in 2.6°C cooler for 18 h. Each loin was weighed for initial purge loss (Appendix 5). The loins were then separated into 2 equal (in length) sections by a cross cut at the midline of each loin. The anterior and posterior ends of each section from each loin were labeled. The following was removed from the anterior end of the posterior section of each loin: 1) a 0.64 cm slice (~20 g) for TBA analysis (Appendix 6); A 0.64 cm slice (~20 g) for proximate analysis (Appendix 7) 2) Two, 2.54 cm chops for subjective color, marbling, and firmness; objective color (Appendix 5); and drip loss analysis (appendix 8). A 10 minute bloom time was allowed for chops before analyzing for color, marbling, and firmness. Following the removal of the two chops, each loin section was weighed for 7 day purge loss (Appendix 9) analysis and vacuum packaged in

30.5 x 40.6 cm vacuum bags (Cryovac, Simpsonville, SC) using Mutlivac (AG800, SeppHaggenmuller KG, Germany) set at 3.0 vacuum, 4.5 bar heat.

*A. Color*

Two, 2.54 cm chops from the anterior end of the posterior section of each loin were used for color, marbling, firmness, and drip loss. Subjective color was analyzed by methods described in Pork Quality and Composition (Baas et al, 2000; Appendix 5).

Objective color was measured using a Minolta Chromameter CR-310 (Commission International D'Edairerage (CIE) L*a*b*, Ramsey, NJ). Three readings were taken and averaged, of each exposed surface of each sample for L* (lightness), a* (redness), and b* (yellowness) values.

*B. Marbling*

Subjective color was analyzed according to National Pork Producers Pork Quality Standards (Des Moines, IA) (Appendix 5).

*C. Firmness*

Subjective firmness was determined according to National Pork Producers Pork Quality Standards (Des Moines, IA) (Appendix 5).

*D. 48 Hour Drip Loss*

Each loin chop was labeled A (first chop removed from loin) and B (second chop removed from loin) and weighed. The chops were then suspended by string and hook method procedures modified from Baas et al. (2000) and Honikel (1987) for 48 h in 2.8°C cooler. Chops were reweighed after 48 h and percent drip loss was calculated (Appendix 8).

*TBA Analysis*

Thiobarbituric acid analysis was conducted on day 1 and day 33 for phase 1 of project to monitor oxidative rancidity. Day 33 was the day the trained sensory panel evaluated the corresponding samples. Four replicates were run for each sample according to methods established by Tarladgis et al. (1960) and Zipser et al. (1962) modified by Rhee (1978). (Appendix 6)

*Proximate Composition Analysis*

Proximate composition of samples was determined according to AOAC (2000) procedures found in Appendix 7.

*Marinade Uptake Analysis*

For this experiment, two, 2.54 cm chops previously used for 48 h drip loss analysis were utilized. This experiment was done in triplicates according to procedures from Baas et al. (2000) found in Appendix 10.

*Cook Yield Analysis*

The experiment was a continuation of the marinade uptake experiment and was done in triplicates according to procedures from Baas et al. (2000) found in Appendix 10.

*Marination Analysis*

A. *Loin Section Sorting*

Loin sections were sorted into 2 groups: 1) loins with off flavors (32 loin sections) and 2) loins with no off flavors (26 loin sections). The off flavor group was separated into 3 sub groups and organized by weight. Three weight groups were developed for 20 loin sections that were chosen. They were: light weight group of loin sections weighing 0.30 to 0.38 kg (n=8), medium weight group of loin sections weighing 0.38 to 0.46 kg (n=6), and heavy weight group of loin sections weighing 0.46 to 0.88 kg (n=6). Loin sections were grouped by size to minimize tumbling effects during marination.

*B. Marination*

Marinades were developed at MSU according to formulations developed using SAS response surface regression analysis (Version 8.2, SAS institute Inc., Cary, NC) as shown in Appendix 1. Treatments were randomly assigned to loin sections. Treatment marinades were manufactured according to procedures found in appendix 10. The marinades were added into 30.5 x 40.6 cm vacuum bags (Cryovac Co., Simpsonville, SC) that already contained the appropriate loin section. Each vacuum bag (n=20) containing loin section and marinade was vacuum packaged using a Multivac vacuum packager (AGW, SeppHaggenmuller KG, Germany) with 1.5 vacuum and 3.0 bar heat. The 20 loin sections were segregated into light (n=8), medium (n=6), & heavy (n=6) groups (n=3) so they would fit into the tumbler.

*C. Tumbling*

A Lyco vacuum tumbler (model 20, Columbus, WI) set at 70% with 20 psi. of vacuum was used. Each group of loin sections (light, medium, heavy) was tumbled using a 1 minute tumble and 1 minute rest cycle repeated 15 times. The total actual tumbling time was 15 minutes. Loin sections were then removed from tumbler and placed in –23.3°C freezer for 18 h.

*Loin Fabrication*

Marinated and non-marinated (controls) frozen loin sections were fabricated using an electric band saw into 2.54 cm chops for trained sensory evaluation. Twenty loin sections with treatments (1-15), twelve non treated loin sections with off flavors, and 12 loin sections with no off flavors were removed from –23.3°C freezer. Beginning from the anterior end of the posterior section or posterior end of the anterior section, a 1.27 cm slice (~30 g) was removed for TBA analysis and marinated proximate composition. (Appendices 6 & 7). Chops (2.54 cm) were then removed following the location procedures as described previously from the remainder of the loin sections. Chops (2.54 cm) were packaged 2 per and 3 per bag to attain at least 25.4 $cm^2$ of chop cut surface per bag as the loin eye size of a majority of the loin sections was smaller that 12.7 $cm^2$. Chops were packed using 10.2 x 30.5 cm vacuum package bags (Cryovac Co., Simpsonvile, SC) and vacuum packaged using Multivac vacuum packager (AG800, SeppHaggenmuller KG, Germany) set at 2.5 vacuum and 7.0 bar heat with the seal of the bag at least 5 cm from the open end of the bag. After vacuum packaging, a label (Treatment 1-20) was inserted in the remaining open ended portion of each bag and an impulse heat sealer (Diagger, Lincolinshire, IL) was used to enclose tag.

*Trained Sensory Panel*

A descriptive attribute panel at Texas A&M University was utilized for phase I of this research project. The panel was trained according to AMSA (1995) and Meilgard et al. (1991). Each treated pork loin chop was evaluated using Spectrum Universal scale where 0=absence and 15=extremely intense flavor and aromatic/smell. Texture was evaluated using 8 point universal scale where 1=extremely dry and 8=extremely juicy for juiciness, 1=extremely tough and 8=extremely tender for muscle fiber tenderness/overall tenderness and 1=abundant and 8=none for connective tissue. (Appendix 11) Pork loin sections were removed from the freezer (-17.8°C) and tempered for 18 h in a 4°C cooler. Pork loin chops were cooked on a Farberware Open-Hearth Electric Broiler to an internal temperature of 35°C, turned, and brought to an internal temperature of 70°C (USDA guidelines). Cooking was monitored by a type T stainless steel thermocouple placed in the geometric center of each pork loin chop and plugged into a Omega HH21 microprocessor thermometer (Omega Engineering Inc., Samford, CT). Records of cook yield and time of treatment group of chops were determined (Appendix 12). Sample preparation included cutting 1-cm cubes from the center portion of each pork loin chop. To minimize positional bias and halo effects, the order of sample preparation was randomized within each session (Meilgaard et al., 1991).

Testing took place in climate controlled, partitioned booths. Three cubes were placed in a glass custard dish covered with a watch glass and stored in an Alto Shaam oven set at 48.9°C until serving. Each sample was served to panelists through breadbox style domes that separate the food preparation area from the sensory testing area. Cool incandescent lights with red filters were used to disguise visual differences between samples. Panelists were instructed to shake watch glass covered custard dish 3 times, lift the watch glass and sniff, close container, and evaluate for presence of aromatics. Panelists then removed the watch glass, handled sample cubes with an approved odorless plastic spoon, and tasted for aromatic, taste, aftertaste, and texture evaluation. Expectorant cups were provided to prevent taste fatigue as the panelists were instructed not to swallow the samples. Distilled deionized water, unsalted soda crackers, and whole ricotta cheese was used to clean the palate between samples. Twelve (10 treatments, 1 control with taint, 1 control without taint) samples were evaluated on each day for 2 days. Each day was divided into two sessions with 6 samples in the first and 5 samples in the second session. The panelists were standardized each day by evaluating 2 warm-up samples and discussing the results. The first warm-up sample was a sow loin control with no off flavors and the second was a sow loin control with off flavors. There was around 5 minutes between each sample and a 15 minute break between sessions. The serving order of the treatments was randomized by treatment on each sensory day (Appendix 12).

## ***III. Study II - Determination of consumer acceptability of marinated loin chops with atypical flavor and aromas marinated with tripolyphosphate, and sodium bicarbonate.***

*Experimental Design and Data Analysis*

For the analysis of consumer sensory panel data, a randomized complete block design with a mixed-effects model (SAS, 2001) was used. The model included the random effects of replication (1-3), the fixed main effects of treatment (Control, TRT 1-4) where TRT1: 0.70*M* BICARB, 0.50% STP, 15% PUMP; TRT2: 0.70*M* BICARB, 0.25% STP, 15% PUMP; TRT3: 0.35*M* BICARB, 0.50% STP, 15% PUMP; TRT4: 0.30*M* BICARB, 0.25% STP, 15% PUMP; Control: 0.25% STP, 15% PUMP, and the random interaction of replication x treatment, and panelist nested in replication. Treatment means were separated using Tukey multiple pairwise comparison method (1977) and a Type I error rate of 5%.

For all other experiments in Study II, main effects were tested for significance using a mixed-effects model (SAS, 2001). The significant main effect means were separated using Tukey multiple pairwise comparision method (1977). Significance level was determined at $P<0.05$.

*Plant Procurement*

Loin selection, handling, and shipping were conducted as previously described in Study I.

*Product Procurement*

Thirty-four pre-rigor sow loins with off flavors and 6 commodity loins with no off flavors (to use as controls) were sent to the MSU meat laboratory. Upon arrival, a 0.64 cm slice was removed from each loin (n=40) with a knife from the posterior end of each frozen loin for off flavor / no off flavor verification. This was accomplished by microwaving each 0.64 cm slice for 30 s and smelling or tasting sample by a trained research and development personnel. Two additional 0.64 cm slices (10 g total) were removed with a band saw from posterior end of each frozen loin for rigor determination. Each loin was then weighed, vacuum packaged using 25.4 x 76.2 cm bags (Cryovac, Simpsonville, SC), placed on trays, and stored in -10°C freezer. Samples were stored in -20°C freezer.

*Ultimate pH Determination*

Study I showed that all sow loins were through rigor. For Study II, Loins (n=10) were randomly selected from the total (n=34) for rigor determination and verification was accomplished by methods previously described in Study I.

*pH Determination*

Raw (n=34) and marinated treatment combination (n=5) pH's were determined as described in appendix 4.

*Subjective / Objective Quality Analysis*

Twenty-four h purge, 7 day purge, and 48 h drip loss analysis were only conducted on the sow loins with off flavors (n=34) by methods previously described in Study I since the commodity pork loin selection and handling process was different from the sow loins. Color, marbling, and firmness was determined on all loins (n=40) by methods previously described in Study I.

*TBA Analysis*

Study I showed that all sow loins had no lipid oxidation. For Study II, loins (n=17) were randomly selected from the total (n=34) for lipid oxidation determination and verification was accomplished by methods previously described in Study I.

*Proximate Composition Analysis*

Proximate composition of samples was determined according to AOAC (1995) procedures found in Appendix 7.

*Marinade Uptake Analysis*

For this experiment, two 2.54 cm chops previously used for 48 h drip loss / subjective / objective quality analysis were utilized. This experiment was done in triplicate according to procedures from Baas et al. (2000) found in appendix 10.

*Cook Yield Analysis*

The experiment was a continuation of the marinade uptake experiment and was done in triplicate according to procedures from Baas et al. (2000) found in appendix 10.

*Marination Analysis*

A. *Loin Section Sorting*

Sow loin sections with off flavors (n=68) and commodity control loin sections with no off flavors (n=12) for a total of 80 sections were separated into 40 anterior and 40 posterior section groups. Two anterior and 2 posterior sections were randomly selected for each treatment (Appendix 13) for each replication (n=3) to form loin section groups. Forty-eight sow loin sections with off flavors, and 12 commodity control loin sections with no off flavors were used for the entire experiment.

*B. Marination*

Optimization for sodium bicarbonate, tripolyphosphate and injection level was determined by analysis of response surface curves generated by SAS PROC REG and PROC GPLOT from Study I (Version 8.2, SAS institute Inc., Cary, NC). Treatment marinades (n=4) and a control (Appendix 14) were developed from this evaluation. The control marinade was developed to mimic current industry usage.

This experiment was replicated 3 times. Treatment marinades were manufactured according to the procedures found in Appendix 14. Treatment marinades were randomly assigned to loin section groups with the exception of the control loin section group. Each group of loin sections (n=4, + 1 control) was injected by one pass through a Reiser Fomaco automatic injector (model FGM 20/40, Denmark) with conveyor/needle speed set at 12 and pump pressure set at 25-29 psi. The injector was cleaned between each treatment injection. Actual loin section group injection level was calculated for all loin groups.

*C. Tumbling*

A Roschermatic vacuum tumbler (model MM-0, D-4500, Osnarbruck/ W-Germany) with 25 psi. of vacuum was used. Each group of loin sections (T1-T4 + C) was tumbled using a 1 min tumble and 1 min rest cycle repeated 5 times to aid in distributing the marinade. The total actual tumbling time was 5 min. Loin sections (n=4) were then removed from tumbler, vacuum packaged individually using 30.5 x 40.6 cm bags (Cryovac, Simpsonville, SC) in a Multivac vacuum packager (AG800, SeppHaggenmuller KG, Germany) set at 2.5 vacuum and 7.0 bar heat. Loin section were then placed in –23.3°C freezer for 18-20 h.

*Loin Fabrication*

Frozen treatment marinated loin sections (T1-T4 + C) were fabricated using an electric band saw into 2.54 cm chops for consumer sensory evaluation. Beginning from the anterior end of the posterior section or posterior end of the anterior section, 2.54 cm chops were removed and packaged 2 per bag using 10.2 x 30.5 cm vacuum package bags (Cryovac Co., Simpsonvile, SC) and a Multivac vacuum packager (AG800, SeppHaggenmuller KG, Germany) set at 2.5 vacuum and 7.0 bar heat. End pieces from each loin section within each treatment were combined to create composite samples (100-150 g) for marinated proximate composition and TBA analysis (Appendix 6 & 7).

*Shear Force Determination*

Two 2.54 cm marinated chops from each treatment (n=5) and each replication (n=3) were allowed to thaw for 24 h at 4°C. Chops were cooked according to procedures found in the consumer panel section. Chops were allowed to cool to room temperature and then were chilled at 4°C overnight. Three, 1.27 cm cores were taken parallel to the longitudinal axis of the fibers using a drill press-mounted corer. Cores were sheared perpendicular to the fibers using a Warner

Bratzler head on a TA-Hdi Texture Analyzer (Texture Technologies Corp., Scotsdale, NY). The crosshead speed was set at 3.30 mm/s.

*Consumer Sensory Panel*

AMSA guidelines (AMSA, 1995) were followed for sample preparation and presentation to consumer sensory panelists at Michigan State University (East Lansing, MI) on three consecutive days one week after production. Frozen marinated chops from 5 treatments were thawed for 24 h at 2.6°C. One chop from each treatment was cooked per batch on a Taylor clamshell grill (model QS24 Taylor Co; Rockton, IL). The upper plate was set to 104.4°C and the bottom plate was set to 102.8°C with a 2.16 cm gap between plates. Five marinated chops were cooked simultaneously and copper constantan thermocouples (0.051 cm diameter, 15.2 cm length; Omega Engineering Inc,; Stamford, CT) were inserted into two chops per batch to monitor temperature increase during cooking. Final cook temperature of all chops was determined with small diameter hypodermic probe thermocouples (0.089 cm diameter, 5.72 cm length; Cole-Parmer; Vernon Hills, IL). Chops were cooked to a final internal temperature of 71°C $\pm$ 1.5°C. Chops were then placed in Pyrex® two quart bowls (n=5). The bowls were placed in an insulated cooler containing a previously dampened and heated blanket placed at the bottom. The cooler apparatus was transported to an adjacent building by way of underground tunnel to the sensory kitchen. Upon arrival, treatment chops were immediately removed from glass bowls and placed in Pyrex® double broilers with water maintained at 140°C for sample holding. Sample preparation included cutting 1.27 x 1.27 x

2.54 cm samples from the center portion of each pork loin chop. To minimize positional bias, the order of sample presentation was randomized with in each session (Meilgaard, 1991).

The consumer panel evaluations were conducted as two-hour sessions between 10 a.m. and noon on three consecutive days, collecting data from 45 to 47 panelists each day. Expectorant cups were provided to prevent taste fatigue. Distilled, deionized water and unsalted soda crackers were provided to clean the palate between samples. Panelists were asked to determine desirability of juiciness, texture, flavor, and overall acceptability of the pork chops. An 8 point hedonic scale was used where 1=extremely undesirable and 8=extremely desirable.

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# CHAPTER 3

# STRATEGIES TO ELIMINATE ATYPICAL AROMAS AND FLAVORS IN SOW LOINS

## ABSTRACT

Sow loin sections (n=20) with atypical aromas and flavors we termed "sow taint" were treated with a solution of sodium tripolyphosphate (0.25-0.50%) and sodium bicarbonate (0.35-0.70M) and evaluated for flavor and textural attributes by a trained sensory panel. Response surface methodology determined four treatment combinations showing optimizing effects that reduced ($P<0.05$) metallic aroma, metal and sour aftertastes, and detectable connective tissue while improving ($P<0.05$) muscle fiber tenderness, juiciness, and overall tenderness. Consumer sensory panel ratings determined that sow loin chops injected with a 15% solution of sodium tripolyphosphate (0.50%) and sodium bicarbonate (0.35M) were not different ($P>0.05$) than loin chops from a marinated (0.25% sodium tripolyphosphate, 15% injection level) commodity control loin for flavor, texture, juiciness, and overall acceptability. A solution containing sodium tripolyphosphate and sodium bicarbonate minimized atypical aromas and flavors in selected sow loins and may enhance their utilization for value added whole muscle products.

Keywords: Marination, Sow Loins, Sensory Evaluation

## Introduction

Sow meat is primarily utilized in comminuted products such as prerigor fresh pork sausage. Prerigor meat possesses a higher water holding capacity resulting in higher yields and a more uniform darker color than cold boned meat that has been chilled and gone through rigor (Van Laack et al., 1989). Industry feedback (Prochaska and associates, 2001) indicated occurrences of undesirable aromas and flavors found in whole muscle products (i.e., loin) that have been "hot-boned" or removed from prerigor sow carcasses. These atypical aromas and flavors, which we have termed "sow taint", combined with tenderness challenges due to a greater percentage of cross linked insoluble collagen (Hedrick et al., 1989), darker muscle color due to increased myglobin concentration, and inconsistent muscle size hinders the use of sow meat for whole muscle meat products. Acceptable tenderness in whole muscle products can be achieved by use of mechanical (Cordray et al., 1985; Motycka and Bechtel, 1983), enzymatic tenderization (Romans et al., 1994), or cooking methods (Simmons et al., 1985; Pearson and Gillett, 1996; Harmon et al., 1989).

The sow taint we have identified in meat fabricated from prerigor sow carcasses possesses a combination of metallic aromas and metallic and sour aftertastes consumers may find undesirable. Marination, which utilizes injection and/or tumbling to disperse a solution of water, salt and other non-meat ingredients has been used by the meat industry to change a products flavor profile and enhance its textural attributes. The potential exists to utilize marination to combat the problem of undesirable aromas and flavors that have been reported to occur in a percentage of prerigor sow carcasses. Research by Kauffman et al. (1998) indicated an improvement in flavor by injecting a solution of sodium bicarbonate and salt in hot-boned loins from gilts. Several studies have shown the potential of sodium tripolyphosphates to decrease or mask off flavors in pork (Boles and Parrish, 1990; Sutton et al., 1997; and Matlock et al., 1984).

The synergistic effect of sodium tripolyphosphate, sodium bicarbonate, and salt may be an effective intervention strategy to reduce or eliminate atypical aromas and flavors (sow taint) that may occur in hot-boned sow meat. Phosphates increase water holding capacity as well as provide flavor enhancement (Barbut et al., 1988, Matlock et al., 1984, Keeton et al., 1984). Sodium bicarbonate increases buffering capacity during cooking when flavor volatiles are formed (Mottram, 1998) while salt increases the intensity of flavors (Matlock et al., 1984, Barbut et al., 1988). Our hypothesis was marinating sow meat that exhibited atypical aromas and flavors with a solution of sodium tripolyphosphate, sodium bicarbonate and salt will minimize or mask the presence of sow taint.

The first objective of this study was to use a trained sensory panel to identify optimum concentrations of sodium tripolyphosphate, sodium bicarbonate and percent injection level that may minimize the impact of atypical aromas and flavors in hot-boned sow loins. The second objective was to determine the consumer acceptability of these undesirable sow loins when marinated with a solution of sodium tripolyphosphate and sodium bicarbonate.

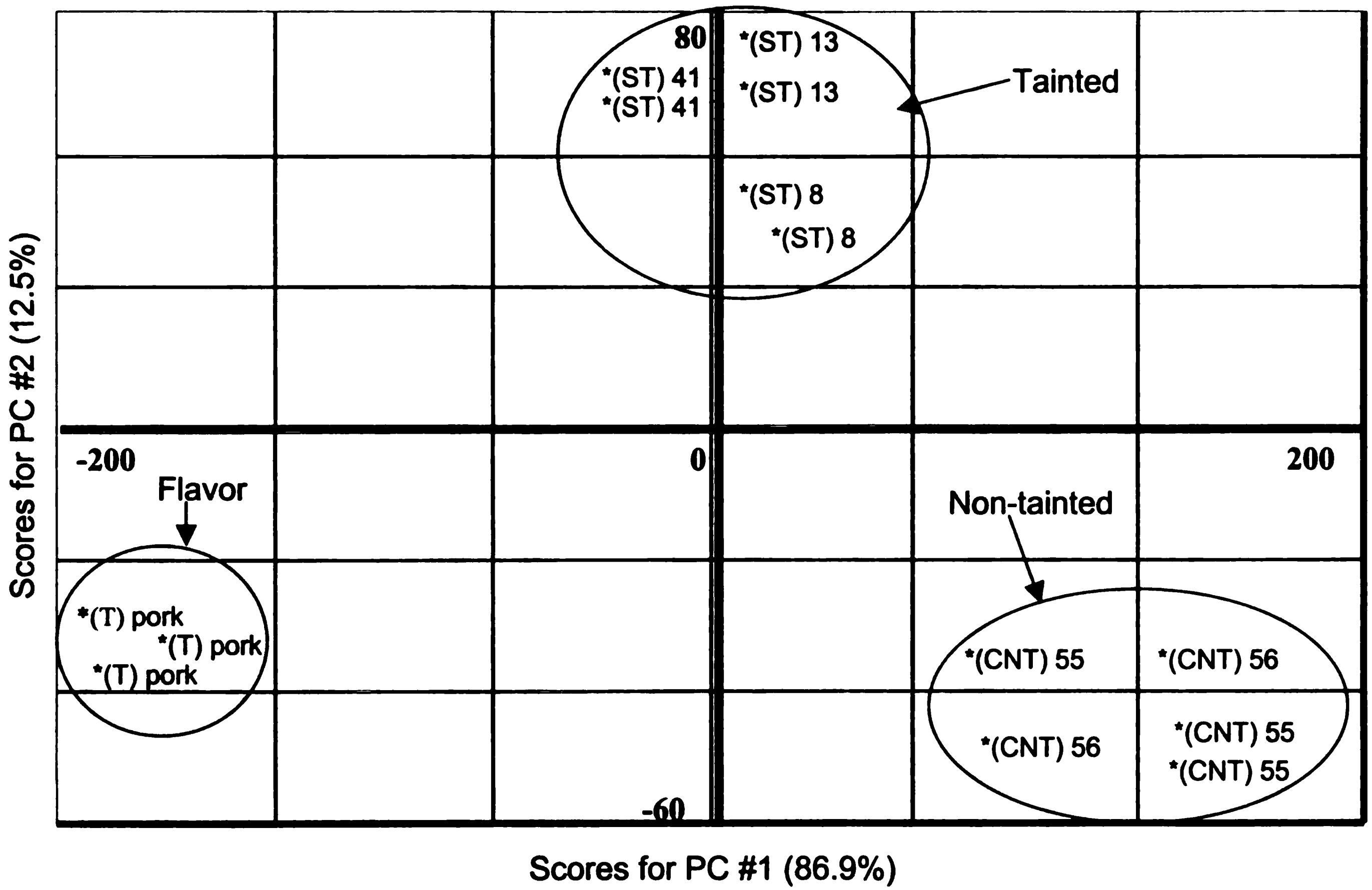
## Materials and Methods

### *Preliminary Study: Identifying sow loins with atypical aromas and flavors with electronic nose technology*

The range of levels and concentrations of sodium tripolyphosphate (STP) and sodium bicarbonate (BICARB) and percent injection levels (PUMP) that minimize the presence of atypical aromas and flavors of sow loins was determined by electronic nose technology. An Applied Sensor 3320 (Parsippany, New Jersey) was utilized to determine if tainted sow loin samples (n=3, ST) could be differentiated from non-tainted samples (n=2, NT). A chemical sensor system composed of a relatively limited number of gas sensors with overlapping sensitivity was used to span a large range of volatile compounds thus creating unique response patterns when exposed to different odors. The primary gas sensors used for this testing were FE102A for amines and esters, FE103A for aldehydes and alcohols.

Triplicate samples (3 g) were run with the following test conditions: idle 25°C, 60°C for 5 min and incubation, and 60°C for 10 min. Principal component analysis was performed using the Applied Sensor 3320 Senstool Software (Version 2.7.5.27). Results of this study (Figure 1) showed that it was possible to differentiate between tainted and non-tainted sow loin samples by detecting the chemical properties from the volatiles emitted by the samples.

**FIGURE 1: Principal component analysis (PCA) plot for sow loin samples with atypical aromas and flavors, samples with no atypical aromas and flavors, and commodity pork samples.**




Tainted (*) = Sow loin samples with atypical aromas and flavors.
Nontainted (x) = Sow loin samples with no atypical aromas and flavors.
Flavor (+) = Commodity pork loin samples used for flavor baseline.
Pork, 8, 13, 41, 55, & 56 = Sample identification codes.
*This figure is courtesy of Applied Sensor, New Jersey.

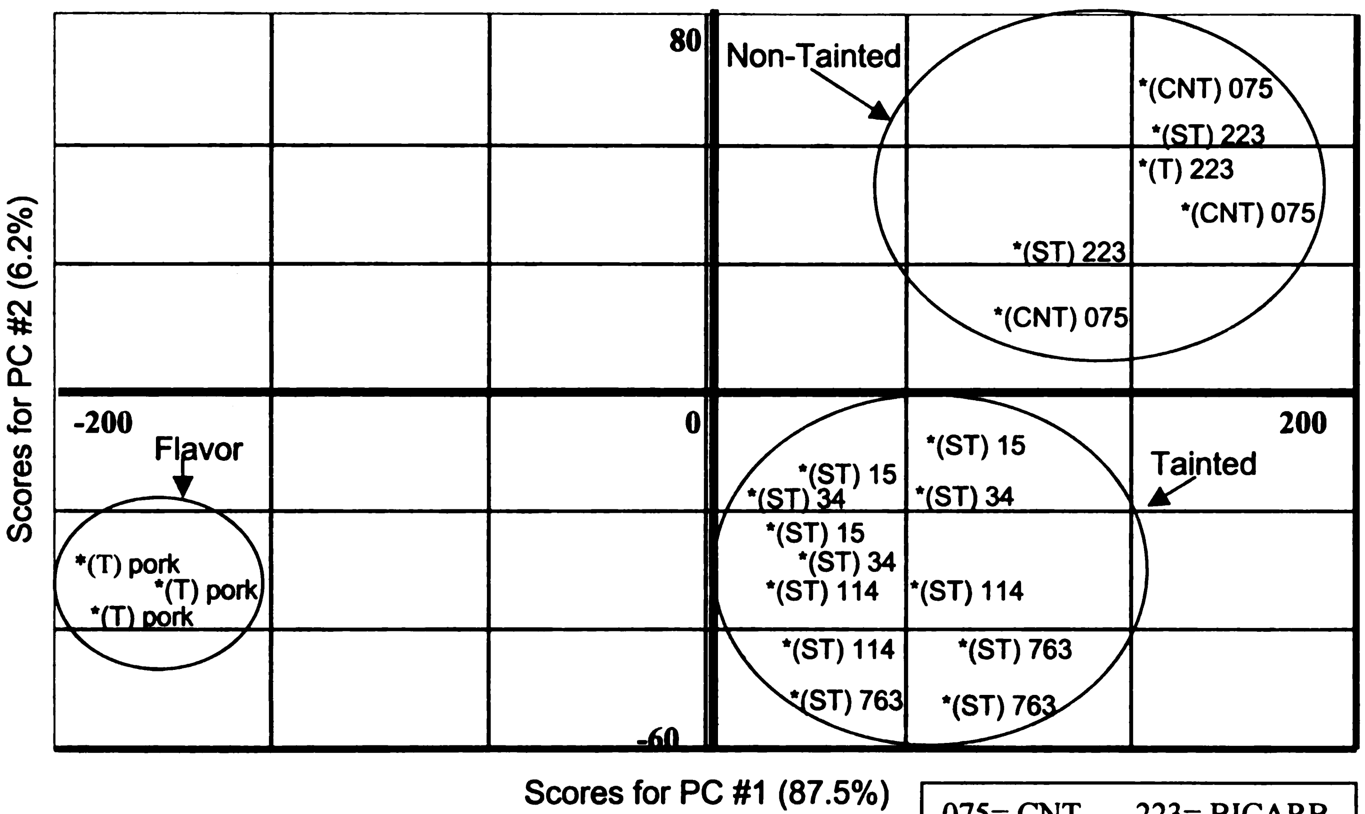
Based on these results a second preliminary study was conducted to determine if various combinations of a solution containing STP (0.3 and 0.5%; Brifisol 512; BK Giulini Corporation, Simi Valley, CA), BICARB (0.25 and 0.5 M; J.T. Baker, Phillipsburg, NJ) and salt (1%) at 15% addition (wt/wt) would minimize the amount of volatile compounds emitted from tainted loin chops. Samples were analyzed as previously described. Results of this preliminary study (Figure 2) indicated that loin chops treated with a 15% solution of STP (0.30%) and 1% salt (Coded sample 223) and loin chops treated with a 15% solution of BICARB (0.5M) and 1% salt were similar to non-tainted control loin chops (Coded sample 15). Based on these results the following parameters were established for the formulation of marinade solutions for further investigation as a $2^3$ central composite design: STP at 0.25 and 0.50%, BICARB at 0.35 and 0.7M concentration, salt at 1% and PUMP at 5 and 15%.

***Study I – Determination of percent sodium tripolyphosphate, sodium bicarbonate concentration, and injection level to minimize atypical aromas and flavors in sow loins.***

*Experimental Design and Data Analysis*

Response surface regression using SAS PROC RSREG (Version 8.2, SAS Institute Inc., Cary, NC) was used for simultaneous analysis of percent STP, concentration of BICARB and percent PUMP. The effects of these variables on the sensory and textural attributes of marinated sow loin chops were investigated. The experiment was

**FIGURE 2: Principal component analysis (PCA) plot for sow loin samples with atypical aromas and flavors, samples with no atypical aromas and flavors, and commodity pork samples treated with solutions containing STP[a] and BICARB[b] at 15% injection level.**




| | |
|---|---|
| 075= CNT | 223= BICARB |
| 114= STP | 34= BICARB |
| 15= STP | 763= ST |

[a] STP = Sodium tripolyphosphate.
[b] BICARB = Sodium bicarbonate.
Group 1(Flavor) = Commodity pork loin samples used for flavor baseline.
Group 2 (Non-tainted, CNT)= Sow loin samples with no detected atypical aromas and flavors.
Group 3 (Tainted, ST) = Sow loin samples with detected atypical aromas and flavors.
*This figure is courtesy of Applied Sensor, New Jersey.

based on a $2^3$ central composite rotatable design (Cochran and Cox, 1957). Based on preliminary research results, the ranges for the variables were: STP 0.30–0.50%, BICARB 0.35-0.70*M*, and PUMP 5-15%. Fifteen combinations of the three variables were generated from the central composite design with one treatment combination (the center point) replicated six times to assess lack-of-fit and ensure concentric variance (Table 1).

Total response surface regression equations were determined significant at P<0.10. The General Linear Models procedure (Version 8.2, SAS Institute Inc., Cary, NC, 2001).) was used to determine the significance of the equation parameters for each response variable by F-test and the level of significance at P<0.10. Regression equations containing these significant parameter estimates were used to generate response surface curves using PROC G3D (SAS, 2001).

*Plant Procurement*

Sow loins were harvested by hot-boning sow carcasses approximately 45 min after exsanguination during one eight h shift at a commercial sow slaughter plant. The loins were denuded of all subcutaneous fat during the hot-boning process. Sow loins (N=16) were determined to have atypical aromas and flavor (sow taint, ST) by microwave cooking for 30 sec and then performing aroma and taste evaluations. Normal, non-tainted control sow loins (N=13, CNT) and ST loins were crust frozen and chilled (average internal temperature of 6.3°C). The loins were wrapped in Saran™, boxed and frozen (–17.8°C). The boxes were placed in insulated styrofoam coolers, packed with dry ice and shipped by overnight priority mail to the Michigan State University Meat Laboratory.

**TABLE 1. Treatment formulations containing sodium tripolyphosphate (STP) and sodium bicarbonate (BICARB) for marinating sow loins at varying injection levels (PUMP).**

| | TARGETED INGOING LEVELS | | | |
|---|---|---|---|---|
| | STP | BICARB | PUMP | Marinade pH[g] |
| TRT[a] | % | M[i] | % | |
| 1 | 0.30 | 0.42 | 7 | 7.05 |
| 2 | 0.30 | 0.63 | 7 | 7.12 |
| 3 | 0.45 | 0.42 | 7 | 6.88 |
| 4 | 0.45 | 0.63 | 7 | 7.05 |
| 5 | 0.30 | 0.42 | 13 | 7.46 |
| 6 | 0.45 | 0.63 | 13 | 7.48 |
| 7 | 0.45 | 0.42 | 13 | 7.36 |
| 8 | 0.45 | 0.63 | 13 | 7.15 |
| 9 | 0.38 | 0.53 | 5 | 6.82 |
| 10 | 0.38 | 0.53 | 15 | 7.55 |
| 11 | 0.25 | 0.53 | 10 | 7.33 |
| 12 | 0.50 | 0.53 | 10 | 7.17 |
| 13 | 0.38 | 0.35 | 10 | 7.15 |
| 14 | 0.38 | 0.70 | 10 | 7.26 |
| 15[e] | 0.35 | 0.53 | 10 | 7.12 |

[a] Treatment combinations.
[g] BRINE pH = pH of marinade solution.
[i] M = Molar concentration.
[e] 15 = Replicated an additional five times to assess lack-of-fit and ensure concentric variance (TRT 16-20).

*Sample Preparation*

Upon arrival, two 0.64 cm slices were removed from the posterior end of each frozen ST and CNT loin for rigor determination. Each loin was individually weighed, vacuum packaged (Multivac AG800, SeppHaggenmuller KG, Germany) set at 3.0 psi vacuum and 4.5 bar heat using 30.5 x 40.6 cm bags (Cryovac, Simpsonville, SC) and tempered in a 2.6° cooler for 24 h. After tempering, each loin was individually weighed to determine initial purge loss. Loins were separated into 2 sections by a perpendicular cut across the length of each loin. The following samples were removed from the anterior end of the posterior section of each loin: one 0.64 cm slice for 2-thiobarbituric acid (TBA) analysis; one 0.64 cm slice for raw proximate composition and pH; two, 2.54 cm chops for subjective color, marbling, and firmness, objective color, drip loss analysis, marination uptake, and cook yields.

*Rigor Determination (pH)*

One gram of frozen sample was placed into a 50 ml centrifuge plastic tube with ten ml of distilled, deionized water. The samples were homogenized with a Polytron mixer (PT-35, Kinematica, AG, Switzerland). The initial pH was measured with an Accumet pH meter (AB 15, Fisher Scientific, Co., Pittsburgh, PA; calibrated with phosphate buffers 4.0 and 7.0). The samples were placed in a –6.7°C cooler for 10 min and then pH was remeasured. Differences between initial and 10 min pH readings were analyzed to determine state of rigor for each loin.

*Rigor Determination (R-Value)*

Two grams of frozen sample were placed in a 50 ml plastic centrifuge tube with 10 ml of 38-40°C 0.6 N perchloric acid, homogenized with a Polytron mixer, transferred to a 30 ml glass centrifuge tube, and centrifuged at 40,000 x *g* for 20 min (RC-5 Superspeed Refrigerated, Sorvall Co., Norwalk, CT). Each tube was vortexed (American Scientific Products, McGaw Park, IL) for 15 s. Three aliquots (60 μl each) of supernatant were pipetted into quartz cuvettes. Three ml of 0.1 *M* phosphate buffer was added and the cuvettes read on a spectrophotometer (Lambda 20, Perkin Elmer, Norwalk, CT) at $A_{250}$ nm wavelength. Loins were determined to have completed rigor mortis if R-value readings showed that nucleotide and derivative concentrations were less than 1.5 μMol/g of meat (Honikel and Fischer, 1977).

*pH Determination*

Tempered ST and CNT sow loin (n=29) pH was determined by homogenizing 1 g of sample with 10 ml of a 5mM sodium iodoacetate and 150mM potassium chloride buffer using a Polytron mixer. The pH was measured using an Accumet pH meter.

*Subjective / Objective Quality Analysis*

Sow loins were analyzed for 24 h purge loss by measuring the initial frozen loin weight, the tempered (24 h) loin weight and dividing that difference by the frozen weight. Day 7 purge was determined by weighing tempered loin sections, then reweighing the loin sections after 7 days of vacuum (3.0 psi) packaged (30.5 x 40.6cm bags) refrigerated storage (2.8°C). the difference between the two weights were divided by the initial weight and multiplied by 100. Two 2.54 cm chops were weighed and suspended by the string and hook method (Baas et al., 2000 and Honikel, 1987) in a 2.8°C cooler for 48 h drip loss determination.

A 10 min bloom time was allowed prior to determining objective color and subjective color, marbling, and firmness. Subjective color, marbling, and firmness was visually determined by observing the exposed cut lean surface of each chop and evaluating each attribute where 1 = very light and 6 = very dark, 1= low amount and 10 = high amount, and 1 = soft and 3 = very firm, respectively (Baas et al, 2000). Objective color was measured using a Minolta Chromameter CR-310 equipped with a $D_{65}$ Illuminant, a 2° standard observer and 50 mm diameter orifice (Commission International D'Edairerage (CIE) L*a*b*, Ramsey, NJ). An average of three readings were taken from the exposed surface of each chop for L* (lightness), a* (redness), and b* (yellowness) values based on a 0-100 scale.

*TBA Analysis*

Thiobarbituric acid analysis was conducted on day 1 to determine baseline oxidative rancidity. Two replicates were run for each sample (n= 29) according to methods established by Tarladgis et al. (1960) and Zipser et al. (1962) modified by Rhee (1978).

*Proximate Composition Analysis*

Moisture (oven drying), fat (Soxhlet ether extraction), and protein (nitrogen measurement, Model FP-2000, LECO Co., St. Joseph, MO) were determined according to AOAC (2000) methods.

*Marinade Uptake / Cook Yield Analysis*

Six gram samples of ground ST and CNT loin section were placed in a 50 ml centrifuge tube with 10 ml of a 0.6M salt solution. Samples were vortexed, incubated at 25°C for 25 min, and centrifuged at 800 x *g* for 20 min. The solute from each sample was drained for 5 min to determine marinade uptake. These samples were then analyzed to determine cook yields by incubating the samples in a water bath set at 80°C for 20 min. The samples were removed from the water bath and the released fluids allowed to drain for 5 min. Cook yield was determined by calculating the difference between the initial and cooked weight, dividing that difference by the initial weight and multiplying by 100 (Baas et al., 2000).

*Marination*

Marinades were formulated (Table 1) using a response surface design (Version 8.2, SAS Institute Inc., Cary, NC) and were randomly assigned to loin sections (n=20) randomly selected from previously fabricated ST loins (N=16). Treatment marinades were manufactured by adding the appropriate amount of water to 300 ml plastic bottle. STP (Brifisol 512; BK Giulini Corporation, Simi Valley, CA), BICARB (J.T. Baker, Phillipsburg, NJ), and NaCl were then added in the above order and thoroughly mixed at 2250 rpm with a 7.62 cm roto mixer bit attached to a drill (SKIL, S-B Power Tool Co., Chicago, IL) for 2 min 30 s, 2 min, and 2 min respectively. Timing did not begin until the entire ingredient was added.

Randomly selected loin sections were placed into 30.5 x 40.6 cm vacuum bags and the appropriate marinade treatment added. Each loin section with added marinade was vacuum packaged with 1.5 psi. vacuum and 3.0 bar heat. The loin sections were segregated into light (n=8; 0.30-0.38 kg), medium (n=6; 0.40-0.46 kg), and heavy (n=6; 0.47-0.89 kg) groups (n=3) to facilitate uniform dispersion of the marinades.

A Lyco vacuum tumbler (Model 20, Columbus, WI) set at 24 rpm with 20 psi. of vacuum was used. Each loin sections weight group was tumbled using a 1 min tumble and 1 min rest cycle repeated 15 times. The total tumbling time was 15 min. Loin sections were then removed from tumbler, vacuum packaged and placed in –23.3°C freezer for 18 h.

*Marinated Loin Fabrication*

Marinated ST and CNT (0.25% STP, 1.0% NaCl) frozen loin sections were fabricated using an electric band saw into 2.54 cm chops for trained sensory evaluation. Beginning from either the anterior end of the posterior loin section or the posterior end of the anterior loin section, a 1.27 cm slice was removed for TBA analysis to be conducted during sensory evaluation. A 0.64 cm frozen sample was removed to determine marinated proximate composition (AOAC, 1995). Loin chops (2.54 cm) were fabricated from the remainder of the loin sections. Loin chops were vacuum packaged (10.2 x 30.5 cm bags, 2.5 psi vacuum, 7.0 bar heat) to provide a minimum of 25.4 $cm^2$ of loin chop surface area per bag due to variations in loin eye size. Samples were placed in insulated coolers, packed in dry ice and shipped by overnight priority mail to the Texas A&M University Sensory Evaluation Laboratory. Upon arrival, loin chops were stored in a freezer (-17.8°C) until utilized for sensory evaluation.

*Trained Sensory Panel*

Pork chops were removed from freezer (-17.8°C) and tempered for 18 h in a 4°C cooler. Pork loin chops were cooked on a Farberware Open-Hearth Electric Broiler to an internal temperature of 35°C, turned, and brought to an internal temperature of 70°C (USDA guidelines). Cooking was monitored by a type T stainless steel thermocouple placed in the geometric center of each pork loin chop and plugged into a Omega HH21 microprocessor thermometer (Omega Engineering Inc., Samford, CT). Sample preparation included cutting 1-cm cubes from the center portion of each ST and CNT loin chop. To minimize positional bias and halo effects, the order of sample preparation was randomized within each session (Meilgaard et al., 1991).

A descriptive attribute panel at Texas A&M University was trained according to AMSA (1995) and Meilgard et al. (1991). To evaluate each treated pork chop using Spectrum Universal scale where 0=absence and 15=extremely intense flavor and aromatic/smell. Texture was evaluated using an 8 point universal scale where 1=extremely dry and 8=extremely juicy for juiciness, 1=extremely tough and 8=extremely tender for muscle fiber tenderness/overall tenderness and 1=abundant and 8=none for connective tissue. Testing took place in climate controlled, partitioned booths. Three cubes were placed in a glass custard dish covered with a watch glass and stored in an Alto Shaam oven set at 48.9°C until serving. Each sample was served to panelists through breadbox style domes that separate the food preparation area from the sensory testing area. Cool incandescent lights with red filters were used to disguise visual differences between samples. Panelists were instructed to shake watch glass covered custard dish 3 times, lift the watch glass and sniff, close container, and evaluate for presence of aromatics. Panelists then removed the watch glass, handled sample cubes with an approved odorless plastic spoon, and tasted for aromatic, taste, aftertaste, and texture evaluation. Expectorant cups were provided to prevent taste fatigue as the panelists were instructed not to swallow the samples. Distilled deionized water, unsalted soda crackers, and whole ricotta cheese was used to clean the palate between samples. Twelve (10 ST chops marinated with various STP, BICARB and PUMP combinations, 1 tainted loin chop control (CT) and 1 non-tainted control (CNT) loin chop treatment) were evaluated on each day for sensory testing over 2 days. Each day was divided into two sessions with 6 loin chops evaluated during each session. The panelists evaluated 2 warm-up chops and discussed the results prior to evaluating the loin chop treatments. The first warm-up sample was a CNT loin chop and the second was a CT loin chop with atypical aromas and flavors. Approximately 5 min was given between each evaluated sample and a 15 min break was given between each session. The serving order of the treatments was randomized by treatment on each sensory day.

***Study II - Determination of consumer acceptability of marinated loin chops with atypical flavor and aromas marinated with tripolyphosphate, and sodium bicarbonate.***

*Experimental Design and Data Analysis*

Determining the optimal parameters for marinades containing varying percentage of STP, concentrations of BICARB, PUMP levels was established from response surface curves generated by PROC G3D from the response surface regression analysis performed in Study I (SAS, 2001). Four treatment marinades (TRT1: 0.70*M* BICARB, 0.50% STP, 15% PUMP; TRT2: 0.70*M* BICARB, 0.25% STP, 15% PUMP; TRT3: 0.35*M* BICARB, 0.50% STP, 15% PUMP; TRT4: 0.30*M* BICARB, 0.25% STP, 15% PUMP) were developed from the evaluation. Consumer sensory panel responses for flavor, juiciness, texture, and overall acceptability of tainted sow loin chops marinated with these four treatment combinations and control were analyzed as a randomized complete block design using a mixed-effects model (SAS, 2001). The model included the random main effect of replication, the fixed main effect of treatment, and the random effects of the interaction of replication x treatment, and panelist nested in replication. The significant main effect means were separated and least significant differences were found using Tukey multiple pair wise comparison method (1977). Significance level was determined at $P<0.05$. The experiment was replicated three times.

*Product Procurement*

Thirty-four hot-boned tainted sow loins (ST) and six non tainted commodity pork loins (CNT) were obtained from a southeast U.S. commercial slaughter plant over an 8 h production shift and were shipped to the Michigan State University Meat Laboratory. Loin selection, shipping, and sample removal were handled in the same manner as previously described in Study I.

*Sow Loin Characterization*

Study I indicated that all sow loins had completed rigor mortis based on the harvesting and processing procedures utilized at the plant. For Study II, ST loins (n=17), were randomly selected for state of rigor and lipid oxidation determination by methods described in Study I. Twenty-four h purge, 7 day purge, 48 h drip loss, and marination uptake/cook yield analyses were conducted on ST loins (n=34) while objective and subjective color, marbling, firmness, and proximate composition were determined on all loins (n=40) described in Study I.

*Marination*

ST loin sections (n=68) and CNT loin sections (n=12) were separated into 40 anterior and 40 posterior sections. Two anterior and 2 posterior sections were randomly selected from the total number of loin sections for each treatment (TRT 1-4) and control marinade (CNT). Forty-eight ST loin sections (24 anterior and 24 posterior sections), and 12 CNT loin sections (6 anterior and 6 posterior) were marinated in for this experiment.

Treatment marinades were manufactured by adding the appropriate amount of water to a 75.7 L container, adding STP, BICARB, NaCl in that order and mixing until each ingredient was completely dissolved with a Rotostat mixer (Model 80XP63SS, Admix Inc., Londonderry, NH) at 2500 RPM for 7 min, 3 min, and 3 min respectively. Mixing time did not begin until the entire ingredient amount was added. Treatment marinades were randomly assigned to ST loin sections. The CNT loin sections were injected with the CM (0.25% STP and 1.0% salt at 15% PUMP). Loin sections (n=4) for each marinade treatment were injected by one pass through a Fomaco automatic injector (Model FGM 20/40, Denmark) with conveyor/needle speed set at 12 and pump pressure set at 25-29 psi. The injection machine was thoroughly cleaned between each treatment group injection. Treatment marinade pH and loin injection levels are reported in Table 2.

Loin sections from each treatment marinade were tumbled separately with a Roschermatic twin arm vacuum tumbler (Model MM-0, D-4500, Osnarbruck/ W-Germany) set at 25 psi. of vacuum and 20 rpm using a 1 min tumble and 1 min rest cycle repeated 5 times. The total actual tumbling time was 5 min. Treated loin sections (n=4) were removed from tumbler, vacuum packaged (2.5 psi. vacuum) individually (30.5 x 40.6 cm bags) and frozen (–23.3°C) for 18-20 h.

*Loin Fabrication*

Marinated loin sections were fabricated as described in Study I. End pieces from each loin section within each treatment were combined to create composite samples for marinated proximate composition and TBA analysis.

**TABLE 2:** **Values for initial, target, actual, target %pump and actual % pump and marinated pH of marinated treatment combinations for sow loins possessing atypical aroma and flavor (sow taint) and non-tainted control commodity loins (CNT).**

| REP | TRT[a] | INTITIAL[b] Kg | TARGET[c] Kg | ACTUAL[d] Kg | TARGET PUMP[e] % | ACTUAL PUMP[f] % | MARINADE pH[g] |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 2.81 | 3.23 | 3.30 | 15.00 | 17.42 | 7.87 |
| 1 | 2 | 3.20 | 3.68 | 3.75 | 15.00 | 17.16 | 7.42 |
| 1 | 3 | 2.95 | 3.39 | 3.45 | 15.00 | 16.92 | 7.43 |
| 1 | 4 | 2.27 | 2.61 | 2.65 | 15.00 | 17.00 | 7.33 |
| 1 | CNT | 4.15 | 4.77 | 4.97 | 15.00 | 19.67 | 6.98 |
| 2 | 1 | 2.90 | 3.34 | 3.38 | 15.00 | 16.41 | 6.71 |
| 2 | 2 | 2.79 | 3.21 | 3.24 | 15.00 | 16.26 | 7.22 |
| 2 | 3 | 2.79 | 3.21 | 3.24 | 15.00 | 16.26 | 6.80 |
| 2 | 4 | 2.83 | 3.26 | 3.33 | 15.00 | 17.60 | 7.23 |
| 2 | CNT | 4.13 | 4.75 | 4.92 | 15.00 | 19.23 | 7.01 |
| 3 | 1 | 3.24 | 3.73 | 3.81 | 15.00 | 17.48 | 7.66 |
| 3 | 2 | 3.20 | 3.68 | 3.76 | 15.00 | 17.45 | 7.52 |
| 3 | 3 | 2.83 | 3.26 | 3.33 | 15.00 | 17.60 | 7.38 |
| 3 | 4 | 2.97 | 3.41 | 3.42 | 15.00 | 15.27 | 7.68 |
| 3 | CNT | 3.99 | 4.59 | 4.82 | 15.00 | 20.68 | 6.94 |

[a] TRT = Marinated treatment combination.
[b] INITIAL = Initial loin group weight (kg).
[c] TARGET = Target loin group weight (kg) for 15% injection.
[d] ACTUAL = Actual loin group weight (kg) after 15% injection.
[e] TARGET PUMP = Targeted injection level of loin group (n=4).
[f] ACTUAL PUMP = Actual injection level (n=4).
[g] MARINADE PH = pH of treatment marinade.

*Consumer Sensory Panel*

AMSA guidelines (AMSA, 1995) were followed for sample preparation and presentation to consumer sensory panelists at Michigan State University (East Lansing, MI) on three consecutive days one week after production. Frozen marinated chops from 4 treatments and 1 control were thawed for 24 h at 2.6°C. One chop from each treatment (n=5) was cooked on a Taylor clamshell grill (Model QS24 Taylor Co; Rockton, IL). The upper plate was set to 104.4°C and the bottom plate was set to 102.8°C with a 2.16 cm gap between plates. Copper constantan thermocouples (0.051 cm diameter, 15.2 cm length; Omega Engineering Inc.; Stamford, CT) were inserted into two chops to monitor temperature rise during cooking and five marinated chops were cooked simultaneously. Final cook temperature of all chops was determined with small diameter hypodermic probe thermocouples (0.089 cm diameter, 5.72 cm length; Cole-Parmer; Vernon Hills, IL). Chops were cooked to a final internal temperature of 71°C $\pm$ 1.5°C. Chops were removed from the grill, placed in separate Pyrex® two quart bowls with the bowls placed in an insulated cooler containing a damp and heated blanket at the bottom. The samples were immediately transported to the Michigan State University Sensory Evaluation Laboratory. Upon arrival, treatment chops were immediately removed from the glass bowls and placed in Pyrex® double broilers heated in a water bath maintained at 140°C for sample holding. Sample preparation included cutting

1.27 x 1.27 x 2.45 cm cubes from the center portion of each pork loin chop. The order of sample presentation was randomized within each session (Meilgaard, 1991).

Consumer panel evaluations (n=45) were conducted in 2 h sessions on three consecutive days. Expectorant cups were provided to prevent taste fatigue. Distilled, deionized water and unsalted soda crackers were provided to clean the palate between samples. Panelists were asked to determine desirability of juiciness, texture, flavor, and overall acceptability of the pork chops. An 8 point hedonic scale was used where 1=extremely undesirable and 8=extremely desirable. Data was collected using SIMS (2000) sensory computer software and comment boxes were provided for each question asked.

*Cook Yields / Shear Force Determination / Proximate Composition*

Chops were cooked by methods previously described in the consumer sensory panel section. Marinated ST and CNT loin chop cook yields were determined by recording the initial weight of two 2.54 cm loin chops, cooking them to an internal temperature of 71°C, allowing them to cool to room temperature and reweighing the cooked loin chops. Percent cook yield was calculated by determining the difference between the initial and cooked loin chop weight, dividing that difference by the initial weight and dividing by 100. The loin chops were then placed on plastic trays covered with plastic film and chilled at 4°C for 12 h. Three, 1.27 cm cores were taken parallel to the longitudinal axis of the fibers using a drill press-mounted corer. Cores were sheared perpendicular to the fibers using a Warner Bratzler head on a TA-Hdi Texture Analyzer (Texture

Technologies Corp., Scotsdale, NY). The crosshead speed was set at 3.30 mm/s. Data was reported in kg of force. Composite samples were collected for cooked proximate composition.

## Results and Discussion

### Study I

*Rigor Determination (pH and R-Value)*

R-value and pH change determination indicated that the completion of rigor had occurred for both ST (n=16) and CNT (n=13) sow loins. Honikel and Fischer (1977) reported that postmortem changes can be monitored by adenine nucleotide level monitoring where value less than 1.5 μMol/g meat sample indicate the completion of rigor. Adenine nucleotide levels for normal porcine muscle at 1 h and 24 h postmortem ranged from 3.5 to 8.5 and 1.0 to 2.2 respectively. Adenine nucleotide levels at 24 h were 1.32 and 1.34 μMol/g for ST and CNT loins respectively, indicating the completion of rigor (Table 3). No significant differences in pH were observed between initial and 10 min pH for either ST or CNT loins. Differences in pH between ST and CNT loins were significant ($P<0.05$) (Table 3).

*pH and TBA Analyses*

ST loin (n=16) pH ranged from 5.60 to 6.60 and CNT loin (n=13) pH ranged from 5.64 to 6.04 (data not shown). No differences were found between ST and CNT loins for pH nor initial TBA (Table 3).

*Subjective / Objective Quality Analyses*

No differences were observed for subjective color and firmness between ST and CNT sow loins (Table 4). However, ST loins were rated significantly higher ($P<0.05$) for marbling than CNT loins. No differences were found for Minolta values for reflectance (L*), redness (a*), and yellowness (b*) between ST

**TABLE 3. Least squares means for rigor determination (R-value and pH difference), pH, TBA values, purge, and drip loss for sow loins possessing atypical aroma and flavor (sow taint, ST), and non-tainted control sow loins (CNT)**

| | RIGOR DETERMINATION | | | | PURGE ANALYSIS AND DRIP LOSS | | | |
|---|---|---|---|---|---|---|---|---|
| | R-VALUE[c] | pH DIF[d] | pH | TBA[e] | Purge1[f] | Purge2[g] | Purge3[h] | Drip Loss[i] |
| Loin Type | | | | mg/kg | % | % | % | % |
| ST[a] | 1.32 | 0.00[m] | 5.91 | 0.00 | 7.33 | 7.60 | 6.72 | 7.57 |
| SEM[j] | 0.01 | 0.01 | 0.05 | 0.03 | 0.65 | 1.14 | 0.82 | 0.64 |
| CNT[b] | 1.34 | 0.02[l] | 5.88 | 0.00 | 8.57 | 6.66 | 7.03 | 8.19 |
| SEM[k] | 0.01 | 0.01 | 0.05 | 0.03 | 0.72 | 1.26 | 0.91 | 0.71 |

[a]ST = Sow loins with atypical aroma and flavor (sow taint).
[b]CNT = Non-tainted control sow loins.
[c]R-value = $\mu$mol/g of meat of adenosine nucleotide present.
[d]pH difference = Difference between initial and 10 minute pH.
[e]TBA=2-Thiobarbituric acid test reported as mg malonaldehyde/kg sample.
[f]PURGE1 = Fluid lost after tempering frozen sow loins (24 h).
[g]PURGE2 = Fluid lost from anterior loin section after 7 days of vacuum packaged storage (2.8°C).
[h]PURGE3 = Fluid lost from posterior loin section after 7 days of vacuum packaged storage (2.8°C).
[i]Drip Loss = Fluid lost from loin chops after 48 h storage (2.8°C; Baas et al., 2000).
[j]SEM = Standard error of the means for ST loins.
[k]SEM = Standard error of the means for CNT loins.
[l-m]Means within same column with different superscripts are different ($p<0.05$).

**TABLE 4: Least squares means for Subjective color, marbling, and firmness; Objective color (L*, a*, b*) values; and raw composition for sow loins possessing atypical aroma and flavor (sow taint, ST), and non-tainted control sow loins (CNT).**

| | SUBJECTIVE MEASUREMENTS[c] | | | OBJECTIVE COLOR[d] | | | RAW COMPOSITION | | |
|---|---|---|---|---|---|---|---|---|---|
| Loin Type | COLOR | MARBLING | FIRMNESS | L* | a* | b* | MOISTURE % | FAT % | PROTEIN % |
| ST[a] | 4.25 | 3.38[g] | 2.06 | 46.45 | 21.33 | 6.13 | 75.72 | 2.91 | 22.87 |
| SEM[e] | 0.20 | 0.22 | 0.08 | 1.27 | 0.41 | 0.33 | 0.48 | 0.44 | 0.52 |
| CNT[b] | 4.62 | 2.46[h] | 1.92 | 45.48 | 21.88 | 6.07 | 75.77 | 2.87 | 23.19 |
| SEM[f] | 0.22 | 0.24 | 0.09 | 1.41 | 0.46 | 0.36 | 0.53 | 0.43 | 0.59 |

[a] ST = Sow loins with atypical aroma and flavor (sow taint).
[b] CNT = Non-tainted control sow loins.
[c] Measurements according to National Pork Producers Pork Quality Standards (Baas et al., 2000).
[d] Commission International D'Edairerage (CIE) L*a*b* were L* = lightness, a* = redness, and b* = yellowness on a 0-100 pink scale.
[e] SEM = Standard error of the means for ST loins.
[f] SEM = Standard error of the means for CNT loins.
[g-h] Means within same column with different superscripts are different ($p<0.05$).

and CNT loins (Table 4), however, L* values for CNT loins were slightly lower indicating a slightly darker lean color.

Twenty-four h purge loss was not significantly different (7.33 vs. 8.57%) between ST and CNT loins (Table 3). Although the purge values reported are high, this may be due to the effects of measuring purge loss of frozen meat after subsequent thawing. Freezing of meat creates ice crystals that may rupture protein fibers thereby allowing more water to exude from the muscle. Seven day purge loss for ST and CNT loin section was not significantly different (Table 3).

Drip loss (48 h) ranged from 3.85 and 12.72% for all sow loins (n=26)(data not shown). No significant differences for drip loss were found between ST and CNT loin chops (Table 3). The higher purge loss values were also noted by Reagan (1983) who stated that hot-boned muscle subjected to a temperature of 0°C may have a much higher purge/drip loss than muscle that is conditioned (some form of conventional chilling) before being frozen.

*Proximate Composition / Marination Uptake and Cook Yield Analyses*

Raw moisture, fat, and protein composition were not significantly different between ST and CNT loins (Table 4). Marination uptake values ranged from 22.78 to 62.50% and cook yield values ranged between 81.83 and 117.39% (Appendix 15). The high degree of variation among samples may be due to the variation of pork quality (pH) among the samples, thereby influencing water-holding capacity.

*Marinated pH, Proximate Composition, and TBA*

Marinated ST and CNT sow loin pH (Table 5) ranged from 6.02 to 7.22. This increase in loin pH was due to the pH of the respective treatment marinades (Table 1), which ranged from 6.55 to 6.82. Marinated TBA values conducted during trained sensory panel evaluation indicate that oxidative rancidity did not contribute to the atypical aromas and flavors required for the development of sow taint. The low fat content of ST and CNT sow loins (Table 4) limited the amount of substrate available for lipid oxidation, thus influencing TBA values. The low TBA values could also be attributed to prerigor processing and the short time required for fabrication, storage and final analysis.

*Trained Sensory Evaluation*

Basic flavors, tastes, aftertastes, aromatics, myofibrillar tenderness, juiciness and connective tissue attributes were evaluated by a trained sensory panel (Table 6). The effects of BICARB, STP, and PUMP significantly ($P<0.05$) affected muscle fiber tenderness, juiciness, overall tenderness, connective tissue, sour aftertaste, metal aftertaste, and metallic aroma based on response surface regression analysis. Response surface graphs were generated for these attributes with factors of PUMP (5-15%), STP (0.25-0.50%), and BICARB (0.35-0.70M).

As STP and BICARB increased (0.50% and 0.70*M* respectively) metallic aftertaste decreased (Figure 3a and 3b). Both unmarinated ST and CNT loin chops were rated by panelists (1.50 and 1.43 respectively) as possessing higher levels of metallic aftertaste. These findings are supported by Chen and

**TABLE 5. Least squares means for moisture, fat, and protein; TBA; and pH of sow loins possessing atypical aroma and flavor marinated with STP[b] and BICARB[c] at varying PUMP[d] levels.**

| | MARINATED COMPOSITION | | | | |
|---|---|---|---|---|---|
| TRT[a] | MOISTURE % | FAT %[i] | PROTEIN % | TBA mg/kg | pH[h] |
| 1 | 72.77 | 3.87 | 22.73 | 0.0068 | 6.02 |
| 2 | 75.72 | 1.09 | 21.95 | 0.0000 | 6.21 |
| 3 | 75.28 | 0.64 | 21.10 | 0.0013 | 6.36 |
| 4 | 74.73 | 0.00 | 22.03 | 0.0080 | 6.43 |
| 5 | 77.77 | 1.64 | 20.75 | 0.0085 | 6.67 |
| 6 | 73.58 | 5.48 | 21.12 | 0.0193 | 7.13 |
| 7 | 77.17 | 0.49 | 22.49 | 0.0163 | 6.68 |
| 8 | 77.46 | 0.21 | 22.11 | 0.0135 | 7.16 |
| 9 | 76.43 | 0.50 | 23.26 | 0.0018 | 6.70 |
| 10 | 74.71 | 2.35 | 21.66 | 0.0023 | 7.17 |
| 11 | 72.14 | 3.25 | 23.90 | 0.0045 | 6.72 |
| 12 | 75.95 | 0.00 | 24.49 | 0.0060 | 7.22 |
| 13 | 76.99 | 0.92 | 20.73 | 0.0010 | 6.40 |
| 14 | 74.62 | 1.91 | 21.07 | 0.0093 | 6.95 |
| SEM[e] | 0.77 | 0.60 | 0.54 | 0.0055 | 0.10 |
| 15[f] | 74.19 | 2.89 | 22.94 | 0.0016 | 6.65 |
| SEM[g] | 0.32 | 0.25 | 0.22 | 0.0023 | 0.04 |

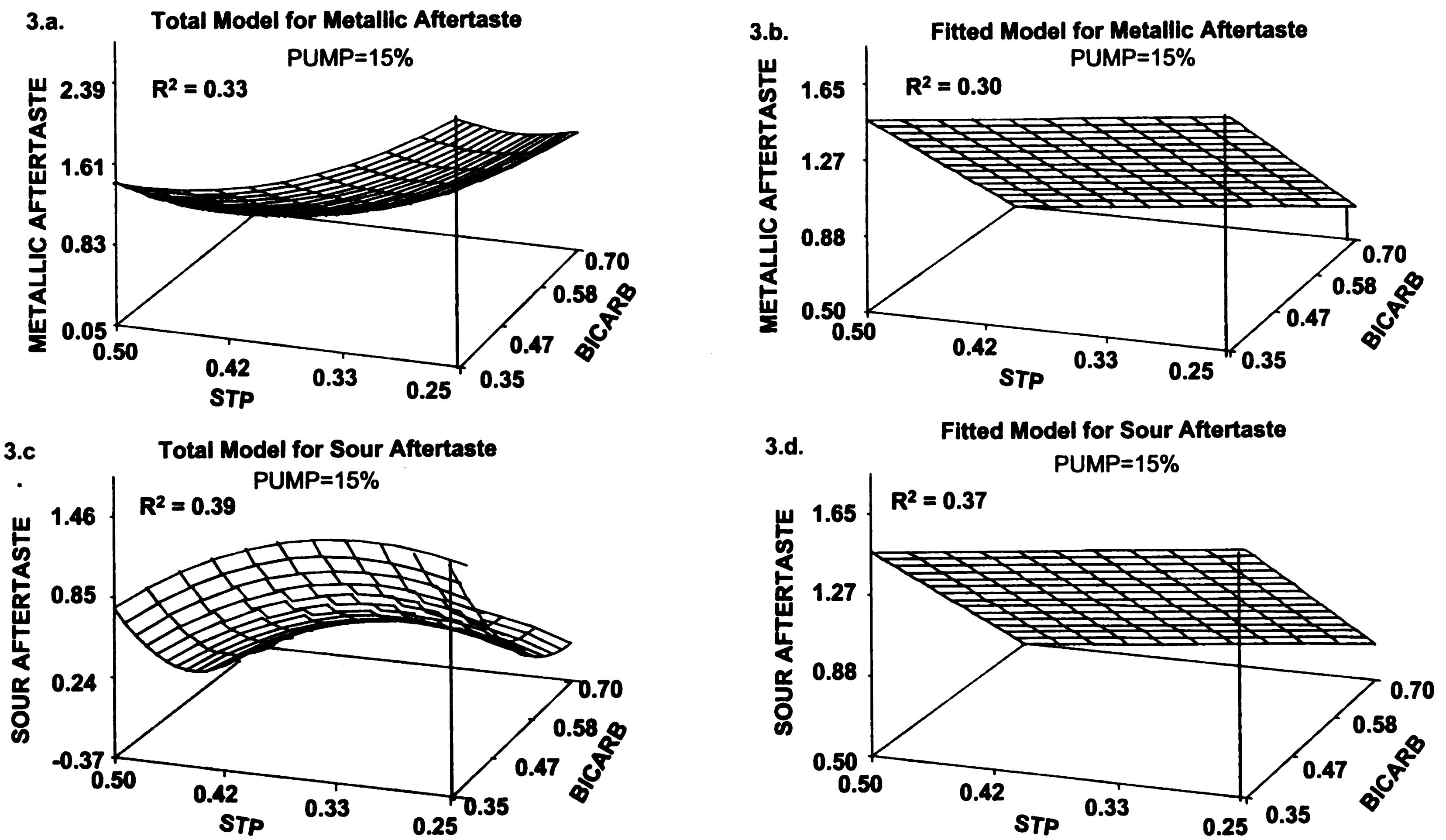
[a] Treatment combinations. See Table 1.
[b] STP = Sodium tripolyphosphate.
[c] BICARB = Sodium bicarbonate.
[d] PUMP= Percentage of marinade solution injected
[e] SEM = Standard error of the mean for treatment combinations 1-14.
[f] 15 = Treatment 15 replicated an additional five times to derive error degrees of freedom to test signifincance (TRT 16-20).
[g] SEM = Standard error of the mean for replicated treatment combination.
[h] pH = pH of marinated sow loins.

**TABLE 6: Least squares means for trained sensory panel scores for sow loin chops possessing atypical aroma and flavor marinated with STP[b] and BICARB[c] at varying PUMP[d].**

| TRT[a] | STP % | BICARB *M* | PUMP % | MUSCLE FIBER TENDERNESS | JUICINESS | OVERALL TENDERNESS | CONNECTIVE TISSUE | AFTERTASTE SOUR | AFTERTASTE METALLIC | AROMATIC METALLIC |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.30 | 0.42 | 7 | 4.13 | 3.95 | 4.27 | 5.58 | 0.55 | 1.14 | 0.12 |
| 2 | 0.30 | 0.63 | 7 | 4.84 | 3.53 | 4.84 | 5.87 | 0.55 | 0.71 | 0 |
| 3 | 0.45 | 0.42 | 7 | 5.56 | 5.09 | 5.56 | 5.30 | 1.98 | 1.99 | 0 |
| 4 | 0.45 | 0.63 | 7 | 6.20 | 5.07 | 6.20 | 7.45 | 1.01 | 0.68 | 0.43 |
| 5 | 0.30 | 0.42 | 13 | 6.34 | 4.93 | 6.34 | 7.02 | 0.87 | 1.82 | 0.29 |
| 6 | 0.45 | 0.63 | 13 | 5.77 | 4.65 | 5.77 | 6.73 | 0.16 | 0.96 | 0.43 |
| 7 | 0.45 | 0.42 | 13 | 6.13 | 5.10 | 5.99 | 7.01 | 0.69 | 1.27 | 0 |
| 8 | 0.45 | 0.63 | 13 | 5.20 | 4.79 | 5.20 | 6.45 | 0.30 | 0.53 | 0.14 |
| 9 | 0.38 | 0.53 | 5 | 4.77 | 3.65 | 4.77 | 6.59 | 0.16 | 0.96 | 0 |
| 10 | 0.38 | 0.53 | 15 | 4.91 | 4.79 | 4.91 | 6.02 | 0.44 | 0.68 | 0.29 |
| 11 | 0.25 | 0.53 | 10 | 6.06 | 5.07 | 6.06 | 6.59 | 0.16 | 1.25 | 0.14 |
| 12 | 0.50 | 0.53 | 10 | 4.20 | 3.50 | 4.20 | 5.45 | 0.30 | 1.25 | 0 |
| 13 | 0.38 | 0.35 | 10 | 4.48 | 4.50 | 4.34 | 5.02 | 0.30 | 1.39 | 0.14 |
| 14 | 0.38 | 0.70 | 10 | 5.99 | 4.95 | 5.99 | 6.87 | 0.55 | 0.71 | 0 |
| SEM[e] | | | | 0.45 | 0.33 | 0.44 | 0.45 | 0.35 | 0.34 | 0.13 |
| 15[f] | 0.35 | 0.53 | 10 | 5.09 | 4.24 | 5.09 | 6.01 | 0.75 | 0.96 | 0 |
| SEM[g] | | | | 0.19 | 0.14 | 0.18 | 0.19 | 0.14 | 0.14 | 0 |
| ST[h] | | | | 4.16 | 4.19 | 4.15 | 5.14 | 1.11 | 1.50 | 0.04 |
| CNT[i] | | | | 3.66 | 3.12 | 3.72 | 5.92 | 0.33 | 1.43 | 0.33 |
| SEM[j] | | | | 0.33 | 0.29 | 0.34 | 0.39 | 0.27 | 0.26 | 0.12 |

[a] Treatment combinations.
[b] STP = Sodium tripolyphosphate.
[c] BICARB = Sodium bicarbonate.
[d] PUMP = Percentage of marinade solution injected.
[e] SEM = Standard error of the means for treatment combination 1-14.
[f] 15 = Treatment 15 replicated an additional 5 times to derive error degrees of freedom to test significance (TRT 15-20).
[g] SEM = Standard error of the means for replicated treatment combination.
[h] ST = Sow loins with atypical aroma and flavor (sow taint).
[i] CNT = Non-tainted control sow loins.
[j] SEM = Standard error of the means for ST and CNT loins.

FIGURE 3: Response surface curves of significant ($P<0.05$) total and fitted regression models for metallic and sour aftertaste of marinated sow loin chops manufactured with 15% injection level (PUMP), 0.25-0.50% sodium tripolyphosphate (STP), and 0.35-0.70 *M* sodium Bicarbonate (BICARB).

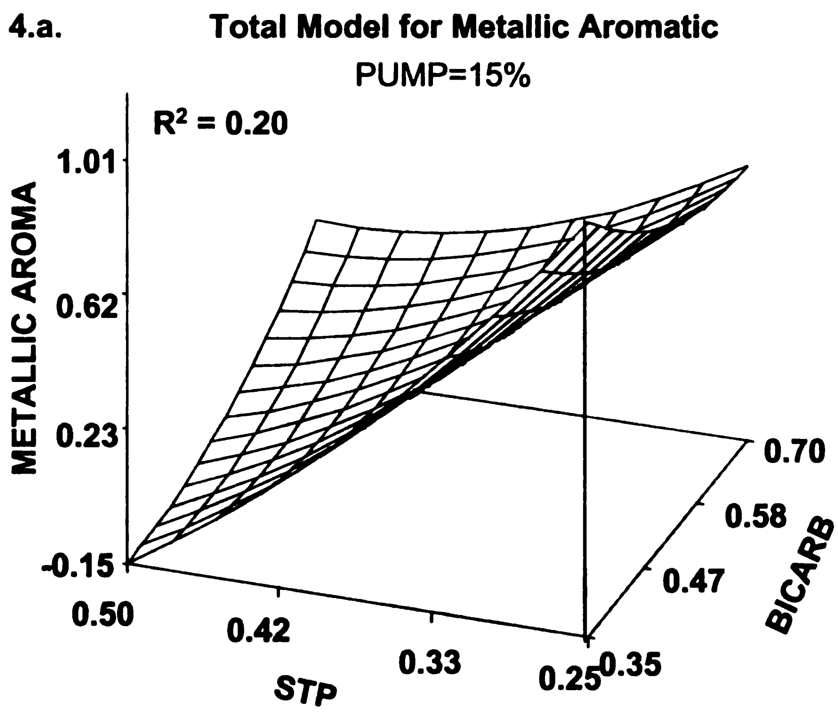


Ho (1998) who stated that metal or metallic aromas are present in cooked pork. Sour aftertaste also showed a lower response (0.50) from higher levels of STP and BICARB (Figure 3c and 3d). This indicates that results from the fitted model approached the non-tainted control responses (Table 6). This was important as the term "sour" was often associated throughout the study with describing the complex atypical aromas and flavors of tainted sow meat. For metallic aroma, the lower levels of BICARB and the higher levels of STP tended to reduce sensory panel responses (Figure 4a and 4b).

Connective tissue residual response increased at lower levels of STP and BICARB (Figure 5a and 5b). This phenomenon could be due to a high injection level (15%) and collective effects STP, BICARB, and NaCl. Therefore, the effects of all three ingredients synergistically could result in high responses at their lower levels. Figure 5c and 5d shows that the highest response for juiciness was reached at lower BICARB concentrations and higher STP levels. It is important to note that the response had a small range from 4.87 to 4.92. Muscle fiber tenderness (Figure 6a and 6b) scores were higher at lower STP levels and BICARB concentrations. However, there was very little difference in response when BICARB was increased. This indicates that injection level may play a larger role in muscle fiber tenderness than STP or BICARB. It appears that a low amount of STP or BICARB is important for an improvement in muscle fiber tenderness. However, STP level may have a more important role in this than BICARB concentration. The higher water level from injection may improve the perception of

**FIGURE 4: Response surface curves of significant (P<0.10) total and fitted regression models for metallic aromatic of marinated sow loin chops manufactured with 15% injection level (PUMP), 0.25-0.50% sodium tripolyphosphate (STP), and 0.35-0.70 *M* sodium Bicarbonate (BICARB).**

4.a.




4.b.

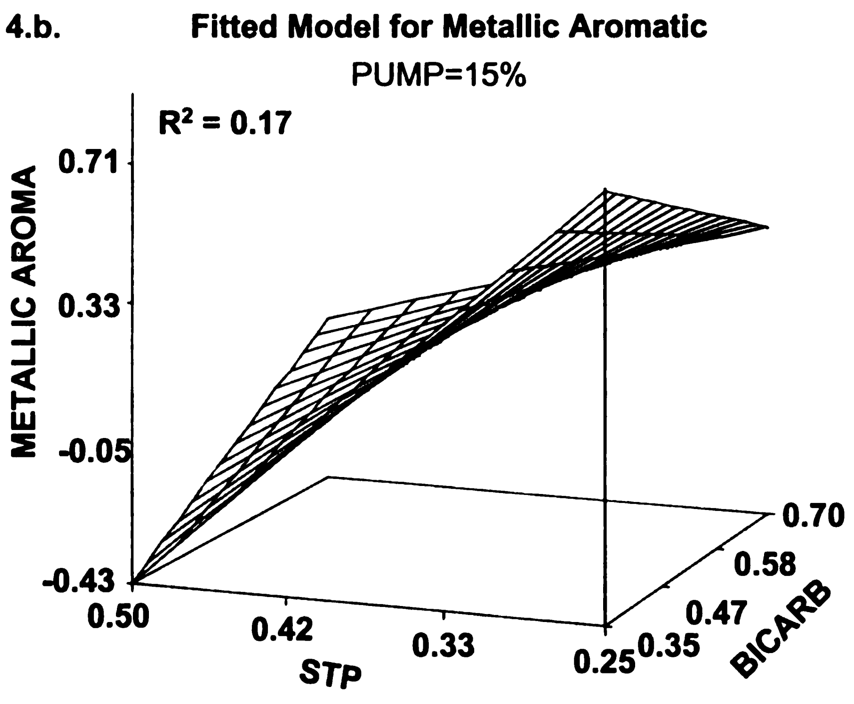


FIGURE 5: Response surface curves of significant ($P<0.05$) total and fitted regression models for connective tissue and juiciness of marinated sow loin chops manufactured with 15% injection level (PUMP), 0.25-0.50% sodium tripolyphosphate (STP), and 0.35-0.70 *M* sodium Bicarbonate (BICARB).

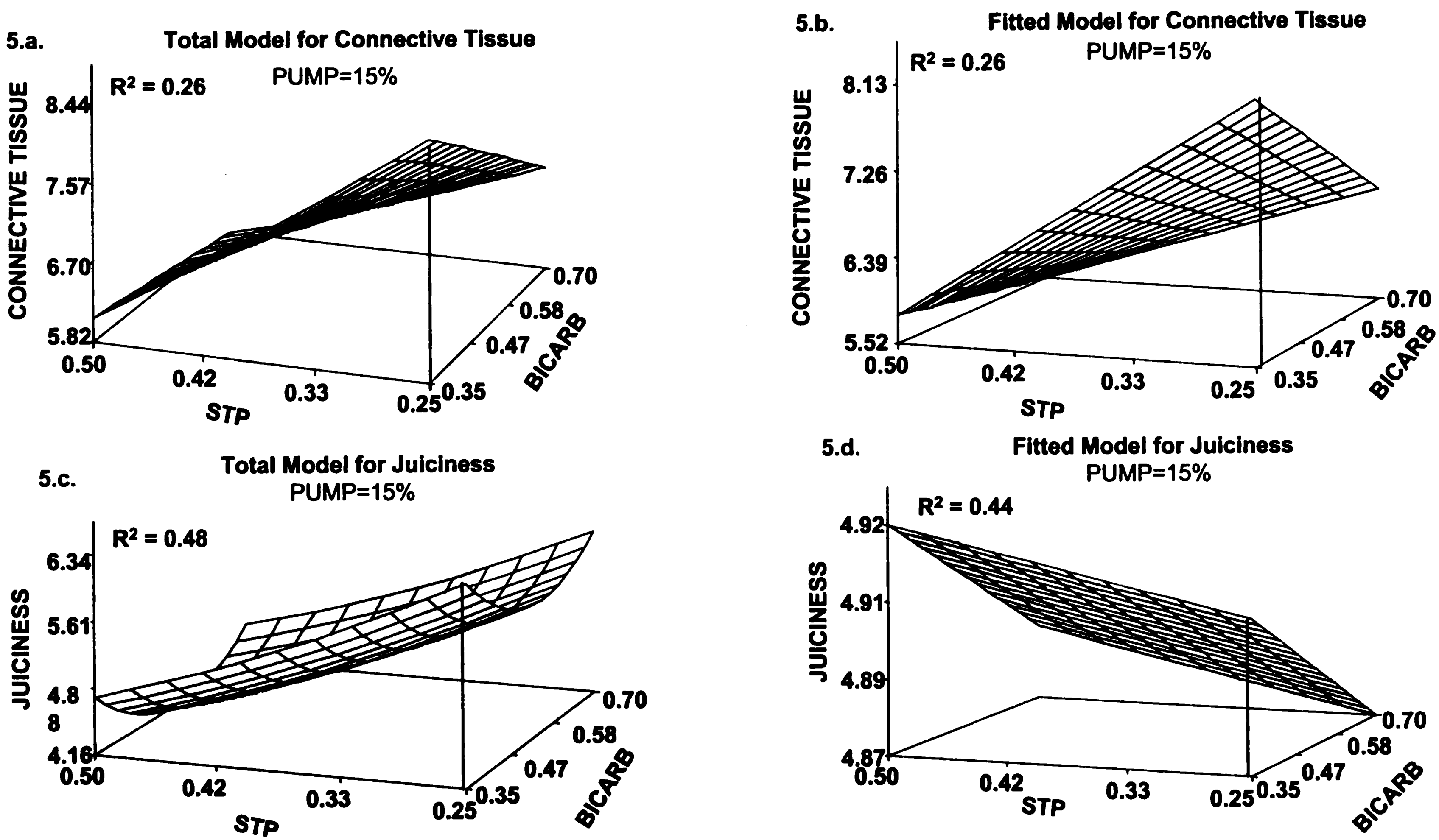
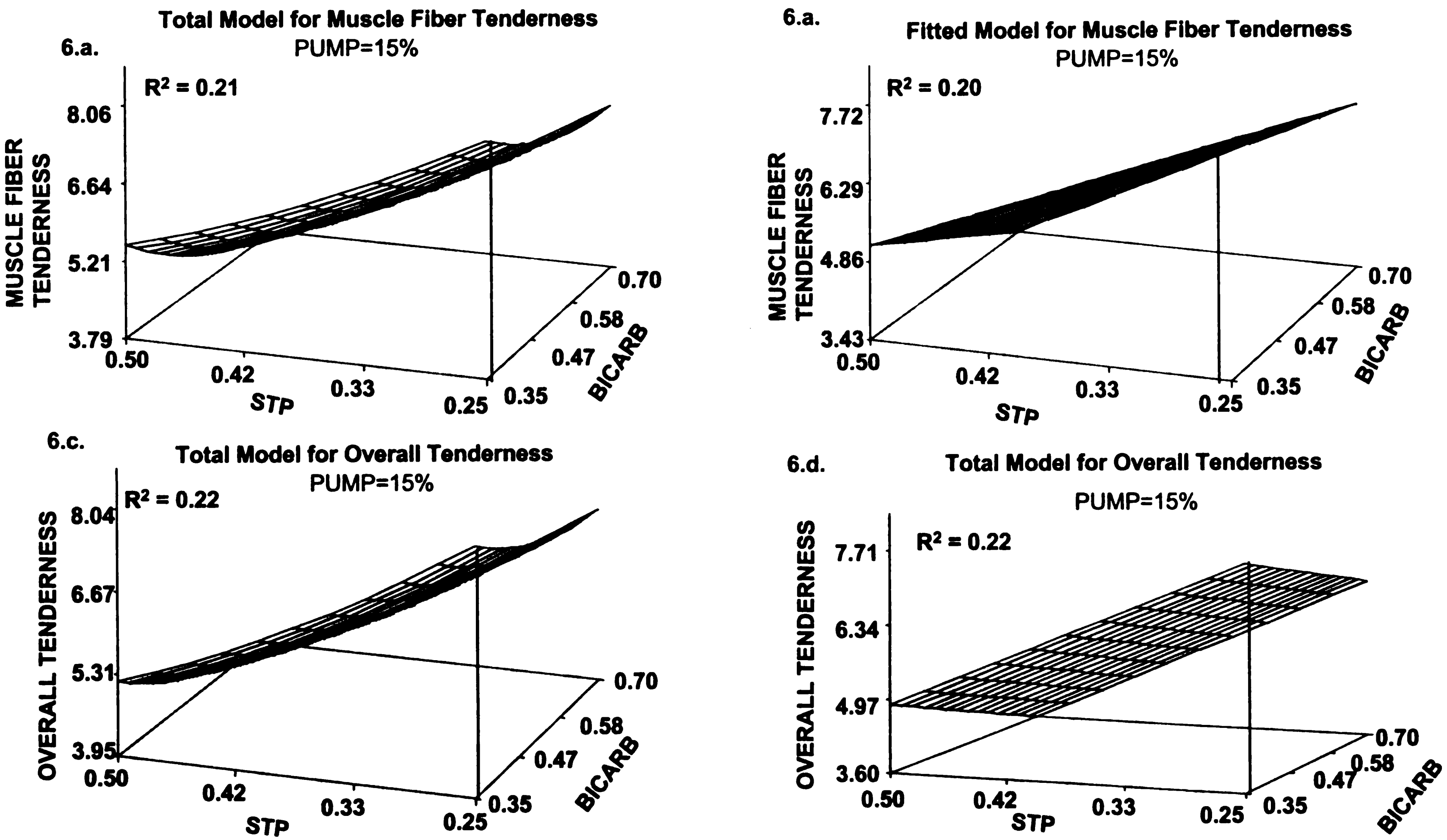


FIGURE 6: Response surface curves of significant (P<0.05) total and fitted regression models for muscle fiber and overall tenderness of marinated sow loin chops manufactured with 15% injection level (PUMP), 0.25-0.50% sodium triplyphosphate (STP), and 0.35-0.70 *M* sodium bicarbonate (BICARB).



tenderness when defined as a combination of juiciness and muscle fiber tenderness. It is important to note that all treatment combinations had a higher response for muscle fiber tenderness than the tainted and non-tainted controls (Table 6).

Overall tenderness responses were higher at lower STP levels and BICARB concentrations (Figure 6c and 6d). This again indicates that injection level may play a larger role than STP or BICARB for overall tenderness to be improved. The figure also indicates that a low amount of STP or BICARB is needed for the improvement of overall tenderness. It is also important to note that all treatment combinations had a higher response for overall tenderness than the tainted and non-tainted controls (Table 6).

From the interpretation of Figures 3-6, optimum levels were identified for STP and BICARB that yielded the highest mean responses for the 7 attributes discussed above. Four STP level and BICARB concentration combinations (TRT1= 0.50% STP, 0.70 *M* BICARB; TRT2= 0.25% STP, 0.70 *M* BICARB; TRT3= 0.50% STP, 0.35 *M* BICARB; and TRT4= 0.25% STP, 0.30 *M* BICARB) were identified from this interpretation. PUMP was not significant and did not show visually large improvements in response surface graphs for the 7 attributes. However, as PUMP increased slightly improved responses were shown for some of the attributes. Therefore, PUMP was held constant at 15% for all treatments.

*Conclusions*

Levels approaching optimization of PUMP, STP, and concentrations of BICARB were determined utilizing response surface regression and a trained sensory panel. Marinade treatments containing STP, BICARB, and NaCl that would offer the most likelihood of atypical aroma and flavor reduction or elimination were successfully developed from the trained sensory panel analyses to more closely investigate the elimination of sow taint. These treatments (TRT1= 0.50% STP, 0.70 *M* BICARB; TRT2= 0.25% STP, 0.70 *M* BICARB; TRT3= 0.50% STP, 0.35 *M* BICARB; and TRT4= 0.25% STP, 0.30 *M* BICARB) were utilized in Study II.

**Study II**

*Rigor Determination (pH), pH, TBA*

Results indicate the loins had achieved rigor completion (Appendix 17). Raw sow loin (n=40) pH ranged from 5.38 to 6.81 (Appendix 18). Of the 40 loins, 1 to 34 represented tainted sow loins and 35 to 40 represented non-tainted commodity pork controls. No significant differences for pH were found between tainted and control loin groups (Table 7). The pH for control commodity pork loins was slightly higher. ST loins (n=17) were randomly selected and evaluated for lipid oxidation. Day 1 TBA values (Appendix 19) ranged from 0.008 to 0.117 indicating very little lipid oxidation

*Subjective / Objective Quality Analyses*

Subjective color, marbling, and firmness scores for ST and CNT loin chops ranged from 3 to 6 (6 point scale), 1 to 4 (10 point scale where each number symbolizes % fat), 1 to 3 (3 point scale), respectively. Objective L*, a*, b* values ranged from 33.13 to 55.73, 18.35 to 24.45, and 0.96 to 8.75

**TABLE 7:** ***Least squares means for Subjective color, marbling, and firmness; Objective color (L*, a*, b*) values; raw composition; pH; marinade uptake; and cook yields for sow loins possessing atypical aroma and flavor (sow taint, ST), and non-tainted control commodity loins (CNT).***

| Loin Type | SUBJECTIVE MEASUREMENTS[c] | | | OBJECTIVE COLOR[d] | | | RAW COMPOSITION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | COLOR | MARB[e] | FIRM[f] | L* | a* | b* | MOIST[g] % | FAT % | PROT[h] % | pH[i] | MU[j] % | CY[k] % |
| ST[a] | 4.32[n] | 2.21 | 2.15 | 44.25[n] | 21.09 | 5.14[n] | 75.98 | 2.42 | 23.58 | 5.79 | 42.04[n] | 100.17[n] |
| SEM[l] | 0.11 | 0.10 | 0.06 | 0.75 | 0.24 | 0.53 | 0.28 | 0.38 | 0.18 | 0.04 | 2.19 | 1.60 |
| CNT[b] | 3.50[o] | 2.25 | 2.17 | 52.51[o] | 20.41 | 6.50[o] | 75.51 | 2.07 | 24.48 | 5.89 | 58.03[o] | 109.93[o] |
| SEM[m] | 0.26 | 0.25 | 0.15 | 1.78 | 0.57 | 0.53 | 0.67 | 0.90 | 0.43 | 0.11 | 5.20 | 3.82 |

[a] ST = Sow loins with atypical aroma and flavor (sow taint).
[b] CNT = Non-tainted control commodity loins.
[c] Measurements according to National Pork Producers Pork Quality Standards (Baas et al., 2000).
[d] Commission International D'Edairerage (CIE) L*a*b*, where L* = lightness, a* = redness, and b* = yellowness on a 0-100 pink scale.
[e] MARB = Marbling.
[f] FIRM = Firmness.
[g] MOIST = Moisture.
[h] PROT = Protein
[i] pH = Raw pH measurement.
[j] MU = Marinade uptake.
[k] CY = Cook yield.
[l] SEM = Standard error of the means for ST loins.
[m] SEM = Standard error of the means for CNT loins.
[n-o] Means within same column with different superscripts are different ($P<0.05$).

respectively (Appendix 20). Kauffman and Marsh (1987) stated that as chronological age of animals increases, the quantity of myoglobin in muscle increases resulting in a darker surface color. Table 7 shows that ST loins were significantly ($P<0.05$) darker than CNT loins for both subjective and objective color (redder and darker). This is in agreement with Nold et al. (1999) who found muscles from gilts were darker in color compared to barrows. No differences were found, however, for objective yellowness or subjective marbling or firmness between ST and CNT loins (Table 7).

Twenty-four h purge loss of ST loins (n=34) ranged between 0 and 6.91% (Appendix 21). Seven day purge loss for ST loin sections ranged between 0.72 and 9.05% (Appendix 13), while 48 h drip loss ranged from 0.42 to 8.45% for ST loin chops (Appendix 21). Twenty-four h, 7 day purge, and 48 h drip loss were not measured for CNT loins. High purge losses could be attributed to high loin temperatures (2-4°C) upon arrival (Appendix 21). Evidence of purge from the initial thawing stages of some of the loins was observed and unable to be captured and included in 24-h purge determination.

*Proximate Composition*

Raw moisture, fat, and protein composition for ST and CNT loins ranged between 71.71 to 78.46%, 0.14 to 9.97%, and 20.73 to 26.04% respectively (Appendix 18). No significant differences were found between the ST and CNT loins for raw moisture, fat, or protein composition (Table 7).

*Marination Uptake and Cook Yield Analyses*

Marination uptake and cook yield values for all ST and CNT loins is reported in Table 7. The CNT loins had a significantly higher ($P<0.05$) marination uptake and cook yield compared to ST loins. This would suggest that ST sow loins would not be able to "pick up" and hold as much marinade as the CNT loins. This could impact the ability of treatment marinades containing STP and BICARB to minimize atypical aromas and flavors of ST loins, potentially lowering consumer sensory acceptability scores.

*Marinated pH, TBA, Proximate Composition*

The pH of composite marinated ST loin samples were higher than unmarinated raw ST loin pH values (Table 8). ST loins marinated with TRT 1 (0.50% STP, 0.70*M* BICARB) and TRT 2 (0.25% STP, 0.70*M* BICARB) had significantly higher ($P<0.05$) pH values than ST loins marinated with TRT 3 (0.50% STP, 0.35*M* BICARB) and TRT 4 (0.25% STP, 0.35*M* BICARB). The CNT loins (0.25% STP) had significantly lower ($P<0.05$) pH values (Table 8). This could be explained by the percent STP and BICARB concentration present in each treatment marinade formulation. Townsend and Olson (1987) reported that STP has an increasing effect on pH. Lindsay (1985) stated that BICARB has excellent pH buffering properties. Kauffman et al. (1998) had an increase (0.6 to 1.0 units) in pH when they used BICARB in hot-boned and post-rigor pork loins. This suggests that BICARB and STP may collectively increase pH in compared to either STP or BICARB alone.

**TABLE 8: Least squares means for lipid oxidation (TBA), pH, cook yield, shear force and proximate composition for sow loins possessing atypical aroma and flavor (sow taint, ST), and non-tainted control commodity loins (CNT) marinated at 15% PUMP[b] with STP[c] and BICARB[d].**

| | | | MARINATED COMPOSITION | | | COOKED COMPOSITION | | |
|---|---|---|---|---|---|---|---|---|
| TRT[a] | TBA[f] | pH[g] | Moisture % | Fat % | Protein % | Moisture % | Fat % | Protein % |
| 1 | 0.019 | 7.52[i] | 76.97 | 1.94 | 21.54 | 74.23[i] | 4.29[j] | 22.33[k] |
| 2 | 0.017 | 7.58[i] | 76.69 | 2.80 | 20.50 | 72.29[jk] | 5.77[i] | 22.73[k] |
| 3 | 0.012 | 6.80[j] | 77.30 | 1.86 | 21.66[i] | 71.73[k] | 6.47[i] | 24.33[j] |
| 4 | 0.017 | 6.70[j] | 77.89 | 1.73 | 21.54 | 73.09[j] | 2.74[k] | 26.15[i] |
| CNT[e] | 0.016 | 6.13[k] | 77.82 | 2.71 | 20.00[j] | 74.62[i] | 3.09[k] | 23.86[j] |
| SEM[h] | 0.004 | 0.08 | 0.72 | 1.02 | 0.32 | 0.21 | 0.19 | 0.19 |

[a] TRT = Treatment combination.
[b] PUMP = Percentage of marinade solution injected.
[c] STP = Sodium tripolyphosphate.
[d] BICARB = Sodium bicarbonate.
[e] CNT = Non-tainted control commodity loins.
[f] TBA = 2-Thiobarbituric acid test for marinated composite samples.
[g] pH = Marinated pH of composite sample.
[h] SEM = Standard error of the means for treatment combinations and CNT.
[i-k] Means within same column with different superscripts are different ($P<0.05$).

Marinated composite ST loin sample TBA values measured during consumer sensory panel evaluation (7 d vacuum packaged storage at 2.8°C), ranged from 0.012 to 0.019 indicating that lipid oxidation would have minimal impact on sensory panel scores. No differences were found between marinated ST loins and marinated CNT loins (Table 8). The low TBA values may be due to due low fat intermuscular fat content (Tables 7 & 8), vacuum packaging and short frozen storage period (7 days) between loin chop fabrication and sensory evaluation.

Marinated proximate composition for composite treatments and control are shown in Table 8. No significant differences were found between any marinated treatments for moisture and fat. However, ST loins marinated with TRT 3 were significantly ($P<0.05$) higher in protein than the control. No other differences for protein were observed between treatments.

*Cook Yields*

Cook yields of sensory chops are reported in Table 9. The loin source of each of these chops was not known as they were randomly assigned within each treatment. Cook yields for ST loins marinated with TRT1 were significantly ($P<0.05$) higher than all other treatments and the control. TRT 4 loin chop cook yields were significantly ($P<0.05$) lower than TRT 1 and CNT loin chops. CNT loin chops were significantly ($P<0.05$) lower in cook yields than all marinated ST loin chops. Marination uptake and cook yield analysis indicated that CNT loin chops should have had higher cook yields than ST sow loin chops. This was not the case. A possible explanation for this is that the controls were marinated with a basic marinade of 0.25% STP and 1.0% salt where all other

**TABLE 9: Least squares means for cook yield and shear force, and scores for sensory attributes of flavor, texture, juiciness, and overall acceptability of sow loins possessing atypical aroma and flavor and non-tainted commodity control (CNT) loins marinated at 15% PUMP[b] with STP[c] and BICARB[d].**

| | MARINADE FORMULATION | | | | | SENSORY ATTRIBUTES[h] | | | |
|---|---|---|---|---|---|---|---|---|---|
| TRT[a] | PUMP % | STP % | BICARB *M* | CY[f] % | SHEAR[g] kg | FLAVOR | TEXTURE | JUICINESS | OVERALL[i] |
| 1 | 15 | 0.50 | 0.70 | $94.98^{k}$ | $1.72^{m}$ | $5.59^{lm}$ | $5.46^{kl}$ | $5.67^{kl}$ | $5.43^{lm}$ |
| 2 | 15 | 0.25 | 0.70 | $93.03^{kl}$ | $2.19^{lm}$ | $5.67^{lm}$ | $5.56^{kl}$ | $5.99^{k}$ | $5.45^{lm}$ |
| 3 | 15 | 0.50 | 0.35 | $91.70^{kl}$ | $2.37^{l}$ | $5.87^{kl}$ | $5.79^{k}$ | $5.98^{k}$ | $5.70^{kl}$ |
| 4 | 15 | 0.25 | 0.30 | $88.57^{lm}$ | $2.89^{k}$ | $5.44^{m}$ | $5.14^{l}$ | $5.57^{l}$ | $5.15^{m}$ |
| CNT[e] | 15 | 0.25 | 0.00 | $81.58^{n}$ | $2.17^{lm}$ | $6.14^{k}$ | $5.90^{k}$ | $5.92^{kl}$ | $5.97^{k}$ |
| SEM[j] | | | | 1.22 | 0.25 | 0.12 | 0.14 | 0.12 | 0.13 |

[a] TRT = Treatment combination.
[b] PUMP = Percentage of marinade solution injected.
[c] STP = Sodium tripolyphosphate.
[d] BICARB = Sodium bicarbonate.
[e] CNT = Non-tainted control commodity loins.
[f] CY = Cook yields of loin chops.
[g] SHEAR = Shear force values measured in kg of force.
[h] SENSORY ATTRIBUTES = Consumer panel scores using an 8 point hedonic scale where 1= extremely undesirable, 8= extremely desirable.
[i] OVERALL = Overall acceptability.
[j] SEM = Standard error of the means for treatment combination (1-4) and CNT chop sensory scores.
[k-n] Means within same column with different superscripts are different ($P<0.05$).

marinade treatments had STP at either 0.25 or 0.50%. and either 0.35 or 0.70*M* BICARB with 1.0% salt.

Targeted injection levels (Table 2) were difficult to achieve since the ST and CNT loin sections (n=4) were considered an extremely small production run for the size of the automatic injection machine used. Most target injection levels were within 2.5% after injection, however, control loin batches were nearly 5.0% over the targeted injection weight. This was due to the conformation of the commodity control loin sections as they were physically deeper loins creating a longer amount of time that the injector needles were in the loins during an injection pass. Extended drain times were required to compensate for overpumping.

*Shear Force Analysis / Proximate Composition*

Least squares means for shear force values for composite marinated treatment and control chops are shown in Table 9. Results from this table show that ST loin chops marinated with TRT 1 required less force to shear ($P<0.05$) compared to chops marinated with other treatment marinades, including CNT loin chops. However, all shear force values were low indicating that all ST and CNT loin chops had acceptable tenderness. Sheard et al. (1999) and Sutton et al. (1997) reported similar findings for loin chops marinated with a solution containing STP. Least squares means for cooked moisture, fat, and protein composition are reported in Table 8. TRT 1 and CNT were significantly higher ($P<0.05$) for percent moisture than TRT 2, 3, and 4 while TRT 3 was significantly lower ($P<0.05$) than TRT 4. For fat, TRT 1 was significantly higher ($P<0.05$)

than TRT 4 and CNT and lower (P<0.05) than TRT 2 and 3. Also, TRT 2 and 3 were significantly higher (P<0.05) than TRT 1, 4, and CNT. TRT 4 was significantly higher (P<0.05) for protein than all other treatments while TRT 1 and TRT 2 had significantly less (P<0.05) protein than TRT 3, 4, and CNT loins.

*Consumer Sensory Evaluation*

Consumer sensory panel least squares means sensory scores (8 point hedonic scale) for flavor (FLAV), texture (TEXT), juiciness (JUICE), and overall acceptability (OVERALL) for marinated ST and CNT loin chops are reported in Table 9. The CNT loin chops were not different (P>0.05) for FLAV compared to ST loin chops marinated with TRT 3. However, TRT 3 was not different (P>0.05) than TRT 1 or 2 with small 95% confidence intervals (-0.70, 0.14 & -0.62, 0.22 respectively) indicating no practical important difference. TRT 4 had a significantly (P<0.05) lower higher sensory score for FLAV but was not different than TRT 1 and 2 (-0.27, 0.57 & -0.19, 0.65 respectively). These results indicate that TRT 3 was not different than the control (-0.69, 0.14) for FLAV. These findings are supported by Kauffman et al. (1998) who saw improvements in flavor by injecting a solution containing BICARB and salt in prerigor loins from gilts.

For TEXT, TRT 4 was significantly (P<0.05) lower than ST loins marinated with TRT 3 and the marinated CNT loin chops. No differences were observed (P>0.05) for ST loin chops marinated with either TRT 1, 2 or 3 compared to CNT loin chops (-0.90, 0.04; -0.80, 0.13; -0.57, 0.36 respectively). Hedrick et al. (1989) suggested that muscles from young pork are more tender than that from older pork (sows). Marination with STP and BICARB are thought to be the reason for these results as Sheard et al. (1999) and Sutton et al. (1997) both found improvements in texture (tenderness) by injecting pork with a marinade containing STP. Sheard et al. (1999) stated that increasing STP levels from 0.30% to 0.50% improved tenderness. ST loin chops with the TRT 4 marinade had the lowest TEXT score which contained the lowest percent STP (0.25%) and BICARB concentration (0.30*M*).

Treatments 1, 2, 3, & 4 were not different than the control (-0.67, 0.15; -0.34, 0.48; -0.35, 0.46; -0.76, 0.06 respectively) for JUICE. However, TRT 2 and 3 loin chops were juicier ($P<0.05$) than TRT 4 loin chops. These observations indicate that juiciness is a direct result of improved water holding capacity from the addition of phosphates (Sheard et al., 1999; Sutton, et al., 1997; and Smith et al., 1984), sodium chloride (Matlock et al., 1984; Schwartz and Mandigo, 1976; and Vote et al., 2000), and sodium bicarbonate (Bechtel et al., 1985).

Least squares means for OVERALL show that TRT 1, 2, and 4 had significantly ($P<0.05$) lower sensory scores than the control. Additionally, TRT 4 had a significantly ($P<0.05$) lower sensory score than TRT 4. However TRT 3 was not different than the control indicating its similar consumer acceptability compared to CNT chops.

As an overall observation of the sensory evaluation, it is worthy to note that although significant differences were observed in this experiment, all sensory attribute responses for all treatments were less than 1 hedonic point from the control responses. This indicates that none of the treatments yielded extremely different sensory scores than the control for any of the attributes as supported by consumer sensory panelist comments. These results show that all treatments showed some type of positive effect to the tainted hot-boned sow loins.

*Conclusions*

The acceptability of ST sow loins marinated with various combinations of STP and BICARB was determined. The focus of this research was to successfully eliminate or reduce atypical aromas and flavors. It has been shown that tainted sow loins marinated with 0.50% STP and 0.35 *M* BICARB at 15% PUMP accomplished this goal as indicated by no observed differences between ST loin chops marinated with TRT 3 (0.50% STP/0.35 *M* BICARB at 15% PUMP) and CNT marinated loin chops (0.25% STP/15% PUMP) for FLAV and OVERALL. Tenderness and juiciness attributes were not a primary focus of this research as texture can be improved by other methods such mechanical tenderization (blade tenderizing) while juiciness was not initially determined to be a problem. However ST loin chops marinated with TRT 3 showed additional improvements in texture and juiciness indicated by consumer panel sensory scores. The potential exists to inject sow meat with atypical aromas and flavors with a solution of sodium tripolyphosphate, sodium bicarbonate and salt to minimize or mask the presence of sow taint.

*Overall Conclusions*

This study concluded that consumer acceptable pork can be produced from ST sow loins by injecting a marinade of salt, STP (0.50%) and BICARB (0.70*M*). Although this study minimized or masked the presence of sow taint, additional quality problems hinder the use of marinated sow loin chops to be used for applications other than as food service. Sow loins in this study possessed a wide range of sizes (length, width, loin eye area) and possessed a much darker lean surface color. These problems would have detrimental effects for “visual” consumer acceptability if marketed at the retail level.

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# APPENDICES

## APPENDIX 1: Study I Marination Procedures

Marinades were developed at MSU according formulations developed using SAS response surface regression analysis (Version 8.0, SAS institute Inc., Cary, NC).

### Marinade Formulations

| Treatment | % pump | % $PO_4$ | g $PO_4$ | Mole $NaHCO_3$ | g $NaHCO_3$ | % Salt | g salt | g water | Total marinade wt. (g) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 7 | 0.30 | 10.00 | 0.42 | 6.41 | 1.00 | 33.17 | 181.82 | 231.37 |
| 2 | 7 | 0.30 | 10.45 | 0.63 | 9.86 | 1.00 | 34.54 | 186.36 | 241,18 |
| 3 | 7 | 0.45 | 15.45 | 0.42 | 6.41 | 1.00 | 34.08 | 181.82 | 237.73 |
| 4 | 7 | 0.45 | 15.45 | 0.63 | 9.62 | 1.00 | 34.54 | 181.82 | 241.39 |
| 5 | 13 | 0.30 | 5.00 | 0.42 | 6.57 | 1.00 | 16.50 | 186.36 | 214.39 |
| 6 | 13 | 0.30 | 5.00 | 0.63 | 9.86 | 1.00 | 16.81 | 186.36 | 218.00 |
| 7 | 13 | 0.45 | 8.18 | 0.42 | 8.18 | 1.00 | 18.36 | 204.54 | 238.26 |
| 8 | 13 | 0.45 | 7.73 | 0.63 | 9.98 | 1.00 | 17.27 | 188.63 | 223.57 |
| 9 | 5 | 0.38 | 20.90 | 0.53 | 8.50 | 1.00 | 54.99 | 190.91 | 275.26 |
| 10 | 15 | 0.38 | 6.23 | 0.53 | 9.51 | 1.00 | 16.36 | 213.63 | 245.69 |
| 11 | 10 | 0.25 | 6.14 | 0.53 | 9.11 | 1.00 | 24.31 | 204.54 | 244.06 |
| 12 | 10 | 0.50 | 11.82 | 0.53 | 8.50 | 1.00 | 23.50 | 190.91 | 234.68 |
| 13 | 10 | 0.38 | 8.63 | 0.35 | 5.61 | 1.00 | 22.72 | 190.91 | 227.84 |
| 14 | 10 | 0.38 | 8.86 | 0.70 | 11.23 | 1.00 | 23.40 | 190.91 | 234.36 |
| 15-20 | 10 | 0.38 | 61.35 | 0.53 | 58.68 | 1.00 | 159.06 | 1318.17 | 1597.00 |

### Marinade Manufacture

1. Add appropriate amount of water according to treatment from above table to 300 ml plastic volumetric flask.
2. Add Brifisol 512 sodium phosphate (BK Giulini Corporation, Simi Valley, CA).
3. Mix with roto mixer bit (3" fan style) on drill (SKIL, S-B Power Tool Co., Chicago, IL) at high speed (2250 rpm) for 2 minutes 30 seconds.
4. Add Sodium Bicarbonate (NaHCO3) powder (J.T. Baker, Phillipsburg, NJ)
5. Mix with roto mixer bit (3" fan style) on drill (SKIL, S-B Power Tool Co., Chicago, IL) at high speed (2250 rpm) for 2 minutes.
6. Add food grade Sodium Chloride (NaCl).

7. Mix with roto mixer bit (3" fan style) on drill (SKIL, S-B Power Tool Co., Chicago, IL) at high speed (2250 rpm) for 2 minutes.

8. Transfer each marinade into 250 ml plastic bottle, measure pH, and cap.

**Marination Procedure**

1. Place 6 x 10 inch (15.24 x 25.4 cm) or 10 x 12 inch (25.4 x 30.48 cm) vacuum bag (Cryovac, Simpsonville, SC) in a 1000 ml plastic volumetric flask and tare scale. (The larger bags were used to accommodate the larger loin sections.)

2. Place randomly selected loin section in bag, weigh, and add randomly selected marinade treatment.

3. Vacuum package each loin section with marinade treatment using Multi Vac AGW (SeppHaggenmuller KG, Germany) set at 1.5 vacuum and 3.0 bar heat.

**Tumbling Procedure**

Loin sections were segregated into 3 groups according to loin section weight. The weight groups with appropriate treatments were as follows:

Light group (n=8): T1, T4, T6, T8, T10, T13, T14, T16

Medium group (n=6): T3, T7, T11, T15, T17, T20

Heavy group (n=6): T2, T5, T9, T12, T18, T19

1. Place group of loin sections into Lyco Vacuum tumbler (model 20, Columbus, WI) at setting 70% for 15 minutes with a 20 psi. vacuum for 15 minutes with a 1 minute rest between each minute of tumbling.

## APPENDIX 2: Rigor Determination (pH)

For this experiment, 10 g samples removed upon loin arrival were utilized. This experiment was done to determine if loins had gone through rigor.

1. Dice frozen sample with a knife into fine pieces.

2. Weigh one gram of sample and place into a 50 ml centrifuge plastic tube (do in duplicates).

3. Add 10 ml of distilled, deionized water to each centrifuge tube.

4. Homogenize sample with Polytron mixer (PT-35, Kinematica, AG, Switzerland) on speed setting 2 for 2, 10 second bursts. Rinse and blot dry Polytron bit between each sample.

5. Measure the pH of sample using Accumet pH meter (AB 15, Fisher Scientific, Co., Pittsburgh, PA) calibrated with buffer 4.0 and 7.0.

6. Allow samples to rest in –6.7°C cooler for 10 minutes.

7. After 10 minute rest, remeasure pH of sample.

## APPENDIX 3: Rigor Determination (R-value)

Honikel, K. O., & Fischer, C. (1977). A rapid method for the detection of PSE and DFD porcine muscles. *Journal of Food Science, 42*(6), 1633-1636.

1. Phosphate Buffer

To prepare 0.1 M of phosphate buffer:

Solution A: dissolve 27.8 g of 0.2 M monobasic sodium phosphate into 1 liter of distilled, deionized water.

Solution B: dissolve 28.39 g of 0.3 M dibasic sodium phosphate into 1 liter of distilled, deionized water.

0.1 M phosphate buffer: add 39 ml of solution A, 61 ml of solution B, and 100 ml of distilled, deionized water to create 200 ml.

2. Perchloric Acid

To prepare 0.6 N of Perchloric Acid:

Add 5.2 ml of 70% Perchloric Acid to 100 ml of distilled, deionized water. Refrigerate solution to 3.3-4.4°C.

**Procedure:**

Preparing control:

1. Add 60 ul of distilled deionized water to cuvette.
2. Add 3 ml of 0.1 M phosphate buffer to cuvette.
3. Cover cuvette with parafilm and invert 3 times to mix.
4. Read on spectrophotometer (Lambda 20, Perkin Elmer, Norwalk, CT) at $A_{250}$ and $A_{260}$ wavelengths.

Preparing samples:

1. Weigh 2 g of frozen and diced uniform sample. Place sample in 50 ml plastic centrifuge tube.

2. Add 10 ml of refrigerated 0.6 N Perchloric Acid (3.3-4.4°C) to 50 ml plastic centrifuge tube containing sample.

3. Place centrifuge tube into 150 ml beaker of ice.

4. Homogenize sample with Polytron mixer (PT-35, Kinematica, AG, Switzerland) set on speed setting 4 with 2, 30 second bursts while sample is on ice. Rinse and blot dry Polytron bit between each sample

5. Transfer homogenate from 50 ml plastic centrifuge tube to 30 ml glass centrifuge tube.

6. Centrifuge homogenate at 40,000 x g for 20 minutes using RC-5 Super speed refrigerated centrifuge (Sorvall Co., Norwalk, CT).

7. Remove 30 ml tubes from centrifuge and place in a bucket filled with ice.

8. Mix each 30 ml tube using Vorex mixer (American Scientific Products, McGaw Park, IL) for 15 seconds.

9. Pipet 3 aliquots (60ul each) of supernatant from each sample and place into 3 quartz cuvettes.

10. Cover cuvette with parafilm and invert 3 times to mix.

11. Read sample on spectrophotometer (Lambda 20, Perkin Elmer, Norwalk, CT) at $A_{250}$ and $A_{260}$ wavelengths.

12. Rinse cuvettes with distilled, deionized water and wipe outside surface of cuvette dry with chemical wipes between samples.

## APPENDIX 4: pH Determination

1. Buffer Preparation

To prepare buffer used to stop glycolysis:

| Buffer Amount | Sodium Iodoacetate | Potassium Chloride |
|---|---|---|
| 500 ml | 0.52g (5mM) | 5.592g (150mM) |
| 1500 ml | 1.56g (5mM) | 16.776g (150mM) |

**Procedure:** (done in duplicate)

1. Homogenize 1 gram of uniform sample with 10 ml of buffer in a 50 ml plastic centrifuge tube with Polytron mixer (PT-35, Kinematica, AG, Switzerland) set on speed setting 4 with 2, 10 second bursts. Rinse and blot dry Polytron bit between each sample.

2. The pH was measured using an Accumet Scientific pH meter (AB 15, Fisher Scientific, Co., Pittsburgh, PA) calibrated using buffers 4.0 and 7.0.

3. The pH meter probe was rinsed with distilled, deionized water between sample readings.

## APPENDIX 5: Objective Color and Subjective Color, Marbling, and Firmness Analysis

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Baas, T., Bell, B., Berg, E., Boyd, D., Cannon, J., Carr, T., Forrest, J., Goodwin, R., Green, B., Johnson, R., van Laack, R., Mandigo, R., McKeith, F., Meisinger, D., Miller, R., Moeller, S., Morgan, B., Prusa, K., Schnell, T., Sellers, H., Sosnicki, A., Wulf, D. (2000). Meat quality evaluation. In E. Berg (Ed.), *Pork Composition and Quality Assessment Procedures* (pp. 26-28). Des Moines, Iowa: National Pork Board.

National Pork Producers Council (1999). Color, texture, exudation; color standards, and marbling standards. *Pork Quality Standards.* Des Moines, Iowa: National Pork Board.

### Sample Preparation

1. Separate loins into 2 equal (in length) sections by a cross cut with a knife at the midline perpendicular to the length of the loin

2. Remove two, 2.54 cm chops from the anterior end of the posterior section of the loin with a knife.

3. Label the first chop removed as "A" and the second chop removed as "B".

4. Allow each chop to bloom for 10 minutes before evaluation.

5 Immediately evaluate each chop after 10 minute bloom time.

### Subjective Color, Marbling, Firmness Evaluation

1. Evaluate chop using Pork Quality Standards (1999).

   Color is evaluated using a scale of 1 to 6 with: 1 = pale pinkish gray to white, 2 = grayish pink, 3 = reddish pink, 4 = dark reddish pink, 5 = purplish red, 6 = dark purplish red.

   Marbling is evaluated using a scale of 1 to 10 with the numerical numbers equaling percent of lipid content.

   Firmness is evaluated using a scale of 1 to 3 with: 1 = soft (cut surfaces distort easily and are visibly soft), 2 = firm (cut surfaces tend to hold their shape), 3 = very firm (cut surfaces tend to be smooth with no distortion of shape)

**Objective Color Evaluation using Minolta Chromameter CR-310 (Commission D'Edairerage (CIE) L*a*b*,Ramsey, NJ) Calibration**

1. Calibrate Minolta Chromameter CR-310 (Commission International D'Edairerage (CIE) L*a*b*, Ramsey, NJ). using a standard white tile.

2. Set Minolta Chromameter on L*a*b*, D65 (daylight illuminator), 2° standard observer, with a 50 mm reading orifice. Take 3 measurements and average them.

## APPENDIX 6: TBA Analysis

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Tarladgis, G. G., Watts, B. M., Younthan, M. T., and Dugan, L. Jr. (1960). *Journal of American Oil Chemists, 37*, 44-48.
Zipser, M.W., Wats, B. M. (1962). *Food Technology, 16*(7), 102.

1. TBA Reagent

Prepare the amount of TBA Reagent needed for your samples according to the table below:

| Thiobarbituric Acid | Distilled Water | Total Vol. Water and Acid |
|---|---|---|
| 1.4416 g | 50 ml | 500 ml |
| 0.7208 g | 25 ml | 250 ml |
| 0.5766 g | 20 ml | 200 ml |
| 0.2883 g | 10 ml | 100 ml |
| 0.1442 g | 5 ml | 50 ml |

Dissolve the Thiobarbituric Acid (Eastman Organic Chemicals) in the distilled water and about 2/3 the total volume of acetic acid. Place flask in sonic cleaner (several minutes) and shake occasionally until TBA is dissolved. Allow reagent to come to room temperature then bring to volume. Store in cooler, may be kept for 2 days.

2. HCl Solution

Make volume as needed; 1:2, HCl : $H_2O$ (v/v).

3. Antifoam (Thomas®, Swedeboro, NJ)

The use of antifoam may not be necessary depending on the product. Fish and egg require antifoam while poultry does not. In this study, antifoam was used.

**Procedure:**

1. Assemble connecting tube (spouts) and graduated cylinders.
2. Turn on condenser water.
3. Add 10 g of thawed and diced sample to 100 ml plastic bottle containing 50 ml distilled water plus 10 ul antioxidant solution (Tenox 5 – food grade BHA+BHT).

4. Homogenize sample plus solution using Polytron mixer (PT-35, Kinematica, AG, Switzerland) on speed setting 4 for 1 minute (Homogenized samples can be held in cooler if needed).

5. Into 500 ml extraction flasks, add 4, 4 mm glass beads (Fisher Scientific, Pittsburgh, PA), homogenized meat sample, 2.5 ml HCl solution, 47.5 ml distilled water, and 2 sprays of antifoam (Note: total volume is 50 ml + 2.5 ml + 47.5 ml = 100 ml).

6. Connect extraction flasks to distilling tubes and tighten heating mantles in place.

7. Turn powerstats to line voltage (setting 85) and heat flasks rapidly.

8. Distill and collect 50 ml of the distillate.

9. Transfer distillate to 50 ml centrifuge tubes, cap and hold in refrigerator for TBA reaction. (Can be held for 18 hours).

TBA Reaction / Spectrophotometric Determination

10. Invert each test tube containing the 50 ml distillate and pipette 5 ml into each of 2 tubes labeled "A" and "B". Prepare 2 blanks by pipetting 5 ml distilled water into both tubes labeled "A" and "B".

11. Add 5 ml of TBA Reagent into each tube containing 5 ml of sample and into both blanks. Thoroughly mix each tube using Vortex mixer (American Scientific Products, McGaw Park, IL).

12. Turn water bath on 100° C.

13. Place tubes in test tube rack and immerse into boiling water bath (model 9510 PolyScience, Sorvall Co., Niles, IL) for 30 minutes.

14. Turn Spectrophotometer (Lambda 20, Perkin Elmer, Norwalk, CT) to IDLE (must warm up 20 min.)

15. When the tubes are done heating in the water bath cool them in ice for at least 10 minutes.

16. Mix each test tube with sample for 10 seconds using Vortex mixer (American Scientific Products, McGaw Park, IL).

17. Transfer sample to disposable 4.5 ml cuvette (done in duplicates).

18. Turn Spec to ON: Manually adjust wave length to 530 nm for fresh meat (read samples within 1 hour).

19. Convert % T to optical density and multiply by the constant 7.8 (7.6 for poultry) to convert to mg malonaldehyde/1000 g of sample, i.e. TBA Number.

## APPENDIX 7: Proximate Analysis

AOAC (1995). Meat and meat products. In P. Cunniff (Ed.), *Official methods of analysis of AOAC International* (pp. 1-23). Washington, DC: AOAC International.

**Sample Preparation** (modified from section 983.18 Meat and Meat Products)

1. Section meat into very small (<1 cm squares) pieces. If already frozen, smash samples with a hammer to decrease size of sample for ease of grinding.

2. Add sample to Tekmar grinders (Tekmar Co, Cincinnati, OH) filling grinding chamber half full.

3. Then add dry ice to fill up chamber.

4. Grind 2 to 3 minutes using Tekmar grinder (Tekmar Co, Cincinnati, OH) until sample is ground into a fine powder. It may be necessary to stop in the middle of grinding and stir the sample up for uniform grinding.

5. Transfer finely ground powder to labeled whirl pack bags. Loosely close bag so that dry ice can evaporate and dissipate. This takes about 2 days. Place in freezer immediately to prevent melting of powder.

**Moisture Analysis**

6. Place a medium weigh boat on scale and zero. This is to keep the scale clean. Add paper labeled with sample ID and paperclip. Record the weight then tare the scale.

7. Add 2 grams ($\pm$ .03g) of thoroughly mixed sample to the paper. Once desired weight is reached record weight and fold over top. Secure by folding and tucking top. Place flat on tray. Do all samples in triplicate. Do not stack samples on tray. This will hinder the drying process.

8. Once tray is full, place in drying oven set at 100°C for 20 - 24 hours.

9. After drying, place samples using latex gloves or tongs in dessicator to cool completely before weighing. Once cool, weigh samples and record. This is your final weight for moisture and your initial weight for fat analysis. Use the following formula to determine the percent moisture in your samples:

$$\text{Moisture (\%)} = \frac{\text{wet sample wt.} - \text{dry sample wt.}}{\text{wet sample wt.}} \times 100$$

**Fat Analysis Using Soxhlet Ether Extraction**

10. Take samples from moisture analysis and place in extraction tubes. Make sure that all the samples are below the level where the ether drains off (curved glass on outside of tube).

11. Add petroleum ether to clean boiling flasks until about ¾ full. Add 2 to 3 glass beads as a boiling aid.

12. Connect the extraction flask to the boiling flask and Soxhlet apparatus. Place parafilm on the joint. Mount both to the condensing units on top of extraction flasks using parafilm around joint.

13. Turn on condensing water so it runs at a steady stream.

14. Set Rheostats on high and run for 24 hours.

15. Place ether soaked samples onto a tray in a hood for 2 hours to allow ether to dissipate.

16. Place samples in drying oven for 5 to 10 min to remove any possible moisture then place in dessicator for 1/2 hour to cool.

17. Weigh and record the weight of the samples. Calculate fat on wet basis with the following equation:

$$\text{Fat (\%)} = \frac{\text{dry sample wt.} - \text{extracted sample wt.}}{\text{wet sample wt.}} \times 100$$

**Protein Analysis**

1. Weigh out approximately 1 gram of powdered meat into the tared crucible. Write the weight and sample ID on the side of the crucible with pencil.

2. After weighing out samples, dry for 18 to 20 hours in the drying oven at 100°C. This removes moisture that can cause internal malfunctions with the Leco Protein Analyzer. Do not reweigh samples. Enter wet weight into computer.

Procedures for the LECO FP 2000 Nitrogen Analyzer

1. Open valves completely on oxygen, helium and compressed air tanks. Make sure tanks have adequate levels of gas (gauge should read >100psi) and that the pressure out of the tanks are set at 40 psi.

2. Press escape on upper left hand corner of touch screen until "front panel" comes up and then press it. On right hand side of screen a section labeled "analysis gas" can be found. Push the "on" button to turn gasses on to the machine. Check to see that your furnace temperature is 1050°F (located on left part of screen).

3. Wait about 5 minutes for all gasses to equilibrate then start your leak tests. Press escape from the front panel located in upper left corner. A screen with several icons will appear. Press "maintenance". This will bring up helium leak test, combustion leak test and ballast leak test icons. Press the helium leak test. If it passes move onto the combustion leak test. Once finished, start running blanks. Run a ballast test as it is part of the combustion system.

4. Run several air blanks through to purge the system. To do this escape from the "maintenance" section and push the "analyze" icon. On the bottom of the screen you will see several commands. Push "select ID code". Toggle the highlighted line using the arrows to blanks. Then push exit on bottom. Then push manual weight. This will bring up a touch screen with 0.2000000 on it. Push the enter button at least 10 times to bring up 10 rows of 0.20000. Then push analyze. The machine will run through these ten samples. Numbers should come down to about <.30% protein.

5. Once blanks are at an acceptable number, run 4 to 5 EDTA samples (approximately 0.5g) to verify machine is operating properly.

6. Weigh EDTA samples out in the ceramic boats and write the weight on the side in pencil (at least three decimal places).

7. Select "manual weight" and put your weight into the machine pushing enter after each entry. Once weights are entered, push analyze. Follow the directions on the touch screen. Push your first sample into the chamber about one half inch so the door doesn't catch the boat. Push okay on the screen when it asks you place your sample in the chamber. The next message will tell you to wait because the system is purging. Then the machine will then tell you to push the boat into the chamber. The machine will combust and analyze the sample in approximately 3 minutes.

8. Analyze samples as described in step 7.

## APPENDIX 8: Drip Loss Analysis

Baas, T., Bell, B., Berg, E., Boyd, D., Cannon, J., Carr, T., Forrest, J., Goodwin, R., Green, B., Johnson, R., van Laack, R., Mandigo, R., McKeith, F., Meisinger, D., Miller, R., Moeller, S., Morgan, B., Prusa, K., Schnell, T., Sellers, H., Sosnicki, A., Wulf, D. (2000). Meat quality evaluation. In E. Berg (Ed.), *Pork Composition and Quality Assessment Procedures* (pp. 21-22). Des Moines, Iowa: National Pork Board.

Honikel, K. O. (1987). Critical evaluation of methods detecting water-holding capacity in meat. In A. Romita, C Valin, and A. Talyor (Eds.) *Accelerated Processing of Meat* (pp. 225-239), London: Elsevier Applied Science.

**Sample Preparation** (Modified)

1. The two, 2.54 cm chops removed from the anterior end of the posterior section of each loin used in objective color and subjective color, marbling, and firmness experiments were used for this experiment. Each loin chop was labeled A (first chop removed from loin) and B (second chop removed from loin) and weighed.

2. Weigh each chop.

3. Insert dead lock (or hook) into top portion of chop. Attach string (approximately 30.48 cm in length) to dead lock. Tie loose end of string to another dead lock. (This end will be used for hanging purposes.)

4. Hang each chop by hooking free dead lock to a rack. Make sure chops are hang independently and freely.

5. Enclose chop with a plastic bag to reduce environment effects (wind).

6. Allow chops to hang for 48 hours in 2.8°C cooler.

7. Remove chops from string and dead lock apparatus and reweigh.

8. Percent drip loss is calculated by the following equation:

$$\%\text{ drip loss} = \frac{\text{Initial chop wt.} - \text{48 hour chop wt.}}{\text{Initial chop wt.}} \times 100$$

## APPENDIX 9: Purge Loss Analysis

1. Loin sections (anterior and posterior) were weighed after sections were tempered in 2.6°C cooler for 18 hours.

2. Loin sections were vacuum packaged in 12 x 16 inch (30.48 x 40.64 cm) vacuum bags (Cryovac, Simpsonville, SC) using Multivac vacuum packager (AG800, SeppHaggenmuller KG, Germany) set at 3.0 psi. of vacuum and 4.5 bar heat.

3. Loin sections remained in 2.6°C cooler for 7 days.

4. Remove loins from vacuum package, blot loins semi-dry with paper towel, and reweigh.

5. Percent purge loss was determined using the following calculation:

$$\% \text{ purge loss} = \frac{\text{Initial loin wt.} - \text{Wt. of loin at day 7}}{\text{Initial loin wt.}} \times 100$$

## APPENDIX 10: Marinade Uptake / Cooking Yield Procedures

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Baas, T., Bell, B., Berg, E., Boyd, D., Cannon, J., Carr, T., Forrest, J., Goodwin, R., Green, B., Johnson, R., van Laack, R., Mandigo, R., McKeith, F., Meisinger, D., Miller, R., Moeller, S., Morgan, B., Prusa, K., Schnell, T., Sellers, H., Sosnicki, A., Wulf, D. (2000). Meat quality evaluation. In E. Berg (Ed.), *Pork Composition and Quality Assessment Procedures* (pp. 23). Des Moines, Iowa: National Pork Board.

### Sample Preparation

For this experiment, two, 2.54 cm chops previously used for 48 hour drip loss were utilized. This analysis was performed in triplicate.

1. Make sure no external fat is present on chop. If present, remove.

2. Grind loin chop through 6.4 mm (1/4 inch plate) using Kitchen Aid mixer with grinder attachment (model K5-A, Hobart, Troy, OH).

### Reagent Buffer Preparation

1. Dissolve 35 g Sodium Chloride (NaCl) into 1 liter of distilled deionized water.

### Marinade Uptake Procedure

1. Weigh and number 50 ml centrifuge tube (without cap). Record the weight of tubes to the second decimal point (0.01 g).

2. Weigh 6.00 g $\pm$ 0.01g of representative sample and place into each centrifuge tube (done in triplicates).

3. Add 10 ml of reagent buffer to centrifuge tube.

4. Place screw cap on centrifuge tube and shake gently until sample breaks apart.

5. Mix sample with Vortex mixer (American Scientific Products, McGaw Park, IL) for 15 seconds.

6. Place centrifuge tubes in a 25°C water bath (model 9510, PolyScience, Niles, IL) for 30 minutes.

7. Remove centrifuge tubes from water bath and centrifuge for 20 minutes at 3000 rpm (800 x g) using super speed refrigerated centrifuge (RC-5, Sorvall Co., Norwalk, CT).

8. Remove cap from centrifuge tube and place open side down on cheese cloth for 5 minutes.

9. Weigh samples and tubes (with screw caps off).

10. Calculate marinade uptake (MU) using following equation:

$$MU = \frac{\text{(Wt. tube \& meat after 25°C incubation)} - \text{(Initial wt. of tube \& meat)}}{6.00\ g} \times 100$$

**Cooking Yield Procedure**

11. After final weight determination from marinade uptake experiment (step 9), loosely cap centrifuge tubes and place in 80°C water bath (model 9510, PolyScience, Niles, IL) for 20 minutes.

12. Remove centrifuge tubes from water bath and drain cook-out water and place upside down on cheese cloth for 5 minutes.

13. Chill samples to 20-22°C.

14. Weigh centrifuge tube containing sample to determine cooking yield (CY) using the following equation:

$$CY = \frac{\text{(Wt. of tube \& meat, after 80°C incubation)} - \text{(Initial wt. of tube \& meat)}}{6.00\ g} \times 100$$

## APPENDIX 11: Study I Trained Sensory Panel Ballot

Panelist Name____________________ Date____________________

### PORK FLAVOR / TEXTURE PROFILE BALLOT

| SAMPLE ID # | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
|---|---|---|---|---|---|---|---|---|
| **AROMATICS:** | Aromatic | Flavor | Aromatic | Flavor | Aromatic | Flavor | Aromatic | Flavor |
| Cooked Pork Lean / Brothy | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| Cooked Pork Fat | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| Cardboard | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| Painty | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| Fishy | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| Soapy | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| Soda | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| Metallic | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| Astringent | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| Other | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| **TASTES:** | | | | | | | | |
| Salt | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| Sour | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| Bitter | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| Sweet | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| **AFTERTASTES:** | | | | | | | | |
| Soapy | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| Other | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| **TEXTURES** | | | | | | | | |
| Muscle Fiber Tenderness | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| Juiciness | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| Overall Tenderness | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| Connective Tissue | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |

**JUICINESS**
8. Extremely Juicy
7. Very Juicy
6. Moderately Juicy
5. Slightly Juicy
4. Slightly Dry
3. Moderately Dry
2. Very Dry
1. Extremely Dry

**FIBER/OVERALL TENDERNESS**
8. Extremely Tender
7. Very Tender
6. Moderately Tender
5. Slightly Tender
4. Slightly Tough
3. Moderately Tough
2. Very Tough
1. Extremely Tough

**CONNECTIVE TISSUE**
8. None
7. Practically None
6. Traces
5. Slight
4. Moderate
3. Slightly Abundant
2. Moderately Abundant
1. Abundant

## APPENDIX 12: Study I Sensory Panel Sample Randomization

| Replication | Day Evaluated | Treatments Evaluated |
|---|---|---|
| 1 | Friday, Dec. 7 | Tainted control, Non-tainted control,T10, T9, T12, T20, T8, T11, T6, T4, T5, T13 |
| 1 | Tuesday, Dec. 11 | Tainted control, Non-tainted control, T3, T1, T7, T2, T14, T15, T16, T17, T18, T19 |

**APPENDIX 13: Study II Classification of loin sections used for treatments and 7 day purge loss values of sow loins possessing atypical aroma and flavor (sow taint, ST) and non-tainted control commodity loins (CNT).**

| REP | TRT[a] | LOIN[b] | A/P[c] | T/NT[d] | PURGE LOSS (%)[e] |
|---|---|---|---|---|---|
| 1 | 1 | 22 | A | T | 0.72 |
| 1 | 1 | 24 | A | T | 2.23 |
| 1 | 1 | 19 | P | T | 4.61 |
| 1 | 1 | 34 | P | T | 3.13 |
| 1 | 2 | 7 | A | T | 3.16 |
| 1 | 2 | 34 | A | T | 2.33 |
| 1 | 2 | 17 | P | T | 3.73 |
| 1 | 2 | 25 | P | T | 2.52 |
| 1 | 3 | 19 | A | T | 2.46 |
| 1 | 3 | 21 | A | T | 3.85 |
| 1 | 3 | 20 | P | T | 5.69 |
| 1 | 3 | 30 | P | T | 4.07 |
| 1 | 4 | 9 | A | T | 5.45 |
| 1 | 4 | 10 | A | T | 4.11 |
| 1 | 4 | 9 | P | T | 7.32 |
| 1 | 4 | 16 | P | T | 4.30 |
| 1 | CNT | 1 | A | NT | NA[f] |
| 1 | CNT | 2 | A | NT | NA[f] |
| 1 | CNT | 1 | P | NT | NA[f] |
| 1 | CNT | 2 | P | NT | NA[f] |
| 2 | 1 | 23 | A | T | 3.93 |
| 2 | 1 | 30 | A | T | 4.74 |
| 2 | 1 | 1 | P | T | 1.94 |
| 2 | 1 | 13 | P | T | 2.17 |
| 2 | 2 | 17 | A | T | 2.99 |
| 2 | 2 | 32 | A | T | 7.55 |
| 2 | 2 | 6 | P | T | 6.92 |
| 2 | 2 | 33 | P | T | 8.96 |
| 2 | 3 | 16 | A | T | 1.88 |
| 2 | 3 | 33 | A | T | 5.29 |
| 2 | 3 | 7 | P | T | 2.24 |
| 2 | 3 | 27 | P | T | 3.13 |
| 2 | 4 | 3 | A | T | 3.92 |
| 2 | 4 | 8 | A | T | 2.67 |
| 2 | 4 | 28 | P | T | 4.31 |
| 2 | 4 | 29 | P | T | 3.09 |
| 2 | CNT | 3 | A | NT | NA[f] |
| 2 | CNT | 6 | A | NT | NA[f] |
| 2 | CNT | 4 | P | NT | NA[f] |
| 2 | CNT | 6 | P | NT | NA[f] |
| 3 | 1 | 1 | A | T | 3.15 |
| 3 | 1 | 13 | A | T | 1.12 |
| 3 | 1 | 3 | P | T | 1.53 |
| 3 | 1 | 18 | P | T | 2.83 |
| 3 | 2 | 2 | A | T | 1.79 |
| 3 | 2 | 12 | A | T | 9.05 |
| 3 | 2 | 12 | P | T | 4.35 |
| 3 | 2 | 26 | P | T | 3.35 |
| 3 | 3 | 20 | A | T | 3.76 |
| 3 | 3 | 26 | A | T | 3.11 |
| 3 | 3 | 8 | P | T | 1.98 |
| 3 | 3 | 10 | P | T | 1.90 |
| 3 | 4 | 14 | A | T | 4.52 |
| 3 | 4 | 27 | A | T | 3.35 |
| 3 | 4 | 31 | P | T | 1.74 |
| 3 | 4 | 32 | P | T | 4.83 |
| 3 | CNT | 4 | A | NT | NA[f] |
| 3 | CNT | 5 | A | NT | NA[f] |
| 3 | CNT | 3 | P | NT | NA[f] |
| 3 | CNT | 5 | P | NT | NA[f] |

[a] TRT = Marinated Treatment Combination.
[b] LOIN = Corresponding loin section used for treatment combination.
[c] A/P = Anterior or Posterior loin section.
[d] T/NT = Tainted or non-tainted loin section.
[e] PURGE LOSS = 7 day purge loss (%).
[f] NA = Purge loss not measured.

## APPENDIX 14: Study II Marination Procedures

### Marinade Formulations:

| Treatment 1 | 15% pump marinade | | |
|---|---|---|---|
| | lbs | g/mL | %/M |
| Water | 60.000 | 27,272.40 | |
| Sodium Chloride | 4.700 | 2,135.92 | 1.00 |
| Sodium Bicarbonate | 3.529 | 1,603.62 | **0.70** |
| Tripolyphosphate | 2.350 | 1,067.96 | 0.50 |
| Total | 70.579 | 32,074.49 | |

| Treatment 2 | 15% pump marinade | | |
|---|---|---|---|
| | lbs | g/mL | %/M |
| Water | 60.000 | 27,272.40 | |
| Sodium Chloride | 4.600 | 2,090.47 | 1.00 |
| Sodium Bicarbonate | 3.529 | 1,603.62 | **0.70** |
| Tripolyphosphate | 1.150 | 522.62 | 0.25 |
| Total | 69.279 | 31,483.70 | |

| Treatment 3 | 15% pump marinade | | |
|---|---|---|---|
| | lbs | g/mL | %/M |
| Water | 60.000 | 27,272.40 | |
| Sodium Chloride | 4.600 | 2,090.47 | 1.00 |
| Sodium Bicarbonate | 1.764 | 801.81 | **0.35** |
| Tripolyphosphate | 2.300 | 1,045.24 | 0.50 |
| Total | 68.664 | 31,204.51 | |

| Treatment 4 | 15% pump marinade | | |
|---|---|---|---|
| | lbs | g/mL | %/M |
| Water | 60.000 | 27,272.40 | |
| Sodium Chloride | 4.500 | 2,045.03 | 1.00 |
| Sodium Bicarbonate | 1.764 | 801.81 | **0.35** |
| Tripolyphosphate | 1.120 | 508.98 | 0.25 |
| Total | 67.384 | 30,622.82 | |

| Control | 15% pump marinade | | |
|---|---|---|---|
| | lbs | g/mL | %/M |
| Water | 60.000 | 27,272.40 | |
| Sodium Chloride | 4.350 | 1,976.86 | 1.00 |
| Sodium Bicarbonate | 0.000 | 0.00 | **0.00** |
| Tripolyphosphate | 1.100 | 499.90 | 0.25 |
| Total | 65.450 | 29,743.75 | |

**Marinade Manufacture**

1. Add appropriate amount of water according to treatment from above table to 75.7 liter (20 gallon) barrel..
2. Add Brifisol 512 sodium phosphate (BK Giulini Corporation, Simi Valley, CA).
3. Mix with Rotostat mixer (Model 80XP63SS, Admix Inc., Londonderry, NH) at 2500 rpm for 7 minutes. (begin timing mixing once all phosphate is added)
4. Add Sodium Bicarbonate ($NaHCO3$) powder (J.T. Baker, Phillipsburg, NJ)
5. Mix with Rotostat mixer (Model 80XP63SS, Admix Inc., Londonderry, NH) at 2500 rpm for 3 minutes. (begin timing mixing once all sodium bicarbonate is added)
6. Add food grade Sodium Chloride ($NaCl$).
7. Mix with Rotostat mixer (Model 80XP63SS, Admix Inc., Londonderry, NH) at 2500 rpm for 3 minutes. (begin timing mixing once all sodium chloride is added)
8. Repeat steps for each marinade (n=5).

**Marination Procedure**

1. Weigh loin section group to determine initial injection weight. Calculate targeted injection weight.
2. Place appropriate loin sections (n=4) onto conveyer.
3. Reweigh loin section group to determine injected weight and drain or add additional marinade until targeted injection weight it met.

**APPENDIX 15: Study I Least squares means for marination uptake and cook yields of of sow loins possessing atypical aroma and flavor (sow taint, ST).**

| LOIN[a] | MARINATION UPTAKE % | COOK YIELD % |
|---|---|---|
| 1 | 46.44 | 99.83 |
| 2 | 24.28 | 82.89 |
| 3 | 28.50 | 84.28 |
| 4 | 34.89 | 91.67 |
| 5 | 35.72 | 92.78 |
| 6 | 26.89 | 77.61 |
| 7 | 62.50 | 117.39 |
| 8 | 36.89 | 92.56 |
| 9 | 32.28 | 86.44 |
| 10 | 36.28 | 93.78 |
| 11 | 26.95 | 84.11 |
| 12 | 33.44 | 88.17 |
| 13 | 30.61 | 84.83 |
| 14 | 26.50 | 85.39 |
| 15 | 22.78 | 81.83 |
| 16 | 29.78 | 84.55 |
| SEM[b] | 4.57 | 3.43 |

[a] LOIN = Sow loins with atypical aroma and flavor (sow taint).
[b] SEM = Standard error of the means for sow loins with taint.

**APPENDIX 16: Study I Cooking times and yields of marinated treatment combinations for sow loins possessing atypical aroma and flavor (sow taint, ST) and non-tainted control commodity loins (CNT).**

| | COOKING ANALYSIS | | LOIN TRACKING | |
|---|---|---|---|---|
| | TIME | YIELD | LOIN[b] | SECTION[c] |
| TRT[a] | min | % | | |
| 1 | 0:22 | 74.04 | 2 | P |
| 2 | 0:29 | 71.75 | 3 | A |
| 3 | 0:17 | 81.95 | 11 | A |
| 4 | 0:22 | 77.95 | 3 | P |
| 5 | 0:26 | 76.61 | 12 | A |
| 6 | 0:26 | 73.78 | 1 | A |
| 7 | 0:17 | 80.33 | 5 | A |
| 8 | 0:29 | 76.26 | 5 | P |
| 9 | 0:38 | 70.61 | 7 | A |
| 10 | 0:23 | 76.21 | 10 | A |
| 11 | 0:29 | 78.89 | 8 | A |
| 12 | 0:33 | 71.26 | 4 | A |
| 13 | 0:29 | 73.73 | 6 | A |
| 14 | 0:25 | 77.22 | 13 | A |
| 15 | 0:15 | 78.24 | 16 | A |
| 16 | 0:53 | 81.83 | 15 | A |
| 17 | 0:28 | 76.76 | 14 | A |
| 18 | 0:18 | 73.80 | 2 | A |
| 19 | 0:27 | 72.26 | 9 | A |
| 20 | 0:24 | 78.74 | 4 | P |
| CNT[d] | 0:15 | 74.70 | 28 | P |
| CNT[d] | 0:27 | 67.45 | 29 | P |
| ST[e] | 0:14 | 84.52 | 7 | P |
| ST[e] | 0:23 | 70.88 | 13 | P |

[a] TRT = Treatment combination.
[b] LOIN = Loin used for treatment combination.
[c] SECTION = Loin section used where "A"= anterior section and "P"= posterior section.
[d] CNT = Non-tainted control sow loins.
[e] ST = Sow loins with atypical aroma and flavor (sow taint).

**APPENDIX 17: Study II Least squares means for rigor determination (pH change) for randomly selected sow loins possessing atypical aroma and flavor (sow taint, ST).**

| LOIN[a] | pH DIFF[b] |
|---|---|
| 1 | 0.035 |
| 4 | -0.075 |
| 7 | 0.015 |
| 10 | 0.010 |
| 15 | 0.050 |
| 19 | -0.010 |
| 23 | 0.040 |
| 27 | 0.070 |
| 30 | 0.015 |
| 34 | 0.030 |
| SEM[c] | 0.020 |

[a] LOIN = Sow loins selected for rigor verification.
[b] pH DIFF= Differences in pH units between initial and 10 minute pH.
[c] SEM = Standard error of the means for randomly selected tainted loins.

**APPENDIX 18: Study II Least squares means for raw composition, pH, marinade uptake, and cook yields of of sow loins possessing atypical aroma and flavor (sow taint, ST) and non-tainted control commodity loins (CNT).**

RAW COMPOSITION

| LOIN | ST/CNT[a] | MOISTURE % | FAT % | PROTEIN % | pH[b] | MU[c] % | CY[d] % |
|---|---|---|---|---|---|---|---|
| 1 | ST | 76.08 | 2.29 | 23.97 | 5.77 | 53.22 | 99.45 |
| 2 | ST | 77.50 | 1.64 | 23.58 | 6.18 | 63.00 | 107.84 |
| 3 | ST | 75.80 | 0.96 | 24.85 | 5.93 | 51.39 | 99.06 |
| 4 | ST | 74.62 | 3.58 | 24.04 | 5.73 | 45.39 | 102.89 |
| 5 | ST | 75.22 | 2.26 | 24.43 | 6.02 | 48.00 | 96.83 |
| 6 | ST | 76.67 | 1.25 | 22.56 | 5.51 | 37.22 | 99.17 |
| 7 | ST | 76.74 | 0.94 | 24.49 | 5.72 | 40.22 | 92.83 |
| 8 | ST | 77.73 | 1.39 | 23.35 | 6.09 | 71.28 | 109.17 |
| 9 | ST | 77.83 | 0.45 | 22.71 | 5.47 | 17.72 | 83.17 |
| 10 | ST | 78.16 | 0.14 | 22.11 | 5.45 | 20.78 | 85.89 |
| 11 | ST | 74.10 | 3.94 | 23.54 | 5.78 | 30.45 | 93.22 |
| 12 | ST | 76.71 | 2.96 | 22.81 | 5.38 | 35.56 | 94.39 |
| 13 | ST | 76.51 | 0.27 | 24.43 | 5.91 | 29.50 | 92.06 |
| 14 | ST | 76.43 | 1.90 | 23.75 | 5.65 | 32.33 | 99.28 |
| 15 | ST | 71.72 | 9.97 | 20.73 | 5.89 | 43.89 | 102.28 |
| 16 | ST | 78.21 | 1.55 | 22.23 | 6.12 | 44.94 | 95.89 |
| 17 | ST | 76.21 | 1.99 | 24.32 | 5.85 | 32.61 | 96.28 |
| 18 | ST | 76.52 | 0.95 | 24.41 | 5.85 | 36.67 | 96.67 |
| 19 | ST | 72.88 | 5.71 | 26.04 | 5.78 | 46.17 | 107.89 |
| 20 | ST | 76.67 | 1.25 | 24.30 | 5.55 | 33.33 | 104.05 |
| 21 | ST | 76.00 | 1.68 | 22.51 | 5.70 | 44.94 | 111.28 |
| 22 | ST | 76.48 | 1.08 | 24.59 | 6.81 | 58.72 | 142.17 |
| 23 | ST | 77.16 | 0.48 | 24.36 | 5.56 | 30.22 | 100.89 |
| 24 | ST | 77.65 | 1.13 | 23.45 | 5.81 | 34.72 | 94.00 |
| 25 | ST | 72.04 | 9.17 | 21.23 | 5.88 | 52.11 | 101.11 |
| 26 | ST | 77.31 | 0.53 | 24.14 | 5.73 | 35.17 | 98.89 |
| 27 | ST | 72.05 | 6.73 | 23.36 | 5.82 | 41.89 | 99.67 |
| 28 | ST | 75.48 | 1.62 | 23.96 | 5.62 | 34.39 | 91.94 |
| 29 | ST | 75.40 | 1.94 | 24.30 | 5.66 | 33.17 | 94.22 |
| 30 | ST | 75.79 | 2.14 | 23.56 | 5.56 | 47.33 | 95.72 |
| 31 | ST | 75.77 | 1.61 | 24.29 | 5.64 | 46.89 | 104.89 |
| 32 | ST | 75.42 | 5.10 | 21.67 | 5.58 | 46.67 | 97.61 |
| 33 | ST | 76.10 | 2.32 | 23.71 | 5.69 | 48.00 | 106.56 |
| 34 | ST | 78.46 | 1.42 | 24.04 | 6.15 | 61.56 | 108.67 |
| 35 | CNT | 75.13 | 3.11 | 24.30 | 6.18 | 58.44 | 113.11 |
| 36 | CNT | 75.64 | 2.30 | 24.38 | 5.78 | 31.34 | 101.11 |
| 37 | CNT | 74.70 | 1.81 | 25.16 | 5.75 | 43.23 | 112.44 |
| 38 | CNT | 75.56 | 1.94 | 24.70 | 5.85 | 74.33 | 114.06 |
| 39 | CNT | 75.26 | 2.03 | 24.52 | 5.85 | 78.67 | 105.06 |
| 40 | CNT | 76.78 | 1.22 | 23.83 | 5.94 | 62.17 | 113.78 |
| SEM[e] | | 0.19 | 0.26 | 0.18 | 0.03 | 2.40 | 2.14 |

[a] ST/CNT = Sow loins with taint (ST) or non-tainted control commodity loin (CNT).
[b] pH = Raw pH measurement.
[c] MU = Marinade Uptake.
[d] CY = Cook Yield.
[e] SEM = Standard error of the means for ST and CNT loins.

**APPENDIX 19: Study II Least squares means for lipid oxidation (TBA) of of sow loins possessing atypical aroma and flavor (sow taint, ST).**

| LOIN[a] | TBA[b] |
|---|---|
| 1 | 0.057 |
| 3 | 0.021 |
| 5 | 0.048 |
| 7 | 0.035 |
| 9 | 0.120 |
| 11 | 0.045 |
| 13 | 0.061 |
| 15 | 0.008 |
| 17 | 0.037 |
| 19 | 0.039 |
| 21 | 0.068 |
| 23 | 0.068 |
| 25 | 0.117 |
| 27 | 0.042 |
| 29 | 0.040 |
| 31 | 0.063 |
| 33 | 0.040 |
| SEM[b] | 0.022 |

[a] LOIN = Sow loins with atypical aroma and flavor (sow taint).
[b] TBA = 2-Thiobarbituric acid test reported as mg malonaldehyde/kg sample.
[c] SEM = Standard error of the means for sow loins with taint.

**APPENDIX 20: Study II Least squares means for Subjective color, marbling, and firmness and Objective color (L*, a*, b*) values of sow loins possessing atypical aroma and flavor (sow taint, ST) and non-tainted control commodity loins (CNT).**

| | | SUBJECTIVE MEASUREMENTS[b] | | | OBJECTIVE COLOR[c] | | |
|---|---|---|---|---|---|---|---|
| LOIN | ST/CNT[a] | COLOR | MARBLING | FIRMNESS | L* | a* | b* |
| 1 | ST | 5 | 3 | 2 | 41.62 | 23.23 | 4.87 |
| 2 | ST | 4 | 2 | 2 | 40.53 | 21.59 | 4.56 |
| 3 | ST | 6 | 1 | 3 | 36.58 | 18.35 | 2.41 |
| 4 | ST | 4 | 2 | 2 | 48.09 | 22.94 | 5.82 |
| 5 | ST | 5 | 3 | 3 | 40.36 | 20.62 | 4.21 |
| 6 | ST | 3 | 2 | 2 | 53.74 | 18.62 | 5.58 |
| 7 | ST | 4 | 2 | 1 | 45.01 | 20.15 | 4.26 |
| 8 | ST | 5 | 2 | 2 | 40.83 | 21.98 | 4.84 |
| 9 | ST | 3 | 1 | 2 | 45.98 | 19.20 | 3.92 |
| 10 | ST | 3 | 3 | 2 | 47.78 | 19.74 | 4.40 |
| 11 | ST | 5 | 3 | 2 | 42.85 | 24.45 | 7.24 |
| 12 | ST | 4 | 2 | 2 | 44.42 | 22.19 | 6.65 |
| 13 | ST | 5 | 2 | 2 | 41.61 | 21.55 | 4.26 |
| 14 | ST | 5 | 2 | 2 | 41.00 | 22.36 | 5.48 |
| 15 | ST | 4 | 2 | 3 | 47.65 | 23.94 | 7.95 |
| 16 | ST | 5 | 2 | 2 | 41.43 | 21.62 | 4.99 |
| 17 | ST | 4 | 2 | 2 | 43.53 | 21.33 | 4.48 |
| 18 | ST | 4 | 2 | 2 | 42.26 | 20.89 | 5.02 |
| 19 | ST | 4 | 4 | 3 | 48.20 | 20.83 | 6.38 |
| 20 | ST | 3 | 1 | 2 | 44.24 | 20.44 | 4.46 |
| 21 | ST | 4 | 2 | 2 | 43.12 | 20.42 | 5.70 |
| 22 | ST | 6 | 2 | 3 | 33.12 | 18.00 | 3.02 |
| 23 | ST | 3 | 1 | 2 | 43.45 | 20.62 | 5.31 |
| 24 | ST | 5 | 2 | 1 | 43.20 | 20.72 | 4.87 |
| 25 | ST | 5 | 4 | 3 | 49.63 | 22.48 | 8.75 |
| 26 | ST | 5 | 1 | 2 | 43.92 | 19.97 | 4.05 |
| 27 | ST | 4 | 4 | 3 | 47.07 | 21.68 | 6.14 |
| 28 | ST | 3 | 2 | 2 | 47.83 | 20.75 | 4.38 |
| 29 | ST | 3 | 2 | 2 | 50.54 | 20.82 | 6.22 |
| 30 | ST | 3 | 2 | 2 | 48.27 | 20.74 | 5.13 |
| 31 | ST | 5 | 2 | 2 | 40.40 | 20.64 | 3.64 |
| 32 | ST | 6 | 2 | 2 | 55.73 | 19.91 | 6.83 |
| 33 | ST | 5 | 2 | 2 | 40.00 | 22.52 | 4.84 |
| 34 | ST | 5 | 2 | 2 | 40.50 | 20.82 | 4.23 |
| 35 | CNT | 4 | 2.5 | 2 | 50.13 | 19.54 | 5.08 |
| 36 | CNT | 3 | 2 | 2 | 54.64 | 19.81 | 6.49 |
| 37 | CNT | 3 | 2 | 3 | 54.88 | 20.67 | .96 |
| 38 | CNT | 4 | 2 | 2 | 51.99 | 20.38 | 6.78 |
| 39 | CNT | 3 | 3 | 3 | 53.55 | 22.15 | 7.44 |
| 40 | CNT | 4 | 2 | 1 | 49.89 | 20.53 | 5.29 |
| SEM[d] | | 0.00 | 0.08 | 0.00 | 0.64 | 0.42 | 0.20 |

[a] ST/CNT = Sow loins with atypical aroma and flavor and non-tainted control commodity loins.
[b] Measurements according to National Pork Producers Pork Quality Standards (Baas et al., 2000).
[c] Commission International D'Edairerage (CIE) L*a*b* where L* = lightness, a* = redness, and b* = yellowness on a 0-100 pink scale.
[d] SEM = Standard error of the means for ST and CNT loins.

**APPENDIX 21: Study II Least squares means for drip loss and values for 24 h purge loss (%) and loin temperature of sow loins possessing atypical aroma and flavor (sow taint, ST).**

| LOIN[a] | DRIP LOSS[b] % | PURGE LOSS[c] % | LOIN TEMPERATURE[d] C° |
|---|---|---|---|
| 1 | 1.10 | 1.61 | 2.89 |
| 2 | 0.69 | 0.83 | 3.67 |
| 3 | 1.72 | 2.27 | 2.22 |
| 4 | 2.09 | 1.32 | 2.33 |
| 5 | 1.67 | 1.56 | 2.89 |
| 6 | 8.45 | 4.88 | 2.56 |
| 7 | 1.96 | 0.96 | 2.61 |
| 8 | 1.85 | 3.31 | 3.50 |
| 9 | 4.37 | 2.90 | 2.61 |
| 10 | 4.48 | 2.92 | 2.83 |
| 11 | 1.73 | 1.92 | 2.94 |
| 12 | 6.10 | 3.89 | 2.33 |
| 13 | 0.42 | 0.00 | 2.89 |
| 14 | 2.34 | 0.88 | 3.00 |
| 15 | 0.61 | 0.96 | 2.67 |
| 16 | 1.04 | 0.00 | 2.61 |
| 17 | 1.50 | 2.81 | 1.06 |
| 18 | 1.31 | 0.61 | 2.44 |
| 19 | 2.81 | 2.81 | 2.83 |
| 20 | 5.61 | 5.39 | 2.72 |
| 21 | 4.09 | 1.71 | 2.44 |
| 22 | 0.41 | 0.28 | 2.56 |
| 23 | 5.65 | 5.16 | 3.00 |
| 24 | 2.06 | 1.11 | 2.50 |
| 25 | 0.67 | 2.36 | 2.56 |
| 26 | 2.17 | 1.09 | 2.39 |
| 27 | 0.91 | 0.44 | 2.78 |
| 28 | 1.81 | 1.37 | 2.89 |
| 29 | 1.76 | 0.00 | 2.56 |
| 30 | 1.85 | 3.15 | 2.56 |
| 31 | 4.84 | 3.65 | 2.72 |
| 32 | 7.25 | 6.91 | 2.56 |
| 33 | 5.56 | 2.79 | 2.67 |
| 34 | 2.38 | 1.77 | 3.06 |
| SEM[e] | 0.21 | | |

[a] LOIN = Sow loins with atypical aroma and flavor (sow taint).
[b] % DRIP LOSS = Fluid lost from loin chops after 48 h storage (2.8°C; Baas et al., 2000).
[c] PURGE LOSS = Fluid lost after tempering frozen sow loins (24 h).
[d] LOIN TEMPERATURE = Internal loin temp upon arrival to MSU meat laboratory.
[e] SEM = Standard error of the means for sow loins with taint.

**APPENDIX 22: Study I Least squares means for trained sensory panel scores[h] for "other" classification of tainted sow longissimus dorsi chops marinated with sodium tripolyphosphate, sodium bicarbonate with varying injection levels.**

| TRT[a] | SOUR | SWEET | BEEFY | EARTHY | BURNT/BROWNED | ACID | METAL | BARNYARD | MATURE ANIMAL |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0.04 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0.61 | 0 | 0 | 0 | 0.14 |
| 3 | 0 | 0 | 0 | 0 | 0.04 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0.28 | 0.69 | 0 | 0 | 0.14 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0.83 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 1.40 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0.28 | 0 | 0.76 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0.14 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 1.12 | 0 | 0.43 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 0.26 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0.83 | 0 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 | 0 | 0.40 | 0 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 | 0 | 0.04 | 0 | 0 | 0 | 0 |
| SEM[b] | 0 | 0 | 0.07 | 0.06 | 0.32 | 0 | 0.07 | 0.03 | 0.03 |
| 15[c] | 0 | 0 | 0 | 0 | 0.46 | 0 | 0 | 0 | 0 |
| SEM[d] | 0 | 0 | 0 | 0 | 0.13 | 0 | 0 | 0 | 0 |
| ST[e] | 0.13 | 0 | 0.13 | 0 | 0.07 | 0.20 | 0 | 0 | 0 |
| CNT[f] | 0 | 0 | 0 | 0 | 0.43 | 0 | 0 | 0 | 0 |
| SEM[g] | 0.11 | 0 | 0.11 | 0 | 0.18 | 0.16 | 0 | 0 | 0 |

[a] Treatment combinations.
[b] SEM = Standard error of the mean for treatment combinations 1-14..
[c] 15 = Replicated treatment combinations 15-20.
[d] SEM = Standard error of the mean for treatment combinations 15-20.
[e] ST = Tainted sow lion chops with no treatment.
[f] CNT = Non-taint sow loin chops with no treatment.
[g] SEM = Standard error of the mean for taint and no taint control chops.
[h] Trained taste panel scores are based on 15 point universal spectrum scale: 0 = none; 15 = high intensity.

**APPENDIX 23: Study I Least squares means for trained sensory panel scores[h] for "other" classification of tainted sow longissimus dorsi chops marinated with sodium tripolyphosphate, sodium bicarbonate with varying injection levels.**

| TRT[a] | WILD | MUSTY | SMOKED | PROCESSED HAM | CITRUS | OILY | SERUM BLOODY | NUTTY |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0.03 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0.03 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0.29 | 0 | 0.03 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0.03 | 0 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0.03 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0.03 | 0 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0.03 | 0 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0.03 | 0 | 0 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0.03 | 0 | 0 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 | 0.43 | 0 | 0 | 0 | 0 |
| SEM[b] | 0.06 | 0 | 0.07 | 0.14 | 0 | 0 | 0 | 0 |
| 15[c] | 0 | 0 | 0.05 | 0.07 | 0 | 0 | 0 | 0 |
| SEM[d] | 0 | 0 | 0.03 | 0.06 | 0 | 0 | 0 | 0 |
| ST[e] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CNT[f] | 0 | 0.06 | 0 | 0 | 0 | 0 | 0 | 0 |
| SEM[g] | 0 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 |

[a] Treatment combinations.
[b] SEM = Standard error of the mean for treatment combinations 1-14..
[c] 15 = Replicated treatment combinations 15-20.
[d] SEM = Standard error of the mean for treatment combinations 15-20.
[e] ST = Tainted sow loin chops with no treatment.
[f] CNT = Non-tainted sow loin chops with no treatment.
[g] SEM = Standard error of the mean for taint and no taint control chops.
[h] Trained taste panel scores are based on 15 point universal spectrum scale: 0 = none; 15 = high intensity.

**APPENDIX 24: Study I Least squares means for trained sensory panel scores[i] for "Flavor" classification of tainted sow longissimus dorsi chops marinated with sodium tripolyphosphate, sodium bicarbonate with injection levels.**

| TRT[a] | C[h] PORK LEAN/BROTHY | C[h] PORK FAT | CARDBOARD | PAINTY | FISHY | SOAPY | SODA | CHEMICAL | METALLIC | ASTRINGENT |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.84 | 1.57 | 0.70 | 0 | 0 | 0.59 | 1.61 | 0.12 | 1.82 | 1.50 |
| 2 | 4.47 | 1.42 | 0.56 | 0 | 0.14 | 0.45 | 1.89 | 0.12 | 1.82 | 1.79 |
| 3 | 5.18 | 1.57 | 0 | 0 | 0 | 0.31 | 1.47 | 0.40 | 2.11 | 1.64 |
| 4 | 5.00 | 1.42 | 0.05 | 0 | 0 | 0.36 | 1.65 | 0.11 | 2.02 | 2.20 |
| 5 | 5.57 | 1.42 | 0.48 | 0 | 0 | 0.50 | 1.37 | 0.26 | 1.87 | 2.06 |
| 6 | 5.43 | 1.42 | 034 | 0 | 0 | 0.36 | 1.65 | 0.11 | 1.87 | 1.77 |
| 7 | 5.47 | 1.57 | 0.42 | 0 | 0 | 0.59 | 1.18 | 0.12 | 1.96 | 1.79 |
| 8 | 5.28 | 1.42 | 0.63 | 0 | 0 | 0.50 | 2.08 | 0.26 | 1.87 | 1.77 |
| 9 | 5.43 | 1.85 | 0.77 | 0.43 | 0 | 0.36 | 1.65 | 0.26 | 1.59 | 1.34 |
| 10 | 5.43 | 1.13 | 0.20 | 0 | 0 | 0.50 | 1.22 | 0 | 1.73 | 1.34 |
| 11 | 5.43 | 1.56 | 0.34 | 0 | 0 | 0.50 | 1.22 | 0 | 2.30 | 1.91 |
| 12 | 5.00 | 0.99 | 0.63 | 0 | 0 | 0.50 | 1.51 | 0.26 | 1.59 | 1.06 |
| 13 | 5.00 | 1.56 | 0.05 | 0 | 0 | 0.36 | 1.79 | 0.26 | 1.87 | 1.91 |
| 14 | 4.75 | 1.85 | 0.42 | 0 | 0 | 0.45 | 1.04 | 0.12 | 1.96 | 1.50 |
| SEM[b] | 0.35 | 0.23 | 0.29 | 0.09 | 0.05 | 0.16 | 0.27 | 0.15 | 0.19 | 0.23 |
| 15[c] | 4.86 | 1.54 | 0.43 | 0 | 0.02 | 0.53 | 1.23 | 0.24 | 1.83 | 1.55 |
| SEM[d] | 0.15 | 0.10 | 0.12 | 0 | 0.02 | 0.07 | 0.12 | 0.06 | 0.08 | 0.09 |
| ST[e] | 3.64 | 1.06 | 1.35 | 0.20 | 0 | 0.31 | 0.25 | 0.13 | 2.01 | 1.69 |
| CNT[f] | 4.42 | 1.06 | 0.71 | 0 | 0 | 0.38 | 0.32 | 0.06 | 1.80 | 1.62 |
| SEM[g] | 0.29 | 0.16 | 0.28 | 0.09 | 0 | 0.09 | 0.21 | 0.08 | 0.24 | 0.22 |

[a] Treatment combinations.
[b] SEM = Standard error of the mean for treatment combinations 1-14..
[c] 15 = Replicated treatment combinations 15-20.
[d] SEM = Standard error of the mean for treatment combinations 15-20.
[e] ST = Tainted sow loin chops with no treatment.
[f] CNT = Non-tainted sow loin chops with no treatment.
[g] SEM = Standard error of the mean for taint and no taint control chops.
[h] C = Cooked.
[i] Trained taste panel scores are based on 15 point universal spectrum scale: 0 = none; 15 = high intensity.

**APPENDIX 25: Study I Least squares means for trained sensory panel scores[h] for "After Taste" classification of tainted sow longissimus dorsi chops marinated with sodium tripolyphosphate, sodium bicarbonate with varying injection levels.**

| TRT[a] | BITTER | SWEET | SOUR | SALTY | METAL | BURNT/BROWNED | SODA | NUTTY |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.58 | 0 | 0.55 | 0.50 | 1.14 | 0.06 | 1.00 | 0 |
| 2 | 1.37 | 0 | 0.55 | 0.36 | 0.71 | 0.06 | 0.57 | 0 |
| 3 | 1.44 | 0 | 1.98 | 0.50 | 1.99 | 0.06 | 0.71 | 0 |
| 4 | 1.61 | 0 | 1.01 | 0.93 | 0.68 | 0 | 0.79 | 0 |
| 5 | 1.46 | 0 | 0.87 | 0.79 | 1.82 | 0 | 0.36 | 0 |
| 6 | 1.32 | 0 | 0.16 | 0.79 | 0.96 | 0.40 | 0.51 | 0 |
| 7 | 1.16 | 0 | 0.69 | 0.22 | 1.27 | 0.49 | 0.28 | 0 |
| 8 | 0.89 | 0 | 0.30 | 1.22 | 0.53 | 0 | 0.65 | 0 |
| 9 | 0.89 | 0 | 0.16 | 0.79 | 0.96 | 0.26 | 0.22 | 0 |
| 10 | 1.18 | 0 | 0.44 | 0.50 | 0.68 | 0.26 | 0.65 | 0 |
| 11 | 1.46 | 0.28 | 0.16 | 0.07 | 1.25 | 0 | 0.22 | 0 |
| 12 | 1.03 | 0 | 0.30 | 0.50 | 1.25 | 0.54 | 0.36 | 0.29 |
| 13 | 1.32 | 0 | 0.30 | 0.65 | 1.39 | 0 | 0.65 | 0 |
| 14 | 0.73 | 0 | 0.55 | 0.79 | 0.71 | 0.06 | 0.43 | 0 |
| SEM[b] | 0.33 | 0.07 | 0.35 | 0.32 | 0.34 | 0.21 | 0.25 | 0.06 |
| 15[c] | 0.97 | 0.02 | 0.75 | 0.48 | 0.96 | 0.26 | 0.70 | 0 |
| SEM[d] | 0.14 | 0.03 | 0.14 | 0.14 | 0.14 | 0.09 | 0.10 | 0 |
| ST[e] | 1.65 | 0 | 1.11 | 0 | 1.50 | 0.09 | 0 | 0 |
| CNT[f] | 1.29 | 0 | 0.33 | 0 | 1.43 | 0.16 | 0.27 | 0 |
| SEM[g] | 0.18 | 0 | 0.27 | 0 | 0.26 | 0.12 | 0.15 | 0 |

[a] Treatment combinations.
[b] SEM = Standard error of the mean for treatment combinations 1-14..
[c] 15 = Replicated treatment combinations 15-20.
[d] SEM = Standard error of the mean for treatment combinations 15-20.
[e] ST = Tainted sow loin chops with no treatment.
[f] CNT = Non-tainted sow loin chops with no treatment.
[g] SEM = Standard error of the mean for taint and no taint control chops.
[h] Trained taste panel scores are based on 15 point universal spectrum scale: 0 = none; 15 = high intensity.

**APPENDIX 26: Study I Least squares means for trained sensory panel scores[h] for "After Taste" classification of tainted sow longissimus dorsi chops marinated with sodium tripolyphosphate, sodium bicarbonate with varying injection levels.**

| TRT[a] | FATTY | CHEMICAL | CARDBOARD | MATURE ANIMAL | CITRUS | ACID |
|---|---|---|---|---|---|---|
| 1 | 0 | 0.15 | 0.15 | 0 | 0 | 0 |
| 2 | 0 | 0.15 | 0.01 | 0 | 0 | 0 |
| 3 | 0 | 0.15 | 0.01 | 0 | 0 | 0 |
| 4 | 0 | 0.26 | 0 | 0.29 | 0 | 0 |
| 5 | 0 | 0.26 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0.26 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0.15 | 0.01 | 0 | 0 | 0 |
| 8 | 0 | 0.55 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0.40 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 0.29 | 0 | 0.14 | 0 | 0 | 0 |
| 12 | 0 | 0.26 | 0 | 0 | 0 | 0 |
| 13 | 0 | 0.26 | 0 | 0 | 0 | 0 |
| 14 | 0 | 0.15 | 0.01 | 0 | 0 | 0 |
| SEM[b] | 0.06 | 0.16 | 0.08 | 0.06 | 0 | 0 |
| 15[c] | 0 | 0.19 | 0.06 | 0 | 0 | 0 |
| SEM[d] | 0 | 0.07 | 0.03 | 0 | 0 | 0 |
| ST[e] | 0.13 | 0.13 | 0 | 0 | 0 | 0 |
| CNT[f] | 0 | 0.06 | 0.07 | 0 | 0 | 0 |
| SEM[g] | 0.11 | 0.10 | 0.05 | 0 | 0 | 0 |

[a] Treatment combinations.
[b] SEM = Standard error of the mean for treatment combinations 1-14..
[c] 15 = Replicated treatment combinations 15-20.
[d] SEM = Standard error of the mean for treatment combinations 15-20.
[e] ST = Tainted sow loin chops with no treatment.
[f] CNT = Non-tainted sow loin chops with no treatment.
[g] SEM = Standard error of the mean for taint and no taint control chops.
[h] Trained taste panel scores are based on 15 point universal spectrum scale: 0 = none; 15 = high intensity.

**APPENDIX 27: Study I Least squares means for trained sensory panel scores[h] for "Taste" classification of tainted sow longissimus dorsi chops marinated with sodium tripolyphosphate, sodium bicarbonate with varying injection levels.**

| TRT[a] | SALT | SOUR | BITTER | SWEET | SOAPY |
|---|---|---|---|---|---|
| 1 | 3.40 | 2.55 | 2.29 | 0.76 | 0.56 |
| 2 | 3.11 | 2.40 | 2.57 | 0.04 | 0.42 |
| 3 | 2.97 | 2.55 | 2.43 | 0.47 | 0.42 |
| 4 | 3.28 | 2.65 | 2.72 | 0.18 | 0.36 |
| 5 | 3.42 | 2.50 | 2.57 | 0.32 | 0.64 |
| 6 | 3.56 | 2.22 | 2.72 | 0.90 | 0.36 |
| 7 | 2.83 | 2.40 | 2.43 | 0.33 | 0.56 |
| 8 | 3.56 | 2.36 | 2.72 | 0.47 | 0.60 |
| 9 | 3.42 | 1.93 | 2.43 | 1.04 | 0.64 |
| 10 | 2.99 | 2.08 | 2.43 | 1.18 | 0.50 |
| 11 | 2.85 | 2.22 | 2.43 | 0.90 | 0.22 |
| 12 | 3.28 | 1.93 | 2.43 | 0.61 | 0.50 |
| 13 | 3.56 | 2.65 | 2.15 | 0.75 | 0.36 |
| 14 | 3.40 | 2.26 | 2.14 | 1.04 | 0.42 |
| SEM[b] | 0.26 | 0.19 | 0.22 | 0.25 | 0.17 |
| 15[c] | 3.16 | 2.30 | 2.38 | 0.52 | 0.51 |
| SEM[d] | 0.11 | 0.08 | 0.09 | 0.11 | 0.07 |
| ST[e] | 2.40 | 2.49 | 2.75 | 0 | 0.50 |
| CNT[f] | 2.04 | 2.13 | 2.32 | 0.20 | 0.50 |
| SEM[g] | 0.34 | 0.23 | 0.21 | 0.12 | 0.10 |

[a] Treatment combinations.
[b] SEM = Standard error of the mean for treatment combinations 1-14..
[c] 15 = Replicated treatment combinations 15-20.
[d] SEM = Standard error of the mean for treatment combinations 15-20.
[e] ST = Tainted sow loin chops with no treatment.
[f] CNT = Non-tainted sow loin chops with no treatment.
[g] SEM = Standard error of the mean for taint and no taint control chops.
[h] Trained taste panel scores are based on 15 point universal spectrum scale: 0 = none; 15 = high intensity.

**APPENDIX 28: Study I Least squares means for trained sensory panel scores[h] for "Texture" classification of tainted sow longissimus dorsi chops marinated with sodium tripolyphosphate, sodium bicarbonate with varying injection levels.**

| TRT[a] | MUSCLE FIBER TENDERNESS | JUICINESS | OVERALL TENDERNESS | CONNECTIVE TISSUE |
|---|---|---|---|---|
| 1 | 4.13 | 3.95 | 4.27 | 5.58 |
| 2 | 4.84 | 3.53 | 4.84 | 5.87 |
| 3 | 5.56 | 5.09 | 5.56 | 5.30 |
| 4 | 6.20 | 5.07 | 6.20 | 7.45 |
| 5 | 6.34 | 4.93 | 6.34 | 7.02 |
| 6 | 5.77 | 4.65 | 5.77 | 6.73 |
| 7 | 6.13 | 5.10 | 5.99 | 7.01 |
| 8 | 5.20 | 4.79 | 5.20 | 6.45 |
| 9 | 4.77 | 3.65 | 4.77 | 6.59 |
| 10 | 4.91 | 4.79 | 4.91 | 6.02 |
| 11 | 6.06 | 5.07 | 6.06 | 6.59 |
| 12 | 4.20 | 3.50 | 4.20 | 5.45 |
| 13 | 4.48 | 4.50 | 4.34 | 5.02 |
| 14 | 5.99 | 4.95 | 5.99 | 6.87 |
| SEM[b] | 0.45 | 0.33 | 0.44 | 0.45 |
| 15[c] | 5.09 | 4.24 | 5.09 | 6.01 |
| SEM[d] | 0.19 | 0.14 | 0.18 | 0.19 |
| ST[e] | 4.16 | 4.19 | 4.15 | 5.14 |
| CNT[f] | 3.66 | 3.12 | 3.72 | 5.92 |
| SEM[g] | 0.33 | 0.29 | 0.34 | 0.39 |

[a] Treatment combinations.
[b] SEM = Standard error of the mean for treatment combinations 1-14..
[c] 15 = Replicated treatment combinations 15-20.
[d] SEM = Standard error of the mean for treatment combinations 15-20.
[e] ST = Tainted sow loin chops with no treatment.
[f] CNT = Non-tainted sow loin chops with no treatment.
[g] SEM = Standard error of the mean for taint and no taint control chops.
[h] Trained taste panel scores are based on 8 point hedonic scale: 1 = extremely dry/ extremely tough/ abundant; 8 = extremely juicy/ extremely tender/ none.

**APPENDIX 29: Study I Least squares means for trained sensory panel scores[i] for "Aromatics" classification of tainted sow longissimus dorsi chops marinated with sodium tripolyphosphate, sodium bicarbonate with varying injection levels.**

| TRT[a] | C[h] PORK LEAN/BROTHY | C[h] PORK FAT | CARDBOARD | PAINTY | FISHY | SOAPY | SODA | CHEMICAL | METALLIC | ASTRINGENT |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.25 | 0.69 | 0.10 | 0 | 0 | 0.70 | 0.14 | 0 | 0.12 | 0 |
| 2 | 2.82 | 0.40 | 0.67 | 0 | 0 | 0.27 | 0 | 0 | 0 | 0 |
| 3 | 2.82 | 0.40 | 0.10 | 0 | 0 | 0.55 | 0 | 0 | 0 | 0.13 |
| 4 | 2.69 | 0.25 | 0.07 | 0 | 0 | 0.25 | 0 | 0 | 0.43 | 0.14 |
| 5 | 3.41 | 0.25 | 0.50 | 0 | 0 | 0.25 | 0 | 0 | 0.29 | 0 |
| 6 | 3.55 | 0.39 | 0.35 | 0 | 0 | 0.25 | 0 | 0 | 0.43 | 0.14 |
| 7 | 3.25 | 0.40 | 0.67 | 0 | 0 | 0.55 | 0 | 0 | 0 | 0 |
| 8 | 3.41 | 0.68 | 0.35 | 0 | 0 | 0.25 | 0 | 0 | 0.14 | 0 |
| 9 | 3.41 | 0.53 | 0.78 | 0.28 | 0 | 0.11 | 0 | 0.14 | 0 | 0 |
| 10 | 3.55 | 0.25 | 0.07 | 0 | 0 | 0.25 | 0.14 | 0 | 0.29 | 0.14 |
| 11 | 2.98 | 0.25 | 0.07 | 0 | 0 | 0.11 | 0 | 0 | 0.14 | 0.14 |
| 12 | 3.84 | 0.53 | 0.21 | 0 | 0 | 0.25 | 0 | 0 | 0 | 0 |
| 13 | 2.84 | 0.39 | 0.35 | 0 | 0 | 0.11 | 0.14 | 0 | 0.14 | 0.14 |
| 14 | 3.10 | 0.12 | 0.67 | 0 | 0 | 0.27 | 0 | 0 | 0 | 0 |
| SEM[b] | 0.33 | 0.13 | 0.20 | 0.08 | 0 | 0.20 | 0.07 | 0.05 | 0.13 | 0.08 |
| 15[c] | 3.04 | 0.32 | 0.19 | 0.04 | 0 | 0.45 | 0.04 | 0.02 | 0 | 0 |
| SEM[d] | 0.14 | 0.05 | 0.08 | 0.03 | 0 | 0.08 | 0.03 | 0.02 | 0 | 0 |
| SC[e] | 2.97 | 0.29 | 0.85 | 0.29 | 0 | 0.45 | 0 | 0 | 0.04 | 0.06 |
| NTC[f] | 3.47 | 0.65 | 0.71 | 0.01 | 0 | 0.24 | 0.20 | 0 | 0.33 | 0.13 |
| SEM[g] | 0.29 | 0.18 | 0.27 | 0.12 | 0 | 0.12 | 0.12 | 0 | 0.12 | 0.12 |

[a] Treatment combinations.
[b] SEM = Standard error of the mean for treatment combinations 1-14..
[c] 15 = Replicated treatment combinations 15-20.
[d] SEM = Standard error of the mean for treatment combinations 15-20.
[e] ST = Tainted sow loin chops with no treatment.
[f] CNT = Non-tainted sow loin chops with no treatment.
[g] SEM = Standard error of the mean for taint and no taint control chops.
[h] C = Cooked.
[i] Trained taste panel scores are based on 15 point universal spectrum scale:
0 = none; 15 = high intensity.

**APPENDIX 30: Study I Least squares means for trained sensory panel scores[h] for "Aromatic" classification of tainted sow longissimus dorsi chops marinated with sodium tripolyphosphate, sodium bicarbonate with varying injection levels.**

| TRT[a] | BITTER | SWEET | SOUR | SALTY | METAL | BURNT/BROWNED | SODA | MUSTY | CITRUS | CHEMICAL | CARDBOARD |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0.20 | 0 | 0.27 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0.49 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0.06 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.12 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0.11 | 0 | 0.41 | 0 | 0 | 0.29 |
| 6 | 0 | 0 | 0 | 0 | 0 | 1.39 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0.77 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0.25 | 0 | 0.12 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 0 | 1.54 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0.14 | 0 | 0 | 0 | 0.25 | 0 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0.96 | 0 | 0.12 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 | 0 | 0 | 0.11 | 0 | 0.12 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 | 0 | 0 | 0.20 | 0 | 0.27 | 0 | 0 | 0 |
| SEM[b] | 0 | 0.03 | 0 | 0 | 0 | 0.26 | 0 | 0.26 | 0 | 0 | 0.06 |
| 15[c] | 0 | 0 | 0.02 | 0.02 | 0 | 0.35 | 0 | 0.15 | 0 | 0 | 0 |
| SEM[d] | 0 | 0 | 0.01 | 0.01 | 0 | 0.11 | 0 | 0.08 | 0 | 0 | 0 |
| ST[e] | 0.13 | 0 | 0.07 | 0 | 0.13 | 0.10 | 0 | 0 | 0 | 0 | 0.13 |
| CNT[f] | 0 | 0.13 | 0 | 0 | 0.13 | 0.46 | 0 | 0 | 0 | 0 | 0 |
| SEM[g] | 0.11 | 0.11 | 0.05 | 0 | 0.15 | 0.15 | 0 | 0 | 0 | 0 | 0.11 |

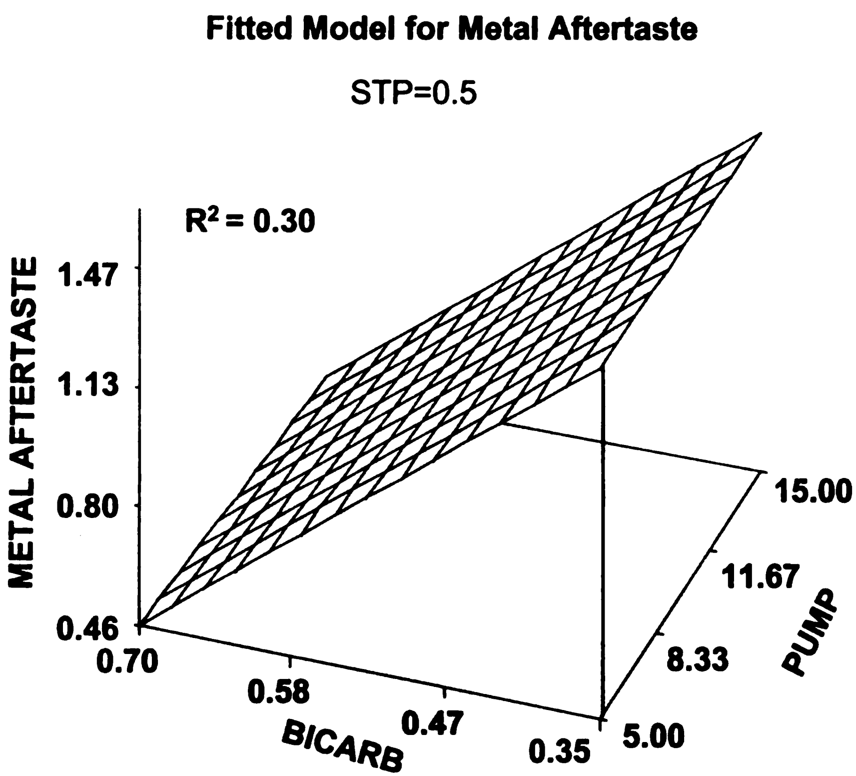
[a] Treatment combinations.
[b] SEM = Standard error of the mean for treatment combinations 1-14..
[c] 15 = Replicated treatment combinations 15-20.
[d] SEM = Standard error of the mean for treatment combinations 15-20.
[e] ST = Tainted sow loin chops with no treatment.
[f] CNT = Non-tainted sow loin chops with no treatment.
[g] SEM = Standard error of the mean for taint and no taint control chops.
[h] Trained taste panel scores are based on 15 point universal spectrum scale:
0 = none; 15 = high intensity.

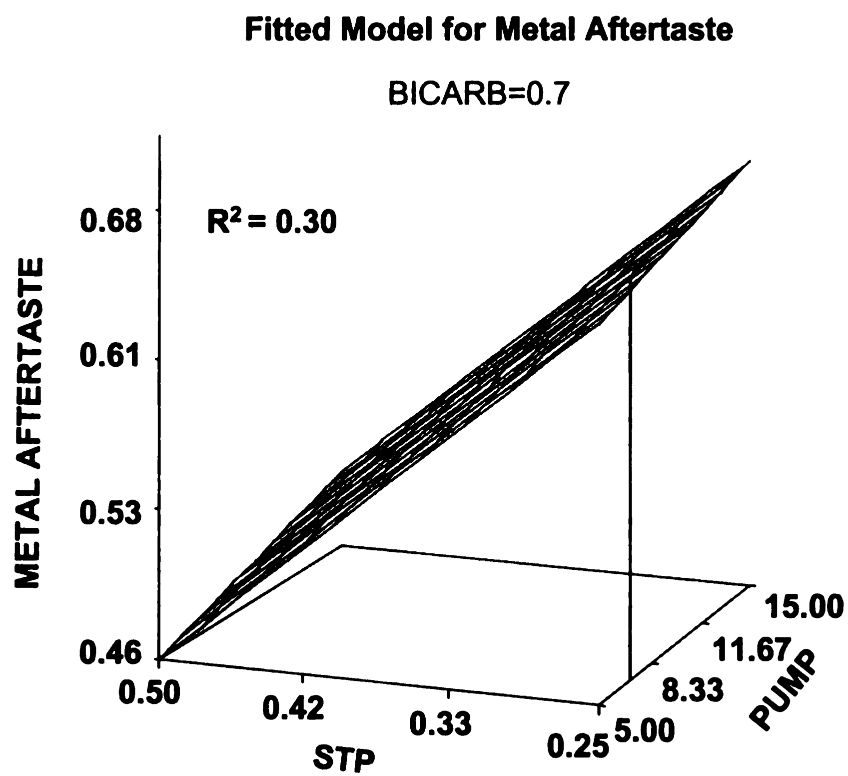
**APPENDIX 31: Study I Least squares means for trained sensory panel scores[h] for "Aromatic" classification of tainted sow longissimus dorsi chops marinated with sodium tripolyphosphate, sodium bicarbonate with varying injection levels.**

| TRT[a] | MATURE ANIMAL | BARNYARD | EARTHY | PERFUME | FRUITY | NUTTY |
|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0.14 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0.28 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0.14 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0.28 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 | 0 | 0 | 0 |
| SEM[b] | 0.07 | 0.10 | 0 | 0 | 0 | 0 |
| 15[c] | 0 | 0.04 | 0 | 0 | 0 | 0 |
| SEM[d] | 0 | 0.04 | 0 | 0 | 0 | 0 |
| ST[e] | 0 | 0 | 0 | 0 | 0 | 0 |
| CNT[f] | 0 | 0 | 0 | 0 | 0 | 0 |
| SEM[g] | 0 | 0 | 0 | 0 | 0 | 0 |

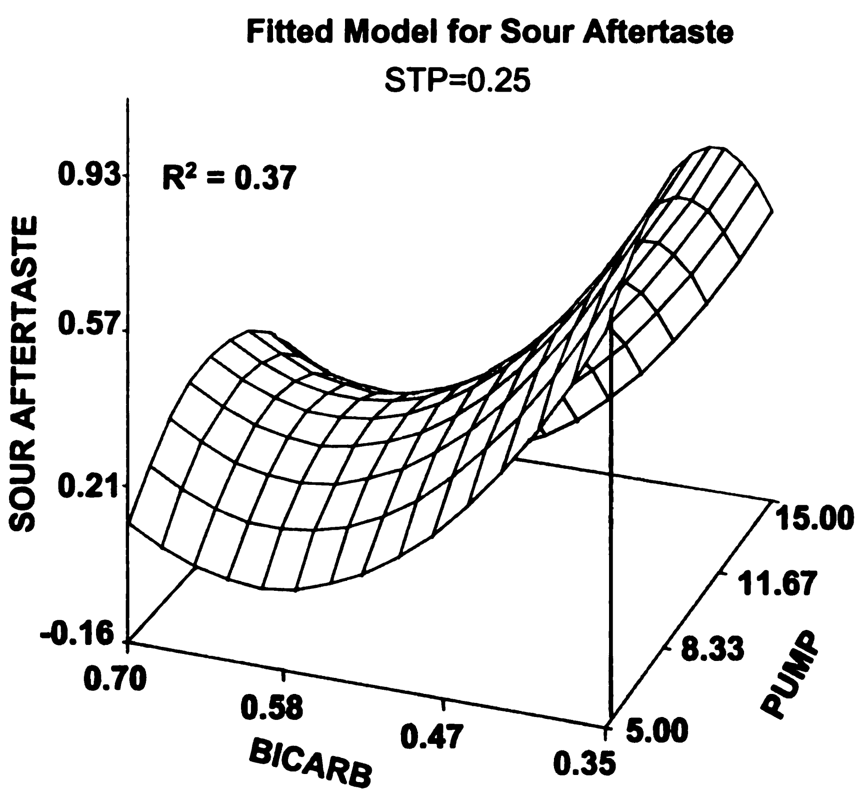
[a] Treatment combinations.
[b] SEM = Standard error of the mean for treatment combinations 1-14..
[c] 15 = Replicated treatment combinations 15-20.
[d] SEM = Standard error of the mean for treatment combinations 15-20.
[e] ST = Tainted sow loin chops with no treatment.
[f] CNT = Non-tainted sow loin chops with no treatment.
[g] SEM = Standard error of the mean for taint and no taint control chops.
[h] Trained taste panel scores are based on 15 point universal spectrum scale: 0 = none; 15 = high intensity.

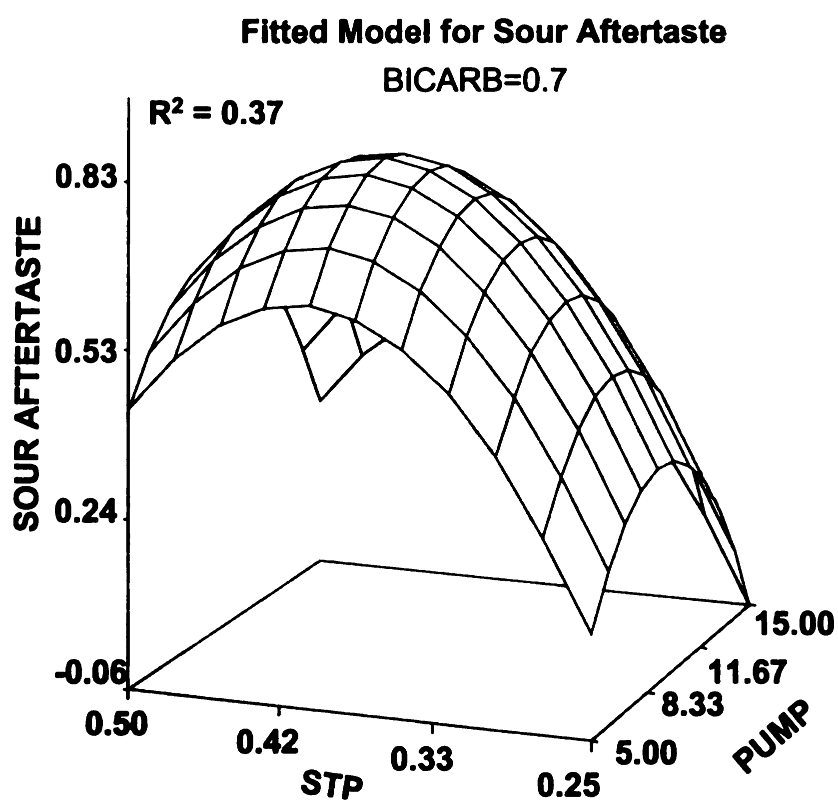
APPENDIX 32: Response surface curves of significant ($P<0.05$) total and fitted regression models for metal aftertaste of marinated sow loin chops manufactured with 5-15% injection level (PUMP), 0.25-0.50% sodium tripolyphosphate (STP), and 0.35-0.70 *M* sodium bicarbonate (BICARB).



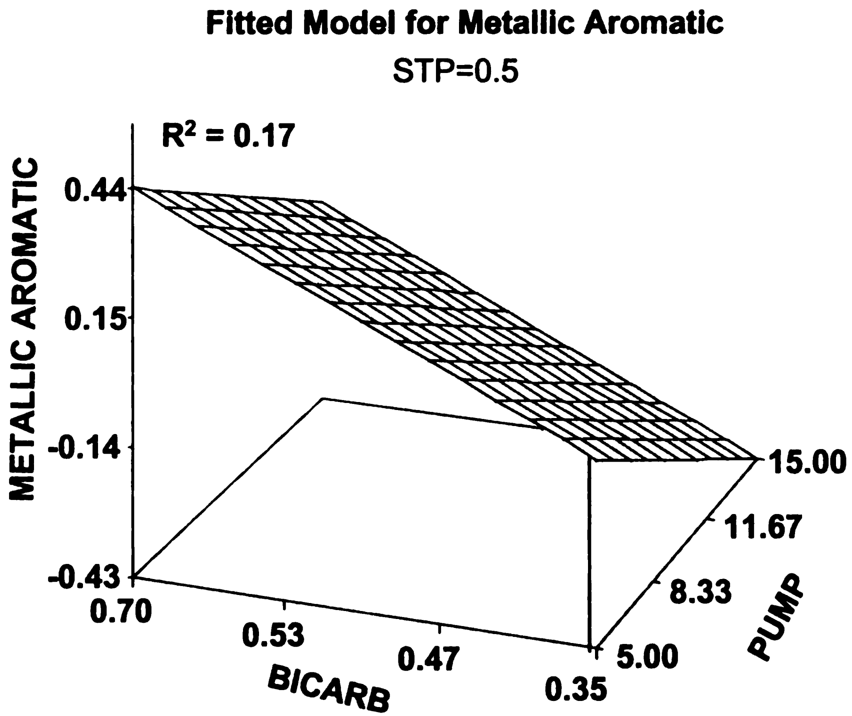



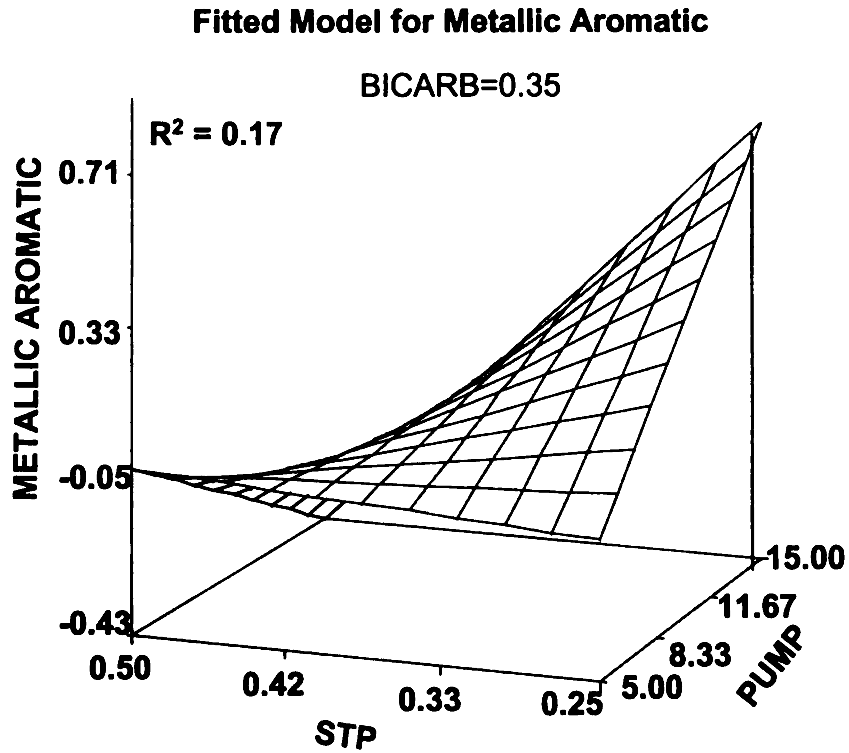
APPENDIX 33: Response surface curves of significant ($P<0.10$) total and fitted regression models for sour aftertaste of marinated sow loin chops manufactured with 5-15% injection level (PUMP), 0.25-0.50% sodium tripolyphosphate (STP), and 0.35-0.70 *M* Sodium Bicarbonate (BICARB).



**APPENDIX 34: Response surface curves of significant (P<0.10) total and fitted regression models for sour aftertaste of marinated sow loin chops manufactured with 5-15% injection level (PUMP), 0.25-0.50% sodium tripolyphosphate (STP), and 0.35-0.70 *M* sodium bicarbonate (BICARB).**

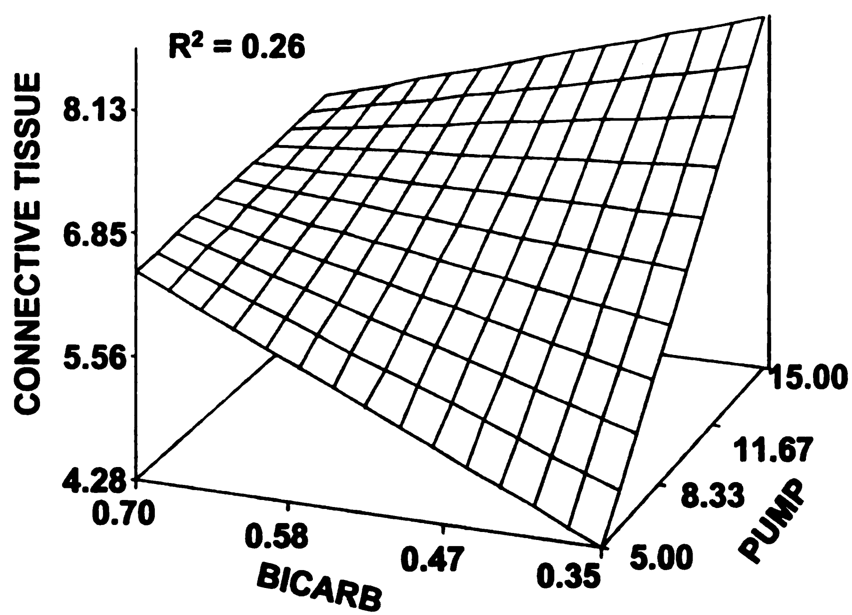


**APPENDIX 35: Response surface curves of significant ($P<0.05$) total and fitted regression models for connective tissue of marinated sow loin chops manufactured with 5-15% injection level (PUMP), 0.25-0.50% sodium tripolyphosphate (STP), and 0.35-0.70 *M* sodium bicarbonate (BICARB).**

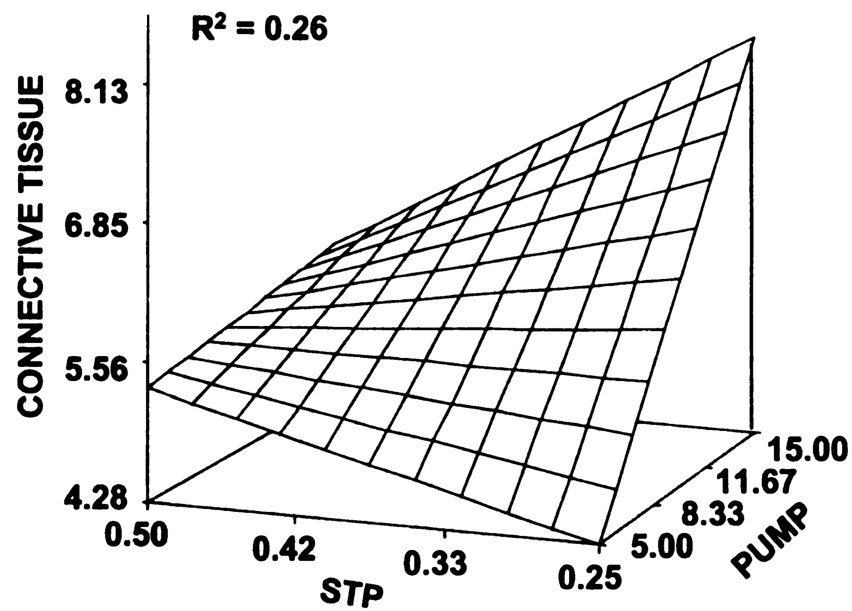
**Fitted Model for Connective Tissue**

STP=0.25



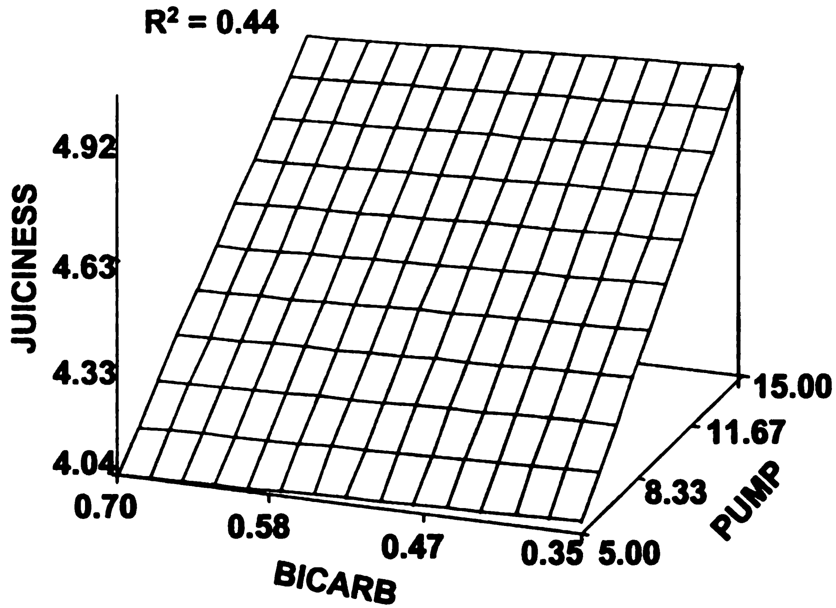

**Fitted Model for Connective Tissue**

BICARB=0.35

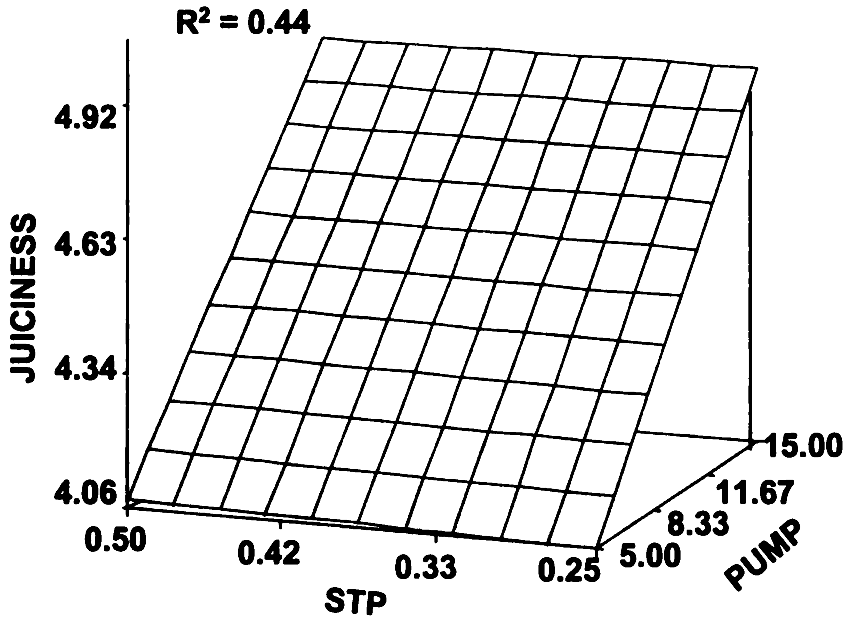


**APPENDIX 36: Response surface curves of significant (P<0.05) total and fitted regression models for juiciness of marinated sow loin chops manufactured with 5-15% injection level (PUMP), 0.25-0.50% sodium tripolyphosphate (STP), and 0.35-0.70 *M* sodium bicarbonate (BICARB).**

**Fitted Model for Juiciness**
STP=0.5



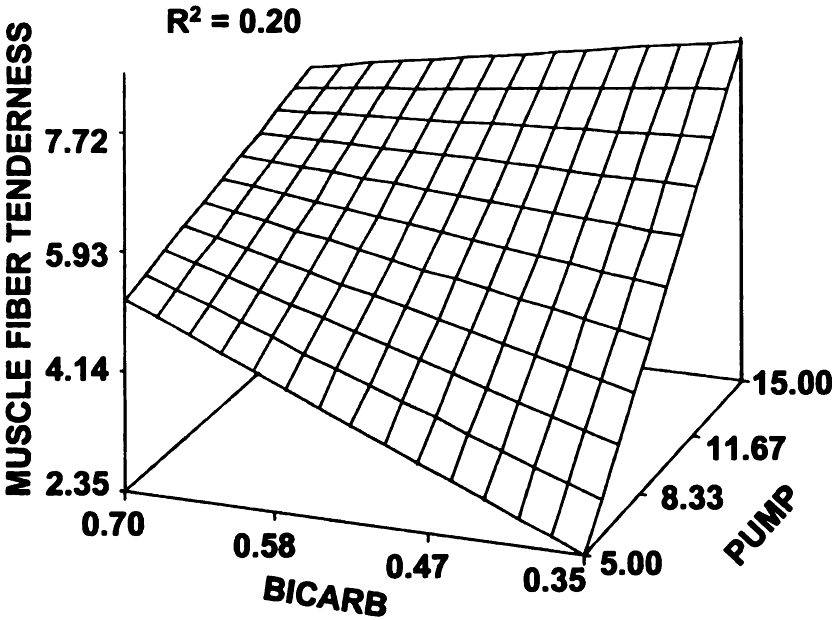

**Fitted Model for Juiciness**
BICARB=0.35



**APPENDIX 37: Response surface curves of significant (P<0.05) total and fitted regression models for muscle fiber tenderness of marinated sow loin chops manufactured with 5-15% injection level (PUMP), 0.25-0.50% sodium tripolyphosphate (STP), and 0.35-0.70 *M* sodium bicarbonate (BICARB).**

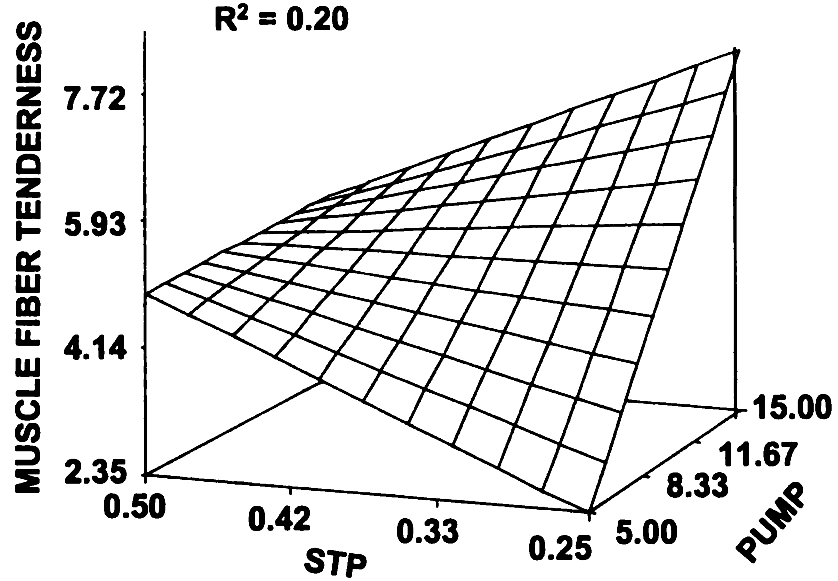
**Fitted Model for Muscle Fiber Tenderness**

STP=0.25




**Fitted Model for Muscle Fiber Tenderness**

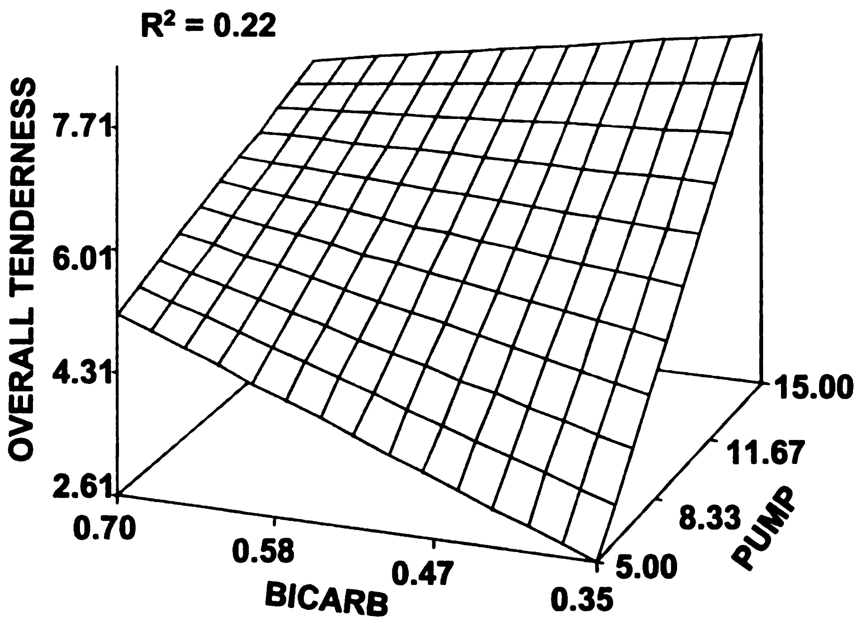
BICARB=0.35



**APPENDIX 38: Response surface curves of significant ($P<0.05$) total and fitted regression models for overall tenderness of marinated sow loin chops manufactured with 5-15% injection level (PUMP), 0.25-0.50% sodium tripolyphosphate (STP), and 0.35-0.70 *M* sodium bicarbonate (BICARB).**

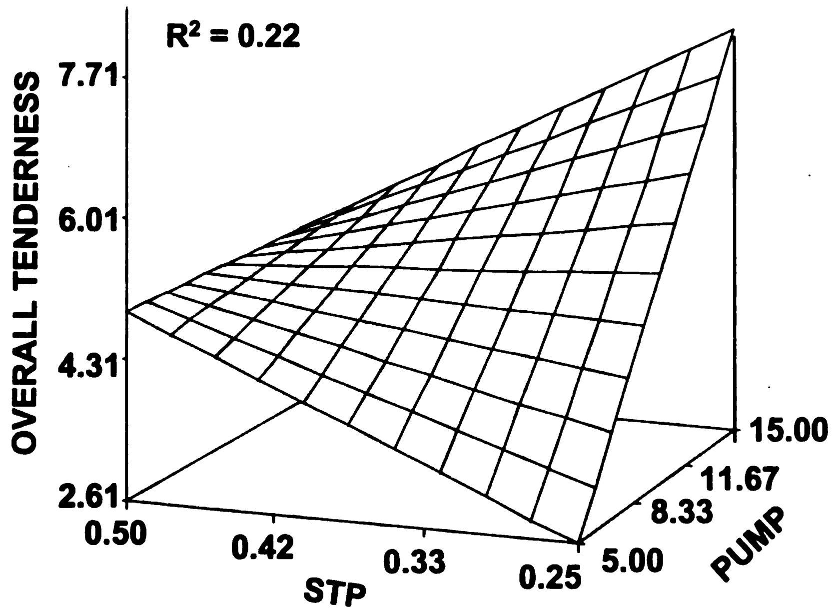
**Fitted Model for Overall Tenderness**

STP=0.25




**Fitted Model for Overall Tenderness**

BICARB=0.35



## RECCOMENDATIONS FOR FUTURE RESEARCH

The results of this thesis work have indicated the feasibility of developing marinades composed of sodium tripolyphosphate and sodium bicarbonate that eliminate detrimental atypical aromas and flavors in tainted sow longissimus dorsi muscle. When injected into tainted sow loins, these marindades were shown to improve flavor, texture, juiciness, and overall acceptability attributes to consumer acceptable levels. This processing technology increases the utilization of tainted sow subprimal cuts for value added whole muscle products. It has also been shown that pre-rigor sow meat is comparative to butcher pork meat in terms of composition and quality of raw materials, functionality, and sensory attributes. Pre-rigor sow meat was actually shown to excel over butcher pork meat for water holding capacity properties of marination uptake potential and cook yields. Sow meat, however, does have limitations. Darker muscle color was found to be one of the most negative attributes of hot-boned sow meat. Future research needs to address this topic to determine what processing technologies may solve this problem.

Although this research focused on a processing strategy to eliminate sow taint, further research needs to investigate deeper into the problem. Future research efforts need to determine methods to successfully analyze tainted sow meat for specific volatile flavor and aroma composition to better understand what volatiles do cause the atypical aromas and flavors identified in this study. With a better understanding of what identified volatiles cause these atypical flavors and aromas, research could focus on specific processing systems to alleviate sow taint according to other practices used in similar type situations.

With knowledge gained from this research, eradicating this problem before sows enter the slaughter/processing system is also an opportunity for research. Future studies need to investigate the occurrence of sow taint in a slaughter plant setting and design a reverse tracking system to identify which farm sow herds the are producing carcasses with atypical aromas and flavors. Upon this discovery, research needs to investigate gestation cycles of the sows, feeding practices, conditioning lengths and times, and overall animal welfare practices on the farm to determine if these factors may be causing the sow taint.

In a final thought, the investigation of sow meat exposes new possibilities of raw materials to produce value added products. Raw materials such as these offer advantages of a lower cost meat ingredient with acceptable quality that could be used to produce a high quality value added product tailored to food service or possibly retail food segments.