CONSUMER PERCEPTION, WILLINGNESS TO PAY, TENDERNESS AND RETAIL DISPLAY OF NON-ENHANCED, ENHANCED AND HIGH-QUALITY PORK LOINS

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Vince Lombardi Jr. wrote, "The difference between a successful person and others is not a lack of strength, not a lack of knowledge, but rather a lack of will".
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Abstract: The objective of this study was to evaluate the effects of three different commercially available pork loins on retail display, trained and consumer sensory panel and consumers intent to purchase. Enhanced (n = 10), non-enhanced (n = 10) and high-quality (n = 10) pork loins were selected from a commercial food distribution company. Loins were cut into 2.54-cm thick chops and randomly assigned retail display, sensory analysis, Warner-Bratzler shear (WBS) force, or instrumental data analysis. For retail display, chops were randomly assigned to 1 of 3 packaging treatments: polyvinyl chloride overwrap (PVC), carbon monoxide (CO-MAP) and high-oxygen modified atmospheric packaging (HiOx-MAP). Visual color measurement for muscle color, surface discoloration and surface color uniformity were recorded on d 0, 2, and 4 of retail display. For trained sensory panel, WBS force analysis, cook loss and Carver Press analysis, chops were evaluated at 3 different degrees of doneness (63, 68, & 74°C). High-quality loins had the highest ($P < 0.05$) fat % compared to enhanced and non-enhanced loins. Chops packaged in CO- and HiOx-MAP were brighter ($P < 0.05$) compared to PVC chops. High-quality chops packaged in PVC had the lowest $a*$ values as well as the highest muscle color score indicative of a less reddish-pink color of lean. A greater percentage (17.8) of consumers chose high-quality pork chops first over enhanced and non-enhanced chops based on the pictures provided in the survey. For WBS force analysis, enhanced loins had lower ($P < 0.05$) shear values compared to non-enhanced loins. In addition, there was no difference ($P > 0.05$) between high-quality and enhanced, or high-quality and non-enhanced loins for WBS force values. Consumer panelist ranked the enhanced chops the highest for overall like, tenderness like and juiciness like, indicating a more tender and juicier product compared to high-quality and non-enhanced loins. In conclusion, the results suggest that enhanced, non-enhanced and high-quality pork loins available in the market have different quality parameters at retail and as a cooked product on consumers acceptability.

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CHAPTER I

INTRODUCTION

For the year 2018, of the world meat and poultry consumption shares, pork ranks the highest (40.1%) in consumption over poultry, beef and mutton/goat (NPB, 2019). In addition, the U.S. ranked 8th as a country in pork consumption (NPB, 2019). The end goal for all segments of the pork industry is to provide consumers with a safe, high-quality product. Fresh pork color, pH, water-holding capacity, marbling and tenderness are attributes commonly associated with pork quality. Each of these factors together or separate have an effect on willingness to pay and the cooked products sensory characteristics including tenderness, juiciness and flavor.

Pork color is a key quality factor that can influence the palatability of a product (Richardson et al., 2018). Darker color of lean is commonly associated with an increase in muscle pH (Suman and Joseph, 2013). Increase in pH has been shown to increase water holding capacity and increase the juiciness and tenderness of pork (Richardson et al., 2018). Muscle color at the point of purchase is an indicator of freshness and anticipated palatability (Brewer, 1998; Brewer et al., 2002a; Richardson et al., 2018) for pork. Modified atmosphere packaging uses a combination of specific gases which can enhance color and shelf life of retail meat products (Jeremiah, 2001). For example, various gases such as oxygen at greater levels (60 – 80%), carbon dioxide, carbon monoxide and nitrogen have been used to stabilize color and quality. High oxygen and low carbon dioxide (CO_2) is a common mixture used today. The high oxygen promotes formation of reddish-pink color and prevent migration of metmyoglobin layer from beneath the surface while CO_2 suppresses the spoilage of microorganisms (Gill, 1996). However, packaging meat products in high-oxygen modified atmosphere packaging has been shown to induce lipid oxidation when stored overtime (Kim et al., 2010). The use of carbon monoxide (CO) gas results in formation of carboxymyoglobin creating a stable reddish-pink meat color (Mancini and Hunt, 2005). Though polyvinyl chloride overwrap packaging seems to be more common at retail for pork products, the use of these modified atmosphere packaging will allow for a more consistent and stable color.

Savell and Cross (1988) suggested a minimum threshold for intramuscular fat of 3% for acceptable palatability in red meat including pork. However, Brewer and McKeith (1999) recommended that a range of 2.2 – 3.4 % minimum intramuscular fat improves eating satisfaction. Marbling has been shown to have conflicting results on its effect of pork palatability attributes. DeVol et al. (1988) found that tenderness was significantly correlated with intramuscular fat ($r = 0.34$) when evaluated by a trained panel. Based upon consumers perspective, Brewer et al. (2001) found no statistical difference in consumers perception on overall juiciness or tenderness based on differences in intramuscular fat. In addition, consumers perspective on willingness to pay for amount of marbling varies amongst studies. Brewer et al. (2001) found consumers were less likely to purchase pork chops with a greater amount of intramuscular fat compared to leaner chops. However, an earlier study showed consumers that understood intramuscular fat's impact on quality were willing to pay for that attribute (Sanders et al., 2007). In order to decrease the variation seen in the pork industry, enhancing pork loins has evolved to satisfy consumers taste. Most enhancement solutions contain salt, phosphate, flavor enhancers and flavoring agents. These solutions combined together are key to increase the water holding capacity, tenderness and juiciness of cooked meat products (Lawrence et al., 2004; Baublits et al., 2006).

Consumers demand specific attributes when they are purchase their food products (Sanders et al., 2007). For that reason, the pork industry needs to have an understanding of the particular attributes consumers evaluate and expect from fresh pork in order to position the industry among the ranks of a competitive meat market. In relation to that, consumers commonly see a variety of labels and claims within products that are intended to address how they are produced. However, these labels and claims may cause confusion amongst consumers (Abrams et al., 2010). Lastly, variation and confusion amongst consumers on cooking of pork leads to variability in palatability traits (Prestat et al., 2002). In 2011, the USDA Food Safety and Inspection service changed the recommended endpoint temperatures of whole muscle cuts of pork from 71 to 63°C in order to maintain food safety, but improve sensory traits. Bryhni et al. (2003) evaluated consumers preference of pork chops cooked at 65°C versus 80°C and found that consumers preferred the lower degree of doneness for juiciness and tenderness attributes.

High-quality pork comprised of a greater amount of intramuscular fat, enhanced loins and non-enhanced, normal pork loins are most commonly seen in retail and food service. It is known the effect MAP has on the color stability of pork products. However, additional research is needed to understand the effect packaging has on the retail display of different commercially available types of pork loins. In addition, understanding visual and palatability sensory characteristics of these three types of loins by consumers can benefit the pork industry in determining requirements for a potential grading system. Therefore, the objective of this study was to evaluate the effect of these three commercially available pork loins on retail display, tenderness, consumer perception and intent to purchase.

CHAPTER II

REVIEW OF LITERATURE

Pork Color

Consumer appeal is an extremely important factor when selecting pork. As a consumer initially walks to a retail case, their concentration and focus goes directly to what they see first, the product color and packaging (Mancini and Hunt, 2005). Consumers routinely use color as a reason to select or reject a meat product. The main component in the contribution to meat color is myoglobin. The product's color is determined by the interaction between myoglobin chemistry and light absorbance and reflectance (Seideman et al., 1984). Myoglobin is a water-soluble protein that is responsible for meat color and constitutes 80 – 90% of the total pigment (AMSA, 2012). The centrally located heme ring contains an iron atom with the 6th binding site occupied by ligands and undergoes four main chemical states: oxymyoglobin, deoxymyoglobin, metmyoglobin, and carboxymyoglobin.

Presence of no ligand at the 6th binding site and the heme iron in the ferrous (Fe^{2+}) state results in myoglobin being in the deoxymoglobin (reduced) state (Suman and Joseph, 2013). This is evident by a purple color and is commonly seen in un-cut whole muscles that have not been previously exposed to oxygen. This myoglobin chemical state is also seen in vacuum-packaged meat. When a product is cut or taken out of a vacuum packaged bag, it is exposed to oxygen, which allows the reduced form of myoglobin (deoxymyoglobin) to react with molecular oxygen at the 6th binding site and transition into the oxymyoglobin state

(Suman and Joseph, 2013). The transfer of oxygen to the muscle resulting in oxymyoglobin is known as oxygenation. Oxymyoglobin is formed spontaneously when meat is exposed to air, but its stability depends on the continuous supply of oxygen as enzymes rapidly utilize the available oxygen. Once the muscle can no longer utilize the available oxygen, the iron portion of the pigment becomes oxidized (Fe^{3+}) and changes to a brown color (Suman and Joseph, 2013). In the oxidized state the pigment is called metmyoglobin. The formation of this color causes major problems for the meat industry. Many consumers do not find the brown color of metmyoglobin appealing and assume it to be spoiled, however, color has no correlation with safety. Case-ready meat has allowed meat purveyors to package meat in a centralized location and modify gas composition with packages. The types of gas can affect the type of myoglobin. Presence of high-oxygen (80% oxygen; four times atmospheric oxygen content) can stabilize bright-red color but increase lipid oxidation. Carbon monoxide can form bright red color by binding the 6th vacant position. Hence, carbon monoxide in combination with other gases such as nitrogen and carbon dioxide is used in Modified Atmosphere Packaging (MAP) (Aberle et al., 2001).

Ideally, the pork industry would prefer to produce red, firm, and non-exudative (RFN) pork for consumers. Red, firm, and non-exudative pork is characterized as having a normal or optimal pH value. A decrease or increase in the pH will result in quality defects for the pork carcass. In the conversion of muscle to meat, there are multiple steps. Following the removal of blood or exsanguination, a series of postmortem changes occur. As the stored oxygen is depleted, aerobic metabolism is shifted into anaerobic glycolysis. Now that the circulatory system within the body is no longer existent due to exsanguination, lactic acid remains within the muscle. The increase in lactic acid within the muscle results in a decrease in muscle pH. Living muscle has a pH of approximately 7.4 and within 6 to 8 h the muscle will decrease to approximately 5.6 (Bowker et al., 2000).

There are multiple factors that can affect color development and color retention of meat. Stress prior to harvest is a key factor affecting color, water-retention, and muscle texture (Rosenvold and Andersen, 2003). Stress can be caused from short-term and long-term pre-harvest handling of pigs. Pre-harvest handling includes comingling of pigs, loading and unloading, and pushing or driving into the harvest facilities. Pre-harvest handling is both an animal welfare and a meat quality issue. During times of stress, animals secrete twice the amount of calcium ions, which results in excessive glycogen within the muscle (Rosenvold and Andersen, 2003). Glycolysis is the process of breaking down glycogen into individual glucose molecules. Glycogen is first broken down into glucose and phosphate with the end product being both lactic and pyruvic acid. Increase in glycogen within the muscle results in a greater amount of lactic acid produced through glycolysis. The increase in lactic acid decreases the pH of muscle and results in a lower pH value compared to normal. The dramatic decrease in pH in combination with increased muscle temperature, results in a pale muscle color, water-loss or exudation, and softness of the muscle tissue (Fernandez et al., 1994). This is due to the muscle fibers ability to not properly hold onto water. When the pH of muscle gets closer to the isoelectric point (pI) the net charge of muscle becomes zero. The pI of meat is 5.2 causing less water to be held by muscle fibers, allowing more free water within the muscle, increasing the reflectance of light, making it a paler color and increasing exudation or water loss (Aberle, 2001). In conjunction with a rapidly declined pH, high carcass temperatures result in denaturing of muscle proteins, especially myosin resulting in a soft muscle texture (Aberle et al., 2001). All these factors combined are referred to as pale, soft, and exudative (PSE) pork. According to Stetzer and McKeith (2003), approximately 15.5% of the pork produced in the U.S. in 2003 had the characteristics of PSE pork.

Genetics is another factor that can cause PSE pork. Halothane and Rendement Napole genes are two genes that affect the animal in different ways. Both the Halothane and Napole genes have positive and negative effects on carcass and meat quality (Hamilton et al., 2000).

Many of the positive effects in relation to carcass composition and quality, include heavy muscled, trim carcasses, resulting in higher yielding pork for the food chain. Unknowingly, breeders were selecting these animals to contain the Halothane and Napole genes, resulting in pigs that stress more commonly referred to as porcine stress syndrome (PSS). The Halothane gene was discovered using Halothane gas to screen for stress receptive pigs, hence the given name, Halothane gene (Channon et al., 2000). The Halothane gene codes for a mutated calcium channel or ryanodine receptor that is in the sarcoplasmic reticulum. A mutated ryanodine receptor allows calcium to leak into the sarcoplasm and affect muscle tissues (Channon et al., 2000). An increased amount of glycogen within muscle results in more lactic acid being produced, reducing the pH more than normal muscle. The Halothane gene accounts for 25-35% of PSE carcasses (Oliver et al., 1993).

The Rendement Napole gene is another genetic mutation that has a major impact on overall pork quality, however, was first used to produce heavy muscled and trim pork carcasses. One major difference between the Napole and Halothane gene is that the Napole gene is only found in the Hampshire breed. Pigs possessing the Napole gene have an altered adenosine monophosphate (AMP) kinase, which regulates glycogen synthase (Moeller et al., 2003). As a result, pigs with this mutation have greater amounts of glycogen in muscle at the time of harvest. An increased amount of glycogen within the muscle results in more lactic acid being produced, reducing the pH more than normal muscle.

In addition to short-term stress, long-term stress is another critical factor to pork quality. Long-term stress is commonly contributed to stress at the farm prior to being sent to the harvesting facility. The long-term stress results in depletion of glycogen from the muscle (Fernandez et al., 1994). As the animals are stressed, the body utilizes glycogen within muscle as a supplementary energy source. With limited glycogen in muscle, only a small amount of lactic acid is produced through anaerobic glycolysis. As previously stated, the buildup of lactic acid results in lowering of muscle pH. Decreased lactic acid production will result in a higher pH value compared to normal meat approximately (> 6.0 vs. 5.6); (Bendall and Swatland, 1988). This higher pH value will result in darker color, firmer texture, and drier appearance or DFD pork (Bendall and Swatland, 1988). This product though it has a dry appearance, tends to be a juicier product compared to RFN or PSE meat due to water being more tightly held by the muscle fibers allowing less light reflectance (Fernandez et al., 1994). The higher pH allows for the muscle fiber to hold onto more water within muscle, making it have a darker appearance due to less water available for light reflectance.

Fresh pork color can be appraised and quantified through multiple subjective and objective measurements. Subjective color is assigned by an experienced and trained personnel using the National Pork Board Color Standards (NPB, 2011). The color scoring scale ranges from one to six. A color score of 1 indicates a lean color of pale, grayish pink to white color. While a color score of 6 indicates a lean color of dark, purplish. Many pork producers utilize these color values to segment or separate product on the processing lines. Utilization of these values help retailers segment pork products for domestic and international retailers. International markets in China and Japan tend to desire the darker pork color compared to the traditional lighter pink color consumers from the U.S. (Ngapo et al., 2007). Objective color measurements are conducted using color instruments. This in return eliminates human error and allows a more accurate option. Colorimeters commonly used in the meat industry are the Hunterlab and Minolta Colorimeter. Both of these devices read the amount of reflectance of light from the pork muscle. The measurement taken from these devices are CIE L^*, a^*, and b^* values. In research, L^*, measures the lightness to darkness (100 = white; 0 = black). Furthermore, a^* values measure the redness to greenness. A more positive a^* values is a more red color whereas a negative value is a more green color. Lastly, b^* measure the yellowness and blueness. A more positive b^* measures yellow, and a more negative is more blue. Brewer and McKeith (1999) reported a normal Minolta

*L** value for pork is 51.5. Furthermore, the NPB (2011) indicates an *L** value of 53 represents a color score value of 3, which is described as reddish-pink.

Pork Marbling

Intramuscular fat is the fat within muscle in the loose connective tissue. This type of fat is also referred to as marbling. The solidification of fat occurs during chilling and helps maintain muscle integrity during fabrication of steaks and chops. Similarly, to muscle color, marbling can also be evaluated by subjective and objective measures. Subjective measurements are conducted by trained professionals using the National Pork Board Marbling Standards (NPB, 2011). These standards consist of a range from one to ten and signify the percent lipid within the muscle evaluated. A marbling score of 1 is associated with 1 percent lipid within the loin chop surface (NPB, 2011). Objective measure for calculating the amount of marbling is fatty acid analysis determining the total lipid content within the muscle and is recorded on a percentage basis. Marbling is evaluated based upon the amount of fat deposited, the size and shape of intramuscular fat. Traditionally, carcasses that have a higher percentage of boneless, closely trimmed retail cuts exhibited less marbling in pork chops (Huff-Lonergan et al., 2002b). These characteristics are then converted to the pork carcass resulting in leaner, lightly marbled pork. Certain breeds of pigs tend to produce a greater amount of intramuscular fat. Huff-Lonergan et al. (2002b) reported Berkshire pigs displayed a greater amount of marbling. U.S. pork exported to countries such as Japan, possess greater amounts of marbling (Ngapo et al., 2007). Consumers in the U.S. desire and request pork with small amount of visual intramuscular fat (Ngapo et al., 2007). However, Fernandez et al. (1999) reported that as the amount of intramuscular fat increases, consumers response for willingness to eat decreases. This indicates consumer perception for high marbled pork is negative. However, it is shown that marbling can increase tenderness and juiciness of pork cuts and increase consumer satisfaction. It is recommended that 2.2 - 3.4 % minimum intramuscular fat improves eating satisfaction (Brewer and McKeith, 1999). As producers, the new goal is to educate consumers on the importance of marbling in pork cuts. This can lead to an increase in tenderness, juiciness, and overall acceptance and therefore increase buying decisions at the retail store.

Lipid Oxidation

Oxidative rancidity is a result of a series of chemical reactions involving oxygen and lipids. Lipid oxidation is one of the leading causes of decrease meat quality especially throughout shelf-life and can result in the formation of off-flavors and odors (Guyon et al., 2016). There are 3-phases to lipid oxidation: initiation, propagation and termination. During the initiation phase, prooxidants such as light, temperature, metals and microorganisms remove a hydrogen atom from a fatty acid to form radicals (Guyon et al., 2016). Polyunsaturated fatty acids are more likely to be involved in lipid oxidation due to their structure with multiple double bonds. The next stage in lipid oxidation is propagation where radicals react with oxygen to form a peroxy-radical. During the last stage, termination, 2 peroxy-radicals react together and stop the process. Thiobarbituric acid reactive substances (TBARS) is a common method used to determine the amount of lipid oxidation within a meat substance. Malonaldehyde is identified as a product of lipid oxidation (Love and Pearson, 1971). In the process, malonaldehyde reacts with thiobarbituric acid and can be read on a spectrophotometer to determine levels of lipid oxidation.

Pork Tenderness

Meat tenderness is an extremely important factor for consumers. Meat tenderness is determined by the amount of connective tissue, intramuscular fat content and myofibrillar structure. There are many intrinsic factors that affect meat tenderness. Age of the animal, connective tissue, marbling content and location of the muscles are key factors that affect tenderness of pork cuts (Lawrie and Ledward, 2014). As an animal ages, there is a greater amount of connective tissue within and surrounding the muscle. This connective tissue forms crosslinkage and is harder to breakdown through extrinsic factors. Marbling is another factor that can influence tenderness of pork cuts. There are four theories to why intramuscular fat or marbling can influence tenderness: bulk density, lubrication, insurance and strain (Aberle, 2001). The bulk density effect is related to the spacing between the marbling and muscle tissue. The marbling is softer in texture compared to the muscle fibers surrounding it. The softer texture makes chewing through the muscle easier due to its soft texture. The lubrication theory states intramuscular fat acts as a lubricant when chewing. The fat will coat the mouth and help and allow ease in chewing the product. The insurance theory relates to an increase amount of marbling ensuring the consumer has a pleasant eating experience. With increasing intramuscular fat, there will be less variation in tenderness and consumer satisfaction. Lastly the strain theory implies that increasing the amount of marbling within the perimysium, will increase the spacing and tension between muscles. This strain on the muscle will make muscle fibers more tender. Muscle location is another intrinsic factor to be concerned with when evaluating muscle tenderness. The pig uses different portions of its body for locomotion and support. Locomotive muscles are tougher than support muscle. These locomotive muscles are used to move the animal and have a greater amount of connective tissue present (Lawrie and Ledward, 2014).

Extrinsic factors are used to enhance tenderness and flavor of pork products. Research has found meat stored for increased time at refrigerated storage postmortem, called aging, improved meat tenderness (Lawrie and Ledward, 2014). Aging allows endogenous proteolytic enzymes in muscle to tenderize meat. The aging process involves storing carcasses, primals, subprimals, or chops for sufficient period of time, at refrigerated temperatures, to maximize palatability characteristics such as tenderness, juiciness, and flavor. Protein proteolysis of structural proteins has been determined to be one of the main causes for increased tenderness postmortem (Koohmaraie, 1992).

During postmortem aging, one of the first observable changes in ultrastructure of postmortem muscle is in myofibrils (Aberle et al., 2001). Muscle becomes more extensible the longer it is aged. Desmin and titin are proteins that undergo proteolytic degradation, resulting in loss of Z-disks integrity and aid in determining meat tenderness. Desmin is an intermediate filament protein localized at the Z-disk in skeletal muscle (Richardson, 1981). Intermediate filaments like desmin, connect adjacent myofibrils at the level of their Z-lines and the myofibrils to other cellular structures. The location of desmin is an important factor in maintaining structural stability. Desmin surrounds the Z-lines of myofibrils, once degradation occurs, it results in loss of structure to the Z-line and increases tenderness (Zhang et al., 2006). Titin is the largest protein found in mammalian tissues, and also the third most abundant (Huff Lonergan et al., 2010). In skeletal muscle, titin is an integral part of forming the Z-line as it spans half the length of the sarcomere and thus aids in sarcomere alignment. Titin has been shown to degrade postmortem and be associated with improved tenderness (Aberle et al., 2001).

Nebulin is a mega-protein that extends from the Z-line to actin. Degradation of nebulin postmortem could weaken actin linkages at the Z-line and thereby weaken the structure of the muscle cell (Aberle et al., 2001). Actin is the second most abundant protein in muscle fibers and has not been considered to undergo major changes during postmortem aging period (Aberle et al., 2001). The weakening of the myofibrils yields a higher proportion of smaller fragments in meat (Nishimura et al., 1998). Based on the fragmentation concept, the myofibril fragmentation index has been used as an indication of meat tenderness and postmortem tenderization.

Many hypotheses have been researched to determine the causes of degradation of myofibrillar proteins during postmortem aging. A study conducted by Goll et al. (1983) indicated that proteases have to be present and have access to activation substrates for protein degradation to occur. Researchers have investigated the role of calcium dependent proteases known as calpains. Calpains were found to be the primary cause for an increase in postmortem tenderization caused by structural protein degradation (Olson et al., 1977). Calpains cause the breakdown in Z-disk structural proteins such as desmin. A study conducted by Morgan et al. (1991) examined the effect of injecting calcium chloride ($CaCl_2$) into the muscles from cow carcasses. The injection of $CaCl_2$ accelerated postmortem aging and improved ultimate meat tenderness. Though the mechanism through which calcium chloride infusion accelerates postmortem proteolysis is unknown, it is believed, based on these studies the primary mode of action of calcium is through activation of calpains (Koohmaraie et al., 1988). Calpain is regulated by an endogenous inhibitor calpastatin, which has been found in all tissues that contain calpains (Huff-Lonergan et al., 1996).

Meat products can be aged by two methods: wet aging or dry aging. Wet aging refers to postmortem aging of meat products in a vacuum package and is the most common practice in the meat industry. In U.S. pork processing plants, pork is vacuum-packaged and distributed to retailers. Wet aging is utilized to prolong shelf-life and palatability of pork during extended periods of shipment and storage.

Instrumental measurements of tenderness are commonly used in research. Warner-Bratzler shear (WBS) force is the most utilized analysis method. The WBS force is the measurement of force required to shear across a muscle fiber. These values replicate the amount of force to penetrate, bite, mince, compress, and stretch the meat. Objective evaluations allow for the comparison of different treatments as well as ascertaining their effect on a characteristic. However, they do not provide information concerning product acceptability or preference for one kind of meat over another (Destefanis et al., 2008). Consumer panels are great predictors of how the public perceives a product. Consumer acceptability and satisfaction is the driver of the meat industry and being able to gain insight on their demand is of utmost importance. Measurements commonly associated with consumer sensory panels are tenderness, juiciness, flavor, overall like, and overall acceptability (Miller et al., 2001). Subjective measures such as consumer panels give more insight of consumer desirability.

Pork Enhancement

Enhancing pork cuts is very common in the industry. These are the addition of non-meat ingredients to fresh pork primals or subprimals in a water-based solution to improve juiciness, tenderness and flavor of pork. Consumers were first taught to cook pork products to a higher degree of doneness. *Trichinella spiralis* are parasites that cause foodborne illness if consumed. During the 1970s and 1980s, pork products were known to carry *Trichinella spiralis* and once consumed by humans, will infect them and cause serious illness and in some cases death (Kotula et al., 1983). Destruction of *Trichinella spiralis* is accomplished by proper cooking of meat products. At 77°C (170°F), *Trichinella spiralis* larvae are instantly ineffective (Kotula et al., 1983). Because of this, pork products were cooked to a very high degree of doneness and results in tough, and dry cuts. Therefore, enhancing pork was the solution to overcome juiciness and tenderness problems of overcooked pork products.

Common ingredients in an enhancement solution include: water, salt and phosphate. Each of these have multiple implications on the final product. Phosphate is commonly used to increase water-holding capacity. Phosphate is an ingredient that is regulated by USDA/FSIS and not to exceed 0.5% of product formulation (Directive, 2016). Adding phosphate to a meat solution will increase muscle pH. Transitioning the pH results in an increase in negative net charges and therefore increase the availability for protein to bind water (Aberle et al., 2001). Keeton (1983) looked at various levels of phosphate added to ground pork and measured their water-holding capacity. As the percent of phosphate increased within ground pork, a decrease in drip loss was shown indicating a greater amount of water retention and water-holding capacity (Keeton, 1983). Increasing the pH of meat may result in a decrease in shelf-life. Meat with a higher pH has been shown to be more favorable for microbial growth. Salt also interacts with salt soluble proteins, causing the swelling of muscle fibers, increasing water retention and decreasing drip loss. Wright et al. (2005) recommended adding 6 - 12% of solution improves pork quality. In addition, salt acts as a flavor enhancer.

One key factor when creating a brine solution to enhance pork is understanding the labeling requirements that are associated with enhancement. The USDA/FSIS requires labeling regulations on packages describing the percent of enhanced solution added to the product (Directive, 2016). Depending on the level at which the product has been enhanced results in different requirements. For meat containing more than 10% total added ingredients, the label must have the words "Containing up to (the actual added level [%]) containing (list of ingredients in descending order of predominance)". Balancing the percentage of salt and phosphate within a brine in crucial to ensure the integrity of the meat product and not allow it to have a similar appearance and texture of a processed meat product.

Industry Today and Future

Currently, pork color and marbling are subjectively measured using the National Pork Board Standards (NPB, 2011). However, technology is continually being developed to find new and quicker methods to determine pork quality factors. Muscle pH probes are becoming much faster and more accurate in determining the pH of products. The increase in speed and accuracy may allow producers to accurately and efficiently segment pork carcasses based upon pH. This may be used to segment pork for quality defects including PSE and DFD, which have a negative visual or sensory experience. Quickly assessing pork color and marbling may introduce the desire for a grading or certification system for pork, similar to beef. A Computer Vision System (CVS) has been developed to quickly determine color and marbling scores (Sun et al., 2016). In this study, results showed for the pork loin color attribute, CVS reached the highest regression coefficient of determination ($R^2 = 0.90$) with instrumental lean color which was better than subjective evaluation ($R^2 = 0.68$). For marbling, the CVS value reached the same evaluation level as subjective marbling scores ($R^2 = 0.62, 0.63$; respectfully). Therefore, utilization of this type of equipment can optimize efficiency in pork plants, allowing for grading and certifications to be developed.

The pork industry has followed the same path as the beef industry in developing and supporting niche markets for selling pork products. In order for a niche market to be successful, consumers have to demand these specialized products and see the benefit in these products compared to normal. One common niche market within the pork industry is associated with breed type. Similar to Certified Angus Beef, the Berkshire breed is commonly associated with high marbled pork products that can result in a huge premium (Honeyman et al., 2006). In addition, the methods in which farmers raise their animals can result in the development of a niche market. Farrowing crates have gained a lot of negative publicity among consumers and animal advocates (Velarde et al., 2015). Many animal activists believe not using farrowing or gestation crates while raising pigs is a more humane method. Labeling pork products as crate free may result in an increase in consumer demand for products and therefore creating a market. Lastly is labeling product as organic or natural, this is a tool used throughout the industry as a way to influence consumers' knowledge. To label a product as organic, the standards prohibit the use of antibiotics and growth hormones and require animals to be fed 100% organic feed (USDA, 2005). As for all meat products, no residual antibiotics are allowed. Furthermore, pigs are not allowed through federal regulation, to be given additional hormones to increase feed efficiency. To label a product as natural, no further processing of the meat shall take place following harvesting (Miller et al., 2001). An example of further processing in the pork industry would be enhancement to increase juiciness and tenderness. Each of these niche markets can be beneficial to the pork industry. If there is not a demand, there is no need for the niche market. Marketing is a practice used by many retailers to promote their business and increase sales. However, consumer satisfaction is assumed to be a more significant determinant in repetitive sales and new customers (Miller et al., 2001). Meat products are similar to any other product in that they are developed, produced, and marketed to appeal to the customer. Consumer studies are used to collect and understand consumer response to the food products and variables or factors that are being studied in order to ensure they will have high consumer acceptance (Resurreccion, 2004).

CHAPTER III

CONSUMERS INTENT TO PURCHASE AND RETAIL DISPLAY OF NON-ENHANCED, ENHANCED AND HIGH-QUALITY PORK CHOPS

Abstract

The objective of this study was to evaluate the effects of three different commercially available pork loins on retail display and consumers intent to purchase. Enhanced (n = 10), non-enhanced (n = 10) and high-quality (n = 10) pork loins were selected from a commercial food distribution company. Loins were cut into 2.54-cm thick chops and assigned to 1 of 3 packaging treatments: polyvinyl chloride overwrap (PVC), carbon monoxide (CO-MAP) and high-oxygen modified atmospheric packaging (HiOx-MAP). Visual color measurement for muscle color, surface discoloration and surface color uniformity were recorded on d 0, 2, and 4 of retail display. Enhanced loins had the highest National Pork Producers Council (NPPC) color score and highest pH compared to high-quality and non-enhanced loins ($P < 0.05$). In addition, high-quality loins had the highest ($P < 0.05$) NPPC marbling score and fat percentage compared to enhanced and non-enhanced loins. CO- and HiOx-MAP packaged chops were significantly brighter ($P < 0.05$) compared to PVC chops. High-quality chops packaged in PVC had the lowest $a*$ values as well as the highest muscle color score indicative of a less reddish-pink color of lean. In addition, pork packaged in PVC had higher surface discoloration and surface color uniformity than CO-MAP indicating a greater percent discoloration and less uniformity. A greater percentage (17.83) of consumers chose high-quality pork chops first over enhanced and non-enhanced chops based on the pictures provided in the survey. In addition, 85.71% consumers of a lower age group (< 21

years) were more likely to purchase the high-quality pork chops. Lastly, there was a significant ($P < 0.05$) moderately positive correlation (r = 0.465) between participants preferred degree of doneness for beef and pork. Of participants that consume beef at 60°C, 19.2% will consume pork loins at 63°C. As the preferred degree of doneness for beef increases, so do consumers preference for pork degree of doneness. In conclusion, packaging high-quality chops in PVC had the highest muscle color and lowest a^* values indicative of a less reddish-pink color, however, consumers had a higher purchase intent for high-quality over enhanced and non-enhanced chops.

Introduction

Mancini and Hunt (2005) stated that visual factors such as color, marbling and subcutaneous fat are key to purchasing decisions for consumers. Muscle color at the point of purchase is an indicator of freshness and anticipated palatability (Brewer, 1998; Brewer et al., 2002a; Richardson et al., 2018). Case-ready meat has allowed meat purveyors to package meat in a centralized location and modify gas composition with packages. The types of gas can affect the type of myoglobin. Presence of high-oxygen (80% oxygen; four times atmospheric oxygen content) can stabilize bright-red color but increase lipid oxidation. Carbon monoxide can form bright red color by binding the 6th vacant position. Hence, carbon monoxide in combination with other gases such as nitrogen and carbon dioxide is used in Modified Atmosphere Packaging (MAP) (Aberle et al., 2001). Though polyvinyl chloride overwrap packaging seems to be more common at retail for pork products, the use of these modified atmosphere packaging will allow for a more consistent and stable color.

Consumers increasingly demand specific attributes when they are purchasing their food products (Sanders et al., 2007). For that reason, the pork industry needs to have an understanding of the particular attributes consumers evaluate and expect from fresh pork in order to position the industry among the ranks of other proteins. Consumers commonly see a variety of labels and claims within products that are intended to address how they are produced. However, these labels and claims may cause confusion amongst consumers (Abrams et al., 2010). Lastly, variation and confusion amongst consumers on cooking of pork leads to variability in palatability traits (Prestat et al., 2002). In 2011, USDA Food Safety Inspection Service changed the recommended endpoint temperature of whole muscle pork cuts from 71 to 63°C in order to maintain food safety, while improving sensory traits.

High-quality pork comprised of a greater amount of intramuscular fat, enhanced loins and non-enhanced, normal pork loins are most commonly seen in retail and food service. It is known the effect MAP has on the color stability of pork products. However, additional research is needed to understand the effect packaging has on the retail display of different commercially available types of pork loins. In addition, understanding consumers purchasing decisions can benefit the pork industry in determining requirements for a potential grading system. Therefore, the objective of this study was to evaluate the effect of these three commercially available pork loins packaged in modified atmosphere packaging on retail display as well as consumers intent to purchase different types of chops.

Materials and Methods

Product Collection

Pork loins (IMPS #412) were selected from a commercial food distribution company in Oklahoma. The pork loins selected for this study represent the variation seen at the retail sector. Enhanced (n = 10), non-enhanced (n = 10) and high-quality (n = 10) pork loins were selected with similar pack dates and transported to the Food and Agriculture Products Center at Oklahoma State University. The pack date was set as d 0 for aging, and loins were aged in the package for a total of 21 d. Following aging, pork loins were sliced into 2.54 cm thick chops and assigned for further analysis. The two most caudal chops from each loin were used to determine proximate analysis, and remaining chops were randomly assigned to retail display.

Muscle pH, Marbling Score & Muscle Color Score

Muscle pH was measured for each loin using a portable pH meter (HANNA Instruments HI99163 Meat pH Meter; Smithfield, RI). The pH was measured internally of each subprimal at three different locations. One pork chop from each loin was randomly selected to determine marbling and color score. Trained panelist evaluated visual color and marbling using National Pork Producers Council (1999). Visual color was assigned using a 6-point scale (1 = pale, grayish-pink; 6 = dark, purplish-red); and visual marbling was assigned using a 10-point scale (1 = 1% intramuscular fat; 10 = 10% intramuscular fat). All evaluations were made in half score increments.

Proximate Composition Analysis

All subcutaneous fat and connective tissue were removed before analysis. Each sample was ground utilizing a tabletop grinder (Big Bite Grinder, 4.5 mm, fine grind. LEM). Two hundred-gram samples from E, N, and H loins were tightly packed in a 140-mm sample cup and analyzed using an AOAC approved FOSS Food Scan™ 78800 near-infrared spectrophotometer (Dedicated Analytical Solutions, Hillerod, Denmark). The proximate composition (protein, water, fat and collagen) was recorded on a percentage basis.

Retail Display

One chop from each loin was randomly assigned to 1 of 3 packaging treatments: 1) polyvinyl chloride overwrap (PVC), 2) carbon monoxide modified atmosphere packaging (CO-MAP; 0.4% CO, 69.6% N, and 30% CO_2) and 3) high-oxygen modified atmospheric packaging (HiOx-MAP; 80% O_2 and 20% CO_2). Chops assigned to PVC packaging were placed into a plastic-foam retail tray with a soaker pad and wrapped with a polyvinyl chloride film. Chops assigned to CO-MAP and HiOx-MAP packaging were placed in Rock-Tenn DuraFresh rigid trays (22.2 cm x 17.1 cm x 4.5 cm; RockTenn Company, Norcross, GA) and sealed with clear, multilayer barrier film (254 cm3 $O_2/m^2/24$ h, at 4.4 °C, LID 1050 film; Cryovac Sealed Air, Duncan, SC). Modified atmosphere packaging was accomplished utilizing a Mondini semiautomatic tray-sealing machine (Model: CV/VG-5, G.; Mondini, Cologne, Italy) and certified gas blends (Stillwater Steel, Stillwater, OK). Immediately after packaging, packages were placed in a coffin-style retail display cases under continuous LED lighting (Philips LED lamps; 12 Watts, 48 inches; Philips, China; color temperature = 3500 K, LUX = 900) and maintained at 2 ± 1°C for 6 d. The packages were rotated daily to minimize the variation due to location within the display case.

A HunterLab MiniScan XE Plus spectrophotometer (2.5 cm aperture, Illuminant A, and 10° standard observed angle; HunterLab Associates, Reston, VA) was used to measure surface color at 3 locations on each chop on each day of retail display. Objective measure of $L*$, $a*$, and $b*$ values were utilized to characterize the surface color. Care was taken to limit accumulation of fat and/or moisture smear on the MAP film after color measurements as described in the AMSA (2012) Meat Color Measurement Guidelines.

A trained color panel was conducted on d 0, 2 and 4 of retail display. Muscle Color (1 = Extremely bright purplish-pink; 8 = Extremely dark purplish-pink), surface discoloration (1 = No discoloration [0%]; 7 = Extensive discoloration [81-100%]) and surface color uniformity (1 = Uniform, no two-toning; 5 = Extreme two-toning) was scored by a 6-member trained panel using American Meat Science Association (2012) as reference.

Lipid Oxidation

Following retail display, lipid oxidation was evaluated. Thiobarbituric acid reactive substances (TBARS) values were measured according to the procedure of Witte et al. (1970). From each steak, 5 g of sample that contained both interior and surface was blended with 25 mL trichloroacetic acid (TCA) solution (20%) and 20 mL distilled water. Samples were homogenized using a Sorvall Omni mixer (Newton, CT) for 1 min and filtered through a Whatman (#1) filter paper. One mL of filtrate was mixed with 1 mL thiobarbituric acid (TBA) solution (20 mM) and incubated in a boiling water bath for 10 min. After incubation, samples were cooled, and absorbance at 532 nm was measured using a Shimadzu UV-2600 PC spectrophotometer. The blank consisted of 2 mL TCA/distilled water (1:1 v/v) and 2 mL TBA solution.

Consumer Retail Study

A retail consumer study was conducted through a survey software (Qualtrics Provo, UT) and approved by the Institutional Review Board (AG-19-32-STW). This study was conducted to determine consumers perspective on pork chops at retail. A total of 142 consumers took the survey. Question 1 asked if participants purchased or consumed pork chops. This allowed only participants that consume or purchase pork (n = 129) to be used for data analysis. The remaining 129 panelist were asked three demographic questions including their gender, age and how often they consume pork and is presented in Table 3.1. Questions 5 and 6 were in relation to pork retail display evaluation. Participants were asked to rank 3 pork chops with similar fat thickness and loin eye shape and size based upon their intent to purchase (1 = most likely to purchase; 3 = unlikely to purchase). The variation between pork chops included the amount of intramuscular fat, muscle color and texture. The three pictures used are found in the appendices. Question 6 asked participants to rank 3 different labels based upon their intent to purchase (1 = most likely to purchase; 3 = unlikely to purchase). These labels included an enhancement label claim that included the percent solution added to the product, an all-natural pork label, and a normal pork label with no claims. The three labels used in the study are found in the appendices. Lastly, question 7 and 8 asked participants what degree of doneness they consume pork chops (medium rare [63°C], medium [68°C], and well done [74°C]) and beef steaks (medium rare [60°C], medium [65°C], medium well [68°C], and well done [71°C]). Pictures of the chops or steaks endpoint temperature was added with the degree of doneness to allow participants a visual representation of each endpoint cooking temperature.

Statistical Analysis

A split-plot design with repeated measures was utilized. Pork loin treatment was the whole-plot and packaging type was the split-plot factor with retail display as the repeated measure. Data were analyzed using the PROC GLM procedure of SAS (SAS 9.4; SAS Inst., Cary, NC). Fixed effect included treatment, packaging type and retail display. Loin number was the random effect for proximate analysis, trained color panel, instrumental color and lipid oxidation. The retail consumer panel data were reported as percentages. The model included treatment, packaging, and retail display day as main effects and treatment x packaging and packaging x retail display day for a two-way interaction. There was not a significant three-way interaction between the main effects. Least squares means were calculated; where ANOVA testing indicated significance, means will be separated using the PDIFF procedure and $\alpha < 0.05$. The correlations among NPPC marbling score and fat percent variables, as well as beef and pork degree of doneness were determined using PROC CORR procedure of SAS. The chi-square test was applied to evaluate the distributions (%) of pork chop type, labeling claim and degree of doneness among gender and age.

Results and Discussion

Marbling Score, Color Score and Muscle pH

Results for marbling score, color score and muscle pH are presented in Table 3.2. Evaluators used the guide from the NPPC to assign a marbling and color score for each loin. The high-quality loins had the highest ($P < 0.05$) marbling score (3.30) compared to both enhanced and non-enhanced pork loins (1.70 and 2.20 respectfully). Enhanced pork loins had the lowest ($P < 0.05$) marbling score of 1.70, indicating approximately 1% intramuscular fat within the chop. Klinkner (2013) completed a retail benchmark study on 117 supermarkets in 67 cities and found that the mean subjective marbling score in 2015 was 2.30. Based upon data from this study, the only pork loins that fall within or above that marbling score would be the high-quality pork chops with a marbling score of 3.30.

There was a statistical difference ($P < 0.05$) for subjective NPPC color scores of pork loins. Enhanced pork loins had a higher subjective color score indicating a darker pink color of lean compared to both the high-quality and non-enhanced pork chops. In addition, enhanced chops were shown to have a higher ($P < 0.05$) pH compared to high-quality and enhanced pork chops. Miller (1998) reported the addition of water, sodium or phosphate will bind more water within the muscle, and less water on the surface, allowing less light reflectance and a darker color of lean. The higher pH may be a cause for the darker pink color of lean.

Proximate Analysis

Results from proximate composition analysis for percent protein, fat and moisture are presented in Table 3.3. Enhanced pork chops had the lowest ($P < 0.05$) percent protein and the highest ($P < 0.05$) percent moisture compared to high-quality and non-enhanced pork loins. The increase in moisture is contributed to the 12% added solution in the product. A study conducted by Brewer and McKeith (1999) found chops that ranked among the highest by consumers appeared more wet than dry. In addition, high-quality pork loins had statistically the highest ($P < 0.05$) fat percent compared to enhanced and non-enhanced loins. High-quality loins had a fat percent of 4.72 which is representative of an NPPC marbling score of 4. There was a significant ($P < 0.05$) strong positive correlation (r = 0.83) between NPPC subjective marbling score and the objective proximate analysis fat percentage for this study. Huff-Lonergan et al. (2002a) also found a significant positive correlation (r = 0.57) between subjective marbling score and percent lipid.

Retail Display

There was a significant packaging type x treatment interaction for L^* (Figure 3.1) and a^* (Figure 3.2) CIE color space values. For L^* values, high-quality chops packaged in PVC had the highest ($P < 0.05$) value compared to enhanced and non-enhanced pork chops packaged in PVC. As shown previously, the high-quality chops had a greater amount of marbling as shown by a higher marbling score and fat percentage (Table 3.2 & 3.3). The greater amount of intramuscular fat may be the cause of the increase L^* values resulting in a brighter color of lean. There was no significant difference ($P > 0.05$) for enhanced chops when packaged in either PVC, CO- or HiOx-MAP. Contrary to the current study, Krause et al. (2003) found enhanced pork chops packaged in CO-MAP had a higher L^* values compared to chops packaged in PVC. Lastly, non-enhanced chops packaged in HiOx-MAP had a higher L^* value ($P < 0.05$) compared to chops packaged in PVC or CO-MAP. Chops packaged in CO-MAP were more consistent amongst treatment groups as shown by no statistical difference ($P > 0.05$) for L^* values between high-quality, enhanced and non-enhanced pork chops. Krause et al. (2003) found similar results showing no difference between non-enhanced and enhanced pork chops when packaged in CO-MAP.

High-quality chops packaged in PVC had the lowest a^* values ($P < 0.05$) shown in Figure 3.2. This may be due to the increase in intramuscular fat. The color of meat is dependent on the chemical state of myoglobin within the muscle. Enhanced and non-enhanced pork chops were leaner cuts as shown by a lower NPPC marbling score and fat percentage (Table 3.2 & 3.3) allowing more lean available to bind with either carbon monoxide gas or higher concentrations of oxygen creating a more desirable color. Enhanced and non-enhanced pork chops packaged in CO-MAP had a higher ($P < 0.05$) a^* compared to PVC or HiOx-MAP within treatment groups. Krause et al. (2003) found similar findings showing enhanced and non-enhanced pork chops packaged in CO-MAP had a significantly higher a^* value compared to other packaging types.

There was a significant display day x packaging type interaction for trained panelists' scores on muscle color (Figure 3.4) and surface discoloration (Figure 3.5). As seen in both figures, there is an increase ($P < 0.05$) in both muscle color score and surface discoloration score for PVC packaged chops as retail display day increases. For muscle color, there was no difference ($P > 0.05$) between d 2 and 4 for pork chops packaged in CO-MAP. Lastly, there was no difference ($P > 0.05$) in muscle color for chops packaged in CO-MAP at d 4 of retail compared to PVC packaged pork at d 0. This indicates pork packaged in CO-MAP can have similar muscle color at d 4 of retail than chops packaged in PVC at d 0. Carbon monoxide binds strongly with the meat pigment myoglobin to form stable carboxymyoglobin. Similar findings were seen in a study conducted by Sørheim et al. (1999) showing an increase in color stability for CO-MAP as retail day increased.

Lipid Oxidation

A treatment x packaging interaction for lipid oxidation was found and is reported in Figure 3.6. Non-enhanced chops packaged in PVC had the highest ($P < 0.05$) lipid oxidation compared to other treatments and packaging types. Furthermore, there was no difference ($P > 0.05$) between treatments for lipid oxidation when packaged in HiOx-MAP. Lastly, when comparing enhanced and non-enhanced pork chops, chops packaged in CO-MAP had lower ($P < 0.05$) lipid oxidation compared to PVC packaging. Krause et al. (2003) had similar findings as shown by less lipid oxidation for enhanced or non-enhanced chops packaged in CO-MAP compared to PVC packaging. A greater oxygen concentration within packages promotes lipid oxidation, thus decreasing shelf-life and consumer acceptability (Kim et al., 2010). Therefore, it should be expected that HiOx-MAP would result in the greatest lipid oxidation. However, based upon the current study, HiOx-MAP resulted in among the lowest lipid oxidation following retail display.

Consumer Retail Study

Figure 3.6 represents consumers intent to purchase normal, high-quality and enhanced pork chops based upon the picture provided in the survey. Participants were asked to rank each chop (first – third) and the frequencies are presented. As shown, high-quality pork chops with a greater amount of intramuscular fat were selected first among participants 17.8% of the time. Normal chops were ranked second 25.1% of the time and enhanced chops were selected third or last 19.4% of the time by participants. There are varying results on consumers perception of intramuscular fat within a muscle for purchasing decisions. Similar to the current study, Sanders et al. (2007) found marbling perceptions were highly significant and positively associated with the willingness-to-pay for more marbling. The consumers who understood marbling's impact on quality were willing to pay more for that attribute (Sanders et al., 2007). However, Brewer et al. (2001) reported that consumers were less likely to purchase highly marbled pork and preferred leaner chops. In addition, Brewer (1998) found that during in-home evaluation, 40% of consumers chose lean chops (< 1% intramuscular fat), 42% chose medium marbling (2 - 2.5% intramuscular fat) and 18% chose highly marbled chops (3 - 3.5% intramuscular fat). Based on fat percentage (Table 3.2) high-quality chops used in this study contained intramuscular fat that would fall in the highly marbled category. Sanders et al. (2007) also stated niche markets for leaner products may be best suited for the health-conscious consumers. Meat grading is a tool used to segment carcasses based upon a set criterion. This creates competition in the marketplace and drives producers to meet those standards established. In order to have a grading system, variation must be presence in order to assign value. Variation within the pork industry may include marbling, color, pH or water holding capacity. In the current study, enhanced and non-enhanced pork loins were only 10 cents/lb different. This small variation in price may have little effect on consumers buying decisions. Additional research should be conducted to determine consumers intent to purchase various pork chop quality attributes with price as an additional attribute.

Figure 3.7 represents the consumers intent to purchase chops based on the label provided ($P < 0.05$). Only 9.6% of participants would purchase pork chops first if labeled with a natural claim. According to USDA's Economic Research Service, increasing sales of organic and natural food products are being driven by health-conscious consumers (Brewer, 1998). Pork chops with a normal label with no claim were ranked second on the intent to purchase 16.5% of the time. Pork chops labeled with an enhancement claim were split between first and third on intent to purchase. Participants ranked the enhanced label first 13.2% of the time on their intent to purchase, while 13.7% of participants ranked it third or last. Enhancement has become a common practice to improve the tenderness and juiciness of pork (Robbins et al., 2002; Moeller et al., 2009). If consumers are properly informed and understand the positive aspects of enhanced pork loins there may be an increase in intent to purchase these products. Brewer et al. (2002a) asked consumers in retail markets to evaluate and assign a purchase intent of enhanced pork loins. More than 36% of participants would purchase enhanced pork, however, they expressed concern about the ingredients on the label.

In 2011, USDA Food Safety Inspection Service changed the recommendation endpoint temperature of whole muscle pork cuts from 71 to 63°C in order to maintain food safety, while improving sensory traits. Figures 3.9 and 3.10 are in relation to pork degree of doneness and participants intent to consume. Figure 3.9 shows the relationship of beef degree of doneness vs. pork degree of doneness. When comparing consumers preference on beef degree of doneness with pork degree of doneness, of the participants that consume beef at 60°C (medium rare), 19.2% would consume pork chops at 63°C (medium rare). A higher percent (59.6%) of these participants would consume pork at 68°C. Participants that would consume beef at a higher degree of doneness, 83.3% of those participants would consume pork at a higher degree of doneness with 0.0% consuming pork at the lowest degree of doneness. There was a significant ($P < 0.05$) moderately positive correlation (r = 0.465) between beef degree of doneness and pork degree of doneness. Figure 3.10 represents the relationship of pork degree of doneness based on participants gender. A higher percent of male participants (8.5%) would consume pork at 63°C (medium rare) than female participants (1.6%). As degree of doneness increases, we see the inverse as shown by a larger percent of females (25.6%) consuming pork cooked to 68°C versus males (14.7%). It has been shown that cooking pork to a lower degree of doneness can enhance sensory attributes of pork (Prestat et al., 2002; Baublits et al., 2006; Richardson et al., 2018; Honegger et al., 2019). By properly educating consumers on the importance of cooking pork to a desired lower endpoint temperature, they may have a more pleasurable eating experience.

Conclusion

Packaging pork in modified atmosphere packaging especially in CO-MAP, resulted in a more stable and desirable reddish-pink color. In addition, high-quality pork chops when packaged in PVC had the lowest $a*$ and highest muscle color indicating a less ideal reddish-pink pork color. Pork chops packaged in PVC had a higher surface discoloration score compared to CO-MAP showing the benefits of color stability CO gas possess. As the display day increased from d 0 to d 4, pork chops packaged in PVC increased in muscle color and surface discoloration score. Pork packaged in CO- or HiOx-MAP had similar muscle color scores as PVC packaged pork at d 0 or d 2 respectfully. Consumers preferred pictures of high-quality chops (17.8%) over enhanced (9.3%) and non-enhanced (6.2%) chops. In addition, consumers interpretation of the enhanced label varies as shown by consumers selecting the enhanced label either first or third a similar percentage of times. Perception of degree of doneness for pork correlates with beef. Males are more likely to consume pork at 63°C compared to females. However, still a smaller percentage of participants would consumer pork at a higher degree of doneness than what USDA recommends. Proper education of these key quality factors and their effect on palatability is extremely important and may allow for less variation amongst different types of pork loins.

Table 3.1 Demographic background of consumer panelists (n = 129) for retail pork chop evaluation

Parameter	Frequency (%)
Gender	
Male	51.20
Female	48.80
Age, years	
≤ 21	5.43
22 to 29	17.05
30 to 39	17.05
40 to 49	17.05
50 to 59	35.66
≥ 60	7.75
Pork Chops Consumed	
Daily	0.00
3 or more times a week	2.33
Once a week	12.40
Once every 2 weeks	24.03
Once a month	29.46
Once every 2 months	13.95
2-3 times a year	17.83

Table 3.2 Least squares means for National Pork Producers Council (NPPC) marbling[1] and color scores[2] and pH of high-quality, enhanced, and non-enhanced pork loins (n = 30)

Treatment	Marbling Score	Color Score	pH
High-Quality	3.30[a]	3.26[b]	5.47[b]
Enhanced	1.70[c]	3.91[a]	5.91[a]
Non-Enhanced	2.20[b]	3.28[b]	5.45[b]
SEM	0.17	0.15	0.03
P-value	$P < 0.0001$	$P = 0.0051$	$P < 0.0001$

[abc]Within a column, least squares means lacking a common superscript differ ($P < 0.05$)

[1]NPPC guidelines to assign a marbling score using a 10-point scale: (1 = 1% intramuscular fat; 10 = 10% intramuscular fat)

[2]NPPC guidelines to assign a color score using a 6-point scale: (1 = pale, grayish-pink; 6 = dark, purplish-red)

Table 3.3 Least squares means for proximate compositions of high-quality, enhanced and non-enhanced pork loins (n = 30)

Treatment	Protein, %	Fat, %	Moisture, %
High-Quality	23.06^{a}	4.72^{a}	71.55^{c}
Enhanced	22.19^{b}	2.41^{b}	74.28^{a}
Non-Enhanced	23.56^{a}	2.77^{b}	73.01^{b}
SEM	0.20	0.37	0.31
P-value	P = 0.0003	P = 0.0003	P < 0.0001

^{abc}Within a column, means lacking a common superscript differ ($P < 0.05$)

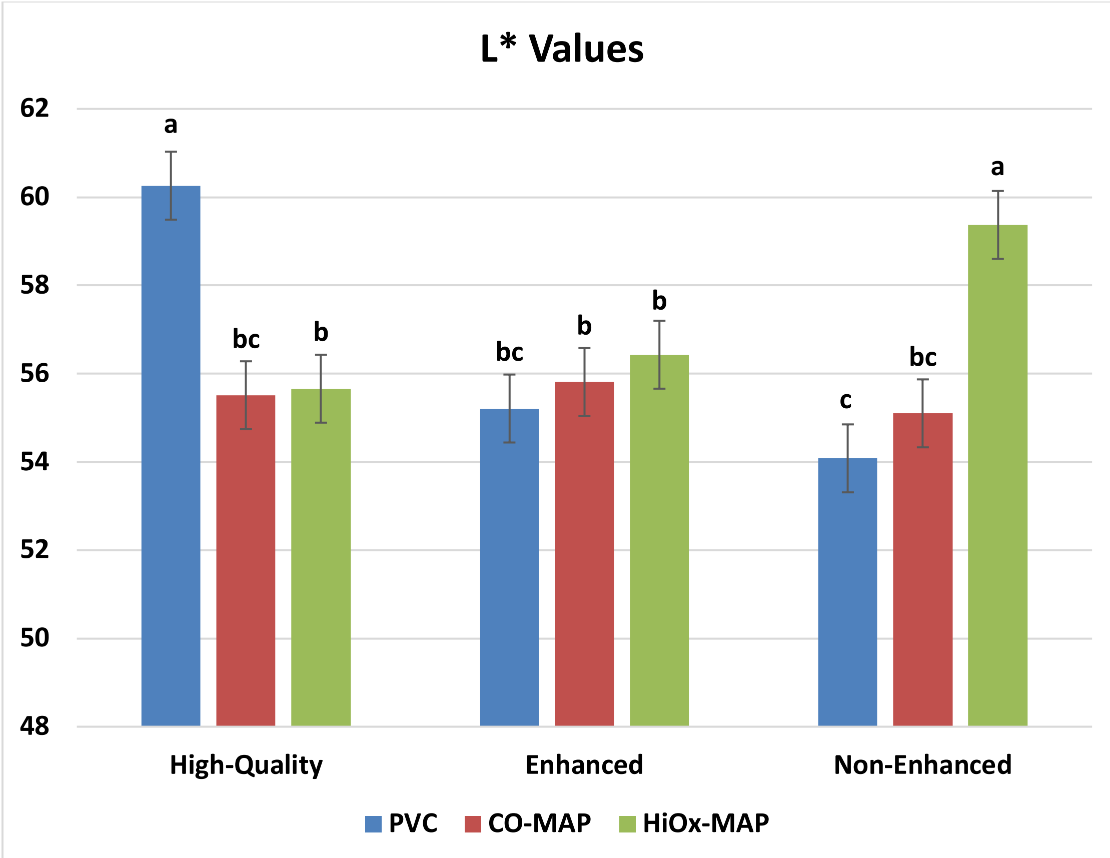

Figure 3.1 Least squares means of *L** CIE color space values (0 = black, 100 = white) by packaging type × treatment (n = 27). Means lacking a common superscript (a-c) differ ($P < 0.05$). Chops from each treatment (high-quality, enhanced and non-enhanced) were packaged in 1 of 3 packaging types: polyvinyl chloride overwrap (PVC), carbon monoxide modified atmosphere packaging (CO-MAP) and high-oxygen modified atmospheric packaging (HiOx-MAP).

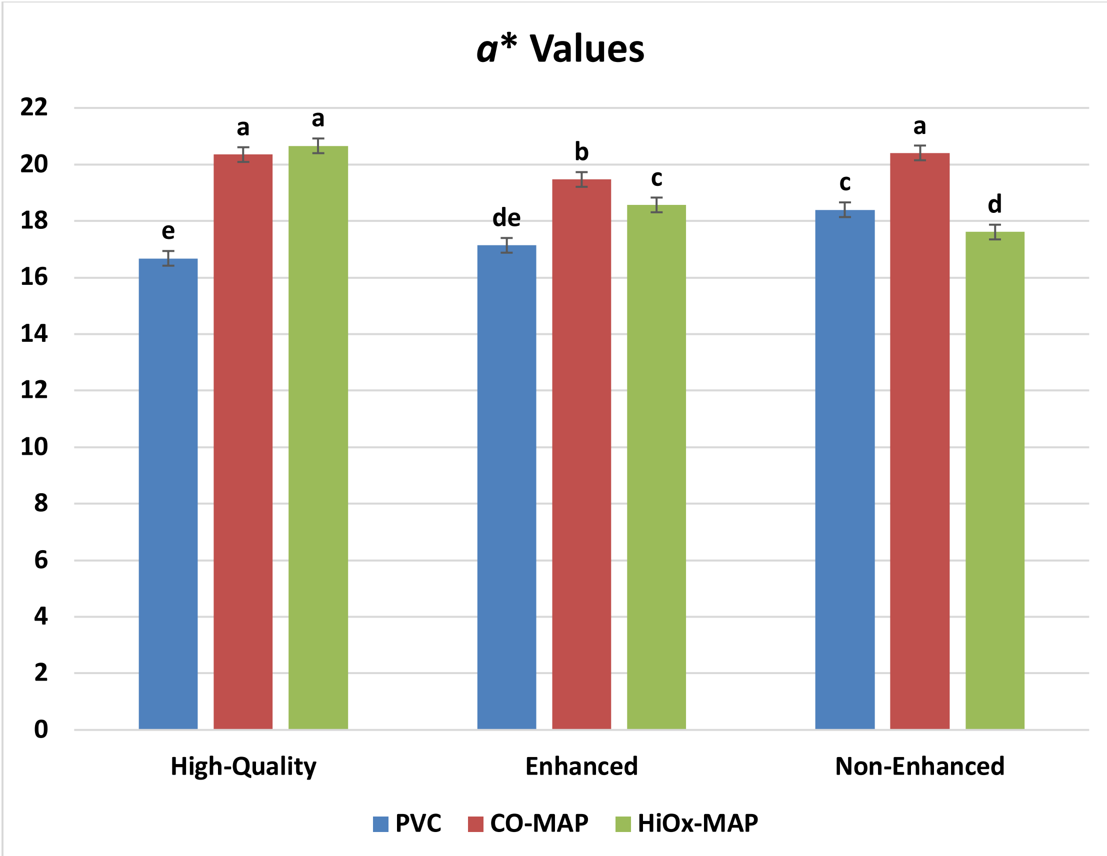

Figure 3.2 Least squares means of *a** CIE color space values ([-] = green, [+] = red) by packaging type x treatment (n = 27). Means lacking a common superscript (a-e) differ ($P < 0.05$). Chops from each treatment quality, enhanced and non-enhanced) were packaged in 1 of 3 packaging types: polyvinyl chloride overwrap (PVC), carbon monoxide modified atmosphere packaging (CO-MAP) and high-oxygen modified atmospheric packaging (HiOx-MAP).

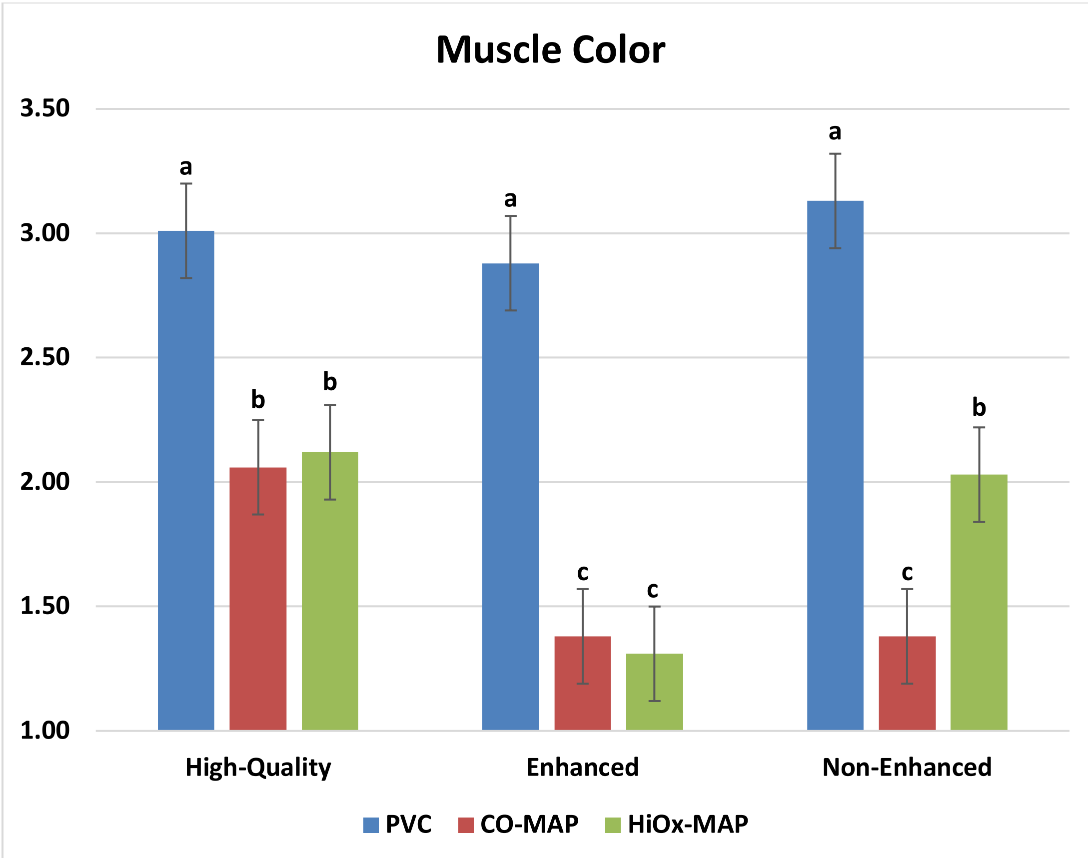

Figure 3.3 Least squares means of trained panelists' scores for pork color attributes by treatment x packaging type (n = 27). Means lacking a common superscript (a-c) differ ($P < 0.05$). Panelist used the following scale: muscle color (1 = Extremely bright purplish-pink; 8 = Extremely dark purplish-pink). Chops from each treatment (high-quality, enhanced and non-enhanced) were packaged in 1 of 3 packaging types: polyvinyl chloride overwrap (PVC), carbon monoxide modified atmosphere packaging (CO-MAP) and high-oxygen modified atmospheric packaging (HiOx-MAP).

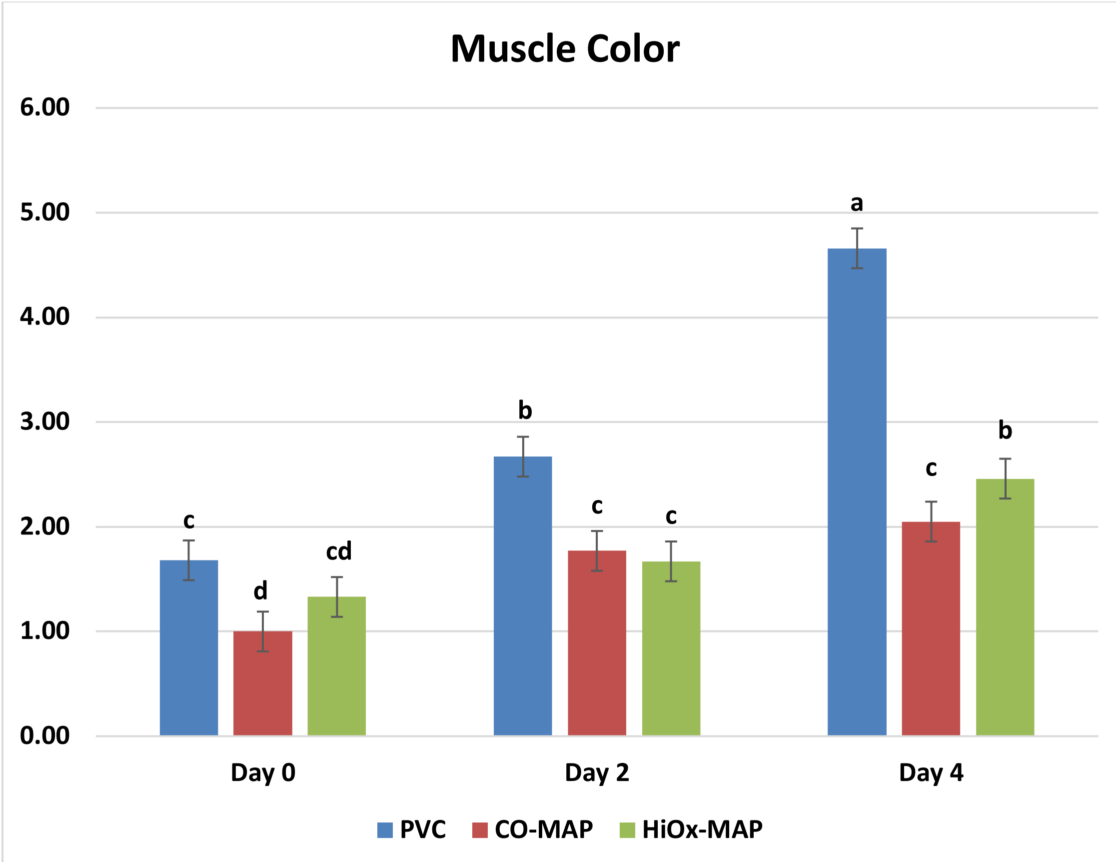

Figure 3.4 Least squares means of trained panelists' scores for pork color attribute by display day x packaging type interaction (n = 27). Means lacking a common superscript (a-d) differ ($P < 0.05$). Panelist used the following scale on d 0, 2 and 4 of retail display: muscle color (1 = Extremely bright purplish-pink; 8 = Extremely dark purplish-pink). Chops were packaged in 1 of 3 packaging types: polyvinyl chloride overwrap (PVC), carbon monoxide modified atmosphere packaging (CO-MAP) and high-oxygen modified atmospheric packaging (HiOx-MAP)

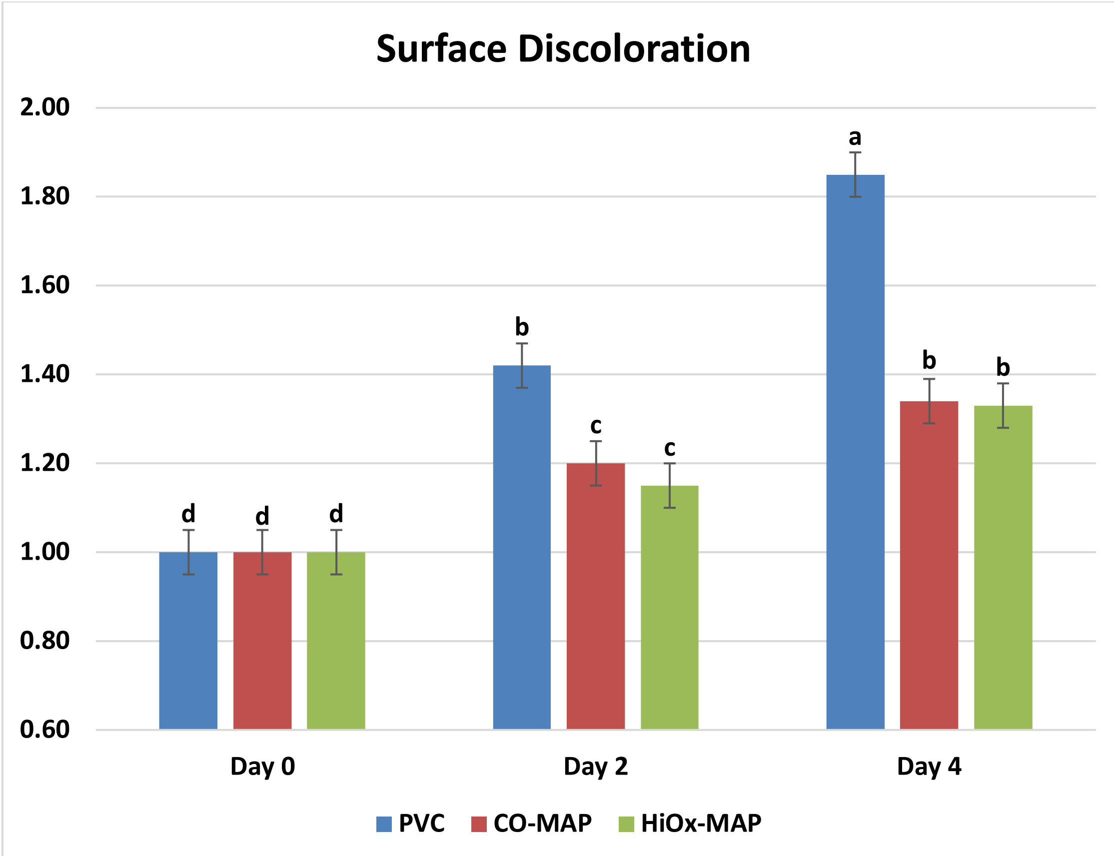

Figure 3.5 Least square means of trained panelists' scores for pork color attributes by display day x packaging type interaction (n = 27). Means lacking a common superscript (a-c) differ ($P < 0.05$). Panelist used the following scale on d 0, 2 and 4 of retail display: surface discoloration (1 = No discoloration [0%]; 7 = Extensive discoloration [81-100%]). Chops were packaged in 1 of 3 packaging types: polyvinyl chloride overwrap (PVC), carbon monoxide modified atmosphere packaging (CO-MAP) and high-oxygen modified atmospheric packaging (HiOx-MAP).

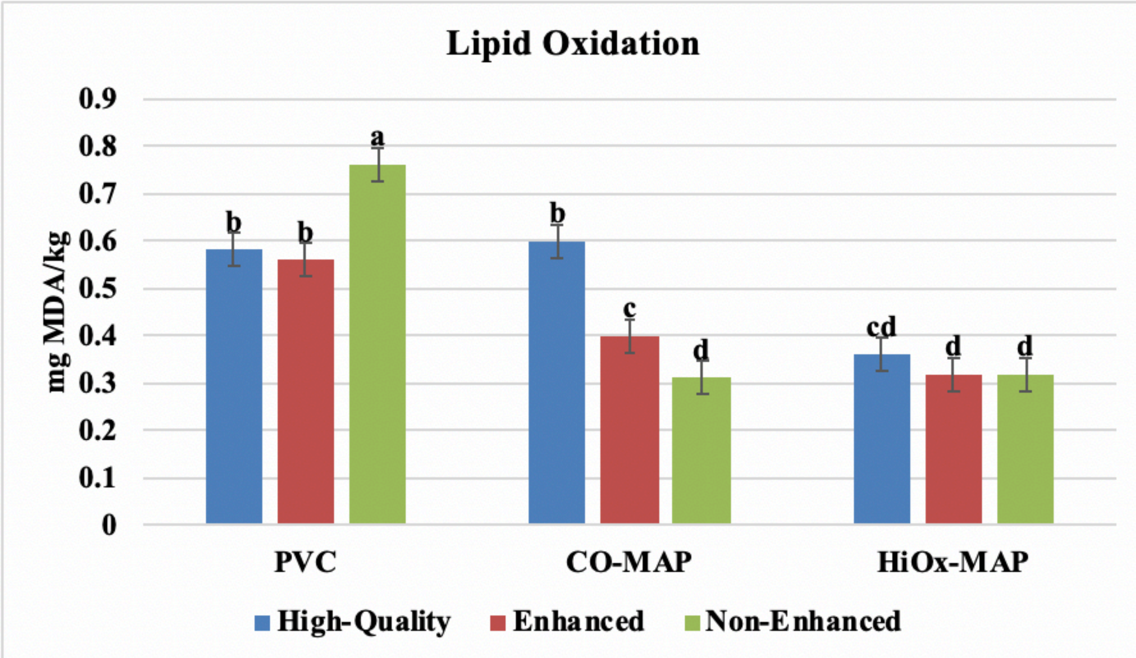

Figure 3.6 Effects of treatment x packaging on lipid oxidation of pork chops after retail display (n = 27). Least squares means lacking a common superscript (a-d) differ ($P < 0.0001$). Chops from each treatment (high-quality, enhanced and non-enhanced) were packaged in 1 of 3 packaging types: polyvinyl chloride overwrap (PVC), carbon monoxide modified atmosphere packaging (CO-MAP) and high-oxygen modified atmospheric packaging (HiOx-MAP). Lipid oxidation was expressed as mg malondialdehyde (MDA)/kg of meat.

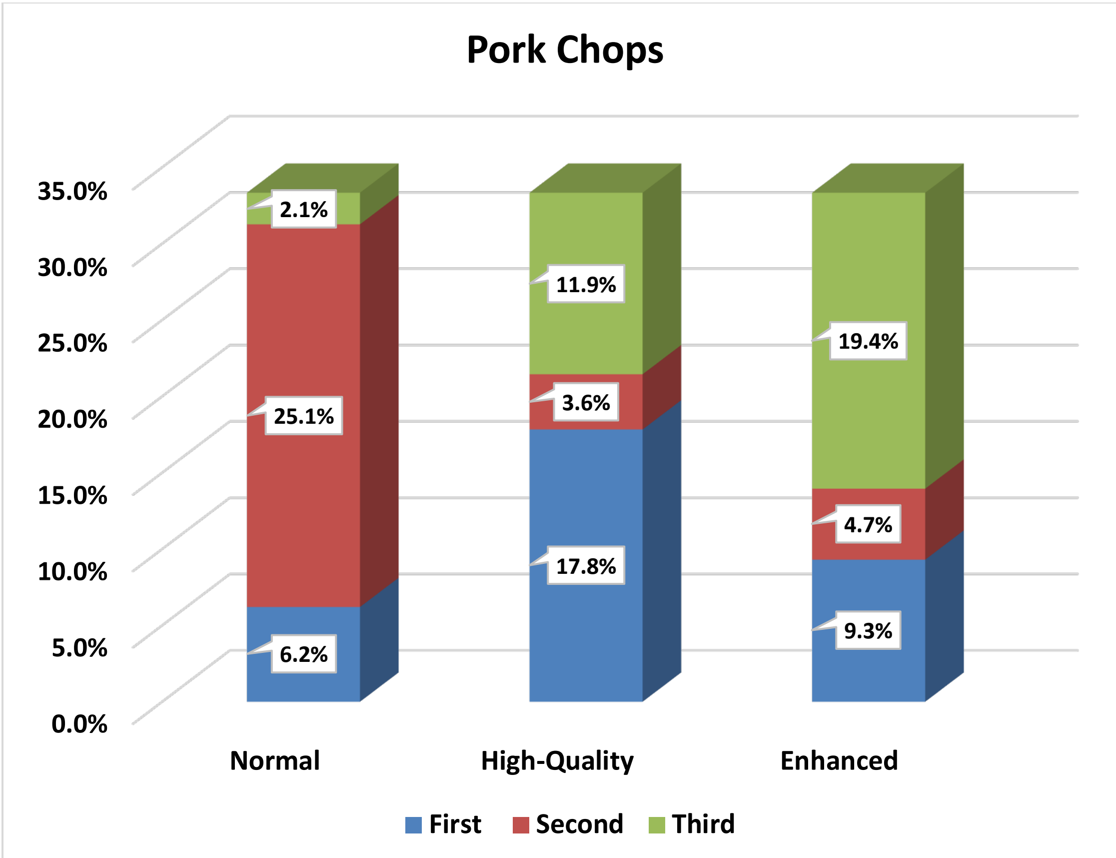

Fig 3.7 Consumers intent to purchase normal, high-quality or enhanced pork chop first, second or third. Distributions differ ($P < 0.05$) among normal, high-quality and enhanced pork chops by chi-square test

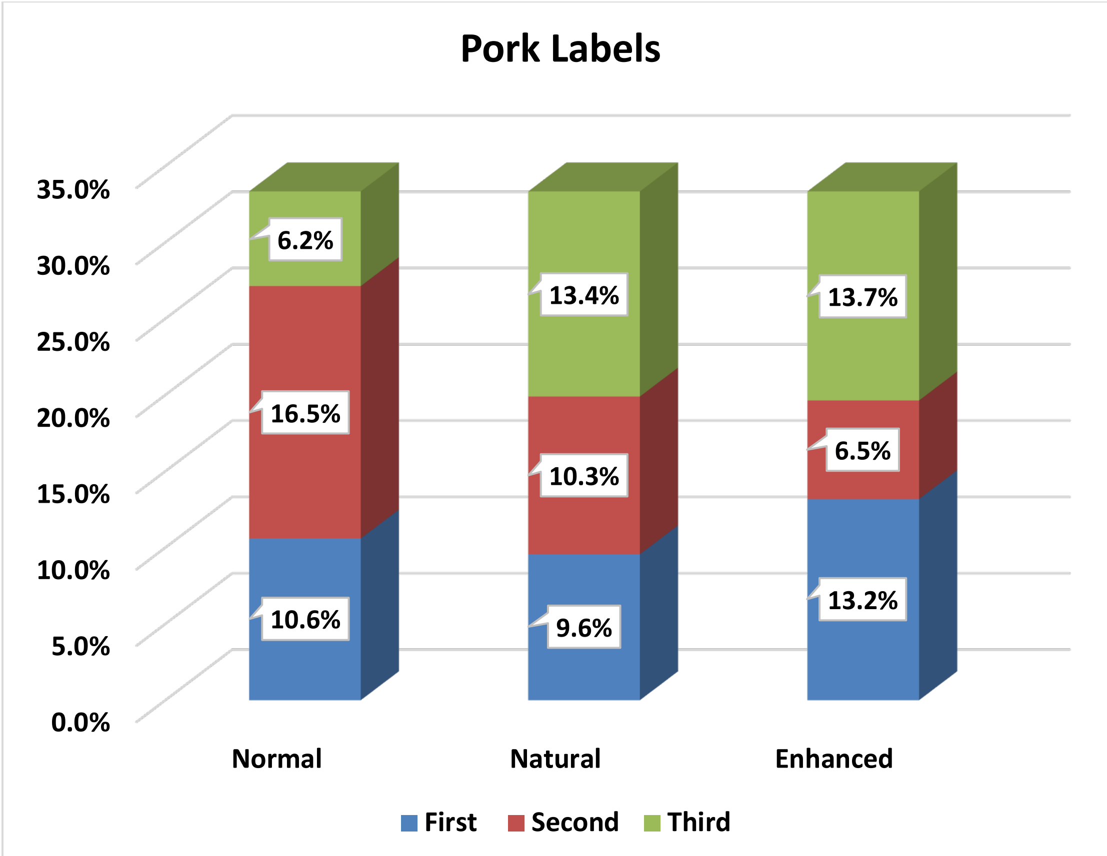

Fig 3.8 Consumers intent to purchase normal, natural or enhanced pork chop based on label provided first, second or third. Distributions differ ($P < 0.05$) among normal, natural and enhanced pork chops labels by chi-square test

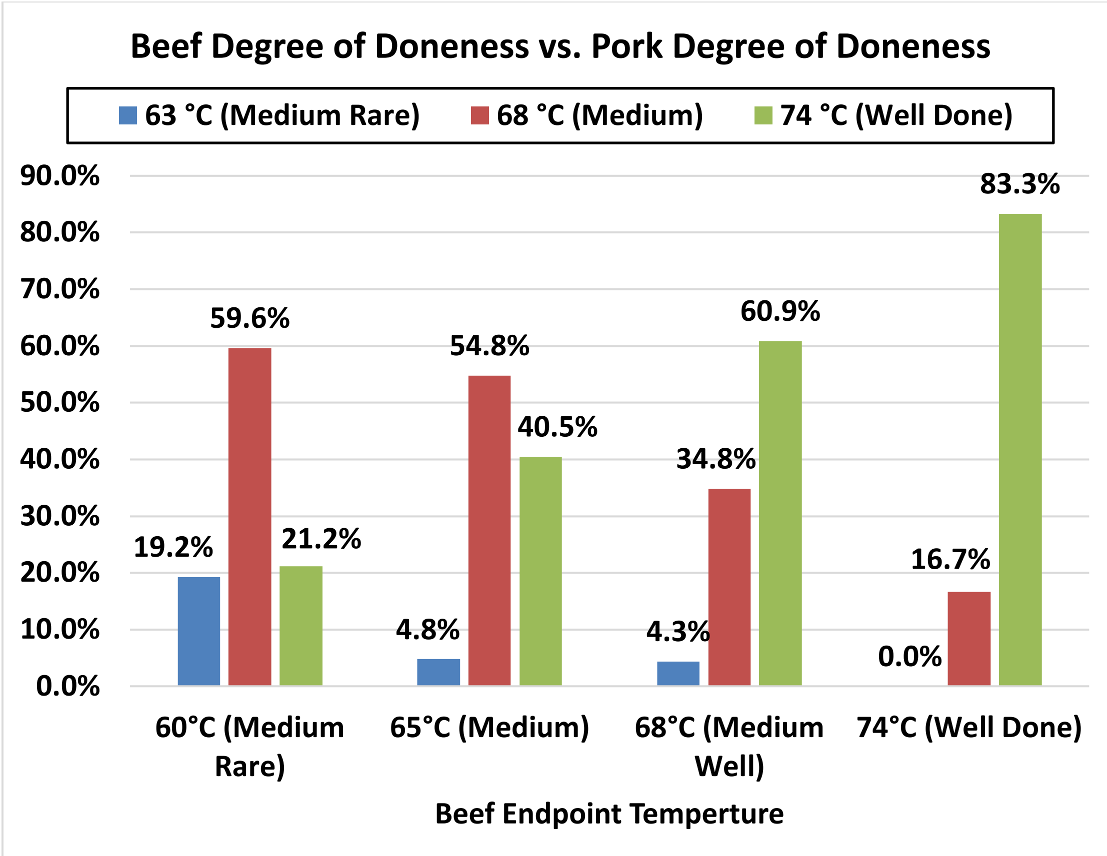

Fig 3.9 Relationship of beef degree of doneness vs. pork degree of doneness. Distributions differ ($P < 0.05$) among beef degree of doneness and pork degree of doneness by chi-square test

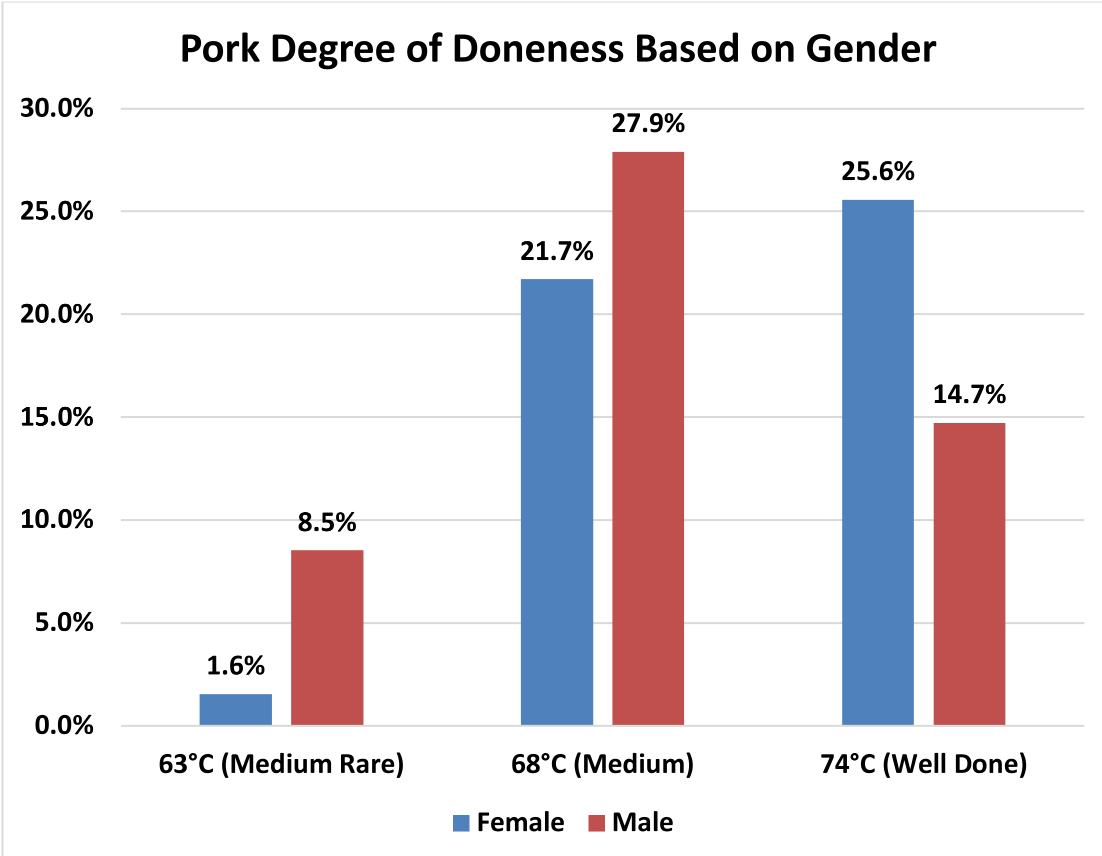

Fig 3.10 Relationship of pork degree of doneness based on gender. Distributions differ ($P < 0.05$) among pork degree of doneness and gender by chi-square test

CHAPTER IV

TRAINED AND CONSUMER SENSORY PANEL AS WELL AS OBJECTIVE MEASUREMENTS OF NON-ENHANCED, ENHANCED & HIGH-QUALITY PORK LOINS COOKED TO THREE DEGREE OF DONENESS

Abstract

The objective of this study was to evaluate the effects of three different commercially available pork loins on trained and consumer sensory panel as well as tenderness at three different endpoint temperatures. Enhanced (n = 10), non-enhanced (n= 10) and high-quality (n = 10) pork loins were selected from a commercial food distribution company. Loins were cut into 2.54-cm thick chops and assigned to instrumental or subjective measurements. Instrumental data analysis consisted of proximate analysis, cook loss and Warner-Bratzler shear (WBS) force analysis. Subjective measurements included marbling and color score as well as trained and consumer sensory panel. For trained sensory panel, WBS force analysis, cook loss and Carver Press analysis, chops were evaluated at 3 different degrees of doneness (63, 68, & 74°C). Enhanced loins had the highest National Pork Producers Council (NPPC) color score and highest pH compared to high-quality and non-enhanced loins ($P < 0.05$). In addition, high-quality loins had the highest ($P < 0.05$) NPPC marbling score and fat percentage compared to enhanced and non-enhanced loins. For WBS force analysis, enhanced loins had a lower ($P < 0.05$) shear value compared to non-enhanced loins. In addition, there was no difference ($P > 0.05$) between high-quality and enhanced, or high-quality and non-enhanced loins for WBS force values. Enhanced

loins showed no difference (*P* > 0.05) for trained panelist tenderness evaluation scores when cooked at all three endpoint temperatures. There was no difference (*P* > 0.05) for high-quality and non-enhanced chops at 68 or 74°C. In the consumer panel, participants ranked price as their highest importance for intent to purchase. Consumer panelist ranked the enhanced chops the highest for overall like, tenderness like and juiciness like, indicating a more tender and juicier product compared to high-quality and non-enhanced loins. Lastly, high-quality loins ranked statistically higher (*P* < 0.05) than non-enhanced loins for overall like and juiciness like, however not for tenderness like when rated by consumers. In conclusion, enhanced chops rated the highest among the instrumental and subjective tenderness and palatability measurements.

Introduction

The end goal for all segments of the pork industry is to provide consumers with a safe, high-quality product. Fresh pork color, pH, water-holding capacity, marbling and tenderness are attributes commonly associated with pork quality. Mancini and Hunt (2005) stated that visual factors such as color, marbling and subcutaneous fat are key purchasing decisions for consumers. Each of these factors together or separate have an effect on the cooked products sensory characteristics including tenderness, juiciness and flavor. Pork color is a key quality factor that can influence the palatability of a product (Richardson et al., 2018). Darker color of lean is commonly associated with an increase in muscle pH (Suman and Joseph, 2013). Increase in pH has been shown to increase water holding capacity and increase the juiciness and tenderness of pork (Richardson et al., 2018). Savell and Cross (1988) suggested a minimum threshold for intramuscular fat of 3% for acceptable palatability in red meat including pork. However, Brewer and McKeith (1999) recommended that a range of 2.2 – 3.4% minimum intramuscular fat improves eating satisfaction. Marbling has been shown to have conflicting results on its effect of pork palatability attributes. DeVol et al. (1988) found that tenderness was moderately correlated with intramuscular fat (r = 0.34) when evaluated by a trained panel. Based on consumer perspective, Brewer et al. (2001) found no statistical difference in consumers perception on overall juiciness or tenderness based on differences in intramuscular fat.

In order to decrease the variation of pork palatability, enhancing pork loins has evolved to satisfy consumers taste. Most enhancement solutions contain salt, phosphate, flavor enhancers and flavoring agents. These solutions combined together are key to increase the water holding capacity, increasing the tenderness and juiciness of cooked meat products (Lawrence et al., 2004; Baublits et al., 2006). In 2011, the USDA Food Safety and Inspection service changed the recommended endpoint temperatures of whole muscle cuts of pork from 71 to 63°C in order to maintain food safety, but improve sensory traits. Bryhni et al. (2003) evaluated consumers preference of pork chops cooked at 65°C versus 80°C and found that consumers preferred the lower degree of doneness for juiciness and tenderness attributes.

High-quality pork comprised of a greater amount of intramuscular fat, enhanced loins and non-enhanced, normal pork loins are most commonly seen in retail and food service. It is known the effect MAP has on the color stability of pork products. However, additional research is needed to understand the palatability sensory characteristics of these three types of loins cooked at different degrees of doneness and how it can benefit the pork industry in determining requirements for a potential grading system. Therefore, the objective of this study was to evaluate the effect of these three commercially available pork loins on retail display, tenderness, consumer perception and intent to purchase

Materials and Methods

Product Collection

Samples were obtained from the same loins as were described in Chapter 3.

Drip Loss Analysis

One chop from each loin was used for drip loss analysis. Only the longissimus muscle was used to analyze drip loss. Samples were weighed, hung, and suspended over a WHIRL-PAK bag and stored at 2 – 4°C for 48 h. After 48 h of hanging, samples were patted dry and weighed. Drip loss was calculated as the percentage of sample weight loss at 48 h.

Carver Press Analysis

Carver press testing was preformed similar to methods described by (Woolley, 2014). One chop from each loin was randomly assigned to 1 of 3 endpoint temperatures. Chops were thawed at 4°C for approximately 24 h and cooked utilizing an XLT Impingement Oven (model 3240-TX, BOFI Inc., Wichita, KS). Chops were cooked at 190°C to their set endpoint temperature. Chops were allowed to cool for approximately 5 min. Each chop was minced into smaller pieces and a 2.5 g meat sample was placed between 2 sheets of desiccated filter paper (VWR Filter Paper 415, 12.5cm, VWR International, Radnor, PA) placed between 2 plexiglass plates and pressed using a Carver Laboratory Press (Fred S. Carver Inc. Summit, NJ) at 1,000 psi for 1 min. The filter papers were removed and separated. The inner (meat) ring and the outer (water) ring were traced and the filter papers were placed in a desiccator and allowed to dry for 24 h. After drying, the filter papers were scanned and the areas (cm^2) of both the meat and water ring were measured.

Instrumental Tenderness (Warner-Bratzler Shear Force)

From each loin, three chops were randomly assigned to three different endpoint temperatures: 63, 68 and 74°C. Chops were thawed at 4°C for approximately 24 h and cooked utilizing an XLT Impingement Oven (model 3240-TX, BOFI Inc., Wichita, KS). Raw chops were weighed prior to cooking to determine cook loss, this value was recorded as “raw weight”. Chops were cooked at 190°C to their set endpoint temperature. Following cooking, chops were weighed and recorded as “cooked weight” then held at 4°C for 18 h to cool. Cook loss was calculated on a percentage bases by taking the raw weight minus cooked weight and dividing it by raw weight. Chilled chops were equilibrated to room temperature before trimmed of visible fat and connective tissue to expose muscle fiber orientation. Six cores (1.27 cm in diameter) were taken by hand from each chop, parallel to the longitudinal orientation of the muscle fibers. An Instron Universal Testing Machine (Model 5943, Instron Corporation, Norwood, MA) was used with a Warner-Bratzler Shear Fixture. Crosshead speed was 200 mm/min and the Bluehill 3 software was utilized. Maximum load (kg) were recorded for each core and the mean maximum load was calculated.

Trained Sensory Panel

Panelist were trained to evaluate overall tenderness, juiciness, pork flavor and salt flavor. Methods for training panelist were similar to those described by Klehm et al. (2018). Pork tenderness was standardized by cooking pork *semimembranosus* muscle to an internal temperature of 80°C (extremely tough) and pork *longissimus lumborum* to an internal temperature of 63°C (extremely tender). Pork juiciness was standardized by cooking pork *semimembranosus* muscle to an internal temperature of 80°C (extremely dry) and an enhanced pork chop cooked to an internal temperature of 63°C (extremely juicy). Pork flavor was standardized by cooking pork *longissimus lumborum* to an internal temperature of 68°C (strongly detectible) and 60:40% lean:fat ground pork to an internal temperature of 71°C (not detectible). Salt flavor was standardized by cooking pork *longissimus lumborum* with 5% added salt to an internal temperature of 71°C (strongly detectible) and pork *longissimus lumborum* to an internal temperature of 71°C (not detectible). Six panelists participated in each session and were asked to evaluate tenderness (8 = extremely tender, 1 = extremely tough), juiciness (8 = extremely juicy, 1 = extremely dry), pork flavor (3 = strongly detectible, 1 = not detectible) and salt flavor (3 = strongly detectible, 1 = not detectible).

From each loin, three chops were randomly assigned to three different endpoint temperatures; 63, 68 and 74°C. Chops were thawed at 4°C for approximately 24 h and cooked utilizing an XLT Impingement Oven (model 3240-TX, BOFI Inc., Wichita, KS). They were cooked at 190°C to their set endpoint temperature. Chops were cut into 1-cm^3 cubes, 2 cubes were placed in a sample cup, assigned a random number and placed in a warmer to maintain temperature through sensory evaluation. Samples were evaluated under red lighting and panelist were provided deionized water and unsalted saltine crackers to cleanse their palettes between samples.

Consumer Sensory Panel

Consumer panels were conducted for sensory evaluation. Chops were thawed at 4°C for approximately 24 h and cooked utilizing an XLT Impingement Oven (model 3240-TX, BOFI Inc., Wichita, KS). Chops were cooked at 190°C to an endpoint temperature of 68°C. Chops were cut into 1-cm^3 cubes, 2 cubes were placed in a sample cup, assigned a random number and placed in a warmer to maintain temperature through sensory evaluation. One pork chop was used to feed 2 consumer panelists. Panelist were provided deionized water and unsalted saltine crackers to cleanse their palettes between samples.

Consumer sensory panel methods were approved by the Institutional Review Board (AG-19-32-STW). A total of fifty panelists were recruited from Oklahoma State University through email and word of mouth. Panelists were asked to complete a demographics ballot as well as a consent form before beginning the panel. The demographics data from the consumer sensory panel are shown in Table 4.1. Panelists then were asked to evaluate chop attributes based on a 9-point scale. Attributes included: overall liking (1 = dislike extremely; 9 = like extremely), flavor liking (1 = dislike extremely; 9 = like extremely), juiciness liking (1 = dislike extremely; 9 = like extremely), and tenderness liking (1 = dislike extremely; 9 = like extremely).

Statistical Analysis

For WBS force, carver press and trained sensory panel, a two factor completely randomized design was utilized with pork loin treatment and endpoint temperature. For drip loss and consumer sensory panel, one factor randomized design was utilized with pork loin treatment. Data were analyzed using the PROC GLM procedure of SAS (SAS 9.4; SAS Inst., Cary, NC). Order and chop number was the random effect for trained sensory panel and consumer sensory panel analysis, and loin was the random effect for instrumental tenderness, proximate analysis, drip loss, cooking loss and carver press analysis. All models included treatment and endpoint temperature as main effects and treatment x endpoint temperature for a two-way interaction. Least squares means were calculated; where ANOVA testing indicated significance, means were separated using the PDIFF procedure and $\alpha < 0.05$. The correlations among NPPC marbling score and fat percent variables were determined using PROC CORR procedure of SAS. The demographics data from the consumer panel was reported as percentages.

Results and Discussion

Marbling Score, Color Score and Muscle pH

Results for marbling score, color score and muscle pH are presented in Table 3.2. Evaluators used the guide from the NPPC to assign a marbling and color score for each loin. The high-quality loins had the highest ($P < 0.05$) marbling score (3.30) compared to both enhanced and non-enhanced pork loins (1.70 and 2.20 respectfully). Enhanced pork loins had the lowest ($P < 0.05$) marbling score of 1.70 indicating approximately 1% intramuscular fat within the chop. Klinkner (2013) completed a retail benchmark study on 117 supermarkets in 67 cities and stated that the mean subjective marbling score in 2015 was 2.30. Based upon data from this study, the only pork loins that fall within or above that marbling score would be the high-quality pork chops with a marbling score of 3.30.

There was a statistical difference ($P < 0.05$) for subjective color scores of pork loins. Enhanced pork loins had a higher subjective color score indicating a darker color of lean compared to both the high-quality and non-enhanced pork chops. In addition, enhanced chops were shown to have a higher ($P < 0.05$) pH compared to high-quality and enhanced pork chops. Miller (1998) reported the addition of water, sodium or phosphate will bind more water within the muscle, and less water on the surface, allowing less light reflectance and a darker color of lean. The higher pH may be a cause for the darker color lean. In addition, Hughes et al. (2014) reported that ultimate pH of muscle was positively correlated to sensory juiciness (r = 0.68) and tenderness (r = 0.78) of cooked meat. Lastly, Moeller et al. (2009) indicated pork muscles with a pH range of approximately 5.8 and 6.4 had a more positive sensory response for trained panelist.

Proximate Analysis

Results from proximate composition analysis for percent protein, fat and moisture are presented in Table 3.3. Enhanced pork chops had the lowest ($P < 0.05$) percent protein (22.19%) and the highest ($P < 0.05$) percent moisture compared to high-quality and non-enhanced pork loins. The increase in moisture is contributed to the 12% added solution in the product. In addition, high-quality pork loins had statistically the highest ($P < 0.05$) fat percent compared to enhanced and non-enhanced loins. High-quality loins had a fat percent of 4.72 which is representative of a NPPC marbling score of 4. There was a significant ($P < 0.0001$) strong positive correlation (r = 0.83) between NPPC subjective marbling score and the objective proximate analysis fat % for this study. Huff-Lonergan et al. (2002a) found similar results showing a significant positive correlation (r = 0.57) between NPPC subjective marbling score and fat percentage. Using NPPC marbling standards can be a practical and efficient tool to determine the marbling of pork carcasses and may be a useful tool for segmenting pork.

Drip Loss & Carver Press Analysis

There was no difference (*P* > 0.05) for drip loss or Carver Press analysis for either main effect or interactions, and therefore data are not represented in tabular form. The variation in muscle pH between treatments should have presented differences for both drip loss and Carver Press. Huff-Lonergan et al. (2002a) evaluated correlation of selected pork quality attributes. The findings showed a significant correlation for muscle pH and muscle color (r = -0.33). In addition, the process of enhancement allows for pork to bind and hold onto available free water, therefore, a lower drip loss should have been seen for these chops. Lastly, discussed further in the study, cooking loss was increased as endpoint temperature increased and therefore differences in Carver Press analysis would have been expected.

Cooking Loss

Mean cooking loss percent values are reported in Table 4.2. As degree of doneness increased from 63°C to 74°C there was a significant increase (*P* < 0.05) in percent loss during cooking. This is expected as higher cooking temperatures cause greater losses of meat juices. Baublits et al. (2006) had similar findings showing chops cooked to a higher degree of doneness (82°C) had a greater cooking loss than chops cooked to a lower degree of doneness (74°C). (Huff-Lonergan et al., 2002a) found a significant correlation for trained panelist scores on tenderness (r = -0.28) and especially juiciness (r = -0.43) compared to percent cooking loss.

Warner-Bratzler shear force

Table 4.3 presents the mean WBS force values by treatment and endpoint temperature main effects. Enhanced pork chops had a significantly lower (*P* < 0.05) shear force value (2.38 kg) compared to non-enhanced pork chops (2.75 kg). A lower shear force value is indicative of a more tender product. The was no difference (*P* > 0.05) between high-quality and enhanced or high-quality and non-enhanced pork chops. Baublits et al. (2006) found similar results as shown by a decrease in shear force values for chops enhanced to 12% compared to non-enhanced chops.

The enhancement process allows for increase space between muscle fibers for water to be bound. This increase space may be the cause of a decrease shear force value allowing for a more tender product. Similar to these findings, Cannata et al. (2010) observed no difference in shear force analysis for chops with increased amount of intramuscular fat. However, Brewer et al. (2002b) showed a decrease in WBS values for chops that had a higher marbling score (3.21) compared to chops with a lower marbling score (2.47).

In addition, Table 4.3 presents the endpoint temperature main effect on WBS force values. Pork chops cooked to a lower degree of doneness (63°C) were more tender ($P < 0.05$) compared to chops cooked to a higher degree of doneness (68 and 74°C). The National Pork Board recommends the cooking of pork loin chops to an internal temperature of 145°F (63°C) (NPB, 2012). Similar findings were observed by Harsh et al. (2018), who found by a lower shear force value for chops cooked at 63°C compared to a higher temperature of 71°C. Endpoint cooking temperature is extremely important as it dramatically affects consumer acceptance on tenderness.

Trained Sensory Panel

Figure 4.1 represents the least squares means of trained panelist scores for overall tenderness by treatment x endpoint temperature. Enhanced loins showed no difference ($P > 0.05$) with similar tenderness scores at all three endpoint temperatures. Baublits et al. (2006) found similar results that showed no difference in trained panelist tenderness scores for pork chops enhanced with either a 6 or 12% solution at various endpoint temperature. As previously stated, the enhancement process allows for increase in separation between muscles and destruction of connective tissue through needle injection allowing for a more tender product at various endpoint temperatures. When cooking chops to 74°C, enhanced chops were statistically more tender ($P < 0.05$) as shown by a higher tenderness value (5.73) than normal chops (4.22). Baublits et al.

(2006) also showed similar findings with the pork loins enhanced to either 6 or 12% having a higher tenderness value indicating a more tender product than non-enhanced loins. Lastly, both high-quality and non-enhanced loins cooked to 63°C were rated more tender by trained panelist than chops of same treatments cooked to either 68 or 74°C.

Trained panelist scores on juiciness and pork flavor as shown in Table 4.4. As the endpoint temperature increased, there was a significant decrease ($P < 0.05$) in juiciness values indicating a less juicy product. These results align with those found in Table 4.4 that showed as the endpoint temperature increased, the cooking loss increased. In addition, chops cooked to 68 or 74°C had a stronger ($P < 0.05$) pork flavor (2.51 and 2.48 respectfully) compared to chops cooked to 63°C (2.22). Heymann et al. (1990) found similar results that showed a decrease in juiciness and an increase in pork flavor as the internal temperature increase. However, Prestat et al. (2002) showed no difference for pork flavor or juiciness when comparing different endpoint temperatures but did show that cooking non-enhanced chops to a lower degree of doneness resulted in a more juicy product.

Consumer Sensory Panel

Figure 4.2 shows the number of participants that ranked particular pork quality and labeling attributes as their first choice when selecting products at retail. The price of the product was ranked the highest amongst panelist for intent to purchase. Reicks et al. (2011) showed the average motivational rating for the price of steaks or roast was 7.7 on a 10-point scale. In a simulated shopping environment study for pork chops, Grunert (2006) found a majority of respondents used price to make their purchase decisions. A smaller portion of participants used intrinsic cues such as lean color or amount of fat to make their purchase decisions. However, in this study, participants ranked marbling and color second and third respectfully in their rank on intent to purchase with labeling claims such as enhancement levels and all-natural claims ranking the lowest.

Table 4.5 presents the least squares means for consumer panelists scores by treatment. Consumers preferred ($P < 0.05$) enhanced pork chops for overall like, tenderness like and juiciness like compared to high-quality and non-enhanced loins and preferred the flavor of enhanced loins ($P < 0.05$) more than non-enhanced loins. Baublits et al. (2006) had similar findings showing consumers overall acceptability as well as overall flavor acceptability was statistically higher for enhanced loins than non-enhanced loins. In addition, high-quality loins were ranked statically higher ($P < 0.05$) for overall like and juiciness like (5.57 and 4.86 respectfully) compared to non-enhanced loins (4.93 and 3.93 respectfully). Similar to the data seen in WBS force (Table 4.3), there was no significant difference ($P > 0.05$) between tenderness of high-quality and non-enhanced pork chops (5.35 and 4.87 respectfully). There are varying results for intramuscular fats impact on consumers perception of juiciness and tenderness. Cannata et al. (2010) showed that as marbling scores increased, both tenderness and juiciness scores by consumers also increased indicating a more tender and juicier product. However, Brewer et al. (2001) found no statistical difference in consumers perception on overall juiciness or tenderness based on differences in intramuscular fat. Though marbling is a common quality factor used to determine a more favorable eating experience for consumers, using additional quality factors with marbling may be more useful to determine the best possible eating experience.

Conclusion

Cooking pork to a higher degree of doneness resulted in greater cooking loss as well as increase in WBS force indicating a more dry and tougher product. As expected, enhanced pork loins ranked higher than high-quality and non-enhanced pork loins on objective analysis as well as trained and consumer sensory data. Enhanced loins were more tender than non-enhanced loins for WBS force analysis. However, there was no difference between high-quality and enhanced or high-quality and non-enhanced loins. In addition, when cooking enhanced chops at various endpoint temperatures there was no difference in trained panelists score for tenderness or juiciness attributes indicating temperature has little to no effect on enhanced loins. Consumers preferred enhanced loins for overall like, tenderness like and juiciness like compared to both high-quality and non-enhanced loins. High-quality loins ranked higher by consumers for overall like and juiciness like, however there was no difference for tenderness like. Cooking pork to a lower degree of doneness results in a more tender product. Lastly, enhanced loins are beneficial for the pork industry, they allow for less variability at higher cooking temperatures resulting in a better eating experience.

Table 4.1 Demographic background of consumer panelist (n = 50) for pork chop evaluation

Parameter	Frequency (%)
Gender	
Male	48.00
Female	52.00
Age, years	
≤ 20	12.00
20 to 29	38.00
30 to 39	12.00
40 to 49	8.00
50 to 59	14.00
≥ 60	16.00
Working Status	
Not employed	5.71
Part-time	41.43
Full-time	10.00
Student	34.29
Income US$	
< 20,000	38.00
20,000 to 29,999	10.00
30,000 to 39,999	12.00
40,000 to 49,999	2.00
50,000 to 59,000	2.00
≥ 60,000	36.00
Urban/Rural	
Urban	48.00
Rural	52.00
Pork Chops Consumed	
Daily	0.00
3 or more times a week	0.00
Once a week	32.00
Once a month	36.00
Once every 2 months	16.00
2-3 times a year	16.00

Table 4.2 Least squares means for cooking loss (%) by endpoint temperature main effect (n = 90)

	Cook Loss (%)
Temperature	
63 °C	14.35[c]
68 °C	19.62[b]
74 °C	25.16[a]
SEM	0.46
P-value	$P < 0.0001$

[abc]Least squares means lacking a common superscript differ ($P < 0.05$).

Table 4.3 Least square means for Warner-Bratzler shear (WBS) values by high-quality, enhanced, and non-enhanced pork loins and endpoint temperature main effects (n = 90)

Main effects	WBS (kg)
Treatment	
High-Quality	2.62[ab]
Enhanced	2.38[b]
Non-Enhanced	2.75[a]
SEM	0.14
Temperature	
63°C	2.16[b]
68°C	2.76[a]
74°C	2.83[a]
SEM	0.14

[ab]Least squares means lacking a common superscript differ ($P < 0.05$).

Table 4.4 Least square means of trained panelists' scores[1] for pork palatability attributes by endpoint temperature main effect (n = 56)

	Juiciness Flavor	Pork Flavor
Temperature		
63°C	5.58[a]	2.22[b]
68°C	4.77[b]	2.51[a]
74°C	3.78[c]	2.48[a]
SEM	0.30	0.06
P-value	$P = 0.0005$	$P < 0.0001$

[abc]Within a column, least square means lacking a common superscript differ (P < 0.05).

[1]Trained panelist used the following scale: overall juiciness (were evaluated utilizing an 8-point scale (1 = extremely dry, 8 = extremely juicy), beef flavor was determined using a 3-point scale (1 = not detectable, 3 = strong)

Table 4.5 Least squares means of consumer panelists' scores for pork palatability attributes[1] of high-quality, enhanced, and non-enhanced pork loins (n = 50)

Treatment	Overall Like	Flavor Like	Tenderness Like	Juiciness Like
High-Quality	5.57^{b}	5.64^{ab}	5.35^{b}	4.86^{b}
Enhanced	6.48^{a}	6.14^{a}	6.66^{a}	6.42^{a}
Non-Enhanced	4.93^{c}	5.21^{b}	4.87^{b}	3.93^{c}
SEM	0.27	0.28	0.31	0.29
P-value	$P = 0.0003$	$P = 0.0433$	$P = 0.0002$	$P < 0.0002$

[abc]Within a column, means lacking a common superscript differ ($P < 0.05$)

[1]Consumer panelist used the following scale: overall liking (1=dislike extremely; 9=like extremely), flavor liking (1=dislike extremely; 9=like extremely), juiciness liking (1=dislike extremely; 9=like extremely), and tenderness liking (1=dislike extremely; 9=like extremely)

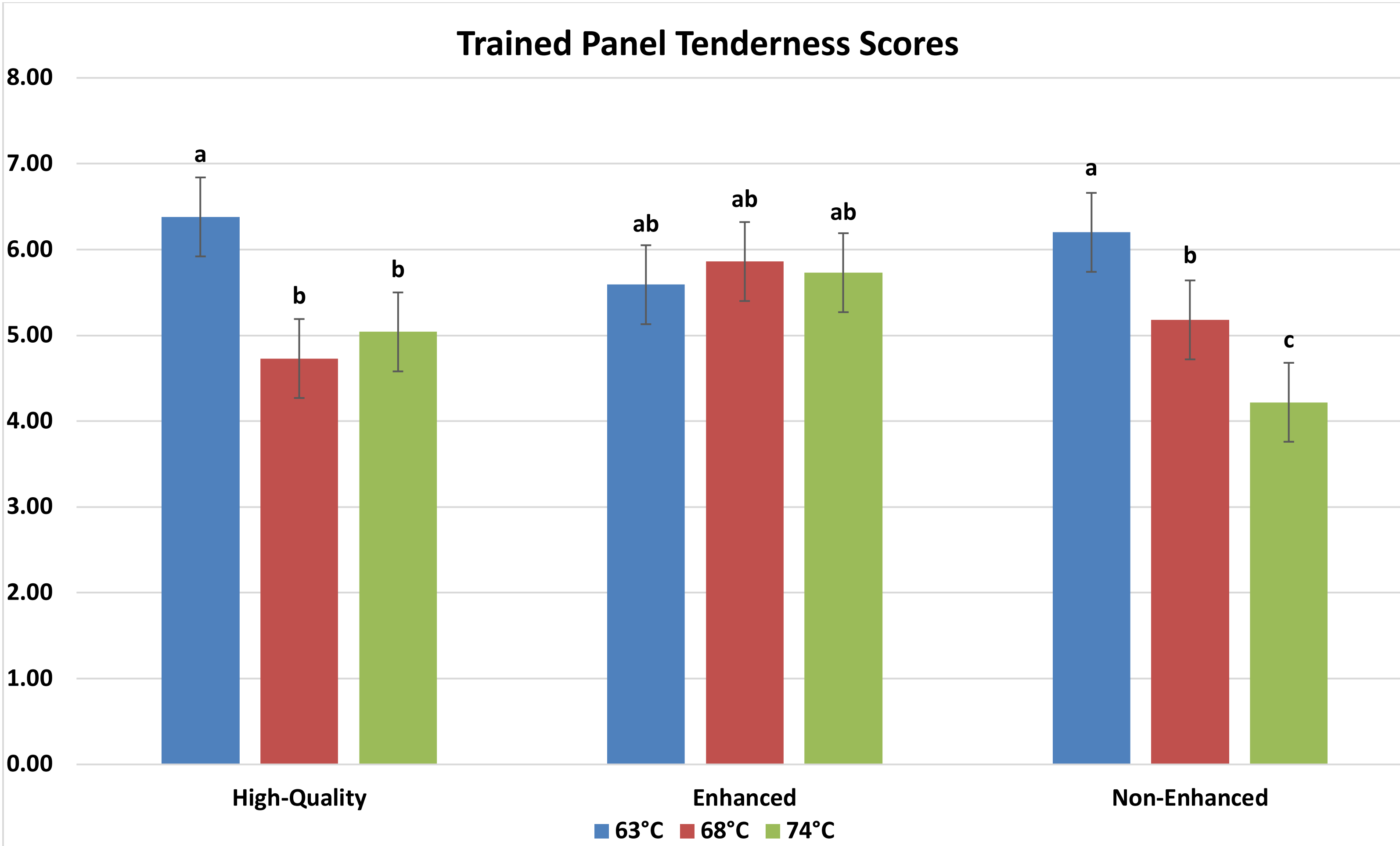

Figure 4.1 Trained panelists' scores for pork tenderness palatability attribute by treatment x endpoint temperature (n = 56). Least squares means lacking a common superscript (a-c) differ ($P < 0.05$). Trained panelist used the following scale on high-quality, enhanced and non-enhanced pork chops: overall tenderness were evaluated utilizing an 8-point scale (1 = extremely tough, 8 = extremely tender)

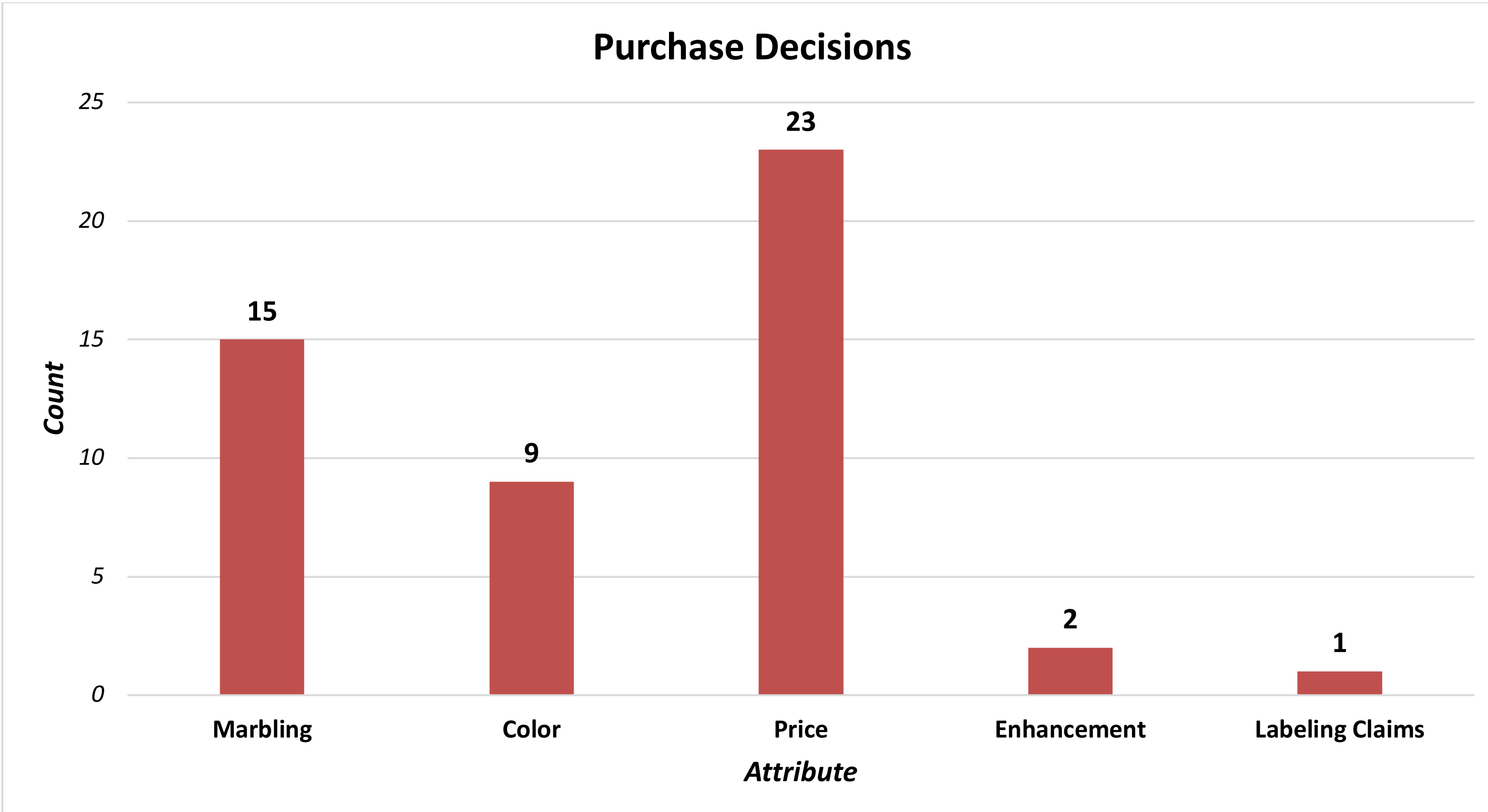

Figure 4.2 Panelist highest ranking purchasing decisions based on pork quality and labeling attributes (n = 50)

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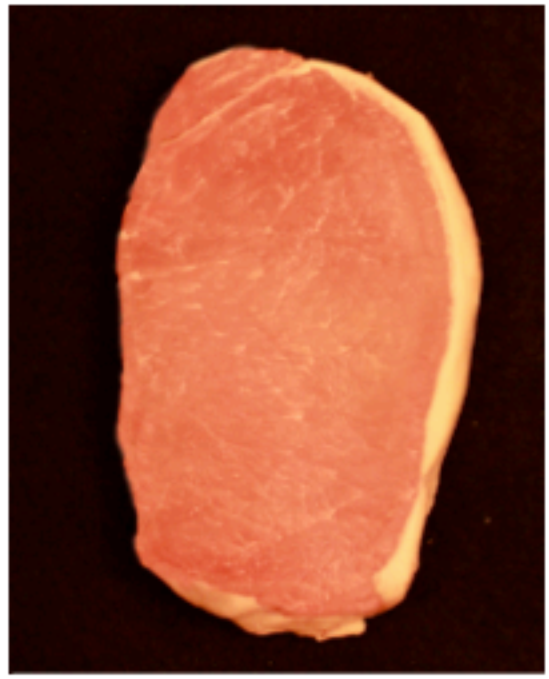
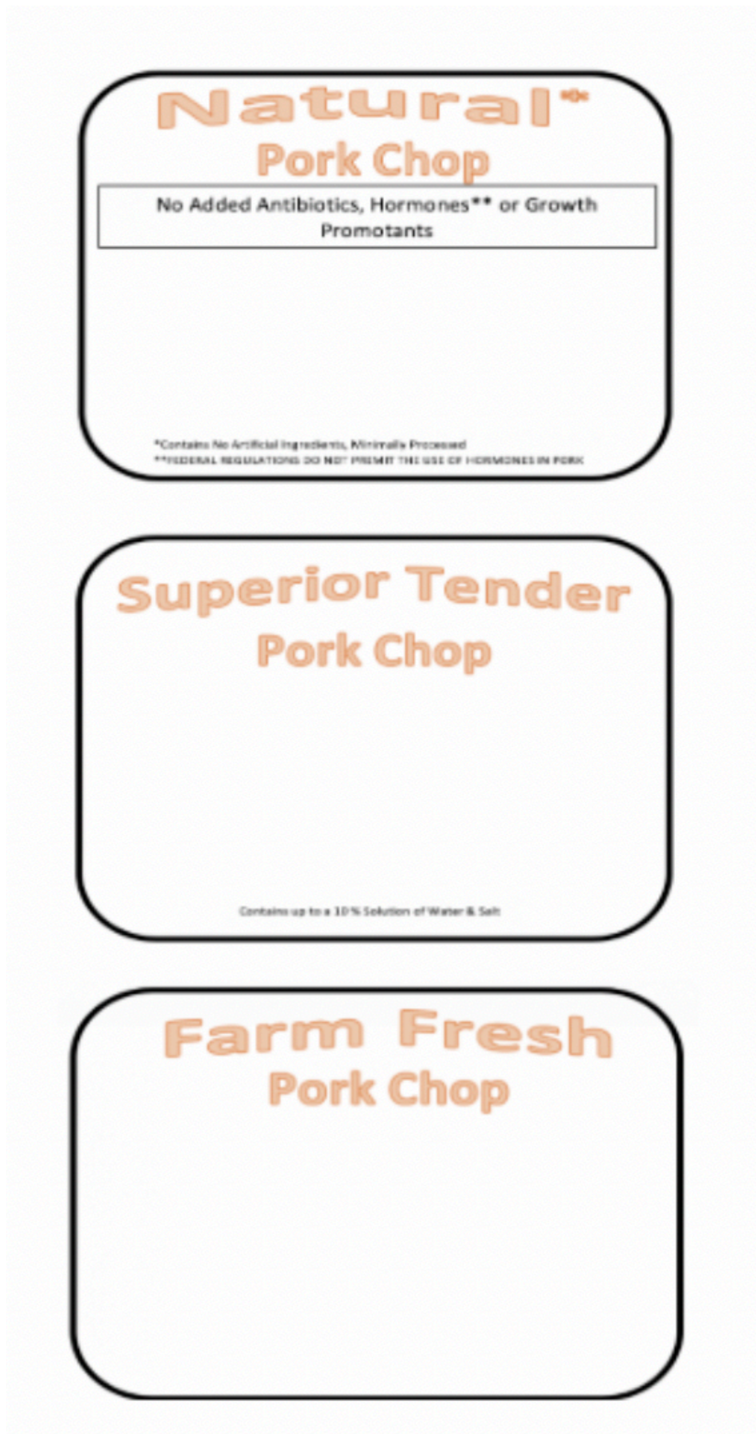
APPENDICES

High-Quality Pork Chop



Enhanced Pork Chop

Non-Enhanced Pork Chop


Natural*
Pork Chop
No Added Antibiotics, Hormones** or Growth Promotants
*Contains No Artificial Ingredients, Minimally Processed
**FEDERAL REGULATIONS DO NOT PREMIT THE USE OF HORMONES IN PORK
Superior Tender
Pork Chop
Contains up to a 10% Solution of Water & Salt
Farm Fresh
Pork Chop

Medium Rare (63°C)

Medium (68°C)

Well Done (74°C)

Medium Rare (60°C)

Medium (66°C)

Medium Well (68°C)

Well Done (71°C)

Panelist No. __________

PANELIST DEMOGRAPHIC INFORMATION

FILL OUT THE FOLLOWING INFORMATION BY PLACING AN X IN THE CORRECT BOX.

1. Please indicate your age by marking the appropriate blank:

    _________ Under 20 years ______ 30-39 years ______ 50-59 years

    _________ 20-29 years ______ 40-49 years ______ 60 years or older

2. Please indicate your income (combined income if both you and your spouse are employed) by marking the appropriate blank:

    _________ Under $20,000 ______ $30,000-$$39,000 ______ $50,000-$59,000

    _________ $20,000-$29,000 ______ $40,000-$49,000 ______ $60,000 or more

3. Please indicate your household size, including yourself:

    ______ 1 ______ 2 ______ 3 ______ 4 ______ 5 ______ 6 or greater

4. Describe where you live?

    _____ Urban _____ Rural

5. Please indicate your current working status:

    ______ Not employed ______ Part-time ______ Full-time ______ Student

6. Describe your education.

    ____ Completed secondary school ____ Completed two year college degree

    _____ Started college, didn't complete ____ Completed four year college degree

    ____ Completed professional school

7. Please indicate your sex:

    ______ Male ______ Female

8. Please indicate your ethnic background:

    ______ White ______ Black ______ Hispanic

    ______ American Indian ______ Asian or Pacific Islander

9. How often do you consume pork chops in your home?

_____ Daily   _____ 3 or more times a week   _____ Once per week

_____ Once a month   _____ Once every 2 months   _____ 2 – 3 times a year

10. Please RANK the following based on amount consumed within a month (1 = Most ; 4 = Least)

_____ Beef   _____ Chicken

_____ Pork   _____ Fish

11. Please RANK the following factors that influence your purchasing decision (1 = Most ; 5 = Least)

_____ Marbling   _____ Color   _____ Price

_____ Enhancement   _____ Labeling Claims (Crate Free, No Antibiotics)

Approved:
Protocol #: AG-19-32

Date ______________________ **Participant No.** _________________

Sample No. ____________________

INSTRUCTIONS

Prior to tasting each sample, please take a bite of a cracker followed by a sip of water. After tasting each sample place a mark in the box that best represents your answer for each of the following questions. The final two questions will be open ended, please answer them as completely as possible.

1. Indicate by placing a mark in the box your **OVERALL LIKE/DISLIKE** of the meat sample.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — No Preference — Like Extremely

2. Indicate by placing a mark in the box your **LIKE/DISLIKE** for the **FLAVOR** of the meat sample.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — No Preference — Like Extremely

3. Indicate by placing a mark in the box your **LIKE/DISLIKE** for the **TENDERNESS** of the meat sample.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — No Preference — Like Extremely

4. Indicate by placing a mark in the box your **LIKE/DISLIKE** for the **JUICINESS** of the meat sample.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — No Preference — Like Extremely

5. Please describe what you **LIKED MOST** about the sample.

____

6. Please describe what you **LIKED LEAST** about the sample

____

Approved:
Protocol #: AG-19-32

VITA

Andrew Michael Cassens

Candidate for the Degree of

Doctor of Philosophy

Dissertation: CONSUMER PERCEPTION, WILLINGNESS TO PAY, TENDERNESS AND RETAIL DISPLAY OF NON-ENHANCED, ENHANCED AND HIGH-QUALITY PORK LOINS

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Professional Memberships:

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