NATIONAL RETAIL PORK BENCHMARKING STUDY: CHARACTERIZING PORK QUALITY ATTRIBUTES OF MULTIPLE CUTS IN THE SELF-SERVE MEAT CASE

A Thesis
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

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In Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE

Major Department:
Animal Sciences

April 2013

Fargo, North Dakota

North Dakota State University
Graduate School

Title

National Retail Pork Benchmarking Study: Characterizing Pork Quality Attributes of Multiple Cuts in the Self-serve Meat Case

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MASTER OF SCIENCE

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ABSTRACT

The objective of this study was to benchmark fresh pork quality in the retail meat case in the United States. Nationally, 117 retail supermarkets in 67 cities were selected for sampling. Center-cut loin chops were observed in-store to obtain subjective color and marbling scores. Ten loin chop, sirloin chop, and blade steak packages representing each brand and enhancement type were purchased for objective analysis of pH, Minolta color (L*, a*, and b*), and tenderness (WBSF). For L*, enhanced loins were darker ($P < 0.05$) than non-enhanced. Enhanced loins and sirloins had greater ($P < 0.05$) pH values than non-enhanced chops. Enhanced loins, sirloins, and blades had lower ($P < 0.05$) WBSF scores than non-enhanced chops and steaks. This research provides retailers, processors, and other industry stakeholders with benchmark values of pork quality, and provides the industry with information to help reduce variation and improve pork quality at the retail level.

ACKNOWLEDGEMENTS

First of all, I would like to express a huge thanks to my fiancée, Erin, for putting up with my busy and demanding schedule at times during my graduate program. You have been my best friend and always supported me as I follow my dreams. Thank you for standing by my side through everything! Your love for me and passion for agriculture has ensured me that we will share a wonderful life together! I can't wait to find out what our life has in store for us!

I would like to thank my family for their continued support and guidance throughout my life and educational career. Dad, thank you for instilling in me a passion for farming and agriculture. You have taught me that there is a right way, and an even better way to be a great livestock steward. Furthermore, in most cases, "it isn't rocket science". Mom, thank you for your continued love, support, and guidance throughout my life, even when I moved the farthest away from home of your three children. You and dad have both always taught me that as long as I am doing what I believe in and I am happy doing it, you will always be there to support me. Travis, you are my best friend! Thank you for being there to laugh with as well as being someone I can always trust to confide in. Bridget, thank you for teaching me what it means to be a leader and that without leaders like us in agriculture, this world would have no future!

To the Animal Sciences faculty and staff at NDSU, thank you for making Fargo and this department my home for the past two years. Dr. David Newman, you have shown me that agriculture is bigger than this town, state, and country! Allowing me to be a big part of BBQ Boot Camp and your extension programs has been fun and allowed me to meet many inspiring and knowledgeable agriculturists in this state. Thank you for giving me this great opportunity to further my education under your guidance. You have truly been a great mentor and friend for these last two years. Roberta Dahlen, thank you for your countless hours of assistance throughout my graduate school career. You are always there to advise me when I don't know what I need to do next and what I should have done earlier!

To the graduate and undergraduate students in the Animal Sciences department, thank you for all your help, encouragement, and friendship. From catering events, socials, weekends, and tail gating events, you have all given me a sense of pride and acceptance here at NDSU. To my graduate committee, Drs. Eric Berg, David Buchanan, and Julie Garden Robinson, thank you for your support and guidance. Your passion for research and education has been the cornerstone of my drive to succeed as a graduate student. I can't thank you enough!

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CHAPTER 1. INTRODUCTION AND LITERATURE REVIEW

Introduction

Pork quality is a combination of many factors and cannot be defined based on one variable alone. Pork quality also has different meaning and applications to each party involved in the production process from farm to plate. It can encompass quality factors including good production practices, food safety, and product eating quality. Pork producers strive to provide packers with lean high yielding hogs, for which they are typically paid a premium. Pork processors and retailers want products that attract consumers and have a long shelf-life (See et al., 1995). Consumer acceptance of pork is the most important aspect of quality and results from a complex combination of both visual appeal and eating satisfaction (Lee et al., 2012). Moeller et al. (2010a) stated that palatability or eating quality is a culmination of taste, flavor, juiciness, and tenderness, and is an important factor that influences choice of protein source at the consumer level.

The first challenge that the swine industry currently faces is consumer perception. A European study (Verbeke & Viaene, 1999) stated that consumers perceive pork as being the worst meat choice when considering leanness, healthiness, taste, and tenderness compared to beef and poultry. Another important factor determining ultimate pork eating quality is end-point cooking temperature. Consumers need education on proper cooking methods, such as cooking fresh pork to a minimum of 145^0F, to achieve the desired taste and tenderness. A pork 'grading system' based on quality indicators does not currently exist in the U.S. pork industry. Therefore, pork quality parameters are typically second to performance parameters.

Pork quality attributes are influenced by breed, genotype, feeding, pre-slaughter handling, slaughter method, chilling, and storage conditions (Rosenvold & Andersen, 2003). There are many current methods and tools used to measure and quantify pork quality attributes, such as ultimate pH, color, marbling, and tenderness. While these attributes are assessed independently, all can be influenced positively or negatively by one another. Understanding these relationships is important to the swine industry because all attributes are responsible for providing consumers with a positive pork eating experience.

A few examples of pork quality attributes affecting one another include pale, soft, and exudative pork (PSE); dark, firm, and dry pork (DFD); and reddish-pink, firm, and non-exudative pork (RFN). Pork that is pale in color, soft in texture, and exudative; meaning water is lost from the interior of the product and can be found on the product surface or in the bottom of a retail meat tray is deemed PSE. Pork that is dark in color, firm in texture, and appears dry on the meat surface is deemed DFD. The ideal pork product can be described as RFN which is reddish-pink in color, has a firm texture, and is non-exudative. The basic principles causing pork to become each of these product types will be discussed later in this chapter. However, it is important to note that all are important to the pork industry because of their effects on overall product palatability.

Pork Color

Color may be the most important factor that influences the appearance and attractiveness of pork to consumers (Tan et al., 2000 & Barbut 2001). Color is associated with previous consumer eating experiences, and serves as an instant indicator of good or bad palatability. However, the appearance of pork at the retail level varies across and within packages (Tan et al., 2000). The addition of non-meat ingredient injections into pork (enhanced pork) is known to improve and stabilize color, as well as improve juiciness and flavor (Miller, 2002). The pork industry utilizes this technology as a tool to improve pork quality. The U.S. industry has readily adapted this processing method allowing enhanced pork to represent 40-45% of total fresh pork in the meat case in the last ten years (Reicks et al., 2008, and Beefretail.org, 2010).

The pork industry currently strives to provide consumers with pork that is reddish pink in color to ensure a moist, tender, and shelf stable product. The National Pork Board's current subjective measurement representing a reddish pink color is a score between 3 and 4 on a scale from 1-6 (NPB, 2011). Wright et al. (2005) reported a mean color score of 3.52 with a standard deviation of 0.85 for all boneless loin chops; a least squares means of 3.59 ± 0.05 for enhanced, and 3.46 ± 0.05 for non-enhanced, justifying an achieved improved color by enhancing pork. Moeller et al. (2010a) reported a mean color score of 3.13 with a 1.01 standard deviation for loin chops suggesting that since Wright's 2005 study, subjective pork color decreased, and variation increased.

Besides subjectively assessing pork color, researchers currently use colorimeters to quantify objective color score. Using colorimeters eliminates human error between researchers and provides a consistent method to quantify color under controlled light conditions. Colorimeters provide researchers with color values expressed as L*, a*, and b*. Minolta L* represents the lightness of a pork sample on a scale from 0-100 with 0 being pure black and 100 being pure white. An L* value near 53 is currently associated with an NPB color standard score of 3.0 as a reference (NPB, 2011). As L* values increase, NPB color standard scores decrease. Minolta L* is used more frequently than either a* or b* values to objectively measure pork color. However, it is worth noting that a* values represent the amount of red (+a*) vs. green (-a*) and b* values represent yellow (+b*) vs. blue (-b*) color space.

Providing consumers with RFN pork is the goal of the pork industry today. Reddish-pink color is indicative of a more desirable pH that is neither too high nor too low, suggested to be between 5.4 and 6.0. If the pH of pork decreases towards its isoelectric point (5.0-5.1), the myofibril proteins actin and myosin, will denature and no longer bind water. Since RFN pork has a desirable pH, proteins are not denatured which allows pork to be non-exudative and be more firm. Non-exudative describes meat's ability to retain free water and in turn be a juicier, more palatable product. With little to no moisture lost, little exudate is found on the meat surface. Moisture on the meat surface is known to reflect more light allowing pork to appear lighter in color. Since RFN pork does not have exudate on the meat surface, it does not reflect more light, so it appears darker in color. Another factor affecting pork color is the presence of the sarcoplasmic protein, myoglobin. Myoglobin is the pigment protein of meat and when it is denatured, meat loses its color intensity (Lonergan, 2008).

Pale soft and exudative pork is most commonly the result of poor genetics, poor handling, increased stress prior to slaughter, or carcass cooling problems post-slaughter. Certain swine genetic lines and breeds are specifically susceptible to becoming PSE. The most prominent example is genetic lines carrying the halothane gene. The halothane gene (HAL) is responsible for creating carcasses with higher yields and lean percentage. However, the pig's muscles have an inability to adequately regulate Ca^{2+} concentrations which poses an increased risk for stress-induced death or acute stress prior to slaughter (Scheffler & Gerrard, 2007). When pigs are stressed prior to slaughter, muscle reacts by increasing glycolysis, causing a depletion of glycogen, or energy reserves, in muscle. Stress can be the effect of poor animal handling causing a physical stress on the pig, or the pig may experience mental stress from doing something new, such as walking up a loading ramp for the first time. Stress causes rapid glycogen metabolism prior to harvest and consequently causes an accelerated rate of postmortem glycolysis. As a result, pH declines rapidly due to lactic acid accumulating in the muscle, which is the end product of anaerobic postmortem glycolysis. If the pH of muscle rapidly declines towards it's isoelectric point while the carcass is still at a high temperature (near that of live animal body temperature), proteins denature resulting in PSE pork. In PSE pork, myosin and actin are denatured and unable to bind water resulting in a soft product with surface exudate. Exudate reflects more light causing pork to appear very pale in color. Myoglobin is also denatured which causes pork to lose its color intensity. To the consumer, this defect provides an undesirable eating experience since it is drier and less tender (Rosenvold, & Anderson 2003).

Opposite of PSE, pork can also be Dark, Firm, and Dry (DFD). DFD pork is often the result of swine genetics that causes pork to sustain a long lasting higher than normal pH. The biochemical nature of this defect is simply the opposite of PSE pork. With a high pH, proteins aren't denatured, but are instead capable of binding more water which results in a firmer product. Also, with less water on the product surface to reflect light, pork appears darker in color (Miller, 2002). Although, DFD pork is very moist when cooked, it obtains two major negative eating quality characteristics including a sweeter than desirable taste, and a shorter shelf life due to the pH being higher than normal providing a more desirable environment for microbial growth.

Pork Marbling

Marbling is also a very important meat quality attribute assessed at the retail level by consumers (Font-I-Funols et al., 2012). The amount of marbling present in pork and its influence on consumer satisfaction may or may not affect consumer satisfaction. Cannata et al. (2010) found that pork loins with more marbling had higher sensory tenderness and sensory juiciness scores than pork loins with lower marbling levels. However, Rincker et al., 2008 reported that pork intramuscular fat (IMF), an objective measurement of marbling, did not influence eating quality or tenderness. Discrepancies between these studies may be explained by factors such as genetics or sampling scheme, but no research has shown marbling to have a negative effect in terms of eating satisfaction.

Marbling can have a negative influence on a consumer's perception of pork lean color. Brewer et al. (2001b) selected pork loins across the full range of marbling in chops possessing a color score between 3 and 4 (NPPC, 1999). As marbling increased, consumers perceived pork lean as being lighter in color even though the actual lean color varied little between 3 IMF categories (Low = ≤1%, medium = 2-2.5%, high = 3-3.5%) and resulted in consumers preferring chops with less marbling. However, once cooked, consumer ratings of juiciness, tenderness, and flavor were significantly greater ($P < 0.05$) for the high IMF pork than the low IMF pork, suggesting a discrepancy between visual raw product acceptance and the cooked product acceptance. This positive association could be influenced by flavor driven from IMF.

Pork pH

Initial (45 minute postmortem) and ultimate (24 hour postmortem) pH can influence the extent of protein denaturation and fresh pork quality attributes such as color and water-holding capacity. This is known to affect processing yields, consumer purchasing decisions, and sensory attributes of fresh or processed pork products (Bidner et al., 2004). Other factors influence sensory attributes, but ultimate pH remains a significant source of variation (Bidner et al 2004). Lonergan et al. (2007) found that lipid content in the pork loin would be expected to minimally improve sensory quality, but ultimate pH had a much more significant role in determining pork sensory quality. Therefore, measuring pH is of importance to better understand the more basic properties of pork that affect overall consumer satisfaction.

The physiological pH of muscle is near 7.2 but decreases post-mortem to reach an ultimate pH of about 5.6 in meat. It is important to understand that the rate by which pH of pork declines is a major contributor to ultimate pH and overall pork quality. When the pH of pork decreases at high temperatures, pork has a higher tendency of becoming PSE. Factors such as genetics, ante mortem stress, and post-mortem chilling are factors that affect the initial and ultimate pH of meat. As pH decreases toward its isoelectric point (5.0-5.1), water-binding proteins denature causing free water or purge to increase (Brewer et al., 2001a). This loss of water causes meat to become less juicy, thus less desirable to consumers who eat such products. However, the solution to this issue isn't to indefinitely increase pH. Instead, as Binder et al. (2004) concluded, loin pH between 5.4 and 6.0 is most desirable. This is because flavor intensity may increase too much at higher pH levels, and pork will likely lose greater amounts of purge at lower pH levels.

Pork Tenderness

Tenderness and juiciness have an influence on the overall palatability of pork. Tenderness is objectively measured using the Warner-Bratzler shear force (WBSF) method. Another common method for quantifying juiciness and tenderness of pork is using trained sensory panelists. Moeller et al., (2010b) found that when pork chops had WBSF values of 24.5N or less, trained sensory panelists showed a favorable response for overall tenderness, and that for every 4.5N increase in WBSF, predicted mean responses for tenderness level decreased. Likewise, chops with lower WBSF values had more favorable trained sensory panelist results for juiciness than chops with higher WBSF values. Marbling was also shown to have a positive influence on sensory qualities of tenderness and juiciness in a study conducted by Cannata et al., (2010), where chops were categorized into three groups by visual evaluation of marbling. Brewer et al., (2001b), found that pork chops with more marbling were also more juicy and tender than chops with less marbling, yet when consumers were given a choice to buy lean or highly marbled chops, they preferred the leaner chops. Rincker et al., (2008) reported that marbling did not influence the overall palatability or tenderness of pork chops and went on to say that selection of pork based on marbling alone may not guarantee a positive eating experience.

Research from Bidner et al. (2004) found that as pork longissimus ultimate pH increased, WBSF decreased. This is because as the pH of meat increases, it maintains a higher affinity to bind water, and meat that has a greater amount of water is likewise more tender.

Pork Loin Enhancement of Non Meat Ingredients

Through meat science research, scientists have a better understanding of the biochemical properties of meat. This knowledge has led to applications that better allow pork to bind water. This 'enhancement' with non-meat ingredients is commonly used in the pork industry to further improve tenderness, to decrease the variation in quality, and to improve the overall quality of pork. By enhancing pork loin muscles, Moeller et al. (2009) found that consumer responses improved across the primary pork quality indicators of marbling, pH, and WBSF. Juiciness and flavor were also improved when pork loins were enhanced. Prestat et al. (2002) also found that pork flavor, tenderness, and juiciness were improved when loin chops were enhanced. For non-enhanced pork chops, as endpoint cooking temperatures incrementally increased (62.8, 68.3, 73.9, & 79.4° C), consumer satisfaction consistently decreased (Moeller et al. 2009). However, consumer ratings remained the same or improved slightly as enhanced pork chops were cooked to each consecutively higher endpoint temperature (Moeller et al. 2009). Similarly, Prestat et al. (2002) reported that as endpoint temperature increased, juiciness decreased in non-enhanced chops, but remained constant in enhanced chops.

Some of the most common non-meat ingredients used to improve tenderness and/or juiciness include water, sodium phosphates, salt, sodium lactate, and potassium lactate (Miller, 2002). Miller (2002) explained that these ingredients aid in improving tenderness and juiciness by either increasing pork pH, or by lowering the isoelectric point of meat proteins which causes them to unfold and allows free water to bind to protein side chains.

Other common non-meat ingredients used to enhance pork include sodium diacetate, lemon juices, organic acids, papaya, pineapple, and flavor agents. Sodium diacetate acts mainly to stop microbial growth and to reduce major food borne pathogen growth (Miller, 2002). Lemon juices and organic acids serve to control lipid oxidation, control microbial growth and add flavor. Papaya and pineapple are natural tenderizers as well as flavor enhancers.

Benchmarking Pork Quality

Many studies have been conducted to benchmark value in the pork supply chain or to quantify pork quality characteristics. One of the first and largest pork benchmarking projects was The Pork Chain Quality Audit Survey and was conducted to identify, quantify, and rank factors influencing pork quality at the slaughter and fabrication segments of the pork chain (Cannon et al., 1996). In that study, a survey was given to pork processors asking questions pertaining to both the slaughter and the fabrication of pork. Results from that survey identified a few major factors affecting pork quality at the packing level including 1) condemnations; 2) skin defects; 3) trimming defects; 4) backfat thickness; 5) percentage muscling; 6) muscle color, firmness, and texture; 7) ecchymosis. All of which would be improved under the proper management, genetics, facilities, and animal handling. Cannon et al. (1996) calculated that these factors accounted for a $10.10 economic loss per pig which represented about 10% of the total value of the live animal. This study was able to clearly identify and benchmark major factors that affect pork quality and cutability at the slaughter and fabrication level of the pork industry.

Person et al. (2005a) went on to benchmark value in the pork supply chain by evaluating how boneless and bone-in ham quality was affected by PSE pork at the processing segment of the pork industry. In that study, hams were selected from the fabrication line of a commercial processor and sorted into two groups based on their pH. Results indicated that processing yields and consumer appeal were impacted for those products manufactured from raw pork that had low pH values or pork that was PSE (Person et al., 2005a).

Person et al. (2005b) also benchmarked value in the pork supply chain by evaluating the relationship between belly thickness, processing yields, and consumer preferences of bacon at the processing segment of the industry. In that study, bellies were sorted subjectively into thin, average, and thick groups. Bellies were then skinned, injected with a curing solution, chilled, smoked, and sliced. Person et al. (2005b) concluded that consumers will likely discriminate against bacon from thick bellies, while processors are offered the greatest processing yields from those same bellies.

Wright et al. (2005) benchmarked value in the pork supply chain by evaluating pork loin, ham, and belly products at the retail level by gathering the price/value relationship of each and determined the opportunities lost with pork quality defects. Packages of loin chops, ham, and bacon were purchased from a large sample size at the retail level to provide a broad geographical representation across the United States (Wright et al. 2005). Wright et al. (2005) reported that 12.5% of the pork loin chops at retail were deemed as low quality pork. Wright et al. (2005) also reported that retail pork quality was quite variable even with the pork industry focusing on quality for so many decades. However, processed pork did not differ greatly in quality and palatability suggesting that processing technologies might help alleviate pork quality problems.

The 2004 National Meat Case Study assessed what meat products were offered to consumers and how they were offered in the retail meat case (Reicks et al., 2008). In that study, in-store audits were conducted and products were not purchased. The goal of the study was to benchmark items available in the meat case, what type of packaging was used, and what was on the product label. As a benchmark study, Reicks et al. (2008) stated the data from that study will be used to track changes seen throughout the entire industry when future meat case studies are conducted. Therefore, when the 2010 National Meat Case Study was conducted, one of the more interesting benchmark data pieces showed that the amount of enhanced pork offered to consumers declined significantly from 45% in 2004 to 39% in 2010 (A snapshot of today's retail meat case, 2010).

Moeller et al. (2010a, b) evaluated consumer and trained sensory panelist responses and their perceptions of pork eating quality as affected by pork quality and end-point cooked temperature. In those studies, loins were selected from three commercial U.S. pork packing facilities. In both studies, consumers and trained panelists only saw the cooked product. These were blind taste panels so the panelists were not able to assess the visual quality of the fresh product. They were only able to see the final cooked product under red incandescent lighting, to minimize sample color variation due to different cooked temperatures. In their results, Moeller et al., (2010a) reported that eating quality would be optimized in a fresh pork loin with greater pH and IMF, lower cooked WBSF, and a chop that is cooked to a lesser degree of doneness. Furthermore, Moeller et al., (2010b) reported that pork chop WBSF and pH were very important indicators of palatability. This research allows other investigators to understand what consumer's demand from a pork quality standpoint using cooked product and no visual purchasing cues.

Benchmarking studies and other pork quality research have played a pivotal role in understanding pork quality factors to consider from farm to plate. Until recently, very little information existed that discussed the quality of pork products offered to consumers at the retail level. Researchers have collected data and conducted surveys evaluating pork quality factors associated with on farm, slaughterhouse, and fabrication line parameters. Further research has evaluated consumer preference factors utilizing taste panels and even purchased pork in retail stores to further quantify, analyze, and better understand consumer appeal and selection. However, a study solely addressing the quality of pork representative of the U.S.'s retail pork supplies in the self-serve meat case, and the corresponding variation, had never been conducted. By benchmarking pork quality at the retail level, researchers are more able to quantify the quality of pork that consumers are offered while also understanding the predicted eating experience they will have once they purchase and cook their pork. With this study being the first of its kind, it will provide pork industry stakeholders with valuable information to be used as a tool to improve pork quality and lessen the variation in available product.

2012 National Retail Pork Benchmarking Study Introduction

At the retail level, many differences in pork quality are observed whether pork is fresh, processed, or enhanced (Wright et al., 2005). Variables considered at the time of purchase include product color, marbling, fat cover, and drip loss (Brewer et al., 2001b and Ngapo et al., 2005). Moeller et al. (2010a) reported that palatability, or eating quality, a culmination of taste, flavor, juiciness, and tenderness, is an important factor that influences choice of protein sources at the consumer level. Therefore, it is understood that consumer acceptance of pork results from a complex combination of visual appeal and eating satisfaction (Lee et al., 2012).

In 2011 the National Pork Board unveiled the marketing campaign "*PORK® Be Inspired*". The new campaign established goals for domestic pork consumers, described as "pork champions". Consumer segmentation research (National Pork Board, 2012) characterizes "pork champions" as men and women who are predominantly medium to heavy fresh pork users, representing 82 million Americans and 68% of all in-home fresh pork consumption. Campaign goals include a 10% increase in fresh pork consumption per capita and a 10% increase in real per capita domestic expenditures. According to the United States Department of Agriculture statistics, approximately 75% of the U.S. pork supply is consumed domestically (USDA, 2012). This percentage does not take into account factors that could increase the supply of domestic product including a reduction in pork exports or increased domestic production. With such a high proportion of domestic pork consumption it is important to focus on the consistency and quality of pork products presented to pork consumers at the retail level. Also, consumers who purchase fresh pork and feel comfortable cooking it correctly could have drastically different eating experiences, regardless of cooking method, based on the differing degrees of quality available at retail locations.

Many studies have been conducted to benchmark value in the pork supply chain or to quantify pork quality characteristics. However, very little research has been conducted to simply quantify the quality and the variation in pork quality that consumers are offered at the retail level of the pork industry. Because the pork industry does not currently utilize a quality grading system, packers and processors do not purchase or sort a large volume of domestic pork based on quality attributes. Likewise retailers offer very little pork based on quality attributes. There are no cues at the meat case to inform and educate consumers about pork quality. With no visual quality indicators such as pork color, consumers have little knowledge about what to look for.

The National Pork Board grocery shopper intercept study (National Pork Board, 2012) found that consumers are generally confused when purchasing pork products and that pork color does not register as a major consumer purchasing decision factor. Purchasing factors are further compounded by the variation of pork quality that is found in the meat case. Thus, pork consumers are left with a lack of information about pork quality selection in the retail meat case.

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CHAPTER 2. NATIONAL RETAIL PORK QUALITY BENCHMARKING STUDY: LOIN CHOP EVALUATION

Abstract

The objective of this study was to benchmark fresh pork quality in the retail meat case in the United States. Nationally, 117 retail supermarkets in 67 cities were selected for sampling. Center-cut loin chops were observed in-store, in package, to obtain subjective color (n = 2795), and marbling (n = 2767) scores. After in-store analysis, ten packages of each brand and enhancement type were purchased when available for objective analysis including pH, Minolta color (L*, a*, and b*), and tenderness (WBSF). Center-cut loin values (mean ± standard deviation) were: color (3.12 ± 0.85), marbling (2.48 ± 0.95), pH (5.87 ± 0.30), L* (55.30 ± 3.70), a* (5.89 ± 3.11), b* (3.74 ± 1.84), and WBSF (23.35 ± 6.70N). Least squares means for enhanced vs. non-enhanced center-cut loin chops were: color (3.19 vs. 3.18, SEM = 0.03), marbling (2.39 vs. 2.47; SEM = 0.04), pH (5.98 vs. 5.78; SEM = 0.01), L* (54.31 vs. 56.10; SEM = 0.15), a* (5.61 vs. 6.23; SEM = 0.13), b* (3.62 vs. 3.82; SEM = 0.08), and WBSF (21.00 vs. 25.24; SEM = 0.25N), respectively. Frequency distribution for color, marbling, L* and WBSF illustrated a sizeable variation in overall quality of center-cut loin chops.

Materials and Methods

Retail Store Sampling

With the collaboration of six Universities including North Dakota State University, Texas A&M University, The University of Florida, The Pennsylvania State University, The Ohio State University, and California Polytechnic State University, 117 retail stores and markets in 32 different states were visited (Table 2.1). Each University had a principal investigator assisted by a trained team. Prior to data collection, each of the six teams met in Kansas City, MO for a training workshop. At this workshop, investigators finalized the data collection protocol and performed a mock collection at a local retail grocery.

Table 2.1. Center-cut loin chop demographics by region across the United States.

	EC[1]	MA[1]	NE[1]	PA[1]	SE[1]	SW[1]	WC[1]	National
Cities included	8	10	3	15	13	5	13	67
Market areas included	5	4	2	6	6	3	6	32
Stores assessed	12	16	9	25	23	13	19	117
Brands assessed	10	13	10	17	12	9	17	57
Packages Observed[2]								
Enhanced	70	47	30	95	121	60	108	531
Non-Enhanced	51	120	70	142	104	72	101	660
Packages Purchased[3]								
Enhanced	70	47	30	110	146	67	107	577
Non-Enhanced	53	153	92	146	63	63	113	683

[1] EC = East Central, MA = Middle Atlantic, NE = New England, PA = Pacific, SE = Southeast, SW = Southwest, WC = West Central.
[2] Number of packages used for subjective, within store assessment.
[3] Number of packages purchased for objective assessment at Texas A&M University.

Retail stores were sampled between February and April 2012, collecting data between the hours of 9 A.M. and 5 P.M. local time. Center-cut loin chop packages (n = 1191) were randomly selected from the self-serve case and evaluated for subjective measurements of color (NPB 1 - 6, 2011) and marbling (NPB 1 - 6, 2011) in 67 cities across the United States (Table 2.1). Using the 2011 Marketing Guidebook (Stagnito Media, 2011), individual market areas to be sampled were identified (Table 2.2) in 7 different regions and then retail stores within each market area were selected based on the following representation criteria: 1) Geographic population distribution and major retailers, both national and regional. 2) Top five Supermarkets in each market area. 3) Retail stores where middle class income consumers most frequently shop.

Subjective Center-cut Loin Chop Evaluation

Ten packages of center-cut loin chops of each representative brand and each enhancement type (Enhanced (En) and Non-enhanced (Non)) were selected to represent different loins in the self-serve meat case and were evaluated. The principal investigator of each team performed the evaluation of subjective color and marbling (NPB, 2011) under the lighting in the meat case. Selection preference was given to boneless center-cut loin chops but due to regional differences in product availability, bone-in chops were used as well. Every chop that was at least 50% visible in each package was evaluated for each of the previously mentioned attributes.

Table 2.2. Identification of market areas included in retail store sample, per region.

	Region						
	EC[1]	MA[1]	NE[1]	PA[1]	SE[1]	SW[1]	WC[1]
Market Areas	Cincinnati Cleveland Detroit Indianapolis Pittsburgh	Baltimore Buffalo New York-City Philadelphia	Boston Hartford	Los-Angeles Phoenix Portland Salt Lake-City San-Francisco Seattle	Atlanta Charlotte Memphis Miami Nashville Tampa	Dallas Houston San-Antonio	Chicago Denver Des Moines Milwaukee Minneapolis St. Louis

[1] EC = East Central, MA = Middle Atlantic, NE = New England, PA = Pacific, SE = Southeast, SW = Southwest, WC = West Central.

Objective Center-cut Loin Chop Package Selection

When available, ten packages containing at least two center-cut loin chops of each representative brand and each enhancement type were selected to represent different loins in the self-serve meat case and purchased. Due to regional differences in product availability, bone-in chops were purchased when boneless chops were unavailable. Likewise, 2.5cm thick chops were preferred. However, when unavailable, the next thickest available chops were purchased. After purchasing, loin chops were shipped overnight in coolers on reusable frozen ice packs to Texas A&M University (TAMU) for objective analysis described below.

Minolta Color and pH Measurement

Upon arrival at TAMU, packages were opened and allowed to bloom for a minimum of 10 min. Two center-cut loin chops from each package were randomly selected for pH and Minolta color measurements. Center-cut loin chop pH was obtained using a portable pH meter (HI 98240; Hanna Instruments, Italy). After bloom, objective color (CIE L*, a*, and b* color space values) was measured using a Minlota Colorimeter (CR-300, 8 mm diameter head, 10° standard observer, D^{65} light source; Minolta Company, Ramsey, NJ) calibrated to white and black tiles.

Warner Bratzler Shear Force

Two different chops from each package were randomly selected for Warner Bratzler shear force (WBSF). The two WBSF chops were vacuum sealed and frozen. Chops were thawed for 48 h in a cooler at 4°C and then cooked using a clam-style cooker (George Foreman Grill) to an internal temperature of 65°C. Internal temperature was monitored using iron constantan thermocouples inserted into the geometric center of each chop (TT-J-36-SLE; Omega Engineering, Inc., Stanford, CT) and a hand-held temperature recorder (model HH-21; Omega Engineering, Inc., Stanford, CT). Chops were cooled for 4 h to approximately 22.2°C prior to shear force assessment. Four to six 1.27 cm diameter cores were removed from each chop parallel to the longitudinal orientation of the muscle fibers. Each core was sheared with a Warner-Bratzler shearing device (United Smart-1 Test System SSTM-500; United Calibration Corp., Huntington Beach, CA) certified by United Testing Systems, Inc. The 1.168 cm Warner-Bratzler stainless steel blade was used to hold cores and head speed of 200 mm/minute was used with 9.072 kg load cell to segment cores. Maximum force for each core was recorded in kg, and analyzed as the average of the cores removed from each chop. All averaged values were converted into Newton's from kg (1 kg = 9.80665002864 N).

Statistical Analysis

Data were analyzed using generalized least squares (PROC MIXED, SAS Institute, Cary, NC). Chops were the experimental unit. The model included enhancement type as a fixed effect and package within region, retailer, store, and brand as a random effect.

Results and Discussion

Product Demographics

The number of enhanced (En) and non-enhanced (Non) center-cut loin chop packages used for subjective assessment of pork color and marbling as well as the number of packages purchased for objective assessments (pH, Minolta color, and WBSF) per region can be found in Table 2.2. Overall, 531 En and 660 Non packages of pork were used for subjective assessments. Similarly, 577 En and 683 Non packages of pork were purchased for objective assessments. A total of 1,191 packages of center-cut loin chops were observed for subjective attributes in the retail meat case, and 1,260 packages were purchased to obtain additional objective measurements.

Subjective Pork Quality Attributes

Overall, a mean color score of 3.12 was observed for center-cut loin chops in the retail meat case (Table 2.3). This average color score was slightly less than what was observed in the last pork benchmark study. In that benchmark study, Wright et al. (2005) sampled boneless loin chops in the retail meat case and reported a mean color score of 3.52, albeit the scores were still characterized as having a reddish-pink lean color. A mean marbling score of 2.48 was observed (Table 2.3) which is slightly greater than the mean marbling score of 2.37 that was observed by Wright et al. (2005) in boneless loin chops. These results suggest that subjective pork quality attributes observed in the retail meat case are fairly consistent with what was observed previously by Wright et al. (2005).

There were small differences between En and Non center-cut loin chop color scores (3.19 vs. 3.18, respectively, $P = 0.78$) or marbling score (2.39 vs. 2.47, respectively, $P = 0.08$, Table 2.4). Figure 2.1 presents the distribution of color score for En and Non center-cut loin

Table 2.3. National representation of center-cut loin chop quality attributes simple statistics.

Trait	n	Mean	Min.	Max.	SD	CV
Color[1]	2795	3.12	1.00	6.00	0.85	27.12
Marbling[2]	2767	2.48	1.00	6.00	0.95	38.14
L*[3]	1705	55.30	41.44	68.62	3.70	6.69
a*[4]	1705	5.89	-6.90	16.96	3.11	52.87
b*[5]	1705	3.74	-1.21	11.78	1.84	49.19
pH	1817	5.87	4.60	7.20	0.30	5.03
WBSF[6], N	1910	23.35	8.38	55.35	6.70	28.68

[1] Color scale: 1 = pale pinkish gray to white; 6 = dark purplish red (NPB, 2011).
[2] Marbling scale: 1 = devoid; 10 = abundant (NPB, 2011).
[3] Lightness scale: 0 = black; 100 = white.
[4] Redness scale: negative number = green; positive number = red.
[5] Yellowness scale: negative number = blue; positive number = yellow.
[6] WBSF = Warner Bratzler shear force.

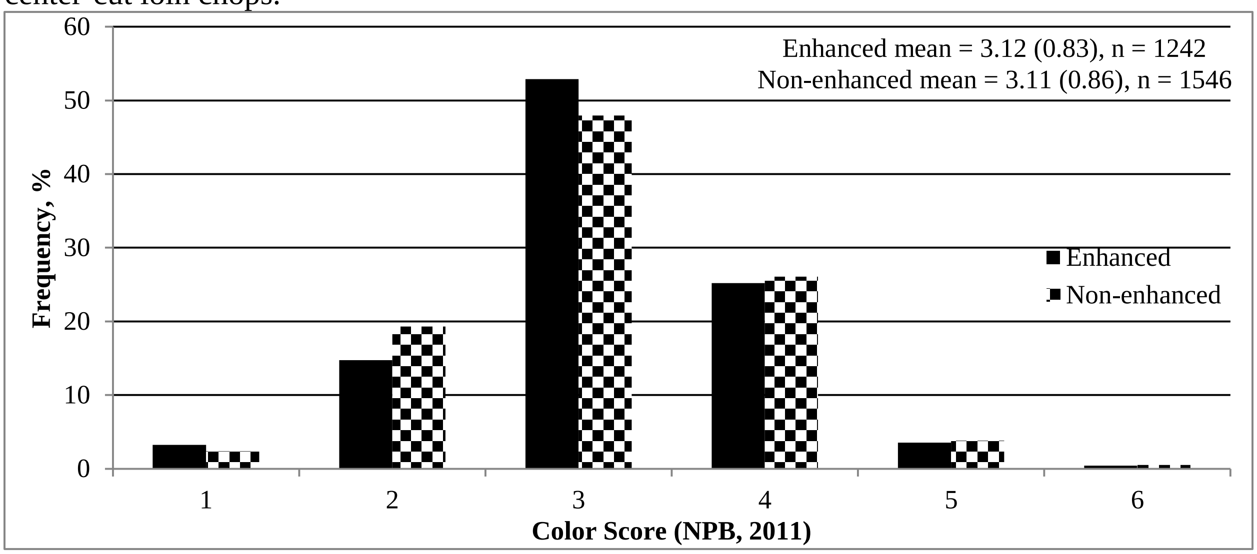
Table 2.4. Least squares means of enhanced (En) and non-enhanced (Non) center-cut loin chop quality attributes in a national sample.

Trait	En	Non	SEM	*P* - value
Color[1]	3.19	3.18	0.03	0.78
Marbling[2]	2.39	2.47	0.04	0.08
L*[3]	54.31	56.10	0.15	<0.01
a*[4]	5.61	6.23	0.13	<0.01
b*[5]	3.62	3.82	0.08	0.05
pH	5.98	5.78	0.01	<0.01
WBSF[6], N	21.00	25.24	0.25	<0.01

[1] Color scale: 1 = pale pinkish gray to white; 6 = dark purplish red (NPB, 2011).
[2] Marbling scale: 1 = devoid; 10 = abundant (NPB, 2011).
[3] Lightness scale: 0 = black; 100 = white.
[4] Redness scale: negative number = green; positive number = red.
[5] Yellowness scale: negative number = blue; positive number = yellow.
[6] WBSF = Warner Bratzler shear force.

chops. The mean color score for En chops was 3.12, of which 53% of the chops had a color score of 3 and 40% scored 2 or 4 (15% & 25% respectively). Furthermore, 18% of En chops had a color score less than 3 while 29% had a color score greater than 3. The mean color score for Non chops was 3.11, of which 48% of the chops had a color score of 3 and 45% scored 2 or 4 (19% & 26% respectively). Furthermore, 22% of Non chops had a color score less than 3 while, 30% had a color score greater than 3. Interestingly, 93% of both En and Non chops were reported as having a color score between 2 and 4. A color score of 2 is characterized as being grayish pink and a 4 as being dark reddish pink, thus, these data suggest that there is still a considerable amount of variation in the retail meat case. Table 2.3 further illustrates the variation in color scores observed in retail outlets, with the standard deviation being nearly equal (0.85) to a single unit of measurement and a corresponding coefficient of variation of 27.12%. Both of these statistics suggest that a large amount of variation in pork quality was observed in the retail meat case. Similar results were observed for marbling (Fig. 2.2) where En chops had a mean score of 2.41 with 45% scoring a 2 and 45% scoring a 1 or 3 (14% & 31% respectively). The mean marbling score for Non chops was 2.53 with 47% scoring 2 and 40% scoring a 1 or 3 (9% & 31% respectively). Again, a sizeable amount of variation in marbling score was observed, with a standard deviation of 0.95 units and coefficient of variation of 38.14%.

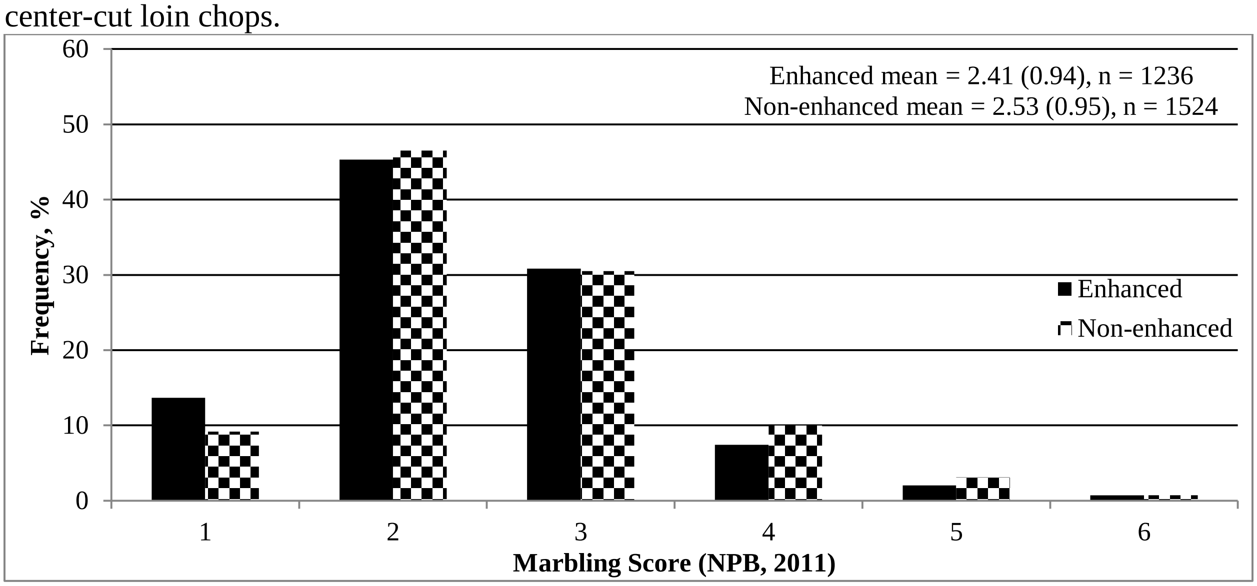
Figure 2.1. Frequency distribution of subjective color scores for enhanced and non-enhanced center-cut loin chops.



Objective Pork Quality Attributes

Center-cut loin chop quality attributes simple statistics are presented in Table 2.3. Overall, center-cut loin chops had a mean Minolta L* value of 55.30 which ranged from 41.44 to 68.62. The mean Minolta a* value was 5.89 ranging from -6.90 to 16.96. Center-cut loin chops had a Minolta b* value of 3.74 which ranged from -1.21 to 11.78. Results for center-cut loin chops pH provided a mean value of 5.87 which ranged from 4.60 to 7.20. For tenderness, center-cut loin chops had a mean WBSF value of 23.35 N which ranged from 8.38 to 55.35 N. Least squares means for En and Non center-cut loin chops are presented in Table 2.4. Enhanced center-cut loin chops had an L* value significantly lower ($P < 0.01$) than that of Non chops even though no subjective color score differences were observed. Minolta a* values for En chops were significantly lower ($P < 0.01$) than values for Non chops. Enhanced chops, as expected, had a pH value that was significantly greater ($P < 0.01$) than Non chops and is consistent with the observed lower L* value of En chops. Wright et al. (2005) also reported that En loin chops had a significantly lower L* and corresponding higher pH value. Moeller et al. (2010) found that as ultimate pH increased from pH 5.40 to 6.40, the proportion of consumer overall-like ratings predicted to be ≥ 6 (on an 8 point scale with 1 being least desirable and 8 being the most desirable) increased by approximately 3% for each 0.2 unit increment. Consistent with Wright et al. (2005), En chops had a significantly lower ($P < 0.01$) WBSF than Non chops.

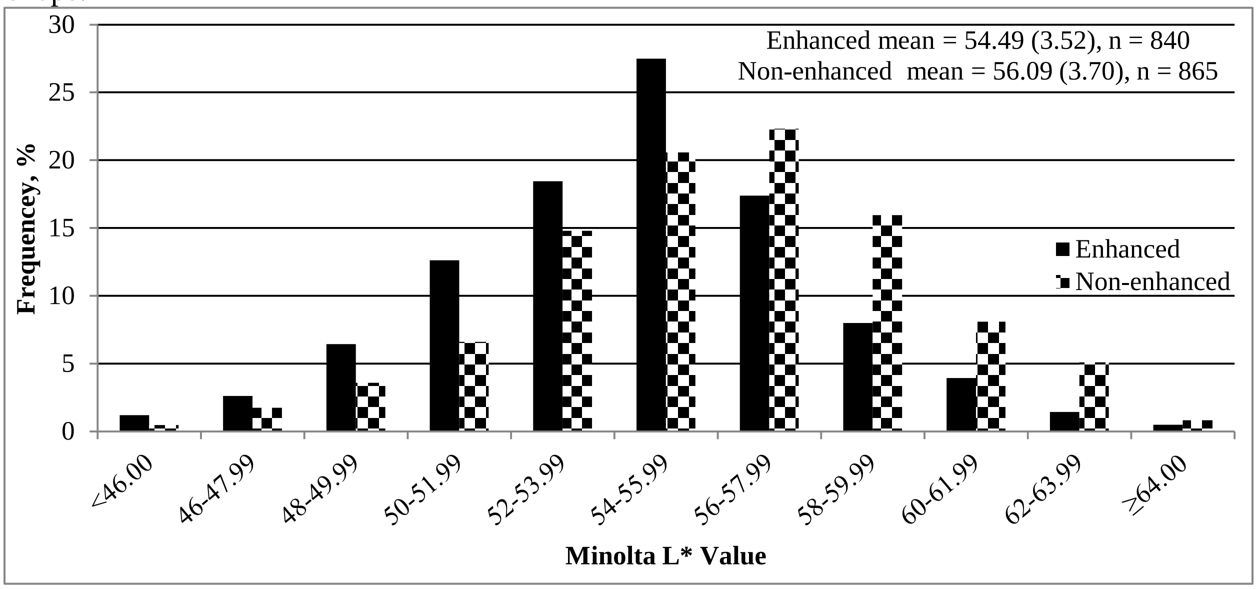
Figure 2.2. Frequency distribution of subjective marbling scores for enhanced and non-enhanced center-cut loin chops.



The frequency distribution for Minolta L* values for enhanced and non-enhanced center-cut loin chops are given in Figure 2.3. Enhanced chops had a mean L* value of 54.49 and 28%

of these chops were in the L* value range of 54.00 to 55.99, 41% of the chops had an L* < 54.00 and 31% had an L* > 55.99. Non-enhanced chops had a mean L* value of 56.09 and 22% of these chops were in the L* value range of 56.00 to 57.99, 48% of the chops had an L* < 56.00 and 30% had an L* > 57.99. Currently, the NPB color standards chart for subjective color evaluation are provided with a reference to a Minolta L* values. For example, a color score of 1 is associated with a Minolta L* value of 61, and a color score of 6 is associated to a Minolta L* value of 31. Thus, from the current study's subjective mean color results of 3.12 En and 3.11 Non, a Minolta L* value close to 49 would be expected when comparing values to NPB color standards. However, mean Minolta L* values reported in the present study (54.49 for En and 56.09 for Non) are indicative of a subjective color score of 2.0 (referenced Minolta L* value of 55). One possible explanation for this discrepancy between subjective and objective color is that different retailers use different light sources in their self-serve meat cases. This may result in pork appearing darker or lighter to the subjective evaluator under a controlled light source. Barbut (2001) reported that pork presented under incandescent (INC) lighting was more desirable ($P < 0.05$) than pork presented under both fluorescent (FL) and metal halide (MH) light sources. Pork presented under INC lighting was described as pink. Under FL lighting, pork was described as being pink brown or dark pink. Under MH light sources, pork was described as brown or dull pink. Barbut (2001) went on to say that under both MH and FL light sources, pork reflected more light, and so appeared lighter. Another possible explanation is that by adding non-meat ingredients to pork to create an enhanced product, a higher pH is obtained which allows pork proteins to bind more free water and allows less moisture to appear on the meat surface (Miller, 2002). When less moisture appears on the surface of meat, less light is reflected resulting in a darker appearing product (Miller, 2002). Therefore, by enhancing pork, retailers are in turn able to provide pork products that appear darker to consumers when evaluated at the retail store.

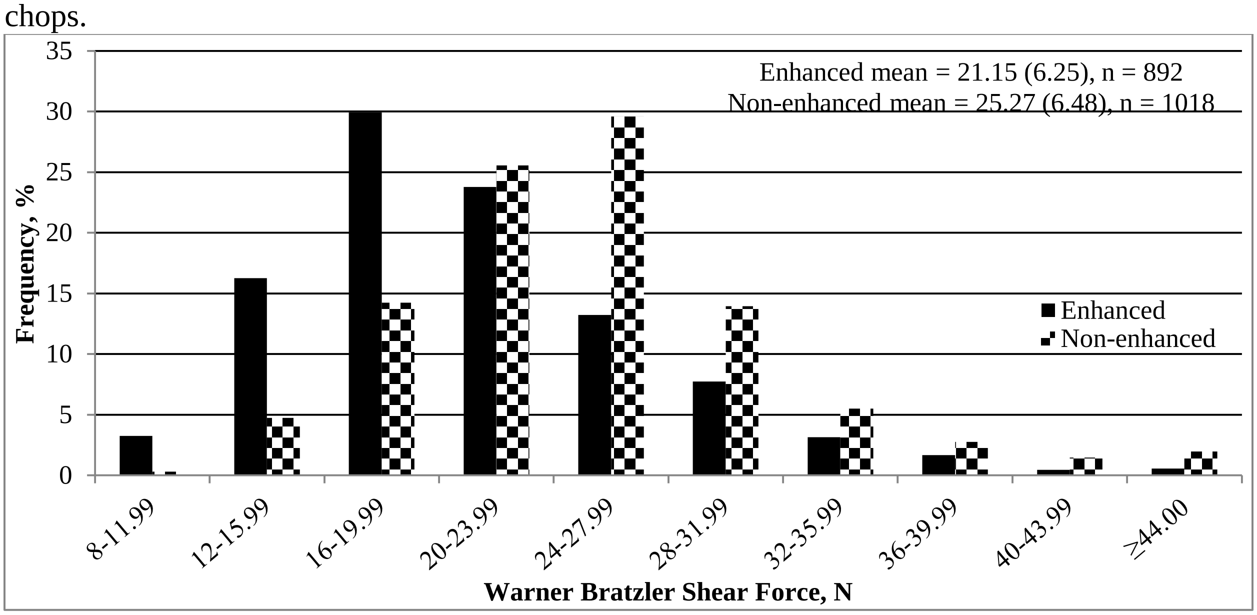
Figure 2.3. Minolta L* frequency distribution of enhanced and non-enhanced center-cut loin chops.



Packaging type is also known to affect the appearance of fresh meat color. Carpenter et al. (2001) reported that beef packaged in overwrapped packages with polyvinyl chloride (PVC) was more appealing to consumers than beef packaged in modified atmosphere packaging (MAP) and vacuum skin packaging (VSP). They found that beef packaged in MAP were more likely to be described as purple or brown than either PVC or VSP, and that PVC overwrapped beef was most often described as red. Carpenter et al. (2001) suggested that the red color of beef was not as visually distinct in MAP because the meat was not in contact with the surface of the package as it would be in VSP or PVC overwrap. In the current study, investigators found that a majority (90%, not reported) of pork center-cut loin chops were sold in the retail case in PVC overwrapped packages. However, not all of the packages were presented with the meat actually touching the overwrap which may explain some of the subjective vs. objective color score discrepancies. Future research that evaluates the correlation of L* to subjective color scoring is needed. This could prove to be beneficial to researchers and other pork industry stakeholders to better analyze and quantify pork lean color as a quality attribute.

Frequency distribution of WBSF for enhanced and non-enhanced center-cut loin chops are given in Figure 2.4. Enhanced chops had a mean WBSF value of 21.15 N and 24% of these chops were in the WBSF value range of 20.00 to 23.99 N followed by 49% of the chops being < 20.00 N and 27% being > 23.99 N. Non-enhanced chops had a mean WBSF value of 25.27 N and 30% of these chops were in the WBSF value range of 24.00 to 27.99 N followed by 45% of the chops being < 24.00 N and 25% being > 27.99 N. According to Moeller et al. (2010), positive consumer responses were observed for overall-like, juiciness-like, and juiciness-level of pork loin chops if WBSF values were less than 24.5 N. Furthermore, Moeller et al. (2010) reported that for every 4.9 N increase in WBSF above 24.5 N the proportion of consumer responses of ≥ 6 for overall-like decreased by 4%. In the current study, we found that 73% of the En chops and 45% of the Non chops had WBSF values < 24.00 N suggesting that consumers would be more likely to have a positive eating experience if they purchased En chops.

Figure 2.4. Shear force frequency distribution of enhanced and non-enhanced center-cut loin chops.



Regional Pork Quality Attributes

Least squares means of En and Non center-cut loin chops quality attributes per region are presented in Table 2.5. Subjective color was similar between En and Non chops in each region except the SW where En chops had a greater ($P < 0.05$) score than Non chops. Subjective marbling was greater ($P < 0.05$) in En chops than Non chops in the EC, MA, and SE regions. All other regions had similar En and Non marbling scores. Minolta L* values were greater ($P < 0.05$) for Non chops than En chops in the EC, MA, PA, SE, and SW regions. All other regions had similar En and Non Minolta L* values. The EC, MA, and PA regions each had En chops with Minolta a* values that were lower ($P < 0.05$) than Non chops. The SE region had En chops with a Minolta a* value that was greater ($P < 0.05$) than Non chops. The NE, SW, and WC regions each had similar En and Non Minolta a* values. Minolta b* values for En chops were lower ($P < 0.05$) than Non chops for the EC and PA regions. The MA region had En chops with a b* value significantly greater than Non chops. All other regions had similar En and Non Minolta b* values. The NE region had similar En and Non pH values; all other regions had En chops with greater ($P < 0.05$) pH values than Non chops. Numerically, En chops were more tender in every region than Non chops. However, only the MA, PA, SE, SW, and WC regions had En chops with significantly lower ($P < 0.05$) WBSF values than Non chops.

Conclusion

In the current study investigators reported that 93% of both En and Non chops had a subjective color score range between 2 and 4. Of that percentage, 18% En chops and 22% of Non chops scored less than a color score 3. Objective Minolta L* color results indicate that there is a sizeable amount of variation available as well. With a subjective color score of 3 being indicative of an L* value of 49, data from the present study suggest that only 10% of En chops

Table 2.5. Least squares means per region of enhanced (En) and non-enhanced (Non) center-cut loin chop quality attributes.

	Region															*P*-value		
	EC[1]		MA[1]		NE[1]		PA[1]		SE[1]		SW[1]		WC[1]		SEM			
	En	Non	En	Non	En	Non	En	Non	En	Non	En	Non	En	Non		R	E	R*E
Color[2]	2.66	2.84	3.28	3.08	3.60	3.65	3.37	3.29	3.30	3.35	3.89[a]	3.30[b]	2.69	2.70	0.14	<0.01	0.08	<0.01
Marbling[3]	2.34[a]	2.95[b]	1.99[a]	2.28[b]	2.08	2.19	2.34	2.34	2.60[a]	3.05[b]	2.44	2.33	2.42	2.34	0.16	<0.01	<0.01	<0.01
L*[4]	54.90[a]	56.74[b]	53.90[a]	57.29[b]	54.28	55.41	54.76[a]	55.81[b]	55.12[a]	56.62[b]	51.02[a]	55.35[b]	54.50	55.29	0.65	<0.01	<0.01	<0.01
a*[5]	4.68[a]	6.11[b]	5.56[a]	7.13[b]	6.80	6.24	5.39[a]	6.35[b]	5.82[a]	4.82[b]	8.15	7.98	4.27	4.63	0.56	<0.01	0.05	<0.01
b*[6]	3.10[a]	4.03[b]	4.31[a]	2.94[b]	3.47	3.51	3.19[a]	4.24[b]	3.50	3.28	2.89	3.18	4.79	5.17	0.32	<0.01	0.14	<0.01
pH	5.90[a]	5.75[b]	5.89[a]	5.74[b]	5.80	5.70	5.93[a]	5.83[b]	5.95[a]	5.81[b]	6.41[a]	5.75[b]	5.97[a]	5.82[b]	0.05	<0.01	<0.01	<0.01
WBSF[7], N	23.18	24.88	19.40[a]	24.22[b]	22.15	24.41	20.02[a]	26.21[b]	21.77[a]	24.59[b]	17.27[a]	25.51[b]	21.99[a]	26.24[b]	1.08	<0.01	<0.01	<0.01

[1] EC = East Central, MA = Middle Atlantic, NE = New England, PA = Pacific, SE = Southeast, SW = Southwest, WC = West Central.
[2] Color scale: 1 = pale pinkish gray to white; 6 = dark purplish red (NPB, 2011).
[3] Marbling scale: 1 = devoid; 10 = abundant (NPB, 2011).
[4] Lightness scale: 0 = black; 100 = white.
[5] Redness scale: negative number = green; positive number = red.
[6] Yellowness scale: negative number = blue; positive number = yellow.
[7] WBSF = Warner Bratzler shear force.
[a-b] Least squares means with different superscripts in the same region differ ($P < 0.05$).

and 6% of Non chops had an L* value of ≤ 49. Results indicate that 73% of En chops and 45% of Non chops were tender (WBSF ≤ 24.5 N) and would provide consumers with a positive eating experience based on consumer response criteria relating WBSF levels with tenderness and overall like response criteria reported by Moeller et al. (2010).

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CHAPTER 3. NATIONAL RETAIL PORK QUALITY BENCHMARKING STUDY: SIRLOIN CHOP AND BLADE STEAK EVALUATION

Abstract

The objective of this study was to benchmark fresh pork quality in the retail meat case in the United States. Nationally, 117 retail supermarkets in 67 cities were selected for sampling. Ten packages of non-enhanced and enhanced sirloin chop and blade steaks of each brand were purchased when available for measurements of pH, Minolta color (L*, a*, and b*), and tenderness (WBSF). Sirloin values (mean ± standard deviation) were: pH (5.88 ± 0.29), L* (51.92 ± 3.22), a* (19.50 ± 2.74), b* (9.99 ± 1.66), and WBSF (18.71 ± 5.17). Least squares means for enhanced vs. non-enhanced sirloin chops were: pH (5.95 vs. 5.72; SEM = 0.02), L* (51.72 vs. 52.21; SEM = 0.25), a* (20.19 vs. 17.91; SEM = 0.22), b* (9.98 vs. 9.93; SEM = 0.14), and WBSF (16.70 vs. 23.20; SEM = 0.33N); respectively. Blade values (mean ± standard deviation) were: pH (6.22 ± 0.27), L* (45.27 ± 2.79), a* (19.70 ± 2.12), b* (8.13 ± 1.71), and WBSF (17.12±4.65). Least squares means for enhanced vs. non-enhanced blade steaks were: pH (6.22 vs. 6.16; SEM = 0.02), L* (45.46 vs. 45.23; SEM = 0.20), a* (20.21 vs. 18.87; SEM = 0.14), b* (8.42 vs. 7.97; SEM = 0.12), and WBSF (16.53 vs. 18.19; SEM = 0.32N), respectively.

Materials and Methods

Retail Store Sampling

With the collaboration of six Universities including North Dakota State University, Texas A&M University, The University of Florida, The Pennsylvania State University, The Ohio State University, and California Polytechnic State University, 117 retail stores and markets in 32 different states were visited (Table 3.1). Each University had a principal investigator assisted by a trained team. Prior to data collection, each of the six teams met in Kansas City, MO for a training workshop. During the workshop, investigators finalized the data collection protocol and performed a mock collection at a local retail grocery. Retail stores were sampled between February and April 2012 between 9 A.M. and 5 P.M. local time. Of the 117 stores, sirloin chops were purchased in 59 and blade steaks were purchased in 69 (Table 3.1). Using the 2011 Marketing Guidebook (Stagnito Media, 2011), individual market areas to be sampled were identified (Table 3.2) in 7 different regions and then retail stores within each market area were selected based on the following representation criteria: 1) Geographic population distribution and major retailers, both national and regional. 2) Top 5 Supermarkets in each market area. 3) Retail stores where middle income consumers most frequently shop.

Table 3.1. Sirloin chop and blade steak demographics by region across the United States.

	EC[1]	MA[1]	NE[1]	PA[1]	SE[1]	SW[1]	WC[1]	National
Sirloin Chops								
Cities included	3	3	3	12	11	5	8	45
Market areas included	3	3	2	6	7	3	6	30
Stores assessed	3	3	2	19	13	9	10	59
Brands assessed	3	3	2	12	7	4	8	31
Packages Purchased[2]								
Enhanced	11	6	1	82	44	31	32	207
Non- Enhanced	10	14	5	58	12	9	16	124
Blade Steaks								
Cities included	6	5	2	11	10	3	9	46
Market areas included	5	2	2	6	6	3	6	30
Stores assessed	10	5	4	14	17	5	14	69
Brands assessed	6	5	3	10	9	5	13	35
Packages Purchased[2]								
Enhanced	38	10	6	41	75	5	28	203
Non-Enhanced	50	15	9	53	36	11	60	234

[1] EC = East Central, MA = Middle Atlantic, NE = New England, PA = Pacific, SE = Southeast, SW = Southwest, WC = West Central.
[2] Number of packages purchased for objective assessment at North Dakota State University.

Package Selection

When available, ten packages of sirloin chops and blade steaks of each representative brand and each enhancement type (Enhanced (En) and non-enhanced (Non)) were selected to represent different loins in the self-serve meat case and purchased. Due to regional differences in product availability, bone-in sirloin chops were purchased when boneless chops were unavailable. Likewise, 2.5cm thick chops and steaks were preferred; however, when unavailable, the next thickest available chops or steaks were purchased. After purchasing, sirloin chops and blade steaks were shipped overnight in coolers on reusable frozen ice packs to North Dakota State University (NDSU) for further objective pork quality analysis.

Table 3.2. Identification of market areas included in retail store sample, per region.

	Region						
	EC[1]	MA[1]	NE[1]	PA[1]	SE[1]	SW[1]	WC[1]
Market Areas	Cincinnati Cleveland Detroit Indianapolis Pittsburgh	Baltimore Buffalo New York-City Philadelphia	Boston Hartford	Los-Angeles Phoenix Portland Salt Lake-City San-Francisco Seattle	Atlanta Charlotte Jacksonville Memphis Miami Nashville Tampa	Dallas Houston San-Antonio	Chicago Denver Des Moines Milwaukee Minneapolis St. Louis

[1] EC = East Central, MA = Middle Atlantic, NE = New England, PA = Pacific, SE = Southeast, SW = Southwest, WC = West Central.

Minolta Color and pH Measurement

Upon arrival at NDSU, packages were opened and allowed to bloom for minimum of 10 min. The *Gluteus medius* muscle of sirloin chops and the *Serratus ventralis* muscle of blade steaks were used to obtain pH, objective color, and Warner-Bratzler shear force values. In the event that either of these muscles were too small for the 50 mm orifice of the Minolta Colorimeter to cover, too thin to obtain pH, or too small to obtain cores for WBSF, then any of the remaining measurements would be obtained where possible. After bloom, objective color (CIE L*, a*, and b* color space values) was measured using a Minolta Colorimeter (CR-410, 50 mm diameter orifice, 2^o observer, C light source; Minolta Company, Ramsey, New Jersey). To obtain pH measurements, a portable pH meter (HI 99163; Hanna Instruments, Italy) equipped with a glass-tipped pH probe (FC232D, Hanna Instruments, Italy) was inserted into the middle of the chop parallel to the cut surface.

Warner Bratzler Shear Force

Following collection of objective color and pH measurements, the *Gluteus medius* muscle of sirloin chops and the *Serratus ventralis* muscle of blade steaks were cut away from the remaining chop or steak. They were then vacuum sealed and frozen. Prior to cook, chops and steaks were thawed for 48 h in a cooler at 4^{o}C. Chops were cooked using a clam-style cooker (George Foreman Grill, model GRP 99, Lake Forest, IL) to an internal temperature of 65^{o}C and then removed from the cooker. Temperature was monitored from the geometric center of each chop or steak with a copper-constantan insulated wire (Neoflon PFA) and temperatures were recorded using an Omega handheld digital thermometer (model HH801B; Omega Engineering Inc, Stamford, CT). Chops and steaks were cooled for 4 h to approximately 22.2^{o}C prior to shear force assessment. Four to six 1.27 cm diameter cores were obtained from each chop or steak parallel to the muscle fibers (AMSA, 1995). Cores were sheared on a WBSF machine (G-R Electrical Manufacturing Co., Manhattan, KS) perpendicular to the muscle fibers. Maximum force for each core was recorded in kg, and analyzed as the average of the cores removed from each chop or steak. All averaged values were converted into Newtons from kg (1 kg = 9.80665002864 N).

Statistical Analysis

Data were analyzed using generalized least squares (PROC MIXED, SAS Institute, Cary, NC). Chops or steaks were the experimental unit. The model included enhancement type as a fixed effect and package within region, retailer, store, and brand as a random effect. In addition, Pearson correlations were calculated as pooled within class (region and enhancement) correlations. These were found using partial correlation from PROC GLM (SAS Institute, Cary, NC) to determine the relationship between pH, Minolta color (L*, a*, and b*), and WBSF.

Results and Discussion

Product Demographics

The number of En and Non sirloin chop and blade steak packages purchased and used for objective assessments (pH, Minolta color, and WBSF) per region are presented in Table 3.1. Overall, 207 En and 124 Non packages of sirloin chops were purchased. Regionally, differences were seen in product availability of sirloin chops. In the NE, EC, and MA regions, there was a very limited selection of sirloin chops available to consumers. On the contrary, the PA region had a much greater selection of sirloin chops available. Similarly, 203 En and 234 Non packages of blade steaks were purchased. Once again, there were regional differences in product availability of blade steaks. The EC, PA, SE, and WC had a larger selection of blade steaks available than the 3 remaining regions.

National Sirloin Chop Quality Attributes

Simple statistics of sirloin chops quality attributes are presented in Table 3.3. Overall, sirloin chops had a mean Minolta L* value of 51.92 which ranged from 43.06 to 61.64. The National Pork Board's color standards chart for subjective pork color evaluation provides a reference to Minolta L* values. A mean L* value of 51.92 would be representative of a subjective color score between 2 and 3. The color description for a color score of 2 is grayish pink and a color score of 3 is described as being reddish pink. The pork industry strives to provide consumers with pork that is at least reddish pink. Based on the current study, sirloin chops are slightly less than what is desired. The mean Minolta a* value was 19.50 which ranged from 9.44 to 27.07. Sirloin chops had a mean Minolta b* value of 9.99 which ranged from 5.38

to 14.36. Results for pH provided a mean value of 5.88 which ranged from 5.11 to 6.87. For tenderness, sirloin chops had a WBSF value of 18.71N which ranged from 7.71 to 40.11N.

Table 3.3. National representation of sirloin chop quality attributes simple statistics.

	n	Mean	Min.	Max.	SD	CV
L*[1]	918	51.92	43.06	61.64	3.22	6.20
a*[2]	918	19.50	9.44	27.07	2.74	14.06
b*[3]	918	9.99	5.38	14.36	1.66	16.56
pH	1063	5.88	5.11	6.87	0.29	4.92
WBSF[4], N	1019	18.71	7.71	40.11	5.17	27.65

[1] Lightness scale: 0 = black; 100 = white.
[2] Redness scale: negative number = green; positive number = red.
[3] Yellowness scale: negative number = blue; positive number = yellow.
[4] WBSF = Warner Bratzler shear force.

Enhanced and Non-enhanced Sirloin Chop Quality

Least squares means for En and Non sirloin chops are presented in Table 3.4. Enhanced sirloin chops had an a* value significantly greater ($P < 0.01$) than that of Non chops. Enhanced chops had a pH value significantly higher ($P < 0.01$) than Non chops which is consistent with the observed lower L* value of En chops. Moeller et al. (2010) found that as the ultimate pH of loins increased from pH 5.40 to 6.40, the proportion of consumer ratings for overall-like predicted to be ≥ 6 (on an 8 point scale with 1 being least desirable and 8 being the most) increased by approximately 3% for each 0.2 unit increment. Enhanced sirloin chops were significantly more tender ($P < 0.01$) than Non chops.

Table 3.4. Least squares means of enhanced (En) and non-enhanced (Non) sirloin chops quality attributes in a national sample.

Trait	En	Non	SEM	*P*-value
L*[1]	51.72	52.21	0.25	0.12
a*[2]	20.19	17.91	0.22	<0.01
b*[3]	9.98	9.93	0.14	0.77
pH	5.95	5.72	0.02	<0.01
WBSF[4], N	16.70	23.20	0.33	<0.01

[1] Lightness scale: 0 = black; 100 = white.
[2] Redness scale: negative number = green; positive number = red.
[3] Yellowness scale: negative number = blue; positive number = yellow.
[4] WBSF = Warner Bratzler shear force.

Sirloin Chop Quality Attributes Frequency Distribution

Frequency distribution for Minolta L* values for enhanced and non-enhanced sirloin chops are given in Figure 3.1. Enhanced chops had a mean L* value of 51.74 and 22% of chops were between the range of 50.00 and 51.99 with 32% of sirloin chops being < 50.00 and 46% being > 51.99. Non-enhanced chops had a mean L* value of 52.26 and 21% of chops were between 52.00 and 53.99 with 45% of sirloin chops being < 52.00 and only 34% being > 55.99. Frequency distribution of WBSF for En and Non sirloin chops are given in Figure 3.2. En chops had a mean WBSF value of 16.57 and 35% of these chops were in the WBSF value range of 16.00 to 19.99 followed by 49% of the chops being < 16.00 and 16% being > 19.99 N. Non chops had a mean WBSF value of 23.00 N and 32% of these chops were in the WBSF value range of 20.00 to 23.99 followed by 29% of the chops being < 20.00 and 39% being > 23.99 N. According to Moeller et al. (2010), positive consumer responses were observed for overall-like, juiciness-like, and juiciness-level of pork loin chops when WBSF values were less than 24.5 N. Furthermore, Moeller et al. (2010) reported that for every 4.9 N increase in WBSF above 24.5 N a sizeable negative consumer response was given. In the current study, we found that 95% of the En sirloin chops and 61% of the Non chops had WBSF values < 24.00 N. This suggests that if consumers perceive sirloin chop tenderness similar to that of loin chops, then consumers would be more likely to have a positive eating experience if they purchased and consumed En sirloin chops.

Sirloin Chop Quality Attributes Correlations

Correlation coefficients among quality traits of sirloin chops are presented in Table 3.5. All correlations differed significantly from zero ($P < 0.01$). A negative correlation was shown between pH and WBSF (-0.40) indicating that as pH increased, WBSF decreased. Moeller et al.

(2010) found that loin chops with a greater 24 hour pH had increased consumer responses for Juiciness, Tenderness-Like, and Tenderness-level. This helps support the current study's findings that higher pH was indicative of a lower WBSF. There was also a strong negative correlation between pH and L* (-0.44) indicating that as pH increased, L* decreased suggesting that as sirloin chop pH values increased, chops were then darker in color. With a correlation between pH and WBSF as well as between pH and L*, it is plausible to suggest that there could be a correlation between L* and WBSF. However, in this study, there was only a slight correlation between L* and WBSF (0.18).

Figure 3.1. Minolta L* frequency distribution of enhanced and non-enhanced sirloin chops.

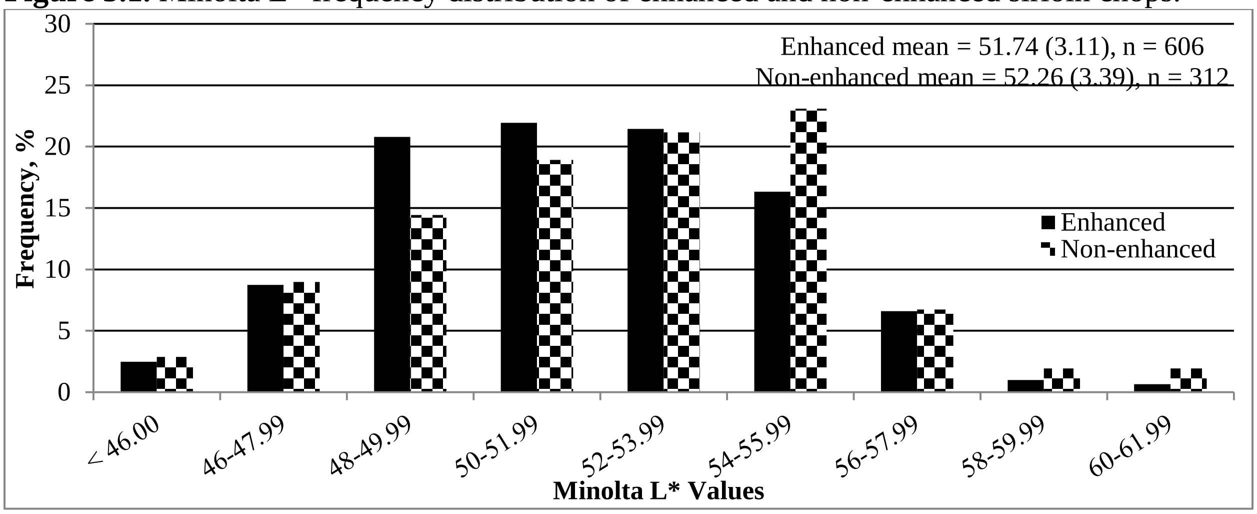


Figure 3.2. Shear force frequency distribution of enhanced and non-enhanced sirloin chops.

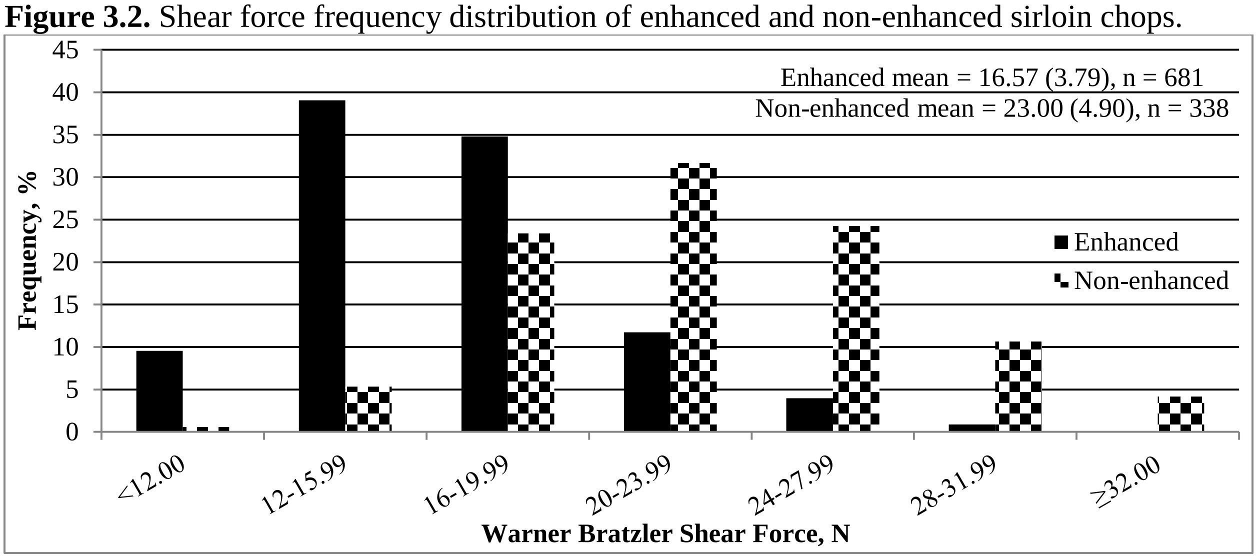


Table 3.5 Correlation coefficients among objective quality traits of sirloin chops.

	pH	L*	a*	b*	WBSF,N
pH		-0.44**	0.28**	-0.40**	-0.40**
L*[1]	-0.44**		-0.28**	0.65**	0.18**
a*[2]	0.28**	-0.28**		0.09**	-0.18**
b*[3]	-0.40**	0.65**	0.09**		0.17**
WBSF[4], N	-0.40**	0.18**	-0.18**	0.17**	

[a] Lightness scale: 0 = black; 100 = white.
[b] Redness scale: negative number = green; positive number = red.
[c] Yellowness scale: negative number = blue; positive number = yellow.
[d] WBSF = Warner Bratzler shear force
** Correlation differs from zero (*P* < 0.01).

Regional Sirloin Chop Quality Attributes

Least squares means of enhanced and non-enhanced sirloin loin chops quality attributes per region are presented in Table 3.6. Minolta L* values were significantly greater (*P* < 0.05) for Non chops than En chops in the EC and SW regions. All other regions had similar En and Non L* values. The EC, PA, SE, and WC regions each had En chops with Minolta a* values that were significantly greater (*P* < 0.05) than Non chops. All other regions had similar En and Non a* values. Minolta b* values for En chops were significantly less (*P* < 0.05) than Non chops for the EC and SW regions. The WC region had En chops with a b* value significantly greater (*P* < 0.05) than Non chops. All other regions had similar En and Non Minolta b* values. The MA region had similar En and Non pH values; all other regions had En chops with significantly greater (*P* < 0.05) pH values than Non chops. The SE region had similar En and Non WBSF values with an En WBSF of 17.88 and Non WBSF of 19.85. All other regions had En chops with significantly smaller (*P* < 0.05) WBSF values than Non chops.

National Blade Steak Quality Attributes

Simple statistics of blade steaks quality attributes are presented in Table 3.7. Overall, blade steaks had a mean Minolta L* value of 45.27 which ranged from 38.76 to 56.66. When referenced to the National Pork Board's subjective color score standard cards, blade steaks in the

Table 3.6. Least squares means per region of enhanced (En) and non-enhanced (Non) sirloin chop quality attributes.

	Region																	
	EC[1]		MA[1]		NE[1]		PA[1]		SE[1]		SW[1]		WC[1]		SEM	*P*-value		
	En	Non	En	Non	En	Non	En	Non	En	Non	En	Non	En	Non		R	E	R*E
L*[2]	50.15[a]	55.44[b]	51.36	49.91	51.54	51.28	52.42	52.12	51.29	51.87	50.42[a]	52.71[b]	52.25	52.57	3.14	0.12	0.20	<0.01
a*[3]	22.21[a]	16.74[b]	20.05	18.03	17.43	18.17	20.01[a]	18.14[b]	20.15[a]	15.52[b]	20.01	20.42	20.43[a]	17.19[b]	2.48	<0.01	0.01	<0.01
b*[4]	9.07[a]	10.94[b]	10.13	8.59	9.02	10.31	10.53	10.17	9.97	9.23	8.82[a]	11.59[b]	9.94[a]	8.65[b]	1.49	0.32	<0.01	<0.01
pH	6.21[a]	5.63[b]	5.94	5.87	5.89[a]	5.36[b]	5.83[a]	5.73[b]	6.01[a]	5.71[b]	6.22[a]	5.73[b]	5.88[a]	5.71[b]	0.21	<0.01	<0.01	<0.01
WBSF[5], N	15.30[a]	25.44[b]	14.56[a]	18.99[b]	15.60[a]	24.75[b]	16.91[a]	23.62[b]	17.88	19.85	14.74[a]	23.03[b]	16.93[a]	25.31[b]	3.39	<0.01	<0.01	<0.01

[1] EC = East Central, MA = Middle Atlantic, NE = New England, PA = Pacific, SE = Southeast, SW = Southwest, WC = West Central.
[2] Lightness scale: 0 = black; 100 = white.
[3] Redness scale: negative number = green; positive number = red.
[4] Yellowness scale: negative number = blue; positive number = yellow.
[5] WBSF = Warner Bratzler shear force.
[a-b] Least squares means with different superscripts in the same region differ ($P < 0.05$).

current study would be between a 3 and 4. A color score of 3 is described as being reddish pink and a color score of 4 is described as dark reddish pink. Therefore, based on the current study, blade steak L* mean of 45.27, the industry is providing blade steaks to consumers with the ideal subjective color. The mean Minolta a* value was 19.70 which ranged from 11.54 to 26.67. Blade steaks had a mean Minolta b* value of 8.13 which ranged from 3.79 to 12.44. Results for pH provided a mean value of 6.22 which ranged from 5.55 to 6.98. For tenderness, blade steaks had a WBSF value of 17.12 N which ranged from 7.08 to 39.86 N.

Table 3.7. National representation of blade steak quality attributes simple statistics.

	n	Mean	Min.	Max.	SD	CV
L*[1]	829	45.27	38.76	56.66	2.79	6.16
a*[2]	829	19.70	11.54	26.67	2.12	10.78
b*[3]	829	8.13	3.79	12.44	1.71	21.06
pH	850	6.22	5.55	6.98	0.27	4.30
WBSF[4], N	749	17.12	7.08	39.86	4.65	27.16

[1] Lightness scale: 0 = black; 100 = white.
[2] Redness scale: negative number = green; positive number = red.
[3] Yellowness scale: negative number = blue; positive number = yellow.
[4] WBSF = Warner Bratzler shear force.

Table 3.8. Least squares means of enhanced (En) and non-enhanced (Non) blade steak quality attributes in a national sample.

Trait	En	Non	SEM	*P*-value
L*[1]	45.46	45.23	0.20	0.39
a*[2]	20.21	18.87	0.14	<0.01
b*[3]	8.42	7.97	0.12	<0.01
pH	6.22	6.16	0.02	0.02
WBSF[4], N	16.53	18.19	0.32	<0.01

[1] Lightness scale: 0 = black; 100 = white.
[2] Redness scale: negative number = green; positive number = red.
[3] Yellowness scale: negative number = blue; positive number = yellow.
[4] WBSF = Warner Bratzler shear force.

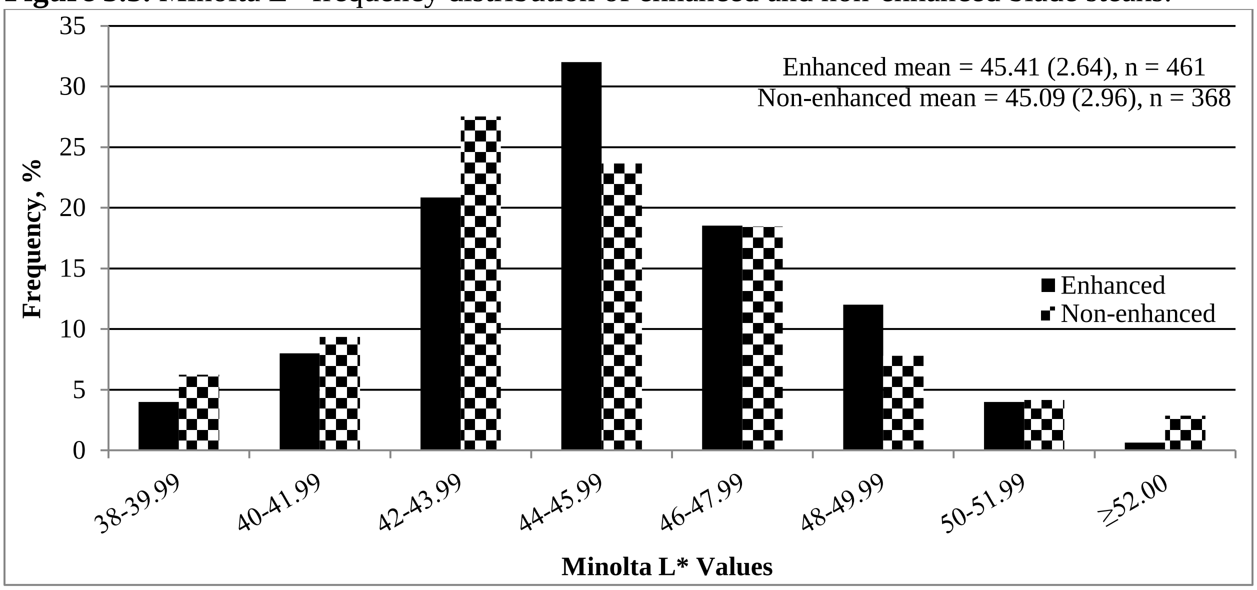
Enhanced and Non-enhanced Blade Steak Quality

Least squares means for En and Non blade steaks are presented in Table 3.8. Enhanced steaks had a*, b*, pH and WBSF values significantly greater ($P < 0.01$) than that of Non steaks.

Blade Steak Quality Attributes Frequency Distribution

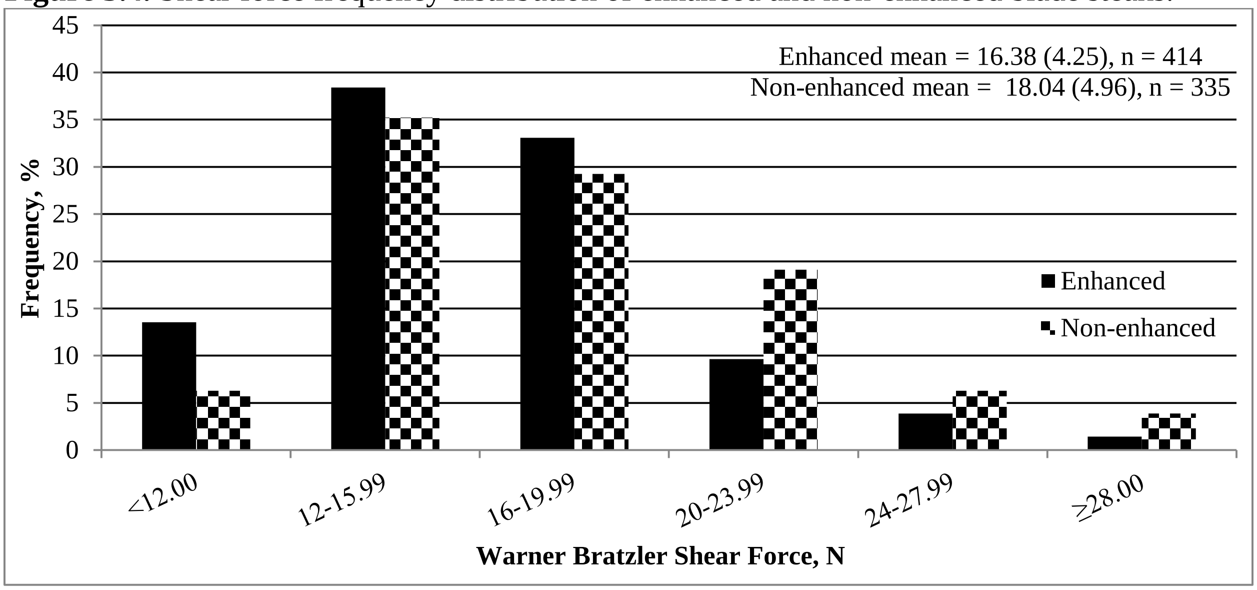
Frequency distribution for Minolta L* values for enhanced and non-enhanced blade steaks are given in Figure 3.3. Enhanced steaks had a mean L* value of 45.41 and 32% of chops were between the range of 44.00 and 45.99 with 33% of blade steaks being < 44.00 and 35% being > 45.99. Non-enhanced steaks had a mean L* value of 45.09 and 24% of chops were between 44.00 and 45.99 with 43% of blade steaks being < 44.00 and 33% being > 45.99. For En and Non steaks, 21% and 28% steaks had L* values between 42.00 and 43.99 respectively.

Figure 3.3. Minolta L* frequency distribution of enhanced and non-enhanced blade steaks.



Frequency distributions of WBSF for enhanced and non-enhanced blade steaks are given in Figure 3.4. Enhanced steaks had a mean WBSF value of 16.38 and 33% of these steaks were in the WBSF value range of 16.00 to 19.99 followed by 52% of the steaks being < 16.00 and 15% being > 19.99 N. Similarly, Non steaks had a mean WBSF value of 18.04 and 29% of these steaks were in the WBSF value range of 16.00 to 19.99 followed by 42% of the chops being < 16.00 and 29% being > 19.99 N. According to Moeller et al. (2010), positive consumer responses were observed for overall-like, juiciness-like, and juiciness-level of pork loin chops when WBSF values were less than 24.5 N. Furthermore, Moeller et al. (2010) reported that for every 4.9 N increase in WBSF above 24.5 a sizeable negative consumer response was given. In the current study, we found that 95% of the En and 90% of the Non blade steaks had WBSF values < 24.00 N. This suggests that if consumers perceive blade steak tenderness similar to that of loin chops, then a high frequency of consumers would have a positive eating experience if they purchased and consumed both En and Non blade steaks since the *Serratus ventralis* muscle which was used for all measurements of blade steaks, is the largest of all muscles in this cut.

Figure 3.4. Shear force frequency distribution of enhanced and non-enhanced blade steaks.



Blade Steak Quality Attributes Correlations

Table 3.9 shows correlation coefficients among quality traits of blade steaks. All correlations differed from zero ($P < 0.05$). A strong negative correlation between pH and WBSF (-0.56) indicated that as pH increased, WBSF decreased. Andrews et al. (2000) found that as pork loin pH increased from 5.5 to 5.8 and from 5.8 to 6.2, significantly less moisture was lost during cooking. When pH decreases too rapidly during post-mortem glycolysis, proteins in pork denature, which results in their inability to bind free water. When cooked, these products are unable to hold onto the free water and so the water is lost as exudate. In such cases, a negative consumer response is seen for juiciness, tenderness-like, and tenderness-level (Moeller et al., 2010). A strong negative correlation was shown between pH and L* (-0.51) indicating that as pH increased, L* decreased suggesting that as blade steak pH values increased, steaks were then darker in color.

Table 3.9. Correlation coefficients among quality traits of blade steaks.

	pH	L*	a*	b*	WBSF,N
pH		-0.51**	0.17**	-0.46**	-0.56**
L*[1]	-0.51**		-0.09*	0.69**	0.37**
a*[2]	0.17**	-0.09*		0.35**	-0.15**
b*[3]	-0.46**	0.69**	0.35**		0.32**
WBSF[4], N	-0.56**	0.37**	-0.15**	0.32**	

[1] Lightness scale: 0 = black; 100 = white.
[2] Redness scale: negative number = green; positive number = red.
[3] Yellowness scale: negative number = blue; positive number = yellow.
[4] WBSF = Warner Bratzler shear force
[**] Correlation differs from zero ($P < 0.01$).
[*] Correlation differs from zero ($P < 0.05$).

Regional Blade Steak Quality Attributes

Table 3.10 presents least squares means of enhanced and non-enhanced blade steaks quality attributes per region. All regions had similar En and Non Minolta L* values. The MA, NE, PA, SE, and WC regions each had En steaks with Minolta a* values that were greater ($P < 0.05$) than Non steaks. The EC and SW regions had similar En and Non Minolta a* values. Minolta b* values for En steaks were lower ($P < 0.05$) than Non steaks in the EC region. The MA, PA, and SE regions had En steaks with a b* value greater ($P < 0.05$) than Non steaks. The NE, SW, and WC regions had similar En and Non Minolta b* values. No differences were observed for pH between En and Non blade steaks in all 7 regions. In the MA, PA, and WC regions, WBSF values for En steaks were lower ($P < 0.05$) than Non steaks. The SE and SW regions had similar En and Non WBSF values even though En values were numerically smaller than Non values. Interestingly, the opposite and unpredictable trend was observed in the EC and NE regions where En steaks had numerically larger WBSF values than Non steaks. However, there was no significant difference between En and Non steaks in both regions.

Table 3.10. Least squares means per region of enhanced (En) and non-enhanced (Non) blade steak quality attributes.

	Region																	
	EC[1]		MA[1]		NE[1]		PA[1]		SE[1]		SW[1]		WC[1]		SEM	*P*-value		
	En	Non	En	Non	En	Non	En	Non	En	Non	En	Non	En	Non		R	E	R*E
L*[2]	44.69	45.85	45.34	45.62	45.37	43.49	45.37	44.71	46.61	45.36	43.51	45.01	44.55	45.49	1.20	0.97	0.16	0.04
a*[3]	18.90	18.73	21.60[a]	19.36[b]	22.28[a]	18.93[b]	20.95[a]	19.18[b]	20.26[a]	18.15[b]	20.19	19.19	20.72[a]	18.70[b]	0.82	<0.01	<0.01	0.01
b*[4]	7.72[a]	8.52[b]	9.39[a]	7.72[b]	9.56	8.28	8.94[a]	8.05[b]	8.94[a]	7.56[b]	6.58	6.82	7.41	8.00	0.69	0.02	<0.01	<0.01
pH	6.17	6.09	6.28	6.26	6.06	6.04	6.23	6.22	6.29	6.17	6.35	6.37	6.13	6.11	0.11	0.31	<0.01	0.84
WBSF[5], N	17.77	16.48	15.02[a]	19.82[b]	15.75	13.84	15.92[a]	17.84[b]	16.77	18.06	13.38	14.06	15.69[a]	19.83[b]	1.89	0.02	0.02	<0.01

[1] EC = East Central, MA = Middle Atlantic, NE = New England, PA = Pacific, SE = Southeast, SW = Southwest, WC = West Central.
[2] Lightness scale: 0 = black; 100 = white.
[3] Redness scale: negative number = green; positive number = red.
[4] Yellowness scale: negative number = blue; positive number = yellow.
[5] WBSF = Warner Bratzler shear force.
[a-b] Least squares means with different superscripts in the same region differ ($P < 0.05$).

Conclusion

In the current study investigators reported that Minolta L* color results of sirloin chops are slightly higher that what would be attributed to a subjective minimum color score of 3. However, blade steak results indicate that the industry is providing a desirable colored blade steak. Sirloin chop tenderness results indicated that 95% of En chops and 61% of Non chops were tender (WBSF $\leq$ 24.5 N) and would provide consumers with a positive eating experience based on consumer response criteria relating WBSF levels with tenderness and overall like response criteria reported by Moeller et al. (2010). Blade steak tenderness results indicate that 95% of En steaks and 90% of Non steaks were tender based on the same criteria.

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CHAPTER 4. OVERALL CONCLUSIONS AND IMPLICATIONS

Consumers are offered pork products with a considerable amount of variation within package, retail store, region, and between enhanced and non-enhanced products. Results of the presents study suggest that the pork industry's advancements in enhancement technology and approach in pork loins has resulted in pork that is more tender and darker in visual color score. However, the pork industry must explore all options available to provide consistent pork quality in both En and Non pork products.

The current study was conducted to quantify pork quality at the point of purchase, in the retail store. Quantifying pork quality attributes and their variation in retail outlets allow the development of benchmarks for existing products and targets for future improvement of pork offered to consumers. Benchmarking data offer value across the entire pork chain, offering the opportunity to identify root causes of variation in quality as well as the development of strategies to mitigate existing issues and improve the overall quality of pork offered to consumers. Long-term, benchmarking data can be used to identify approaches that will increase consumer demand for pork by positively influencing the overall pork eating experience.