VALUE OPTIMIZATION OF MUSCLES FROM THE VEAL CHUCK

By

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To my family,
For always being there for me

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Objectives were to characterize muscles from the veal chuck and evaluate the performance and usefulness of these muscles. For Phase one, IMPS 308 and IMPS 309 were purchased from two separate veal packers, all were from USDA Choice or higher veal carcasses. The chucks were dissected to obtain the following muscles: Complexus (COM), Deep Pectoral (DEP), Infraspinatus (INF), Rhomboidus (RHM), Serratus Ventralis (SEV), Splenius (SPL), Supraspinatus (SUP), Triceps Brachii (TRB) and the Teres Major (TER). Each muscle was weighed to determine percent yield. The heaviest muscle and highest percentage of chuck was the TRB. The lightest muscle and lowest percentage of chuck was the TER. Muscles were vacuum packaged individually and aged fourteen days postmortem prior to freezing. For sensory evaluation, steaks were grilled on Hamilton Beach table top grills to an internal temperature of 71°C. Samples were evaluated by a trained panel that scored overall tenderness, juiciness, flavor, connective tissue and off-flavor. The INF was the tenderest muscle evaluated. The RHM was significantly lower ($P>.05$) in tenderness from all other muscles in the study. The COM had the highest juiciness score. The SUP was found to be not significantly different ($P>.05$) from the COM. The muscle with the lowest juiciness score was the TRB. The INF and the SPL did not differ significantly ($P>.05$) from the TRB juiciness score. The SUP was found to have the most

intense beef flavor. The COM was not significantly different ($P > .05$) from the SUP. The muscle with the lowest flavor intensity score was the SPL with and was not significantly different ($P > .05$) from the INF or the SPL. The INF was found to have the least amount of detectable connective tissue present with the TER being not significantly different ($P > .05$) from the INF. The RHM had the highest connective tissue score which significantly differed ($P < .05$) from all other muscles in the study. Off-flavor scores were low for all muscles evaluated in this study. For phase two, IMPS 309 were purchased from two separate veal packers, all were from USDA choice or higher veal carcasses. Objective color scores were obtained for each carcass at the flank and tenth rib. The muscles extracted included the COM, DEP, INF, SEV, SUP, TRB. Color measurements were taken using a Minolta CR-310 Chroma meter after 15 minutes of bloom time. Muscles were randomly assigned to four aging periods to determine the effect of aging time on retail display attributes. Days of post-mortem aging had an overall effect on subjective evaluations for overall appearance ($P < .05$) with all muscles reacting similarly when placed in a retail display setting. Postmortem aging had a significant ($P < .05$) effect on each muscle for subjective color, discoloration and purge. Post-mortem aging significantly affected subjective and objective color scores, concluding longer periods of post-mortem aging caused the muscles to become lighter ($P < .05$).

This study found that the veal chuck contains muscles that will provide a useful application for dry heat cookery when muscles are separated and fabricated into steaks and that retail display integrity is affected by postmortem aging time. When the effort is made to further fabricate and process these muscle cuts, the potential for adding value to this low priced primal cut is evident.

CHAPTER 1
INTRODUCTION

In recent years veal production has been criticized by many people worldwide. With this criticism have come decreased sales and profits for many veal producers and processors. Four main reasons for this increased criticism by the public are 1) the slaughter of young animals tends to stimulate emotional responses by the public, 2) techniques used in the industry are usually objected to by some people (e.g., dietary practices and housing for the animals), 3) the veal industry in the U.S. is smaller and newer than most other animal industries, and 4) the results of research on the controversial techniques have been limited and in most cases contradictory (Lowell et al., 2004)

Approximately 800,000 calves enter the U.S. special fed-veal systems annually (AMI 1995). About 33% of male dairy calves are used for bob veal production, and about 40% for special fed veal production leaving about 25% for the other feeding systems including beef production (Lowell et al., 2004). Calves that enter the veal production system are usually male dairy calves for which dairy farmers have little use. Calves are usually separated from their mothers one to four days after birth to allow the dairy producer to harvest milk. The earlier the calf is taken from the cow, the less stressful it is to the cow (Lowell et al., 2004). Calves at this age are extremely susceptible to disease and sicknesses. As veal producers this is a major concern not only in an economical sense, but also for animal welfare reasons.

USDA (1995) defines veal as meat from immature bovine animals. This broad definition encompasses four specific types of veal:

- Bob veal – Live weight of less than 150 pounds.
- Special fed veal – fed a special milk replacement diet and marketed at a live weight of 151 to 400 pounds.

- Non special fed veal – fed a variety of diets and marketed at live weights of 151 to 400 pounds.
- Calves – live weight of more than 400 pounds; fed no special diet.

Since special fed veal calves were used in the research presented in this thesis, a more in-depth definition of this type of veal would be as follows.

Special fed veal calves (also referred to as fancy, formula fed or natural veal) are usually fed a milk-based liquid replacement diet that usually follows a pattern of decreasing the iron content of the diet over the life of the calf to help retain the lighter muscle color that is typical of special fed veal. The calves are raised for 18 to 20 weeks in which they reach a market weight of approximately 400 pounds; most special fed-veal calves are currently being raised to a market weight greater than 400 pounds (Lowell et al., 2004).

As the veal industry continues its struggles with loss of consumer interest in its product, the industry is looking for new ways to market veal to make it a more profitable commodity. Most modern marketing of veal products is done using a farm to fork approach. Convincing and proving to consumers that the animals are raised and slaughtered humanely and that the product they are buying is wholesome and of expected quality has become the most common approach to regaining the consumer's interest. To further profit from harvesting veal and utilizing carcasses, processors have become interested in increasing the value of certain muscles that are usually of lesser value. Recent studies conducted by scientists at the University of Florida in conjunction with the University of Nebraska have characterized numerous muscles from the beef chuck and round (Calkins and Sullivan, 2007). The studies conducted have revealed significant positive palatability attributes of many of these muscles. A similar characterization of muscles was performed in this study to characterize nine muscles from the veal chuck in search of ways to better utilize these muscles and add value to the veal chuck. Conclusions from previous studies

have revealed that adding value can be achieved by cutting certain muscles into steaks rather than selling them as part of a roast or grinding them into ground beef.

The objectives of the current research include 1) characterizing veal muscles by determining average sizes and weights of individual muscles from the chuck, 2) determining quality of these muscles and determining eating experiences for each of these muscles, 3) examining the effects of post-mortem aging on shelf-life stability of chuck muscles while in a retail display setting (including stability of color), and finally 4) examining the effects of aging and retail-display on variations in total pigment and heme iron content of muscles from the chuck.

CHAPTER 2
REVIEW OF LITERATURE

Determination of Sensory Attributes for Muscles from the Veal Chuck

Palatability of Meat

There are three major palatability attributes that are often characterized to classify meat and meat products. These three attributes include tenderness, juiciness and flavor. The ranking of these attributes in terms of importance to the consumer's eating experience starts with tenderness and concludes with juiciness, with flavor falling somewhere in the middle. According to Epley (1992), although juiciness and flavor normally do not vary a great deal, tenderness can vary considerably from one cut to another. Tenderness is a heritable trait with an estimate of approximately 40%, which means that 40% of variation in tenderness of cooked beef is due to genetics of the animal (Epley, 1992). Previous studies have documented a genetic basis for differences in beef tenderness and intramuscular fat content (Shackelford et al., 1994; Wulf et al. 1996b). Although these differences become extremely important in the production of beef animals, it is less of a factor in the production of veal because of the similar genetic background of calves used in veal production. Other factors that can greatly affect tenderness are feeding practices, animal disposition, handling practices as well as age of the animal. Epley (1992) concludes that veal is the least variable in tenderness due to the young age of the animal at time of harvest and the lack of natural collagen and connective tissue found in the meat.

There are many variables that constitute whether a piece of meat is classified as tender or not. These include fragmentation, sarcomere length, percent moisture and collagen content (Davis et al., 1979). There are several factors that influence tenderness after the animal is harvested. The rate of chilling and its effects on muscle fibers play the greatest role in meat tenderness postmortem. Certain practices that are currently used to improve tenderness include

electrical stimulation of carcasses, different hanging methods for carcasses as well as mechanical and chemical tenderizers that disrupt tissue integrity (Epley, 1992). Postmortem aging after the completion of rigor mortis also plays a major role in meat tenderization. Aging is a process that utilizes endogenous enzymes to enhance tenderness of meat by breaking down some of the myofibril structure (Epley, 1992). This holding of beef in a cooler, either in its whole carcass or primal state, or under vacuum packaging, usually smaller sub-primal cuts, is known as aging. Although it is often argued as to how long beef should be "aged", studies have shown that an increase in beef tenderness continues approximately seven to ten days after slaughter when held at 3 degrees C (Epley, 1992). These findings are in agreement with Smith et al. (1978) and Mitchell et al. (1991a), who found no significant improvements in tenderness after ten and seven days postmortem aging, respectively. A study conducted by Revilla et al. (2006) explored the effect of breed, sex and aging time on carcass, meat and eating quality of 32 calves of the "Ternera de Aliste" Spanish Quality Label (a Spanish Quality Label that encompasses a beef production zone located in north-western Spain where the local breed Alistano Sanabresa and Swiss Brown cross females are crossed with bulls of Limousin or Charolais breeds (BOE, 1997)). In order to study the effect of breed, calves, bulls and heifers, were slaughtered when they were six to seven months of age. Samples of the longissimus dorsi were aged for three, five and seven days and chemical and sensory analyses were conducted. Results of this study show that there were no differences due to sex, but that Charolais sires produced more tender meat that was juicier and more intense in flavor than the Limousin sired animals while also producing a muscle that was darker in color than that of the Limousin sired calves. Warner-Bratzler shear force values at three and five days of ageing, was found not to be affected by either sex or breed. Warner-Bratzler shear force values were similar to those described in other work for Limousines,

but lower than those reported for young Charolais bulls (Monson et al., 2004 and Ozluturk et al., 2004). In a subsequent study conduct by Perez et al. (2006) it was found that the parameters affecting the choice of veal meat of the "Terner de Aliste" quality appellation was lightness in color of the raw product but in their general relative preferences for samples, tenderness, juiciness and taste of the cooked meat had the greatest weight.

The sensory attribute "juiciness" has been related to the amount of moisture released from the meat and the degree of salivation induced during mastication (Lawrie, 1979; Muir et al., 1998a). This quality could have an important impact on overall palatability of steaks, even if the steaks are thought to be tough. The degree of juiciness creates lubrication during mastication that can give the presumption of a tenderer piece of meat. Epley (1992) reveals that the differences in juiciness in meat may be attributed to the amount of bound/intermediate water and concentration of intramuscular lipids. The consumer separates perceived juiciness into two classes, first impression and sustained juiciness with the major factors being water holding capacity and intramuscular lipid content. Perez et al. (2006) reported that samples with the highest juiciness scores were also those samples that had the highest overall scores in sensory evaluation. Many factors contribute to the juiciness of a steak when it is rated by a sensory panel. Moisture content, ether extractable fat or total lipid, cooking time, temperature and pH play important roles (Stelzleni, 2006). Kim and Lee (2003) concluded that marbling appears to be an important factor in sensory panel ranking of juiciness but that animals finished on grain tended to have increased marbling and ether extractable fat, but showed little difference in juiciness (Stelzleni, 2006).

Moody (1983) defines "flavor" as a result of sensations arising from taste, aroma and pressure and heat sensitive areas of the mouth. Flavor is one of the most important quality attributes of meat. Although meat flavors have attracted much attention, strong knowledge about

the flavor compounds causing strong character impacts for various species is limited (Shahidi, 1994). Mottram (1998) concluded that meat flavor and off-flavor is complex with over 1000 compounds combining to create different flavors between species and also creating off-flavors within species. Thermal reactions by various chemical compounds give meat its flavor. Raw meat has little aroma and only a blood-like taste, leading Mottram (1998) to conclude that the compounds are reactive to cooking/heating of the product. Macleod (1998) breaks down taste compounds into three categories 1) Sweetness which is primarily made up of sugars and L-amino acids, 2) Sourness which is made up of amino acids combined with succinic, lactic and carboxylic acids, 3) Saltiness which is due mainly to inorganic salts. Not only these factors influence the flavor of cooked meat, there are also compounds formed during cooking that determine the aroma attributes that directly influence the characteristic flavor of meat (Mottram, 1998). Macleod (1998) found that to release these aromas, meat undergoes three primary reactions during cooking 1) lipid oxidation and thermal degradation, 2) thermal degradation of proteins amino acids, sugars and peptides and 3) Thermal degradation of thiamine which in turn creates the desired smell and aromas.

In a study by Revilla et al. (2006), it was reported that aging time of veal muscles created more intense flavors and odors which was attributed to the nitrogen containing compounds that may have been formed by the natural degradation that occurs during ageing in which Maga (1976) reports to have a variety of meat flavors.

Defining Color Composition of Meat

Although tenderness, taste and juiciness of meat are extremely important, these parameters are usually measured at consumption of the meat. Color becomes very important when a consumer is making the decision to purchase the product. Color of the meat is often the basis for product selection or rejection by the consumer (Aporta et al., 1996). In industry today,

color of veal meat is also important to producers and processors, because it contributes to the carcass price (Denoyelle et al., 1999). The goal of recent research in color composition has been to measure the meat color on-line and develop a relationship between instrumental color assessment and visual color assessment to predict color score. In a study conducted by Denoyelle et al. (1998), 2300 veal calves were used to standardize instrument color grading with visual color scoring. Meat color was assessed subjectively by three trained judges and objectively by two chromometers CR300 and CR310 at 45 minutes post mortem and prediction equations were derived. The data concluded that these meters could be used in on-line objectivity to correctly classify up to 87% of carcasses. The reason this is important is to reduce man hours in a large scale harvest facility and to also standardize color measurements that are more precise and provide less variability.

Color assessment by consumers is much more unscientific and relies more on preference and environmental conditions. Consumers usually see muscle color in pinks and reds whereas scientific evidence reveals that meats can range from white to dark cherry red. There is an infinite amount of colors and combinations of colors that makes it difficult to describe meat color and meat color changes. Not only are the consumers concerned with the actual color but also discoloration of the muscle. When discoloration occurs, products become tan, brown, gray, green or yellow, and consumers are less likely to buy these products. Two popular methods in scientific research to asses these colors and changes in colors are the use of visual panels and the use of instrumental technology such as the colorimeter and the spectrophotometer. Each method can be used separately or together to express color changes in meat products (AMSA, 2003).

Visual panel

Visual panels have become useful in determining acceptability of meat products. A visual panel is used to simulate consumer evaluation of meat that occurs in a retail setting as well as

benchmarking for instrumental grading. Visual panels assess consumers' likes and dislikes, but are difficult to conduct due to unrepeatable measurements day to day. Inconsistencies have been attributed to personal preferences, environmental differences such as lighting, visual impairments, and product presentation methods.

Visual panel designs can vary in numerous ways from the number of panelists, to the scale that is used to determine sensory values and the meaning of those scores. Many studies use a scoring system where the averaging of perceived color over the entire cut is used, while others break down each section of the product and scores for each of these sections are used. Yet some use a worst point system where the single score is used to describe a 2 cm diameter section of the product. Combinations of all scoring methods may also be used to better determine differences in meat color or discoloration. Sanders et al. (1997), and Stubbs et al. (1999) used a design where the product was evaluated twice daily by a 3-5 member panel for lean color (8=bright cherry red, 1=dark brown or green), fat color (8=creamy white, 1=dark brown or green), surface discoloration (7=no discoloration, 4 = 26-50% discoloration, 1=highly discolored) and overall appearance (8=highly desirable, 1= highly undesirable). A study by Roeber et al. (2001) had a slight variation in design when they used an eight point scale for muscle color, overall appearance and surface discoloration but did not measure fat color.

Not only do differences exist in scoring and evaluation of meat products but researchers may also use different types of panelists. Generally there are three types of panelist used in evaluation studies, they include trained, semi-trained and untrained. Trained sensory panelists are trained to use their skills to describe their sensory experiences using words they generate in previous training sessions. These words are more detailed than those used by consumers, and more useful for research and development departments. Trained sensory panels are usually

comprised of less people due to more repeatability between members. Most trained panels use 3 to 10 members for evaluation. Semi-trained sensory panels are usually comprised of 8 to 25 members and the members are given some instruction on evaluating the product. Untrained panels usually consist of more than 80 people who are given no instruction or guidance about evaluating the product. These untrained panels are usually used to determine consumer taste and preference without any type of distraction or encouragement. The reason behind using more people for the less trained panel is to decrease the effects of extreme differences in tastes and preferences as well as effects of non repeatability within a particular panelist. A study conducted in 2002 by O'Sullivan et al. used pork patties formed from two different muscles to study the differences between trained and untrained panelists. Results show that the distributions for trained panel scores were normally distributed for both types of patties. For the untrained panelists, the scores were skewed for the patties consisting of the Longissimus dorsi muscle but were normal for the Psoas major. The whiter meat of the Longissimus dorsi muscle was better evaluated by the trained group, while the untrained panelist were better at distinguishing between the Psoas major patties because the meat is redder (contains more myoglobin). Researchers concluded that the reason the untrained group of panelists had better results with the Psoas major patties was because they were more familiar with the color of this type of product whereas the trained group had better results with the Longissimus dorsi patties because they were better trained to evaluate this product and had a reference product to compare it with. With the conclusion of this study, O'Sullivan revealed that when familiar products are being evaluated, untrained panels can be used. But when unfamiliar products are being evaluated that trained panelists and reference samples should be utilized.

When visual panels are being conducted it is very important that all samples are handled in exactly the same manner to prevent alterations, which is extremely important when studying treatment effects on meat color (Gonzalez, 2005). These steps must also be repeatable by the researcher and reproducible by other researchers. To ensure a representative sample is obtained and that some factors are standardized, The American Meat Science Association (AMSA) has identified some factors that are very important. Of those factors the most important include: animal nutrition, carcass chill rate, location of muscle sample, fiber orientation, muscle pH, time and temperature of postmortem storage, exposure to oxygen, packaging and display conditions. Along with these factors, AMSA also identified 15 visual appraisal guidelines to follow when conducting a sensory evaluation. Of the 15, the most important include: simulation of the environment in which consumers make their decision (lighting, retail case, temperature), use of samples 12 to 15 mm thick, over wrap material that is most common type of film used, rotate packages in the case from front to back as well as side to side, and standardize the temperature and lighting used (AMSA, 2003). These factors, plus many more, allow researchers to conduct sensory analysis in ways that are comparable to other studies so comparisons between studies are possible.

Instrumental color technologies

As stated earlier, the color of meat is often the main basis for product selection. Consumers expect their beef to be red, pork to be pink and chicken to be white, so numerous research projects have focused on meat colors and why they are different, both within and between species. To make measurements and research projects more repeatable, many researchers have used some type of instrumental color technology to measure actual color. Instrumental color measurements can be expressed in many forms. In 1905 an American artist, A. H. Munsell, expressed color using hue (Munsell Hue), lightness (Munsell Value), and saturation (Munsell

Chroma). These measurements were taken using paper color chips for comparison with an observed color (Gonzalez, 2005). Later this system would be devised into the Munsell Renotation System, which expressed color as a letter combination in terms of hue, value and chroma. The Commission Internationale de l'Eclairage (CIE) has developed other numerical color expression equations that deal with light and color and has been responsible for developing the Yxy color space (1931) and the L*a*b* color space (1976). These methods of color expression use a notation to define a light source or object color, and such numbers are widely used throughout the world (Minolta, 1998).

The color parameters discussed above are obtained through reflectance measurements. In most cases, these measurements closely mirror what the eye and the brain see, and are the most popular for fresh meat color evaluation. The instruments used are useful in estimating deoxymyoglobin, oxymyoglobin, and metmyoglobin. These instruments are useful because numerous individual measurements can be repeated without destroying the product. The tool of choice when taking reflectance measurements is the colorimeter. According to Minolta, manufacturer of colorimeters, white light, from a source being shone on a sample, being reflected at a 45 degree angle, is measured by a photocell after it penetrates an X, Y or Z filter (How does a colorimeter work?, 2003). Once passed through the filter, the energy output of the light source creates a response by the photocell similar to what is seen by the human eye (AMSA, 2003). Most readings are taken in the L*a*b* color space developed by the CIE. The major advantage of using a colorimeter is that it is able to detect minute color differences and express those differences numerically, allowing for easier interpretation of the data (Minolta, 1998).

Researchers also use spectrophotometers to quantify color of meat. This method uses pigment extraction for quantification of myoglobin and hemoglobin. These extraction techniques tend to better separate color differences than reflectance measures but ultimately destroy the sample product. Extraction techniques also tend to over estimate oxymyoglobin and metmyoglobin, and under estimate deoxymyoglobin while destroying the representative sample which makes repeatability impossible (AMSA, 2003). According to Minolta, also manufacturer of spectrophotometers, the measurement of color is taken by illumination of the sample with white light and the amount of light that the sample reflects back at each wavelength interval is used to calculate a color value (How does a reflectance spectrophotometer work?, 2003). Using multiple sensors to measure the spectral reflectance of the observed object at each wavelength or in a narrow range, the microcomputer in the instrument calculates values similar to those of the colorimeter by performing integrations. Unlike the colorimeter, the spectrophotometer can describe color numerically and provide higher accuracy due to its high precision sensor and inclusion of data for a variety of illuminant conditions (Minolta, 1998). Both techniques are widely used depending on availability of samples and types of measurements needed, but the problem comes in the interpretation and reporting of the color measurements.

Researchers have numerous ways of interpreting the data collected by the two previously discussed color devices. After a method of instrumental color evaluation is decided, the system in which to use to report the collected data must be determined. A system that is sometimes used in meat color evaluation is the Munsell Color solid shown in Figure 2-1 (HunterLab, 1983). This method reports the data collected as a point within a three dimensional space that describes the color in terms of hue (H), value (V) and chroma (C). H values are expressed in the three dimensional color solid as red, yellow, green, blue, and purple which are equally spaced in a

circle around the base of the color solid. On a vertical axis, V measurements are spaced out from zero, which represents absolute black, to ten, representing absolute white. The C values describe the color intensity when compared to a neutral gray of the same value. Due to the fact that most instruments do not directly measure color in Munsell Color Solid values, it is not the most popular color reporting system (AMSA, 2003).

Another system available to report color values is the XYZ primary system of the CIE's Color Solid System. This system is based on the theory that colors can be matched by mixing the light primary colors of green, red, and blue which is graphically shown in Figure 2-2 (Frances & Clydsdale, 1975). In some cases, some of the colors can be matched with the subtraction of red light (Gonzalez, 2005). In order to resolve such problems, the CIE developed the XYZ system that allows researchers to describe colors without the use of negative numbers. In Figure 2-2, the relationship between the XYZ triangle and the tristimulus primary RGB system is presented. The shaded area along the B-G axis represents negative values of red needed to match certain colors. In the larger XYZ triangle, all positive values can be used to match all colors. The second part of this system is the consideration of lightness when matching a color. The lightness of a sample is calculated by summing the luminosity of the matching green, red and blue colors. Because the human eye is more sensitive to green light than the other primary colors, the CIE horseshoe shaped spectrum as presented by Francis and Clydesdale (1975) is used when calculating lightness with Y% corresponding to the lightness value (Figure 2-3). The CIE XYZ system can also be calculated using spectrophotometers equipped with a reflectance attachment. The problem with this type of system is that time consuming calculations must be made to make adjustments to the data and therefore this system is not widely used in industry, but is popular in research applications (AMSA, 2003).

The most common method of color evaluation used in research today is Tristimulus Colorimetry, which uses filters to simulate the human eye. Once the data is received by the reflectance colorimeter, it can be expressed by a series of systems including: XYZ tristimulus values, Yxy color space, L*a*b* color space, L*C*h color space and Hunter Lab color space. The XYZ tristimulus values are similar to Yxy color space and are used as the foundation for the present CIE color space (Gonzalez, 2005). Even though XYZ tristimulus values were useful in defining color, they were not easily visualized. In 1931 the Yxy color space was developed by the CIE by using color-matching functions of $x(\lambda)$, $y(\lambda)$ and $z(\lambda)$, shown in Figure 2-5, to determine XYZ values and determining the chromaticity coordinates corresponding to the Yxy values (Minolta, 1998). The Y value is the indicator of lightness with x and y coordinates indicating achromatic colors toward the center, and chromaticity increasing toward the edges (Figure 2-4). When measurements are taken with a colorimeter, the x and y values can be used as coordinates to plot a point on the chromaticity diagram and the Y value indicates the percentage of reflectance ranging from 0-100% (Minolta, 1998).

The L*a*b* color space is the most popular form of measuring color in all fields of research and is very popular when measuring color in fresh meat. The L*a*b* color space is a uniform color space that was developed to remedy the problems with the Yxy color space which was that the equal distances on the x y chromaticity chart does not correspond with the equal differences perceived by the eye. Figure 2-6 is a three dimensional representation of the L*a*b* color space where L* indicates lightness and a* and b* values are the chromaticity coordinates (Minolta, 1998). To better understand this system, Figure 2-7 shows the a* and b* chromaticity values (HunterLab, 1983). The a* values become more positive as color becomes more red and as the value becomes negative, the color becomes more green. A similar relationship exists for

the b* value, except as the value becomes more positive, the color is more yellow and as it becomes negative, the color becomes more blue. At the center of the diagram, the achromatic colors are indicated and as the values move away from the center, the saturation of a given color becomes greater. Positive L* values indicate the color is becoming lighter or more white, while negative values indicate the color is becoming darker or approaching absolute black. It is the systems simplicity that has made it the most commonly used color space available to researchers (Minolta, 1998).

A similar system that is still in use today is the Hunter Color Solid system. Shown in Figure 2-7, this system is very similar in type to the L*a*b* system in that positive a values are red and negative a values are green and the positive b values are yellow and negative b values are blue (HunterLab, 1983). The difference in the two systems lies in the lightness measurement, where in the Hunter Color Solid, L values range from 0-100 where 100 is lighter or absolute white and 0 is darker or absolute black. The Hunter Color Solid system does not use positive and negative values to determine lightness measurements. Just like the CIE L*a*b* system, the Hunter Color Solid system has a major advantage over the Yxy system in that it is more uniform in its measurements (AMSA, 2003).

The final color system available to researchers is the L*C*h color space. This system is also similar to the L*a*b* system but instead of using rectangular coordinates, the L*C*h system uses cylindrical coordinates. In the color space, shown in Figure 2-8, L* indicates lightness, C* indicates chroma, and h indicates hue angle (Minolta, 1998). As shown in Figure 2-8, values for chroma are 0 at the center and increases as points move away from the center. Hue angle is determined by starting at the +a* axis and is expressed in degrees moved from this point on the

figure with +a* being 0° (red), +b* being 90° (yellow), -a* being 180° (green) and –b* being 270° (blue) (Minolta, 1998).

Problems with color measurements exist in all applications of the process. Especially in sample preparation for meats, many factors can affect the end results. It is critical that guidelines from the AMSA are followed to ensure a representative sample of the actual color. The ability to measure each color parameter separate is crucial and proper sample preparation is mandatory. Samples should be thick enough to be opaque (12-15 mm), backings should be white, orientation of muscle fibers should be considered, and type of film used as over-wrap should be standardized as well as preventing frost from accumulating on the sample. When preparing the instrument for measurement, researchers must consider: aperture size and the area of illumination that is being scanned, the number of scans that must be taken to ensure representative color evaluation as well as minimizing pressure being applied to the sample. When taking measurements on lower temperature products, the accumulation of fog on the instrument is possible, so researchers must assure that this does not occur during repeated measurements. If all guidelines set by AMSA are followed, a representative sample can be obtained via instrumental technologies (AMSA, 2003).

Defining and Measuring Tenderness

The two prevalent ways of measuring tenderness of meat products is trained sensory panel and Warner Bratzler shear force Analysis.

Trained Sensory Panel

Trained sensory panels are used when considering sensory characteristics of cooked meat products. Such attributes as flavor and juiciness are difficult to measure by other means other than subjective human evaluation. Panels are used to predict what the population might judge the quality of the product to be. More popular than single person evaluations, sensory panels must be conducted in such a manor as to create conditions to get independent responses from each

individual evaluator. Kramer and Twigg (1970) identified five different types of taste panels available for use by a researcher.

The first is a Consumer Preference panel, which is used to differentiate products by personal preferences or reaction between samples. In order to achieve a reliable conclusion using a Consumer Preference panel, 100 to 1000 panelists must participate in the evaluation of the product. As discussed earlier, the more trained a panel becomes, the less participants are needed. For Consumer Preference panels, two to three samples are served per participant and the participant is asked to select the best sample or indicate if a sample is acceptable or unacceptable.

The second type of panel is a Detection of a Difference panel. This panel uses fewer participants that are highly trained. The panelists serve as laboratory instruments to detect differences between samples and usually consist of a three to five member panel. The participants are asked to identify differences among samples or rank and score samples when given some type of parameters or instruction on how to differentiate the samples.

The third type of panel is Difference Preference. This type of panel is used for product research when many samples must be compared. The Difference Preference panel consists of eight to twenty participants that have some experience in sensory evaluation, and are used to provide an estimate of consumer response to certain products.

The fourth type of panel is The Selection by Best Sample or Process panel. It is used to compare one product to those of similar products. The Selection by Best Sample or Process panel is similar in size to the Difference Preference panel, but samples are ranked in terms of acceptability or preference or the intensity in which each product differs from the set product.

The final type of panel is a Determination of Grade or Quality Level panel. Being one of the most difficult panels to conduct, this type of panel uses panelists that are trained in evaluation of samples in terms of quality or grade standards. Not only does this type of panel compare samples, but it also compares where samples stand in reference to a certain standard or grade. Although there are more than five types of panels, these five discussed are the most common types of used. Many combinations of these panels as well as different types of panels exist, therefore, in order obtain the desired information during a sensory panel, it is important to adapt these base panel types to the research in progress (Kramer and Twigg, 1970).

In an effort to further evaluate meat products the AMSA (1995) has produced four sensory evaluation techniques that are similar to those of Kramer and Twigg (1970). These methods include a Ranking system, Scaling system, Magnitude estimation and Descriptive Sensory Analysis. The Ranking system involves the arrangement of samples by intensity or degree for a selected attribute. The Scaling system can be collected using graphic or line scales, verbal scales or numerical scales that describe the intensity of certain attributes. Verbal scales involve written statements that describe a dimension with appropriate modifiers that are written out in an order. Numerical scales are series of numbers that represent, from low to high, which represent a certain degree of an attribute. The Magnitude estimation method involves the assignment of numbers to establish the relationship of one sample to another reference sample. The final method, Descriptive Sensory Analysis is used to describe quantitative and qualitative properties and is divided into four methods.

The four methods used in Descriptive Sensory Analysis include Flavor Profiling, Texture Profiling, Qualitative Descriptive Analysis and Spectrum method. Flavor Profiling characterizes various aromas, flavors and after-tastes. Most of these flavor profiles involve a four to six

member panel and results are discussed among the panel to arrive at a general consensus on the flavor of the product. Texture Profiling is similar to flavor profiling in that the texture is determined by a number of different texture attributes. The Mechanical characteristics relate to how the sample reacts to stress, such as chewing. Geometrical characteristics involve the size and shape of the sample before and during breakdown and finally, fat and moisture are determined through mouth feel during break down. This is usually the lubrication effect that occurs during the chewing process. The third method referred to as Qualitative Descriptive Analysis has been used to provide a stronger statistical treatment of data. This process allows data to be reported as a "spider web" where each attribute is represented by a strand. And finally, the Spectrum method is used to provide detailed information on the intensity of aroma, flavor and texture using a universal scale (AMSA, 1995).

As mentioned earlier, it is important to adapt the type of panel needed to the type of information needed. The first step is to determine if a sample is only to be identified or if products should be scored on a predetermined scale. Attribute results provide no information on the differences between the samples when a significant difference is found. Attribute tests do however appear to be successful when measuring homogeneity of the products. For example, it would not be feasible to score each attribute of each sample if the purpose of the study is to only pick one sample over another or determine if a sample is acceptable or not. Actual values are not necessary for this type of research and an attribute test is probably sufficient to answer the questions. Kramer and Twigg (1970) suggest that an advantage of a scored test is that the power of the test, over an attribute test, increases as the number of samples evaluated increases.

Selection of panel participants is also important for researchers to assure that proper evaluation of the product is obtained. AMSA (1995) sets forth guidelines for panel participant

recruitment, interviews and selection process. In order for sensory panel evaluation studies to be effective, following the panel selection process and training methods is key. The success or failure of sensory panel depends on the criteria and procedures followed when selecting and training a panel (Meilgaard et al. 1987). The project objectives determine the criteria and procedures followed in selection of the panel. In a laboratory setting, selection procedures are different from consumer panel selection procedures. Figure 2-9 presents a step by step process in which panel members are selected (AMSA, 1995). Step 1 involves the recruitment and personal interview of participants. This recruitment process is usually conducted via advertisements, posted announcements or verbal contact of potential members. Personal interviews of these applicants are then utilized to eliminate unqualified candidates, identify candidates personal interests, availability, dependability, health, sex age, smoking status and food likes and dislikes. These interviews are helpful in deciding which candidates have the most potential of becoming a panel member. AMSA (1995) proposes these interviews be used as a basis for disqualification of a candidate who is either not interested or available as well as classifying candidates as potential participants. Step 2 (Figure 2-9) of the process is screening of a potential panel participant. The purpose of screening individuals is to select candidates with: normal sensory acuity, interest in sensory evaluation, ability to discriminate and reproduce results and show appropriate behavior such as cooperation, motivation and promptness. After each candidate is tested and interviewed, a decision to accept, reject or continue testing must be reached.

After individuals have been selected for panel participation, the panelists must be trained (Figure 2-9, Step 3). AMSA (1995) identifies objectives to be reached in the training process. First is to familiarize each individual with the test procedures, next is to improve an individuals

ability to identify sensory attributes, and finally, memory to allow consistent and accurate evaluation. Training sessions are conducted on an individual or group basis. In these sessions, various samples are presented to the evaluator to allow the evaluator to detect differences. After each evaluation session, results are discussed and panelists are calibrated to identify certain attributes. Each attribute should be discussed in detail and different levels of these attributes should be presented in subsequent training sessions. The goal of these training sessions is to stress the importance of concentration and accuracy but should be performed in a manner that will not influence future decisions made by the panelist (AMSA, 1995).

The fourth step (Figure 2-9, Step 4) in panel selection is Performance Evaluation. This step of the process should be carried out during training and during the study. The Performance Evaluation allows the researcher to identify problems among individual panelists and allow for further training of these individuals. This evaluation also allows the researcher to determine if the individual in question was correctly selected for the study. These Performance Evaluations cover a four day period with three sessions per day and three samples per session and cover the full range of attributes being tested (Gonzalez, 2005). Records of each individual's performance should be kept and reviewed frequently. A member who constantly fails the evaluations or has sub-par performance should not be included in the study to achieve a predetermined panel size (AMSA, 1995).

Trained sensory evaluation of products is a great way to determine many attributes of a sample. Human determination of tenderness, juiciness, flavor, amount of connective tissue, and off-flavors helps researchers in obtaining information that is not attainable by machine technology. Although sensory evaluation is sometimes down graded due to effects of human error and non-repeatability, it is the only way to obtain the degree of some attributes such as

flavor. Although trained sensory panelist provides some insight to acceptability of meat products, many argue that a mechanical component must be implemented to determine a true value for such attributes as tenderness.

Warner Bratzler Shear Force

A majority of consumers in other studies (Huffman et al., 1996) indicated that tenderness is the single most important palatability trait for determining overall steak acceptance. Warner-Bratzler shear force (WBSF) is routinely used by scientists as an objective measurement of meat tenderness and, despite criticism, has remained the most popular and accurate instrumental measurement of meat tenderness (Wheeler et al., 1997). Otremba et al. (1999) and Wheeler et al. (1996) reported WBSF value correlations (r) of −0.68 and −0.85, respectively, with trained panelist overall tenderness ratings for longissimus steaks. Shackelford et al. (1994) reported that a single variable regression equation using WBSF values explained 73% of the variation in trained panelist overall tenderness ratings for longissimus muscle steaks. Because tenderness is an important driver of overall steak acceptability and WBSF is used as an objective measure of tenderness, it is reasonable to assume that WBSF values could be used to predict overall acceptability of steaks (Platter et al., 2003).

Warner Bratzler shear force machines are used to objectively measure tenderness by measuring the maximum amount of force needed to shear through a given meat core. The machine is composed of a blade with a triangular hole that is used to hold the sample. Once the core is obtained it is placed on the blade of the machine and is pulled through two stationary bars. A dynamometer is used to measure the force required to shear through the sample core. The greater the force needed to shear through the sample core, the tougher the muscle fibers are in that sample core. According to Vargas et al. (1999) meat core samples with WBSF values less than 3.85 kilograms are considered to be very tender.

When conducting research that consists of obtaining Warner Bratzler shear force measurements, many factors play a role in getting accurate and repeatable measurements. Factors such as cooking method, cooling method, storage temperature, and coring procedure can have effects on WBSF values. A study by Wheeler et al. (1999) concluded that endpoint cooking temperature of steaks has an effect on WBSF values. In the study, shear force measurements were taken on Longissimus thoracis steaks cooked to endpoint internal temperatures of 60, 70, or 80°C. Steaks that were cooked to 70°C were used to create five different tenderness classes in order to test the effect of tenderness classification and end point temperature on shear force values. Data showed that steaks in the most tender class had increased shear values of 1.31 kg when they were cooked to 80°C instead of 60°C. Also the steaks in the least tender class had elevated shear force values by 3.38 kg when cooked to 80°C rather than 60°C. The conclusion of the study was that endpoint temperature and tenderness class interaction resulted in greater shear force value. It was also concluded that higher endpoint cooking temperatures had a greater impact on less tender longissimus than more tender longissimus steaks.

The cooking of meat results in changes in tenderness due to alterations in connective tissue and myofibrillar proteins. In a study conducted to evaluate the effect of collagen content, the major component of muscle connective tissue; fourteen different raw muscles from Swiss Brown bull carcasses were measured physically for shear force and chemically for collagen content. In the study, Torrescano et al. (2003) used correlation analysis that indicated there is a high positive correlation ($r = .723$; $p < .01$) between total collagen content and WBSF values for raw meat samples. Using this information, it is possible to conclude that higher collagen contents result in tougher meat. During the cooking process, collagen is solubilized by heat, which results in tenderization. The heat also denatures myofibrillar proteins that cause meat to become tougher.

The changes to connective tissue and myofibrillar proteins during the cooking process are time and temperature dependent. In a study that sought to determine the effects of cooking method on measured shear force values, researchers studied the effect of reheating, holding time and holding temperature on WBSF values. The conclusions made by Obuz et al. (2003) showed that the optimal reduction in peak shear force values (4.71 kg to 3.57 kg) can be obtained by cooking steaks to 54°C on a belt grill, holding the samples at 57°C in a water bath for 15 minutes, and reheating the sample to 70°C. The study showed a decrease in connective tissue shear force of 37% and a 12% reduction in myofibril shear force. Therefore selecting the proper protocol can increase tenderness, and selecting the proper protocol for a specific muscle can add value and reduce tenderness variation (Obuz et al., 2003).

Cooking, reheating and holding are not the only factors that can affect shear force values; storage conditions are also known to effect shear force values. In a study conducted by Shanks et al. (2002) a comparison was conducted of steaks that were measured for shear force on the exact day that the aging period ended to steaks that were frozen for two months after the aging period ended. The results concluded that frozen steaks had lower shear force values than fresh steaks for steaks that were aged for 1, 2, 3, 4, 6, 7, 10, 14, or 35 days postmortem. It was hypothesized that this increase in tenderness occurred due to the formation of intracellular ice in the muscle. Correlation analysis indicated that frozen steak's shear force values were not indicative of fresh steak's shear force value at the same period of aging. The data also indicated that shear force values of frozen steaks at short aging periods are useful in predicting the shear force values of fresh steaks aged at a longer time period (Shanks et al., 2002).

Sample core extraction can also have an effect on shear force values. Core samples are usually taken perpendicular or parallel to the muscle fiber direction. A study conducted by

Otremba et al. (1999) concentrated on comparing Warner-Bratzler Shear force values with panel evaluation scores by using a descriptive texture profile sensory panel and a descriptive attribute sensory panel. The objective of the study was to evaluate how shear force values, descriptive texture profile sensory panel and descriptive attribute sensory panel were affected by muscle fiber orientation and the type of blade used for the Warner Bratzler shear force analysis. The correlation coefficient between firmness score and shear force values using the flat blade was .56 ($P < .05$) when the samples were taken parallel to the muscle fibers and evaluated by the descriptive texture profile sensory panel. Correlations were also detected between shear force scores and myofibrillar tenderness, connective tissue amount, and over all tenderness scores when samples were taken parallel to the muscle fiber and sheared with the flat blade. Similar correlations were also found in the same categories when samples were evaluated by the descriptive attribute sensory panel and cores were taken perpendicular to the steak surface and sheared with the V blade. Conclusions of the study resulted in suggestions that will help to correlate sensory panel evaluations with WBSF values. Otremba et al. (1999) suggested that when the meat cores are taken perpendicular to the muscle fiber orientation, the V-blade should be used and that when cores are taken parallel to the muscle fibers, the flat blade should be used. It was also suggested that descriptive attribute sensory panel should be used to evaluate cores removed parallel to the muscle fibers and that descriptive sensory panel will most likely be correlated closer with shear force values than those evaluated by the descriptive texture profile sensory panel, regardless of muscle fiber orientation. It is also suggested that in order to obtain correlated data, selection of the appropriate sensory panel is important (Gonzalez, 2005).

As demonstrated in the previous studies discussed, there are many different protocols that may be used to obtain Warner-Bratzler shear force data. In an effort to evaluate different

protocols used by different institutions a study conducted by Wheeler et al. (1997) used four different institutions who used their own WBSF protocol, and also used a standard protocol provided to them for the study. The different protocols for each institution had some effect on shear force values. Differences in protocol included cooking method, blade thickness and angle, cutting edge, shape and size of cores, coring method and number of times each individual core was sheared. The differences in these protocols resulted in significant differences between institutions. For example, lower endpoint temperatures were used by some institutions which resulted in lower shear force values. When the standardized protocol was used, means, standard deviations, and maximum shear force values were slightly higher for all institutions. Also, differences in mean shear force values among institutions were smaller than when they utilized their own protocol. Researchers also identified differences due to instrumental variations. Older Shear force machines are some times less likely to yield the correct shear force value due to spring tension differences than those in newer machines. Wheeler et al. (1997) suggested that it is possible for different institutions to have the same mean shear values if protocol is standardized and properly calibrated machines are used.

Total Pigment and Heme Iron

As mentioned earlier, most consumers' first impression of meat quality is color. In most cases, consumers prefer red beef, pink pork and white veal. In the veal industry, producers and processors realize a slight premium for producing white veal products. In an effort to capture this premium, production methods of veal have changed in an effort to produce more of the white product. However, animal welfare activists have criticized these production practices that are used to produce such products due to housing methods used and feeding of milk replacers with sub-optimal iron levels. Van Puttens (1982) has shown that these conditions have shown abnormal behavior patterns in animals and was not conducive to the welfare of the animal.

Pigment content of veal has been well documented to be correlated closely with muscle color. Blood hemoglobin concentration of calves is related to the muscle myoglobin content and hence correlates to veal color score at carcass classification. Studies have shown that carcass color of veal in general is not related to postmortem pH and temperature, but associated more with the blood haemoglobin content. In a study by Klont et al. (2000) it was shown that haemoglobin content of the blood was closely related to the visually assessed carcass color at 45 minutes post mortem and it was also related to the instrumentally determined L* value with significant correlation coefficients of .61 and -.61 respectively. Most recent studies have correlated ante mortem haemoglobin content with color scores of certain muscles and have been successful in proving the relationship.

Methods of changing veal quality and color have been explored in various European countries through electrical stimulation. In a study conducted by Eikelenboom (1989), a total of eighty-eight veal calves were raised in groups with access to straw, which is thought to decrease veal quality, to determine if electrical stimulation has an effect on meat quality. One week ante mortem, hemoglobin levels were obtained and animals with similar hemoglobin levels were paired. At slaughter, one animal of each pair was stimulated electrically whereas the other remained non-stimulated. In the study, electrical stimulation resulted in brighter color, lower sarcomere length and lower protein solubility, but no significant difference in total heme pigments were observed for the longissimus muscle at 24 hours post mortem. After six days of aging under vacuum at 3°C, samples from electrically stimulated carcasses showed brighter color, higher drip and cooking loss and lower shear force values, as well as a better taste panel preference score than non stimulated carcasses. Data also indicated that a denaturation of sarcoplasmic proteins may have been responsible for the effects on water retention and muscle

color while the improvement of tenderness was due to the prevention of cold shortening by the treatments. In the end, electrical stimulation was identified by as a possible alternative method of increasing veal quality while also improving animal welfare (Eikelenboom 1989).

Eikelenboom (1989), analyzed samples for the determination of total hematin using a method developed by H.C. Hornsey (1956). Hornsey extracted pigment of cooked meats by using a rapid extraction method using an acetone-acid mixture and filtering the extraction for analysis with a spectrophotometer. The absorbance reading was then plugged into an equation to determine total pigment in parts per million. Hornsey's method is simple and accurate and has been adopted for studying the distribution and fading of color in meat products. Conclusions made by Hornsey (1956) proposes a method for measuring total pigments as parts per million of haematin and is very suitable for following the sequence of events in fading experiments, allowing samples of exposed meat to be withdrawn for analysis at short time interval

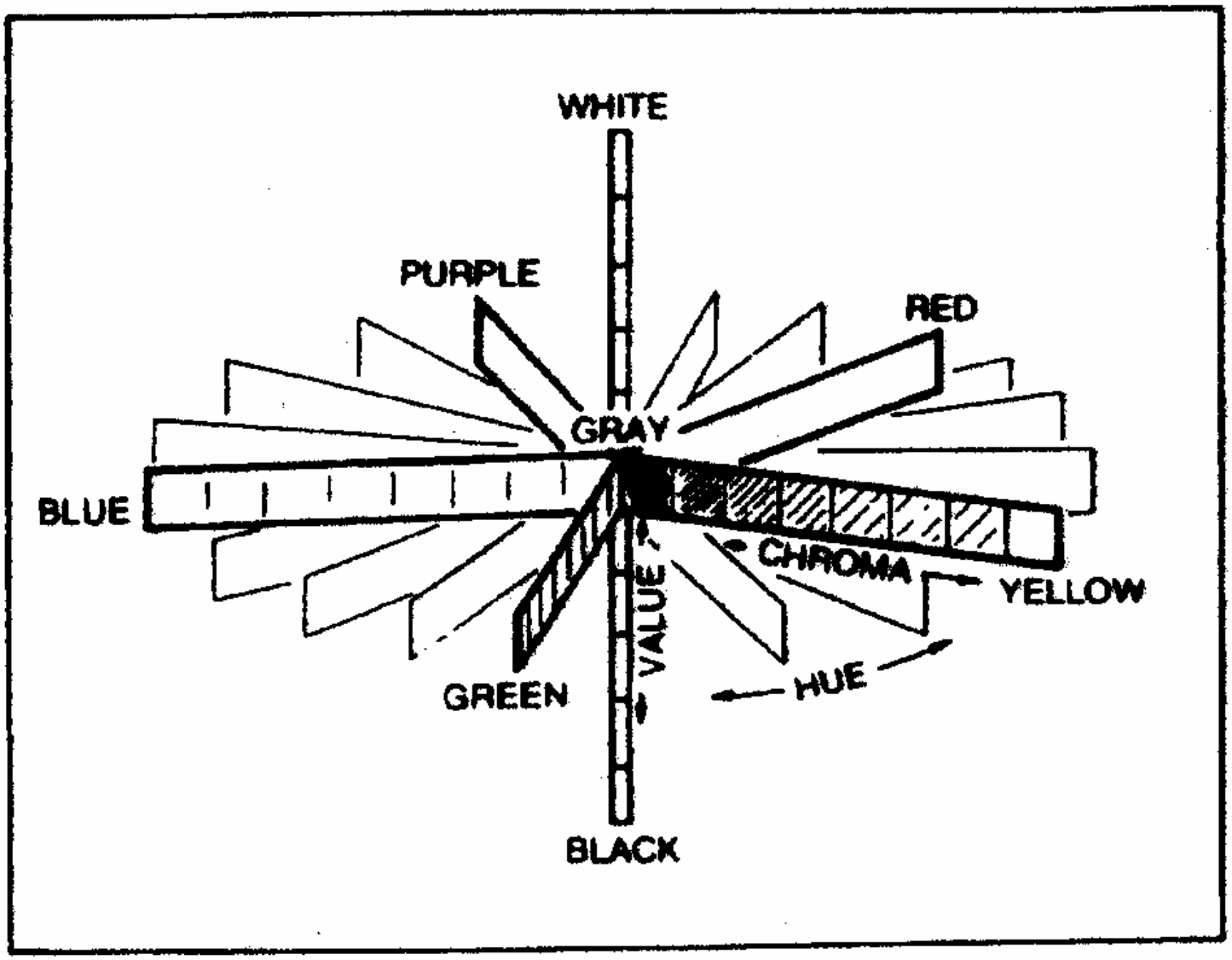

Figure 2-1. The Munsell color solid.

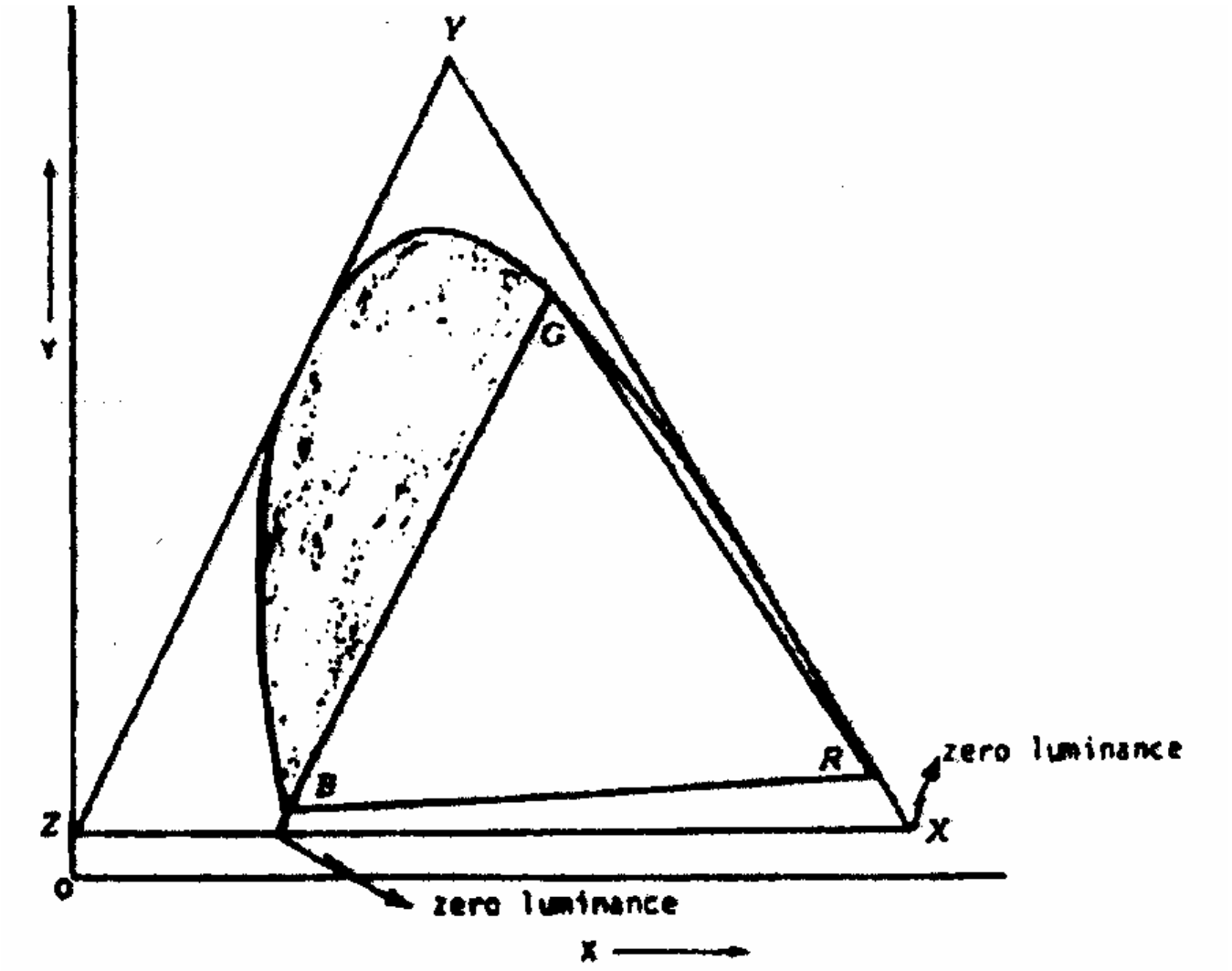

Figure 2-2. The XYZ Triangle of the CIE System.

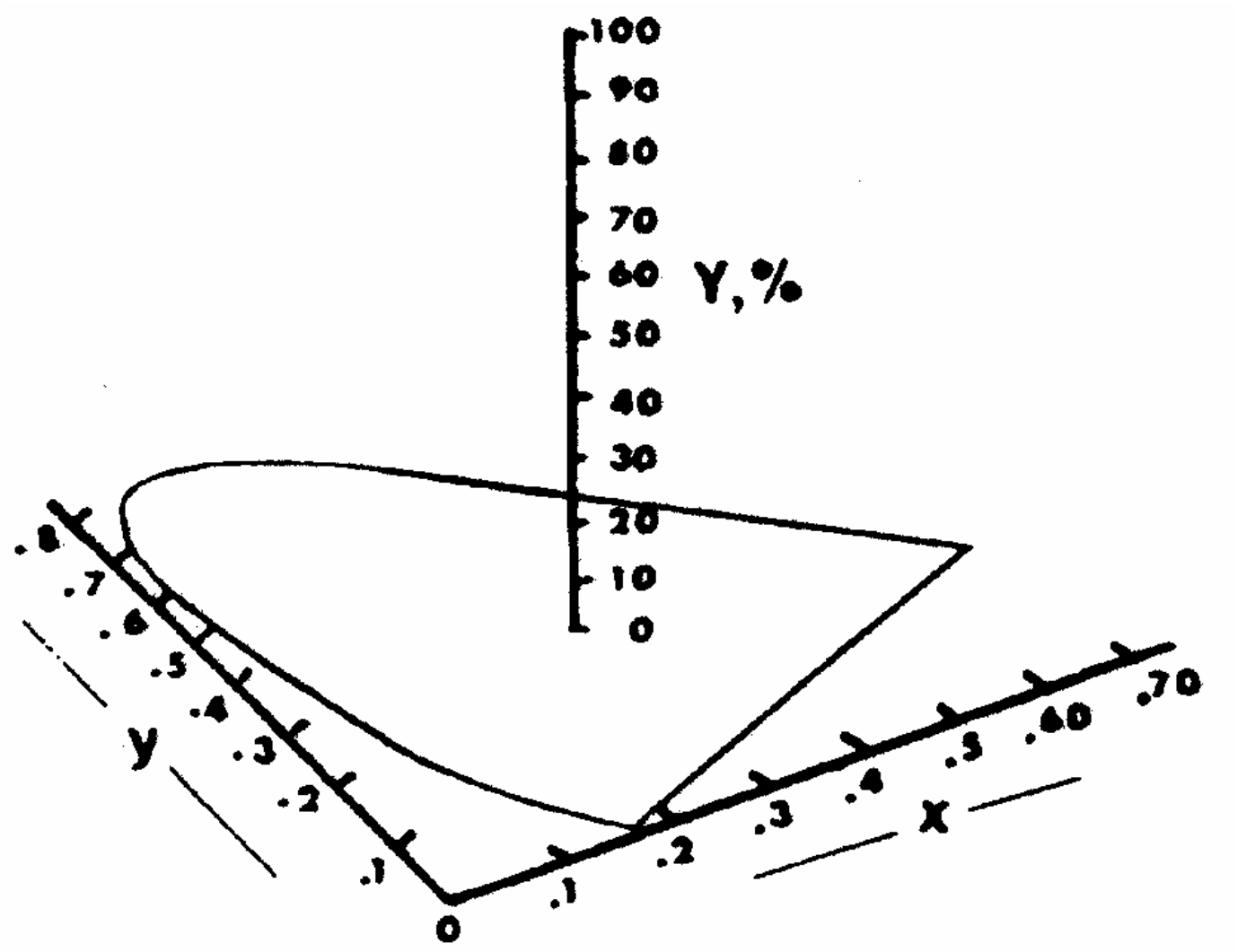

Figure 2-3. The CIE horseshoe-shaped spectrum locus showing percent Y.

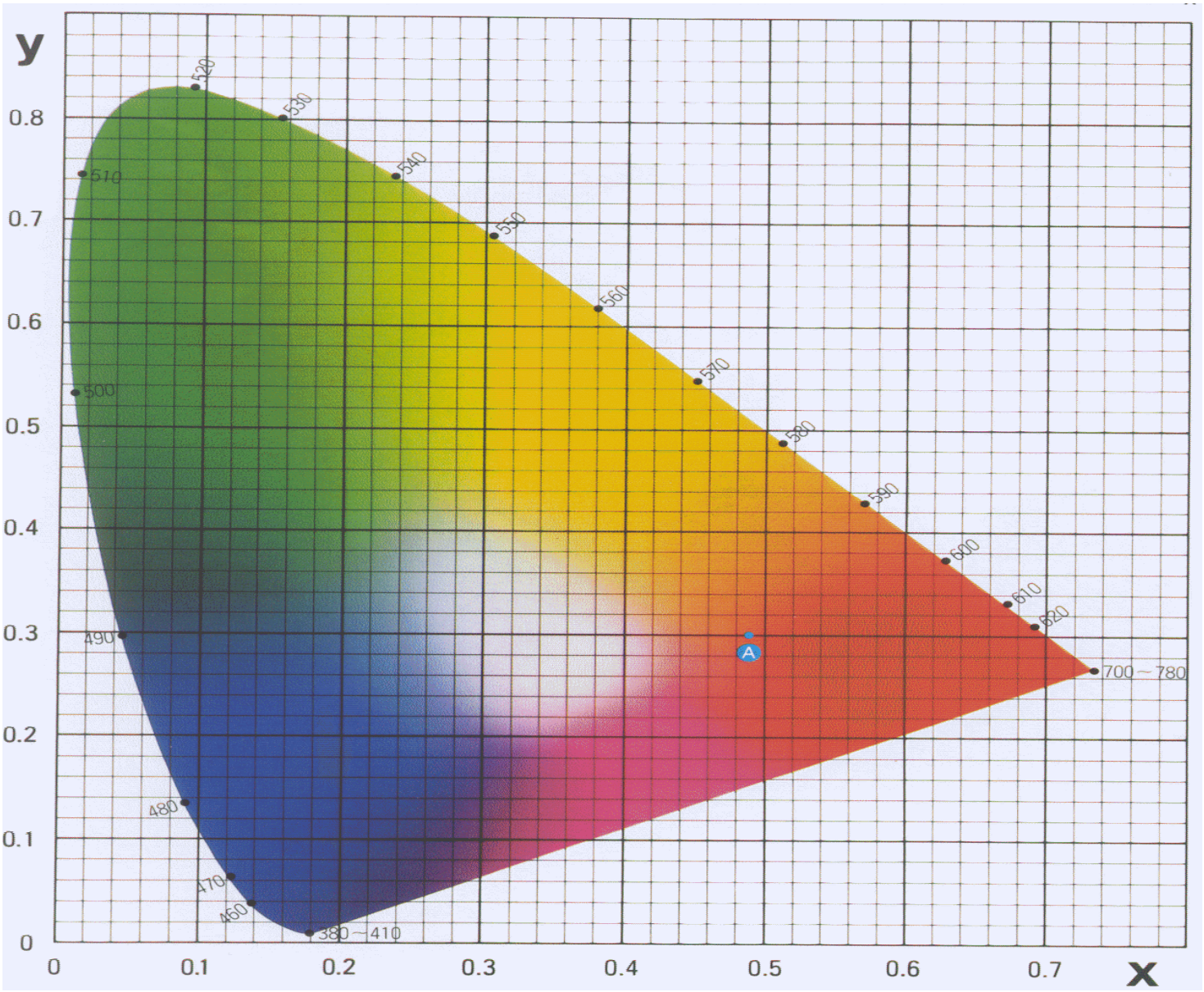

Figure 2-4. 1931 x, y, chromaticity diagram.

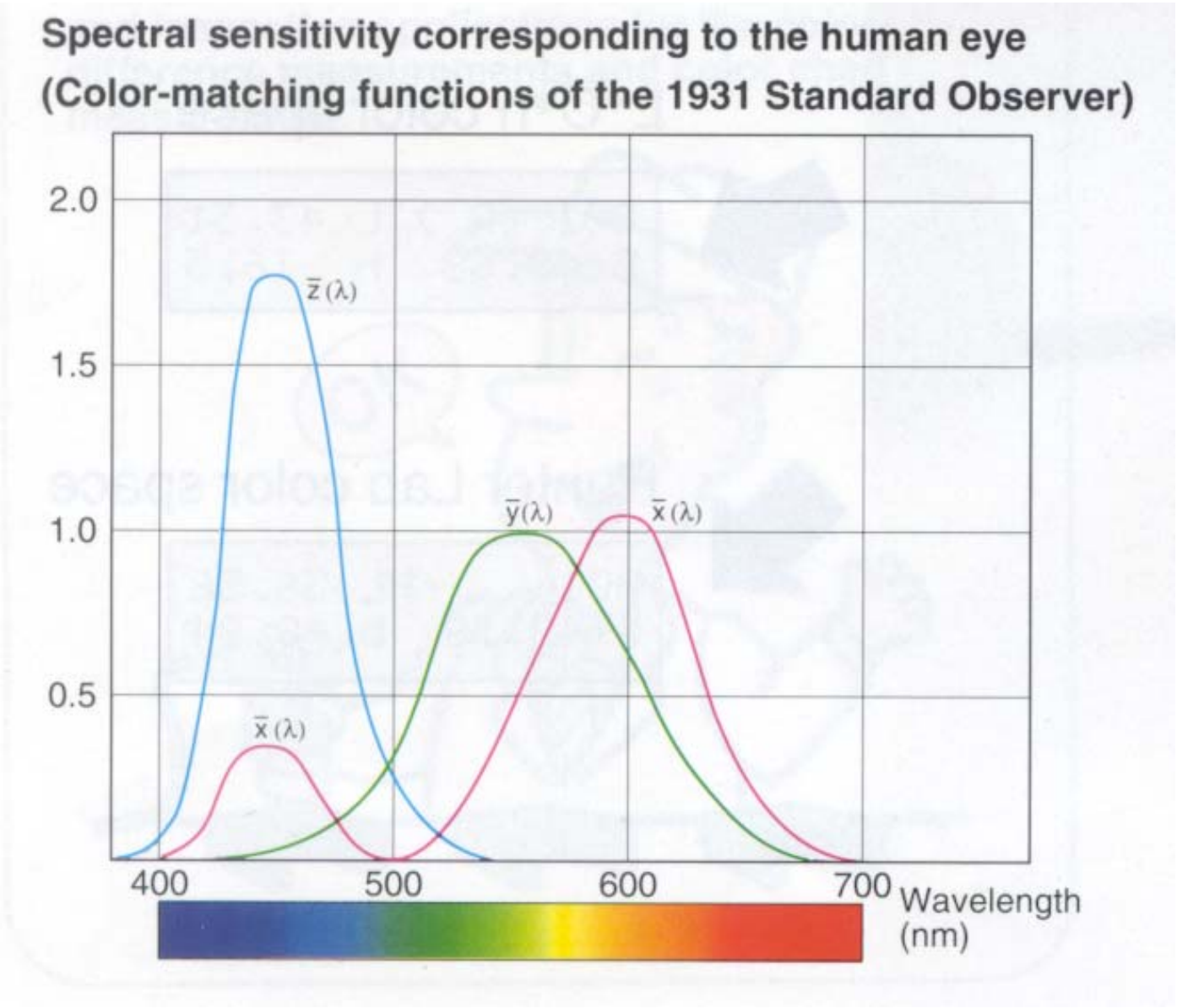

Figure 2-5. Spectral sensitivity corresponding to the human eye and color matching functions of the 1931 Standard Observer.

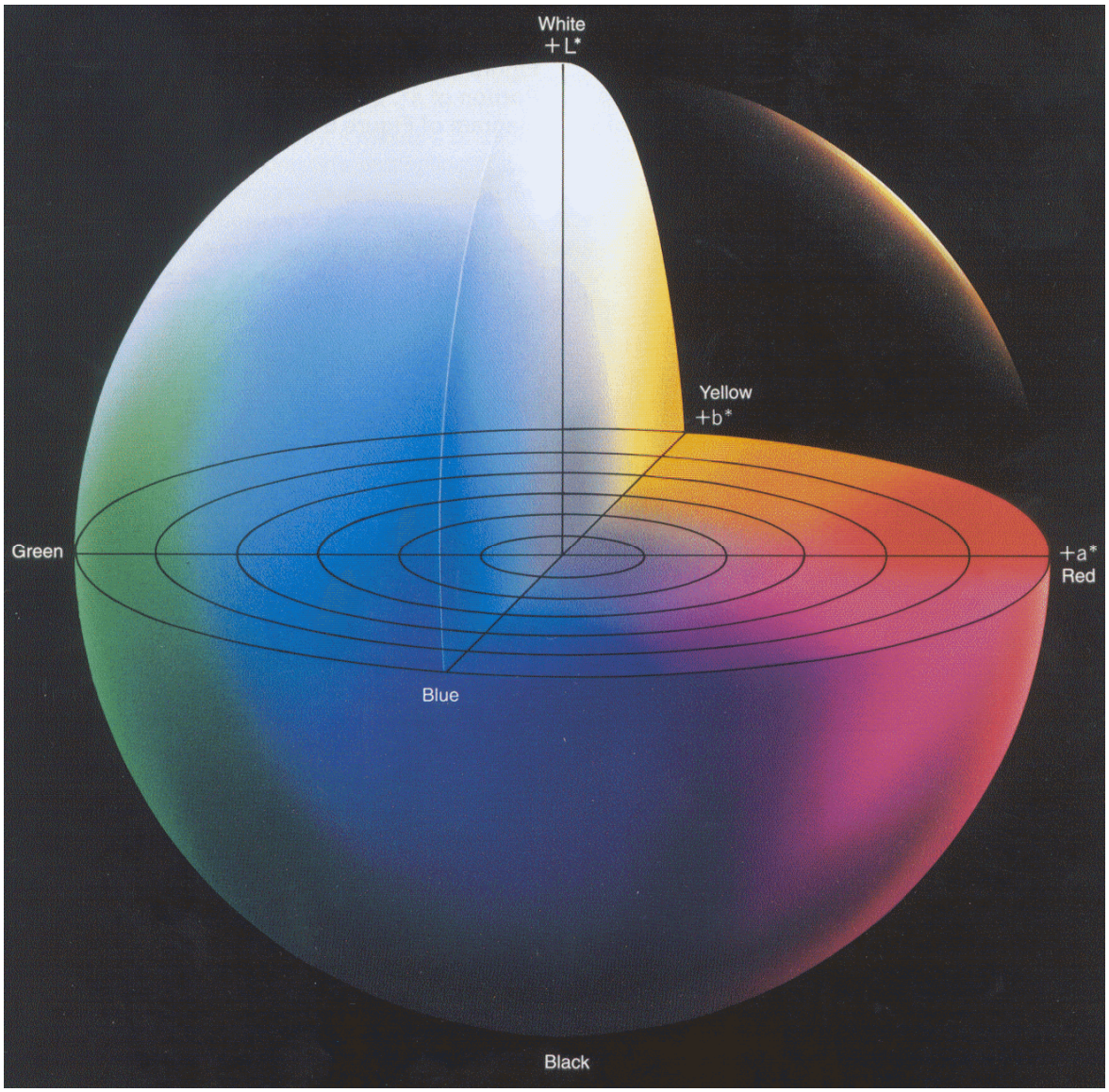

Figure 2-6. Three-dimensional representation of color solid for the L* a* b* color space.

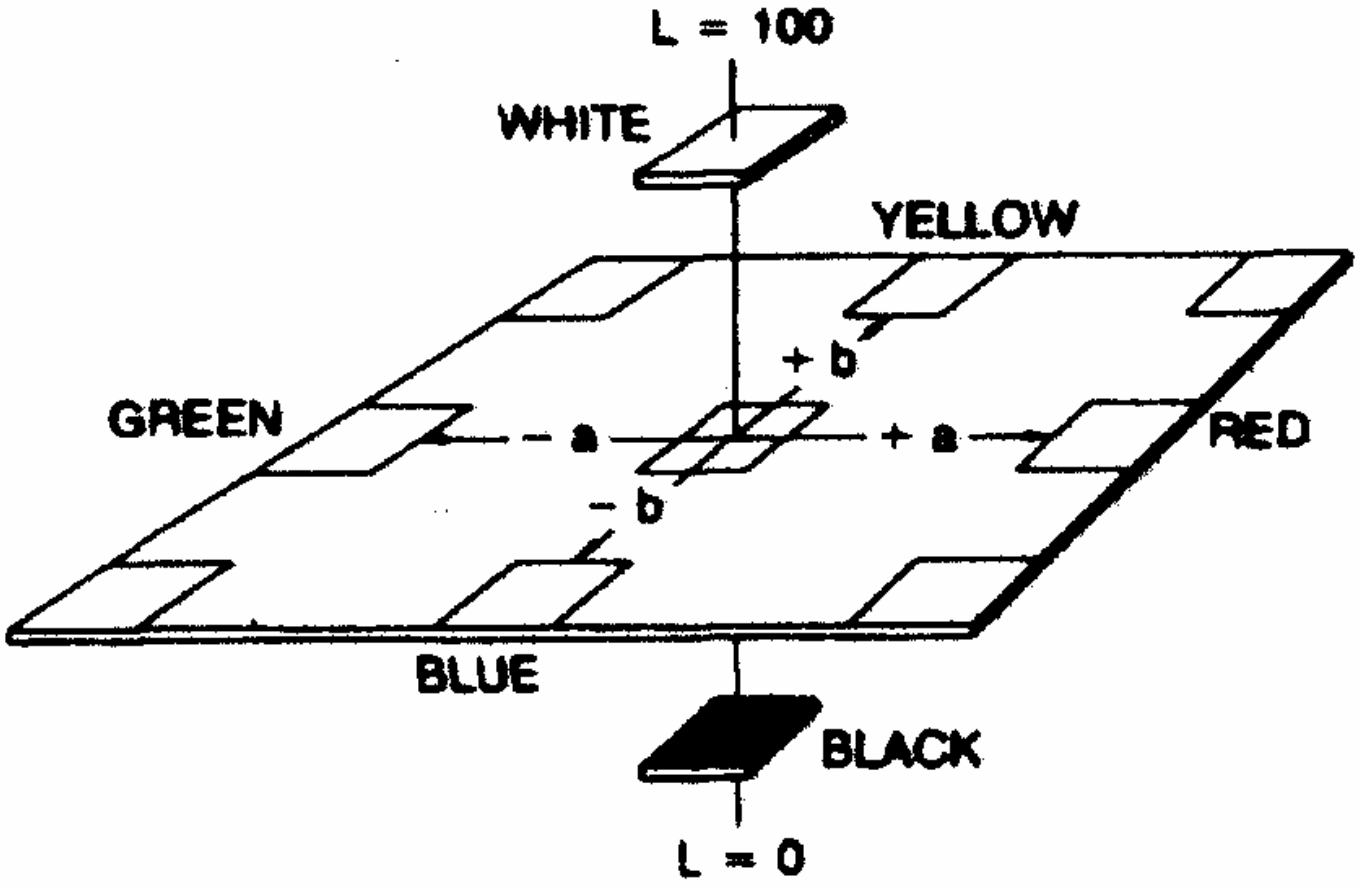

Figure 2-7. Hunter L, a, b solid.

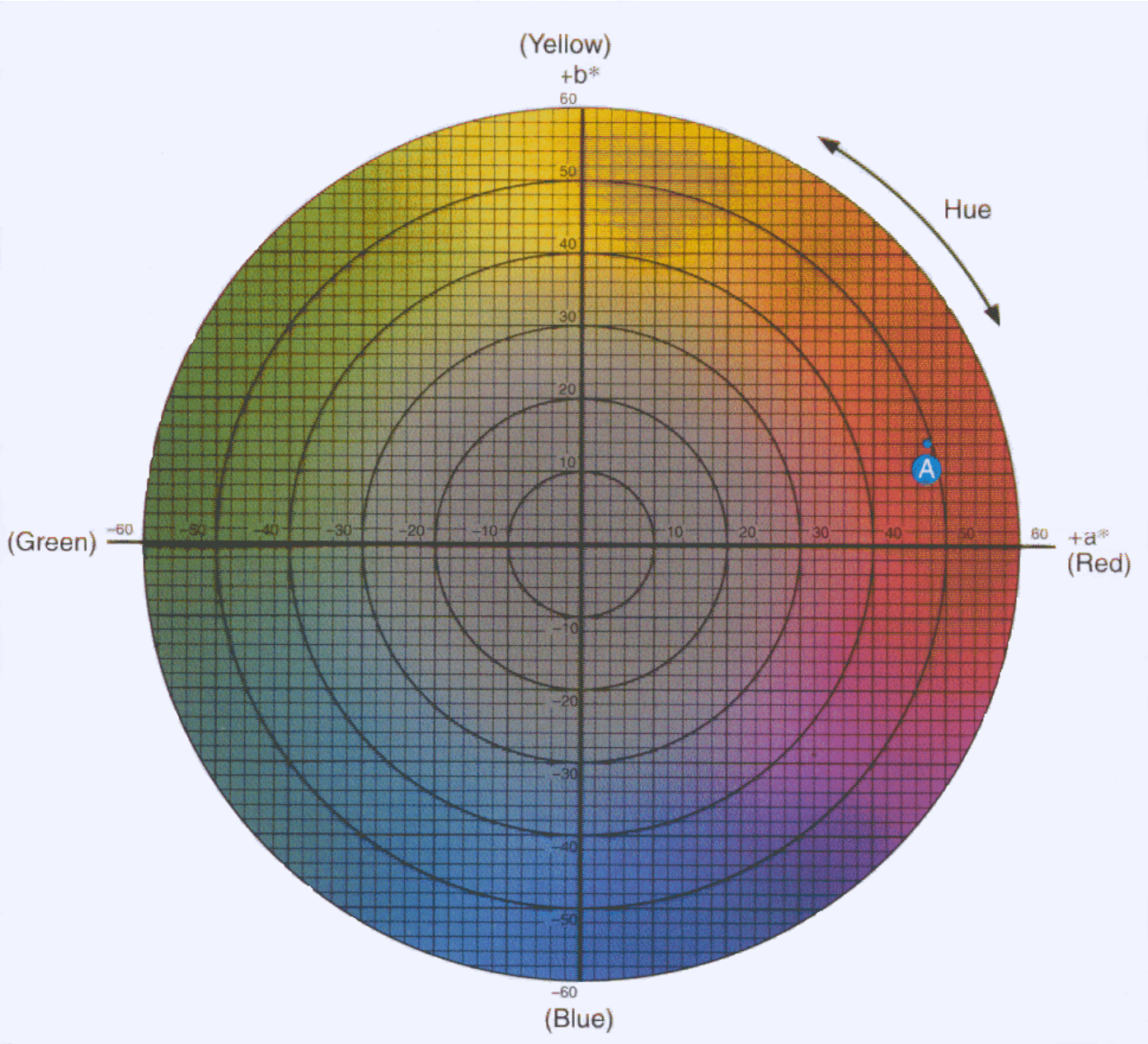

Figure 2-8. a* b* chromaticity diagram.

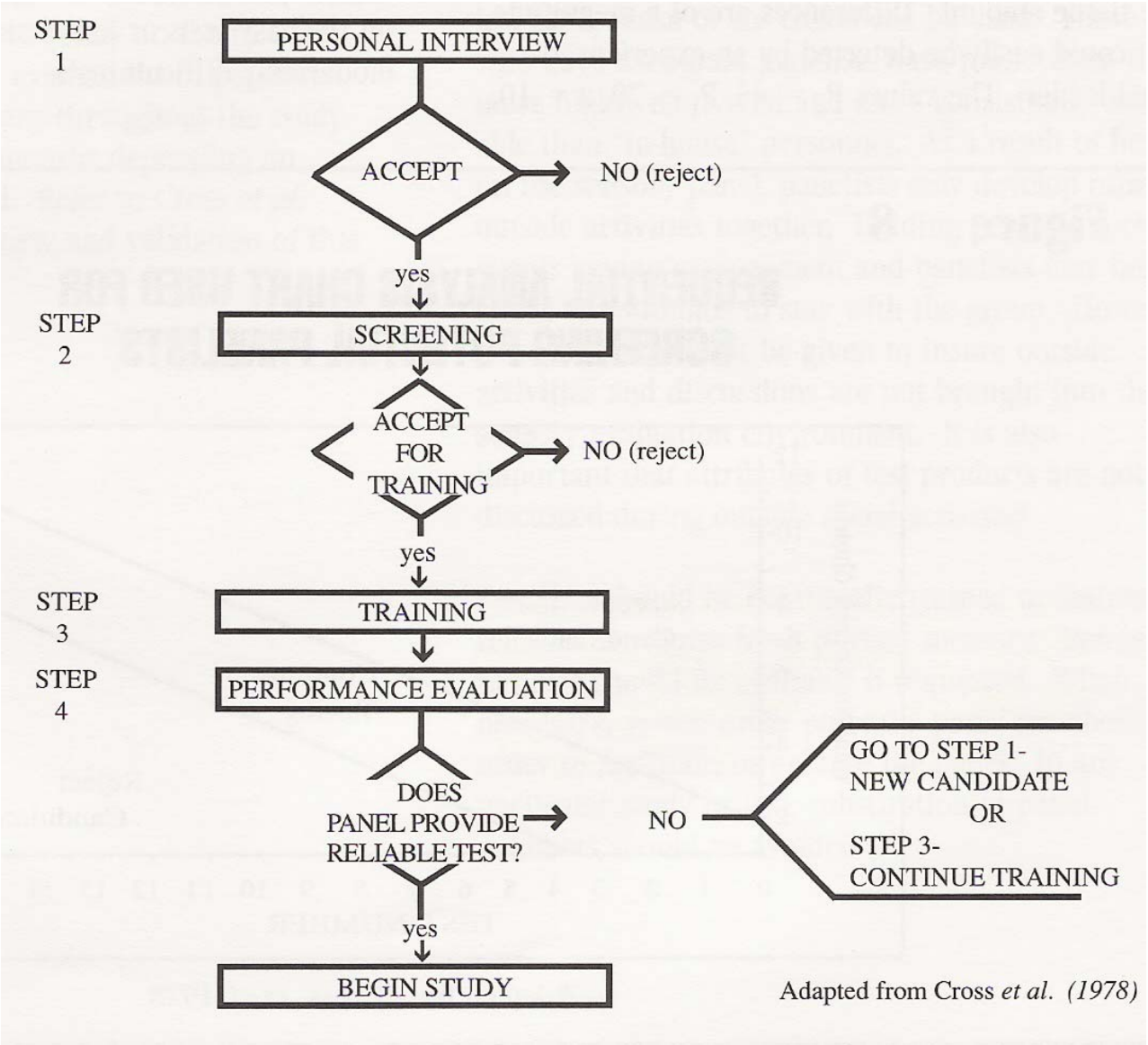

Figure 2-9. Steps in selecting a trained panel.

CHAPTER 3
CHARACTERIZING MUSCLES FROM THE VEAL CHUCK BY WEIGHT, DIMENSIONS AND SENSORY ATTRIBUTES

Introduction

Recent studies conducted by scientists at the University of Florida in conjunction with the University of Nebraska have characterized numerous muscles from the beef chuck and round. The studies conducted have revealed significant positive palatability attributes of many of these muscles. A similar characterization of muscles was performed in this study to characterize nine muscles from the veal chuck in search of ways to better utilize these muscles and add value to the veal chuck. Conclusions from previous studies have revealed that adding value can be achieved by cutting certain muscles into steaks rather than selling them as part of a roast or grinding them into ground beef.

Materials and Methods

Experimental samples

IMPS (Institutional Meat Purchase Specifications) 308 four rib whole chucks and IMPS 309 four rib square cut chucks were purchased from two separate veal packers with known grade and slaughter date. All were from special fed, USDA Choice or higher veal carcasses. Veal chucks were immediately shipped to the University of Florida Meat Processing facility for muscle separation. Whole chucks were squared prior to measurement and dissection. The IMPS 308 and IMPS 309 were weighed whole, and then dissected to obtain the following muscles of interest: Complexus, Deep Pectoral, Infraspinatus, Rhomboideus, Serratus Ventralis, Splenius, Supraspinatus, Triceps Brachii and the Teres Major. The selection of muscles was based on the potential of using these muscles as steak cuts where tenderness is most important; especially when a dry cookery method is used.

Weights, Dimensions and Aging

After dissection a commodity weight was taken of each individual muscle. Each muscle was then denuded using a 7600 Series Townsend Skinner and any additional hand carving to remove membranous material. After denuded weights were taken, measurements of each individual muscle were taken to obtain length, width, minimum depth and maximum depth. Each muscle was vacuum packaged in separate bags and wet aged fourteen days post mortem at 3.8 ± 2º C. At fourteen days post mortem, bags were checked for any leakage, and muscles were frozen at -40°C until sensory evaluation was conducted.

Sensory Evaluation

Prior to sensory evaluation, the two largest muscles were cut into 1 inch steaks with a band saw while frozen which included the Serratus Ventralis and the Triceps Brachii. These muscles were cut across the grain to ensure maximum degree of tenderness would be observed.

Before thawing, steaks were removed from vacuum sealed bags and frozen weights were taken to determine thaw loss. Steaks were thawed for approximately 18 hours at 3.8 ± 2º C, weighed, then grilled on Hamilton Beach Health Smart Indoor/Outdoor table top grills to an internal temperature of 71° C (AMSA, 1995). To assure equal endpoint cooking temperatures, Copper-constantan thermocouples were inserted into the approximate geometric center of each steak. Steaks were turned at 35°C and removed from grill when temperature reached 71°C (medium degree of doneness). Samples were then weighed for determination of cooking loss then wrapped as a whole muscle in tin foil and kept under heat lamps until sensory evaluation was conducted. Upon sensory evaluation, muscles were removed from tin foil and sliced into one-half inch cubes for evaluation.

Food Service Evaluation

For further evaluation of the muscles from the veal chuck, two food-service industry chefs along with two veal industry representatives were contacted to evaluate the quality and possible application of the nine muscles. After evaluating these nine muscles by using multiple cooking methods, the chefs and industry representatives agreed that there were truly some application for these value-added veal cuts.

Results and Discussion

Weights

The heaviest muscle found in the study was the Triceps Brachii which also represents the greatest yield of both the chuck and the whole carcass (Table 3-1). The lightest muscle in the study was found to be the Teres Major which represents the lowest yield percentage for chuck and hot carcass weight. The muscle with the most variation in weight was the Serratus Ventralis; the muscle with the least variation in weight was the Teres Major (variation in denuded weights).

Dimensions

The longest muscle was determined to be the Complexus and the shortest being the Teres major which was also found to be the narrowest muscle in the study (Table 3-2). The widest muscle was the Serratus ventralis. The thinnest muscle over all was the Splenius, and the thickest overall was the Triceps brachii.

Industry Evaluation

Table 3-3 gives some applicable cooking methods that worked well for each muscle and also gives some insight on the types of further processing that was suggested by the chefs to further enhance the products. It should be noted that the sensory data that was obtained supports the amount of further processing needed for each individual muscle. The most tender muscles (Infraspinatus, Teres major, Complexus) will require minimal processing while the toughest

muscles (Splenius, Serratus ventralis, Rhomboideus) will require a more aggressive tenderization method to increase there tenderness to a more acceptable level. One of the major concerns among these industry representatives was the cost of producing these value-added cuts. A cost analysis should be considered to reveal the true applicability of these muscles in the food-service industry.

Sensory Evaluation

Sensory evaluation revealed the most-tender muscle of the veal chuck was the Infraspinatus. On a scale of 1-8 with 1 being extremely tough and 8 being extremely tender, the Infraspinatus was evaluated at 6.9. The Teres Major was found to be not significantly different ($P > .05$) from the Infraspinatus with a tenderness score of 6.8. The toughest muscle in the study was found to be the Rhomboideus which was evaluated at 5.8 on the same 1-8 scale. The Rhomboideus was significantly lower ($P < .05$) in tenderness from all other muscles in the study (Table 3-4). When comparing tenderness levels of these muscles from the veal chuck with the same muscles from the beef chuck, it was found that the muscles were identical in ranking from the most tender to the least tender when compared to a compilation of studies conducted by the University of Nebraska. (Calkins and Sullivan, 2007). The muscles from the veal chuck fell in the same tenderness categories as the same muscles from the beef chuck, with the Infraspinatus and Teres Major being tender, and the Rhomboideus and Serratus Ventralis being less tender than the rest of the muscles presented. Although these muscles are similar in tenderness to those in the beef chuck, the veal muscles are less variable in tenderness, with only the Rhomboideus being of concern for tenderness.

Table 3-5 depicts the sensory evaluation data for the juiciness of veal muscles. On a scale from 1-8 with 8 being extremely juicy and 1 being extremely dry, it was determined that the Complexus had the highest juiciness scores with a sensory evaluation score of 6.5. The

Supraspinatus was found to be similar to the Complexus ($P > .05$) with a juiciness score of 6.3. The muscle with the lowest juiciness scores in the study was found to be the Triceps Brachii with an evaluation score of 5.8. The Infraspinatus and the Splenius were not significantly different ($P > .05$) from the Triceps brachii with scores of 5.9 and 5.8 respectively. When comparing juiciness scores with those reported by Calkins and Sullivan (2007) the veal muscles from the chuck are less variable and tend to be more juicy than those from the beef chuck. The Infraspinatus was recognized as being the juiciest muscle in both the veal and beef chucks, but the Triceps Brachii from the veal chuck was recognized as being the least juicy whereas the same muscle from the beef carcass was recognized to be of intermediate juciness.

On a scale from 1-8 with 1 being extremely bland and 8 being extremely intense, the Supraspinatus was found to have the most intense beef flavor with a sensory score of 5.1. The Complexus was not significantly different ($P > .05$) with a score of 5.0. The blandest muscle of the study was the Splenius with a score of 4.0 with no significant difference ($P > .05$) from the Infraspinatus or the Splenius with evaluation scores of 4.5 and 4.3, respectively. Most of these muscles were found to be slightly bland when evaluated for beef flavor (Table 3-6).

Table 3-7 depicts the amount of connective tissue evaluated in each muscle of the study. It should be noted that large visible seams of insoluble connective tissue were removed from the Infraspinatus after dissection and from the Triceps brachii after cooking. On a scale of 1-8 with 8 being no connective tissue detected and 1 being an abundant amount of connective tissue present, the Infraspinatus was found to have the least amount of connective tissue present with a sensory score of 7.3. Of the muscles evaluated, the Teres major was not significantly different ($P > .05$) from the Infraspinatus or the Triceps brachii with an evaluation score of 7.2. The muscle

with the highest connective tissue score was the Rhomboideus with a score of 5.8, which was significantly different (P > .05) from all other muscles in the study.

Upon completion of sensory evaluation of muscles, no extreme off-flavors were found in any muscle. The off-flavors that appeared most frequently included milky, metallic and grassy. The muscle with the least amount of off-flavor detected on a scale of 1-6 with 1 being extreme off-flavor and 6 being no off-flavor detected was the Triceps Brachii with a sensory score of 5.8. Off-flavor scores were similar (P > .05) for the Rhomboideus, Complexus, Splenius, Supraspinatus, Deep pectoral and Serratus ventralis. The muscle with the most extreme off-flavor was the Teres major with a score of 5.5, which was not significantly different from the Deep pectoral, Serratus ventralis or the Infraspinatus (Table 3-8).

Overall, when comparing the muscles from the veal chuck to a compilation of six decades and 58 papers of beef chuck data (Calkins and Sullivan, 2007), the data and rankings of the muscles from the veal chuck are comparable and often times mimic those of muscles from the beef chuck. Although some differences do exist, it can be concluded that muscles from the veal chuck are comparable and can be ranked in accordance with many years of research on muscles from the beef chuck.

Table 3-1. Average weights (standard deviations) of muscles from the veal chuck.[e]

Muscle	Comm. Wt. [a] (Min., Max)	Denuded Wt. [b] (Min., Max)	% Chuck [c] (Min., Max)	% HCW [d] (Min., Max)
Complexus (COM)	.58 (.12) (.39, .80)	.37 (.09) (.20, 58)	2.33 (1.41, 4.03)	.28 (.15, .46)
Deep pectoral (DEP)	.33 (.09) (.15, .49)	.23 (.07) (.11, .36)	1.43 (.76, 2.17)	.17 (.09, .24)
Infraspinatus (INF)	.69 (.08) (.52, .91)	.53 (.06) (.43, .68)	3.39 (2.39, 4.66)	.41 (.31, .54)
Rhomboideus (RHM)	.23 (.05) (.15, .32)	.16 (.04) (.09, .23)	1.01 (.58, 1.52)	.12 (.06, .17)
Serratus ventralis (SEV)	1.03 (.11) (.81, 1.32)	.74 (.12) (.56, 1.00)	4.69 (3.16, 5.96)	.57 (.43, .68)
Splenius (SPL)	.24 (.03) (.20, .32)	.15 (.04) (.05, .22)	.97 (.39, 1.56)	.12 (.04, .18)
Supraspinatus (SUP)	.65 (.08) (.55, .91)	.47 (.08) (.39, .64)	3.00 (1.71, 4.09)	.36 (.31, .43)
Triceps brachii (TRB)	1.13 (.17) (.82, 1.5)	.87 (.10) (.68, 1.00)	5.49 (3.82, 6.85)	.67 (.48, .81)
Teres major (TER)	.15 (.03) (.11, .21)	.11 (.02) (.08, .16)	.67 (.52, 1.02)	.08 (.06, .13)

[a] Commodity weight of muscle, [b] Denuded weight of muscle, [c] (Denuded muscle weight / Chuck weight), [d] (Denuded muscle weight / Hot carcass weight), [e] All weights are in Kilograms

Table 3-2. Average measurements (standard deviation) of muscles from the veal chuck. [a]

Muscle	Length[b] (Min, Max)	Width[c] (Min, Max)	Min. Depth[d] (Min, Max)	Max Depth[e] (Min, Max)
Complexus	33.50 (3.05) (28.0, 39.0)	11.55 (2.71) (7.0, 17.2)	0.92 (.29) (.5, 1.5)	1.84 (.42) (1.2, 2.5)
Deep pectoral	25.56 (4.82) (18.0, 35.0)	10.22 (1.39) (7.5, 13.0)	0.93 (.31) (.5, 1.5)	1.63 (.29) (1.0, 2.2)
Infraspinatus	27.14 (2.51) (20.5, 31.0)	10.13 (.80) (8.5, 11.0)	1.73 (.42) (.6, 2.5)	2.99 (.32) (2.6, 3.9)
Rhomboideus	26.09 (5.54) (4.5, 30.5)	6.37 (.87) (5.0, 9.0)	0.84 (.25) (.5, 1.4)	1.59 (.24) (1.2, 2.1)
Serratus ventralis	32.89 (4.20) (26.0, 42.5)	18.33 (1.80) (15.3, 22.0)	0.94 (.23) (.3, 1.5)	2.91 (.74) (1.0, 4.7)
Splenius	27.54 (3.95) (20.0, 33.0)	7.72 (2.34) (5.0, 16.5)	0.68 (.25) (.2, 1.1)	1.36 (.41) (.9, 2.5)
Supraspinatus	28.36 (1.96) (23.0, 31.8)	10.10 (1.00) (9.0, 13.0)	1.03 (.24) (.5, 1.6)	3.12 (.40) (2.3, 3.9)
Triceps brachii	26.65 (2.30) (23.6, 31.5)	13.93 (1.17) (12.0, 16.0)	1.38 (.27) (.8, 1.9)	5.13 (.52) (4.0, 6.0)
Teres major	19.21 (3.18) (8.8, 23.2)	5.38 (.99) (4.3, 8.5)	0.78 (.31) (.4, 1.5)	1.73 (.25) (1.3, 2.2)

[a] All measurements are denuded measurements, [b] Length of the muscle in cm, [c] Width of the muscle in cm, [d] Minimum depth of the muscle in cm, [e] Maximum depth of the muscle in cm.

Table 3-3. Industry evaluation.

Muscle	Suggested Cooking Methods and Applications	Suggested Processing Needs (level of tenderization)
Complexus	Flat top grilling, Pan sear, Open grilling	Mechanical Tenderization (mild)
Deep Pectoral	Pan sear, Wet braise, Corned veal application	Mechanical Tenderization (intermediate)
Infraspinatus	Flat top grilling, Pan sear, Braise, Open grilling	Connective tissue removal (none required)
Rhomboideus	Pan searing, Cutlets, K-bobs	Mechanical Tenderization (aggressive)
Serratus Ventralis	Pan fry, Open grilling, Braise, Cutlets	Mechanical Tenderization (aggressive)
Splenius	Pan sear, Flat top grilling	Mechanical Tenderization (aggressive)
Supraspinatus	Pan searing, Braised, Cutlets, Medallions	Mechanical Tenderization (intermediate)
Teres Major	Grilling, Pan sear, Skewer application, Open grilling	None required
Triceps Brachii	Pan searing, Braised with fat based liquid	Mechanical Tenderization (intermediate)

Table 3-3 is a compilation of information from two industry chefs and two industry representatives from two different dates. September 18, 2006: Steve Afflixio, C.E.C., A.A.C., Training Manager/Division Chef; US Foodservice. Paul McNally, District Territory Manager, US Foodservice. September 27, 2006: Mark P. Wachawiak, Chef – Mythos Restaurant, Universal Orlando Resort. Tom Houlton, Thomas Marketing Group, Marketing of Specialty Proteins.

Table 3-4. Overall tenderness of veal muscles.

Muscle [1]	Mean [2]	Standard Error
INF	6.9 [a]	0.08
TER	6.8 [a]	0.08
COM	6.6 [b]	0.08
SUP	6.5 [b]	0.08
TRB	6.5 [b]	0.08
DEP	6.2 [bc]	0.08
SPL	6.2 [c]	0.08
SEV	6.0 [c]	0.08
RHM	5.8 [d]	0.08

[1] Refer to Table 3-1; [2] 8 = extremely tender to 1= extremely tough; [a-d] Means with common superscripts are not significantly different (P > .05).

Table 3-5. Juiciness of veal muscles.

Muscle [1]	Mean [2]	Standard Error
COM	6.5 [a]	0.08
SUP	6.3 [ab]	0.08
TER	6.1 [b]	0.08
SEV	6.0 [b]	0.08
DEP	5.9 [bc]	0.08
RHM	5.9 [bcd]	0.08
INF	5.9 [cde]	0.08
SPL	5.8 [de]	0.08
TRB	5.8 [e]	0.08

[1] Refer to Table 3-1; [2] 8 = extremely juicy to 1 = extremely dry; [a-e] Means with common superscripts are not significantly different (P > .05).

Table 3-6. Beef flavor

Muscle [1]	Mean [2]	Standard Error
SUP	5.1 [a]	0.12
COM	5.0 [ab]	0.12
TRB	4.8 [b]	0.12
SEV	4.8 [b]	0.12
DEP	4.8 [bc]	0.12
TER	4.6 [bcd]	0.12
INF	4.5 [cde]	0.12
RHM	4.3 [de]	0.12
SPL	4.0 [e]	0.12

[1] Refer to Table 3-1; [2] 8 = extremely intense to 1 = extremely bland; [a-e] Means with common superscripts are not significantly different (P > .05).

Table 3-7. Connective tissue

Muscle [1]	Mean [2]	Standard Error
INF	7.3 [a]	0.09
TER	7.2 [a]	0.09
TRB	7.1 [ab]	0.09
SUP	6.9 [bc]	0.09
DEP	6.7 [c]	0.09
COM	6.6 [cd]	0.09
SPL	6.4 [d]	0.09
SEV	6.4 [d]	0.09
RHM	5.8 [e]	0.09

[1] Refer to Table 3-1; [2] 8 = none detected to 1 = abundant amount; [a-e] Means with common superscripts are not significantly different (P > .05)

Table 3-8. Off-flavor.

Muscle[1]	Mean[2]	Standard Error
TRB	5.8[a]	0.06
RHM	5.8[a]	0.06
COM	5.7[ab]	0.06
SPL	5.7[ab]	0.06
SUP	5.7[ab]	0.06
DEP	5.7[abc]	0.06
SEV	5.7[abc]	0.06
INF	5.6[bc]	0.06
TER	5.5[c]	0.06

[1] Refer to Table 3-1; [2] 6 = None detected to 1 = extreme off-flavor; [a-c] Means with common superscripts are not significantly different (P > .05).

CHAPTER 4
EFFECTS OF AGING ON RETAIL DISPLAY ATTRIBUTES AND COLOR OF MUSCLES FROM THE VEAL CHUCK

Introduction

Phase one of the study, presented in Chapter 3, characterized numerous muscles from the veal chuck and identified six muscles that were desirable in tenderness, juiciness and flavor. To further characterize these six muscles, a study that evaluated the shelf-life stability and color attributes was conducted. A shelf-life stability and color evaluation of the veal muscles further characterized the promising muscles identified in phase one of the veal optimization study and will allow veal processors and merchandisers to determine the value of these muscles.

Materials and Methods:

Experimental Samples

IMPS 309 four rib square-cut chucks with USDA Choice quality grade and known slaughter date were randomly selected at two separate veal processors (Strauss Veal and Lamb, Hales Corners, WI and Catelli Brothers Inc., Collingswood, NJ). Veal chucks were taken directly from the fabrication lines at the processing plant and then dissected by a professional de-boner to obtain the following muscles: Complexus (COM), Deep Pectoral (DEP), Infraspinatus (INF), Serratus Ventralis (SEV), Supraspinatus (SUP), and Triceps Brachii (TRB). The muscles were then weighed to determine yields. After weights were taken, the muscles were allowed to bloom for 15 minutes and color measurements were taken using a Minolta CR-310 Chroma meter. After color measurements were obtained, each muscle was cut in half to be divided between the University of Florida and the University of Nebraska for further evaluation. Each muscle was vacuum packaged using a roll stock packager and boxed for shipment.

Aging of Muscles

Upon arrival to the University of Florida Meat Processing facility, the muscles were held at 3.8 ± 2º C for their pre-determined aging periods in cardboard boxes with no light penetration. Aging periods were set at five, twelve, nineteen and twenty-six days postmortem. Animals and sides were randomly assigned to these aging periods, all muscles from a particular animal and side was represented in that same aging period (Table 4-1)

Shelf-life and Color Evaluation

After each respective aging period, muscles were removed from package and weighed to determine packaging purge. After weights were taken, the muscles were completely denuded and a beginning retail weight was taken to later determine retail display purge. Muscles were placed in foam trays with a single Cryovac Dry-loc ac 40 meat and poultry pad, and then covered with a single layer of polyvinyl chloride over-wrap (oxygen transmission rate of 23,250 ml/m^2/24hr.). Color measurements were taken of each muscle using a Minolta CR-310 Chroma meter each day of retail display. The muscles were also evaluated by a trained, five member panel, to visually assess each muscle. Each muscle was scored for overall appearance (8= extremely desirable, 1= extremely undesirable), Color (USDA pork color scale, 1= very light pink, 5= extremely dark red), Discoloration (8= no discoloration, 1= 100% discolored) and purge (6= none detected, 1= abundant). All muscles were presented in the retail case for three days with color measurements and objective evaluation on each day of the study (day 0, 1, 2, 3). After the third day, muscles were removed from the foam trays and a final weight was taken from each muscle to determine retail display purge.

Statistical Analysis

Statistical analysis was conducted using SAS proc mixed data. Day of aging was the main effect being explored for all analysis. Interactions were assessed for muscle, days in retail case

and days in case by days of aging to determine the effects of post-mortem aging on each muscles retail case stability. Although the goal of the study was not to determine a difference in supplier, supplier differences were explored and no significant difference was found. .

Summary of Results and Discussion

Table 4-2 presents the weights of each muscle after shipping and after retail display. Packaging purge was determined for each portion of muscle by subtracting the blotted muscle weight and the dry package weight from the overall meat and package weight. Percent packaging purge was then calculated. Retail purge was calculated by subtracting the out of case weight from the in case weight and dividing by the in case weight to determine percent retail display purge. The muscle with the most purge in the study was the Deep Pectoral with an overall purge of .05% from packaging through retail display.

Table 4-3 represents mean subjective evaluations for overall appearance which were obtained for each muscle within each aging period. It was determined that days of post-mortem aging had a significant effect on subjective evaluations for overall appearance of the muscles ($P < .05$). The three muscles that showed no effect due to days of aging were the Deep Pectoral, Infraspinatus, and the Triceps Brachii. These three muscles are most likely to retain their overall appearance when aged in vacuum sealed packaging at $3.8 \pm 2^{\circ}$ C for up to 26 days post-mortem.

Figure 4-1 gives a representation of the overall muscle appearance over the three day retail period. Means for all muscles in each retail display day are represented in the graph. All muscles behaved similarly for during retail display.

All six muscles in the study reacted similarly for each of the four aging periods for subjective overall appearance scores. The most desirable overall appearance scores were observed in the five, nineteen and twenty-six day aging periods, with no aging periods being statistically different ($P > .05$) (Figure 4-2). The differences in all four aging periods for

subjective overall appearance was minimal and no conclusion could be reached to determine if one aging period had more effect on subjective appearance of the muscles when placed in a retail display.

Table 4-4 represents subjective color evaluation means for each muscle during postmortem aging. Post-mortem aging did significantly affect subjective color scores for all muscles represented in the study ($P < .05$). The three muscles that are most likely to retain their acceptable color over the four aging periods include the Deep pectoral, Serratus Ventralis, and the Triceps Brachii. The Supraspinatus had a decline in color between five and twelve days of aging but retained this color value through 26 days of aging.

Table 4-5 represents the effects of post-mortem aging on subjective color scores. Means for each aging period were taken at each day in the case to determine the day in case*days of aging interaction. It was determined that post-mortem aging had significant effects on the color evaluation for each day in the case ($P < .05$). Muscles with more post-mortem age were lighter in color for all but day zero of retail display. On day zero of retail display, muscles with 26 days of age had the darkest subjective color scores.

All muscles in the study were found to react similarly for color evaluation over the retail display period (Figure 4-3). The largest decline in color was observed between the first and second day of retail display, but none of the days were significantly different from each other ($P > .05$).

Post-mortem aging had a significant effect on muscle discoloration during retail display ($P < .05$). As presented in Table 4-6, the three muscles that did not show a postmortem age effect on discoloration were the Deep pectoral, Infraspinatus and Supraspinatus. The other three muscles discolorations were effected by the different aging periods (Table 4-6). The Complexus and

Serratus ventralis muscles with greater than five days of postmortem age had more discoloration. The discoloration of the Triceps brachii was not consistently influenced by days of post-mortem age.

All muscles in the study were found to react similarly for discoloration over the retail display period (Figure 4-4). As expected, an increase in discoloration was noted for all days of retail display with the largest increase coming after day 1 of retail display. The mean discoloration score for three days of retail display time was comparable to 10% discoloration when averaged across all six muscles, the muscles became 10% more discolored each day of retail display. Table 4-6 gives a valid representation for muscle discoloration scores for the four aging periods.

All muscles in the study were found to react similarly for discoloration over the four aging periods ($P > .05$). Muscles aged for twelve days were found to have the most discoloration when averaged over the retail display days. Five days of post-mortem aging had the most desirable scores and day twelve had the most discoloration when averaged across all three days of retail display (Figure 4-5)

Days of post-mortem aging had a significant effect on subjective muscle purge scores ($P < .05$). The aging period that most commonly represented the highest amount of purge was the 26 day aging period. The only muscle that did not show the most purge for this aging period was the Deep pectoral, although from a practical perspective all differences were small (Table 4-7).

Days of post-mortem aging had a significant effect on subjective purge evaluations over the retail display period ($P < .05$). Interaction was detected between aging periods as well as between days in the retail display (Table 4-8). The aging period with that showed the most abundant purge was the 26 day aging period. It must be noted that no aging period or retail

display period was undesirable in subjective purge (all values between barely detected and none detected).

All muscles were found to react similarly for purge over the retail display period. A slight increase in purge was noted for each day in the retail case with no day being different ($P > .05$) (Figure 4-6).

Days of postmortem aging had a significant effect on L* values ($P < .05$). L* values remain constant for the five and twelve day aging periods but an increase in these values was noted between the twelve and nineteen day post-mortem aging periods (become more white). The only muscle that showed no significant change in L* values across aging periods was the Infraspinatus (Table 4-9).

L* values reacted to retail display day similarly for all muscles ($P > .05$). A slight increase in L* values occurred between days zero and one of retail display and a decrease in these values was found between day one and two of display (Figure 4-7). The data revealed that these muscles become darker after day one of retail display.

All muscles in the study were found to react similarly for L* values over the four aging periods. An average was taken for all days of retail display at each aging period to determine the effects of aging on retail display. Post-mortem aging increased L* values between twelve and nineteen days of aging over the three days of retail display (Figure 4-8).

Days of postmortem aging had a significant effect on a* values ($P < .05$). The greatest change in these values was from the 5 day aging period to the 12 day aging period (Table 4-10). Over this 7 day period the muscles become darker red (increasing a* values). The muscles then remain relatively constant for the other three aging periods.

Days of retail display had a significant effect on a* values ($P < .05$). a* values represent the redness or greenness of muscle color. As values increase, redness of the muscle increases. Shown in Table 4-11, the Complexus and Serratus Ventralis became less red in color during retail display. Other muscles were not consistent in change of a* values (redness) and differences were small during three days of retail display.

Means were taken over retail display for all muscles, it was determined all muscles reacted similarly to days of postmortem aging for a* values ($P > .05$). Figure 4-9 shows there was an increase in a* values between the five and twelve day aging period, with a similar a* value through out the rest of the aging periods (Table 4-12).

Days of post-mortem aging had a statistically significant effect on b* values ($P < .05$). Similar to the a* values the largest increase in b* values (yellowness) was between the five and twelve day aging period. After this increase in b* values the muscles remain fairly consistent over the other three aging periods (Table 4-13).

Days of retail display had a statistically significant effect on b* values ($P < .05$). The most apparent difference in the muscles was between day zero and day one of retail display. All muscles increased in b* values after being displayed for one day. This reveals that the muscles became more yellow after the first day of retail display, but retained their b* value throughout the remaining retail display days.

Days of aging and retail display interaction had a statistically significant effect on b* values ($P < .05$). As apparent in the days of postmortem aging effects (Table 4-12), there was a significant increase in b* values (yellowness) between the five and twelve day aging periods, with all other aging periods being not statistically different (Table 4-14).

Conclusion

When placed in a three day retail setting the six muscles in this study behaved the same for overall appearance, subjective color and muscle purge. Post-mortem aging had no significant effect on overall appearance or subjective color evaluation for the six muscles. Muscle discoloration of the Deep Pectoral, Infraspinatus, and Triceps brachii was not effected by post-mortem aging, nor did post-mortem aging have an effect on overall appearance for the three day retail display period for these muscles. However post-mortem aging had a significant effect on objective color values (L*, a*, b*). The greatest impact of post-mortem aging on objective color (L*, a*, b*) values was observed between the five and twelve day post-mortem aging periods. Between these two aging periods the muscles became darker, redder and more yellow. The muscles then retained this color throughout the remaining aging periods (up to 26 days of age). Although there was a significant effect of post-mortem aging on objective color, the overall impact on veal muscle characteristics was small.

Table 4-1. Aging period assignment.

Carcass	Day 5		Day 12		Day 19		Day 26	
	In	out	in	out	In	out	in	out
1	3/17	3/20			3/31	4/3		
2	3/17	3/20	3/24	3/27				
3					3/31	4/3	4/7	4/10
4			3/24	3/27			4/7	4/10
5	3/17	3/20					4/7	4/10
6			3/24	3/27	3/31	4/3		
7					3/31	4/3	4/7	4/10
8	3/17	3/20	3/24	3/27				
9	3/17	3/20					4/7	4/10
10			3/26	3/29	4/2	4/5		
11			3/26	3/29			4/9	4/12
12	3/19	3/22			4/2	4/5		
13	3/19	3/22					4/9	4/12
14					4/2	4/5	4/9	4/12
15	3/19	3/22			4/2	4/5		
16			3/26	3/29	4/2	4/5		
17			3/26	3/29			4/9	4/12
18	3/19	3/22	3/26	3/29				

[1.] Left sides were assigned to lower aging period for carcasses with odd numbers.
[2.] Right sides were assigned to lower aging periods for carcasses with even numbers.

Table 4-2. Average muscle weights (standard deviation) of muscle from the veal chuck.[1]

Muscle	In Case Wt.[2]	Out of Case Wt.[3]	Packaging Purge %[4]	Retail Display Purge %[5]
COM	.39 (.09)	.38 (.08)	0.01	0.03
DEP	.23 (.05)	.22 (.05)	0.02	0.03
INF	.85 (.11)	.83 (.11)	0.01	0.02
SEV	.82 (.14)	.81 (.14)	0.01	0.02
SUP	.52 (.09)	.51 (.09)	0.01	0.02
TRB	.81 (.12)	.80 (.12)	0.01	0.02

[1] Average weight for portion of muscle; [2] Denude weight of muscle in lbs;[3] Weight of muscle after four days of retail display; [4] Loss due to vacuum packaging for post-mortem aging; [5] Percent of beginning weight lost due to retail display

Table 4-3. Days of post-mortem aging effects on subjective overall appearance. [1]

	Days of post-mortem aging			
Muscle	5	12	19	26
COM	6.6^{a}	5.7^{c}	6.2^{ab}	5.8^{bc}
DEP	6.7	6.7	6.8	6.9
INF	6.7	6.3	6.3	6.4
SEV	6.7^{a}	6.0^{b}	6.5^{a}	6.2^{ab}
SUP	6.6^{ab}	6.5^{b}	7.0^{a}	6.8^{ab}
TRB	6.8^{c}	6.5	6.5	6.9

[1] Scale of 1-8 with 8 =extremely desirable, 1= Extremely undesirable; [2] Means within same rows with different superscripts were significantly different ($P < .05$).

Table 4-4. Days of post-mortem aging effects on subjective color evaluation. [1]

	Days of post-mortem aging			
Muscle	5	12	19	26
COM	3.4[bc]	3.7[a]	3.2[d]	3.4[c]
DEP	3.4	3.4	3.4	3.3
INF	3.0[bc]	3.3[a]	2.9[c]	3.1[ab]
SEV	3.2	3.2	3.2	3.3
SUP	3.4[a]	3.2[b]	3.1[b]	3.1[b]
TRB	3.6	3.6	3.4	3.4

[1] Color evaluation using USDA pork color scale (1-5).
[2] Means within same rows with different superscripts were significantly different (P < .05).

Table 4-5. Effects of post-mortem aging on subjective color evaluations by days in the case. [1]

	Days of post-mortem aging			
Days in Case	5	12	19	26
0	3.2[bc]	3.4[b]	3.2[c]	3.7[a]
1	3.5[a]	3.4[a]	3.2[b]	3.1[b]
2	3.3[ab]	3.4[a]	3.2[bc]	3.1[c]
3	3.4[a]	3.3[ab]	3.2[bc]	3.1[c]

[1] Color evaluation using USDA pork color scale (1-5).
[2] Means within same rows with different superscripts were significantly different (P < .05).

Table 4-6. Effects of post-mortem aging on muscle discoloration. [1]

	Days of post-mortem aging			
Muscle	5	12	19	26
COM	7.5[a]	6.5[b]	6.9[b]	6.4[b]
DEP	7.6	7.3	7.4	7.6
INF	7.5	7.0	7.2	7.2
SEV	7.4[a]	6.8[b]	7.1[ab]	6.8[b]
SUP	7.3	7.3	7.5	7.7
TRB	7.5[ab]	7.1[ab]	7.0[b]	7.5[a]

[1] Scale of 1-8 with 8 = No discoloration, 1 = 100% discoloration
[2] Means within same rows with different superscripts were significantly different ($P < .05$).

Table 4-7. Days of post-mortem aging effects on subjective muscle purge scores. [1]

	Days of post-mortem aging			
Muscle	5	12	19	26
COM	5.9[b]	5.9[ab]	5.9[a]	5.7[c]
DEP	5.9[b]	5.9[ab]	6.0[a]	6.0[a]
INF	6.0[a]	5.9[a]	6.0[a]	5.7[b]
SEV	5.8[b]	6.0[a]	5.9[a]	5.7[b]
SUP	6.0[a]	5.9[a]	5.9[a]	5.5[b]
TRB	5.9[a]	5.9[a]	6.0[a]	5.8[b]

[1] Scale 1-6 with 6 = none detected, 1 = abundant.
[2] Means within same rows with different superscripts were significantly different ($P < .05$).

Table 4-8. Effects of post-mortem aging on subjective purge evaluations by days in the case. [1]

	Days of post-mortem aging			
Days in Case	5	12	19	26
0	6.0	6.0	6.0	6.0
1	6.0[a]	5.9[a]	6.0[a]	5.7[b]
2	5.8[b]	5.8[ab]	5.9[a]	5.8[b]
3	5.8[a]	5.9[a]	5.9[a]	5.5[b]

[1] Scale 1-6 with 1 = abundant purge, 6 = none detected.
[2] Means within same rows with different superscripts were significantly different ($P < .05$).

Table 4-9. Days of post-mortem aging effects on L* values. [1]

	Days of post-mortem aging			
Muscle	5	12	19	26
COM	52.8[b]	50.8[b]	55.0[a]	54.7[a]
DEP	52.7[b]	52.8[b]	53.9[a]	54.2
INF	53.1	53.0	53.6	53.4
SEV	52.9[b]	53.6[ab]	53.6[a]	54.1[a]
SUP	55.4[a]	53.9[b]	55.9[a]	56.0[a]
TRB	52.6[c]	53.0[bc]	54.2[a]	53.7[ab]

[1] Range of 0 to 100 where 0 is absolute black and 100 is absolute white.
[2] Means within same rows with different superscripts were significantly different ($P < .05$).

Table 4-10. Days of Post-mortem aging effects on a* values (redness). [1]

	Days of post-mortem aging			
Muscle	5	12	19	26
COM	16.3[c]	20.9[a]	19.6[b]	19.3[b]
DEP	15.0[b]	21.5[a]	21.8[a]	22.6[a]
INF	15.0[b]	21.2[a]	21.4[a]	22.0[a]
SEV	16.1[b]	20.9[a]	20.8[a]	21.2[a]
SUP	14.8[c]	21.3[b]	21.2[b]	22.6[a]
TRB	16.4[b]	21.3[a]	20.8[a]	22.0[a]

[1] Range -60 to 60, with positive numbers being red and negative numbers being green.
[2] Means within same rows with different superscripts were significantly different (P < .05).

Table 4-11. Effects of retail display on a* values (redness). [1]

	Days of Retail Display			
Muscle	0	1	2	3
COM	20.1[a]	19.8[a]	19.0[a]	17.1[b]
DEP	19.4[c]	21.1[a]	20.7[ab]	19.7[bc]
INF	19.2[b]	20.5[a]	20.5[a]	19.3[ab]
SEV	20.4[a]	20.4[a]	19.8[a]	18.3[b]
SUP	19.0[b]	20.6[a]	20.3[a]	20.0[ab]
TRB	19.8[c]	21.1[a]	20.7[ab]	19.1[bc]

[1] Range -60 to 60, with positive numbers being red and negative numbers being green.
[2] Means within same rows with different superscripts were significantly different (P < .05).

Table 4-12. Days of post-mortem aging effects on b* values (yellowness). [1]

	Days of post-mortem aging			
Muscle	5	12	19	26
COM	8.1[c]	9.3[a]	8.9[ab]	8.5[bc]
DEP	6.0[b]	8.8[a]	8.5[a]	8.9[a]
INF	7.3[b]	9.2[a]	9.2[a]	9.7[a]
SEV	8.0[b]	9.5[a]	9.9[a]	9.6[a]
SUP	7.7[c]	9.2[b]	9.2[b]	10.0[a]
TRB	8.0[b]	9.5[a]	9.5[a]	9.7[a]

[1] Range -60 to 60 with positive b* values being yellow and negative values being blue.
[2] Means within same rows with different superscripts were significantly different ($P < .05$).

Table 4-13. Effects of retail display on b* values (yellowness). [1]

	Days of Retail Display			
Muscle	0	1	2	3
COM	8.2[b]	9.0[a]	9.0[a]	8.7[ab]
DEP	6.6[b]	8.6[a]	8.6[a]	8.4[a]
INF	7.6[b]	9.4[a]	9.5[a]	8.9[a]
SEV	8.7[b]	9.7[a]	9.7[a]	9.0[a]
SUP	7.6[b]	9.6[a]	9.6[a]	9.4[a]
TRB	8.1[b]	9.7[a]	9.7[a]	9.2[a]

[1] Range -60 to 60 with positive b* values being yellow and negative b* values being blue.
[2] Means within same rows with different superscripts were significantly different ($P < .05$).

Table 4-14. Interaction between days of aging and retail display on b* values (yellowness). [1]

	Days of post-mortem aging			
Days in Case	5	12	19	26
0	5.4[b]	8.7[a]	8.7[a]	8.5[a]
1	7.8[b]	9.8[a]	9.6[a]	9.9[a]
2	8.6[b]	9.4[a]	9.5[a]	9.9[a]
3	8.4[b]	9.1[a]	9.0[a]	9.3[a]

[1] Range -60 to 60 with positive b* values being yellow and negative b* values being blue.
[2] Means within same rows with different superscripts were significantly different (P < .05).

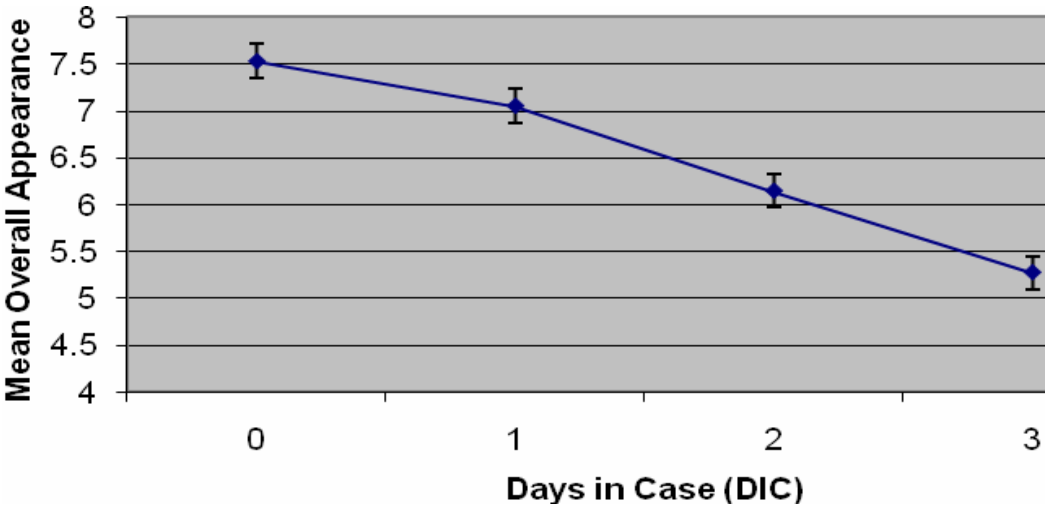

Figure 4-1. Effects of days in case on subjective overall appearance score.
Note: Scale of 1-8 with 8 =extremely desirable, 5=Slightly desirable 1= Extremely undesirable.

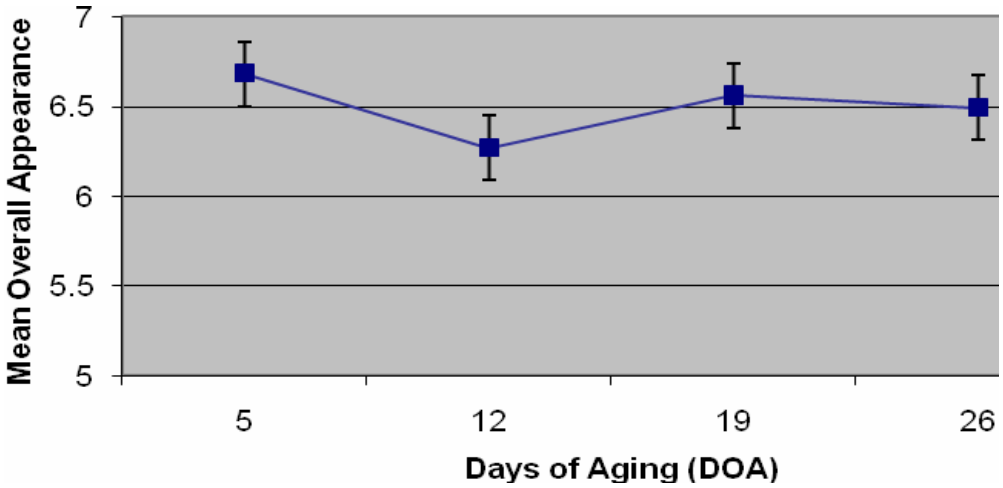

Figure 4-2. Days of post-mortem aging effects on overall appearance score.
Note:[1] Means for each aging period over three days of retail display. [2] Scale of 1-8 with 8 =extremely desirable, 5=Slightly desirable 1= Extremely undesirable.

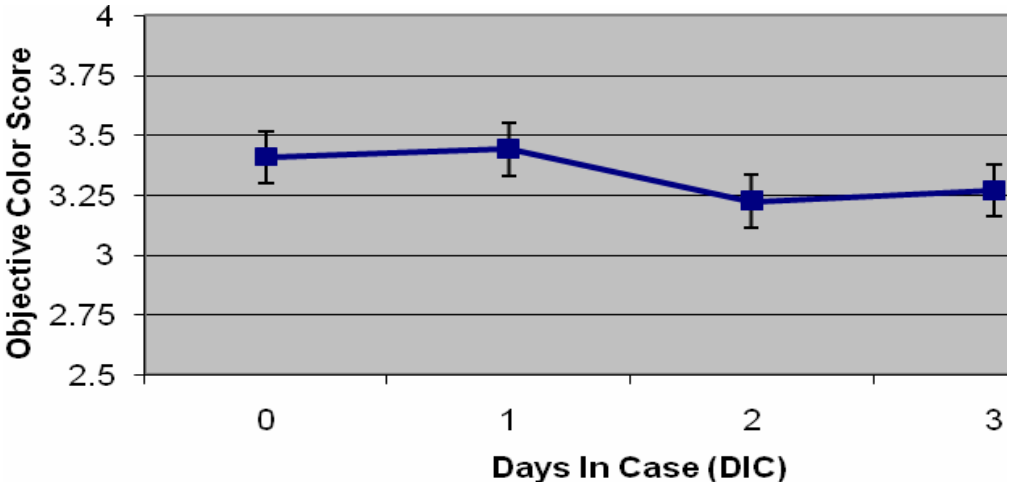

Figure 4-3. Effects of days in the case on subjective color score.
Note: Color evaluation using USDA pork color scale (1-5).

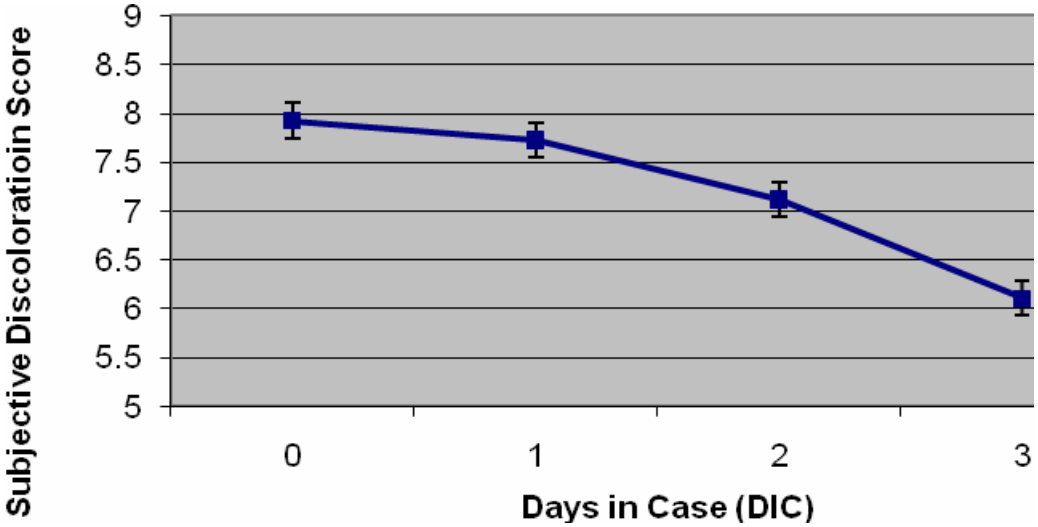

Figure 4-4. Muscle discoloration over retail display.
Note: Scale of 1-8 with 8 = No discoloration, 1 = 100% discoloration.

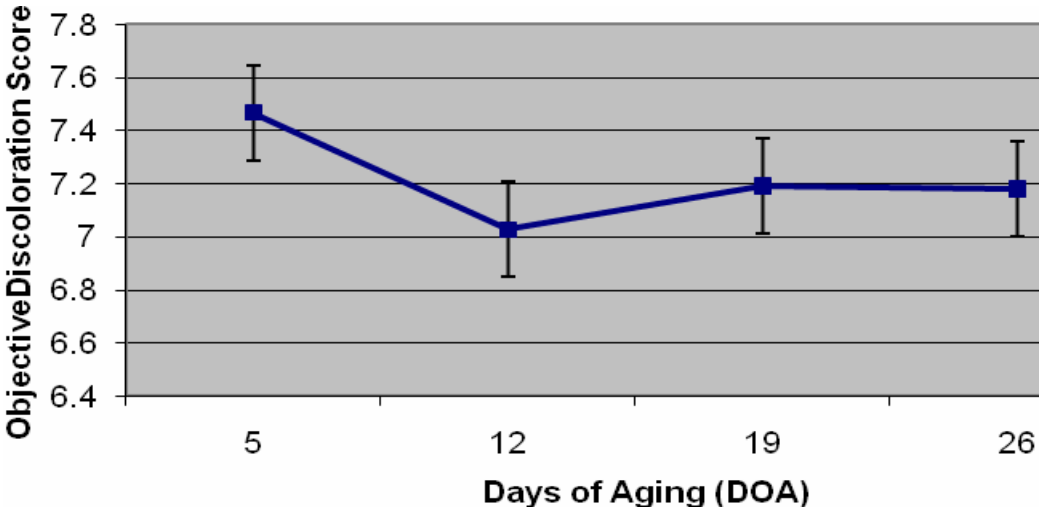

Figure 4-5. Overall means for discoloration for each aging period. [1]
Note: [1] Scale of 1-8 with 8 = No discoloration, 1 = 100% discoloration
[2] Means for each aging period over three days of retail display

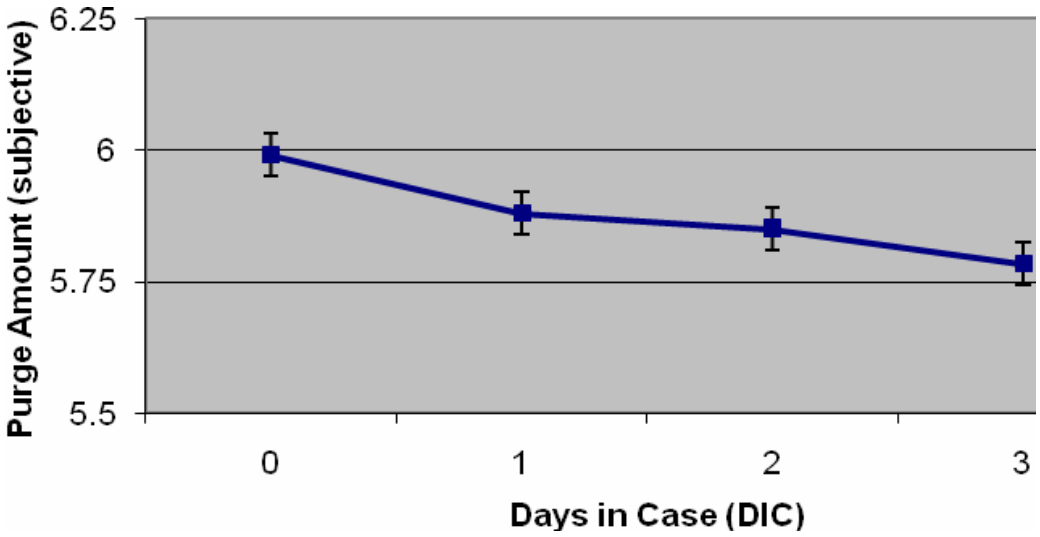

Figure 4-6. Muscle purge over days of retail display.[1]
Note: [1] Scale 1-6 with 1 = abundant purge, 6 = none detected.

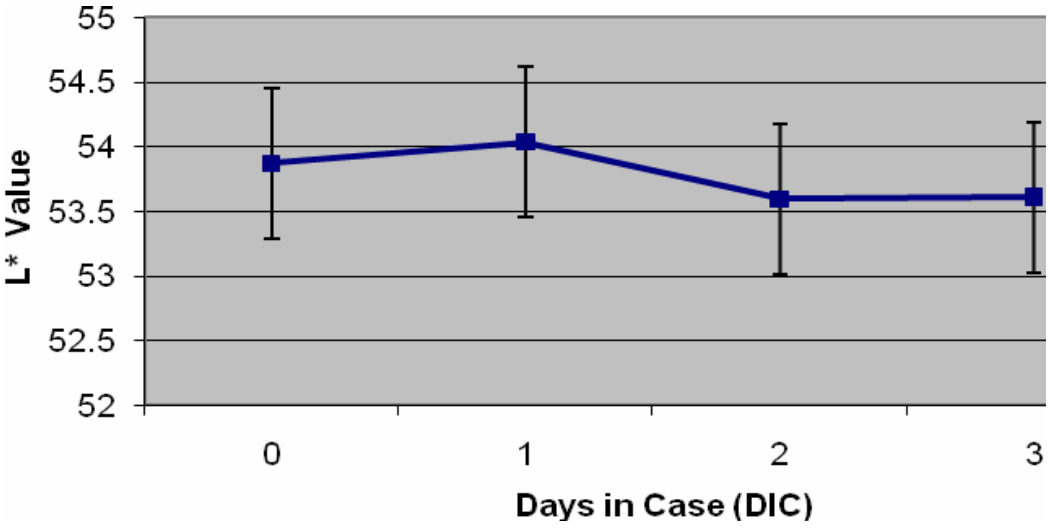

Figure 4-7. Changes in L* due to days of retail display. [1]
Note: [1] Range of 0 to 100 where 0 is absolute black and 100 is absolute white.

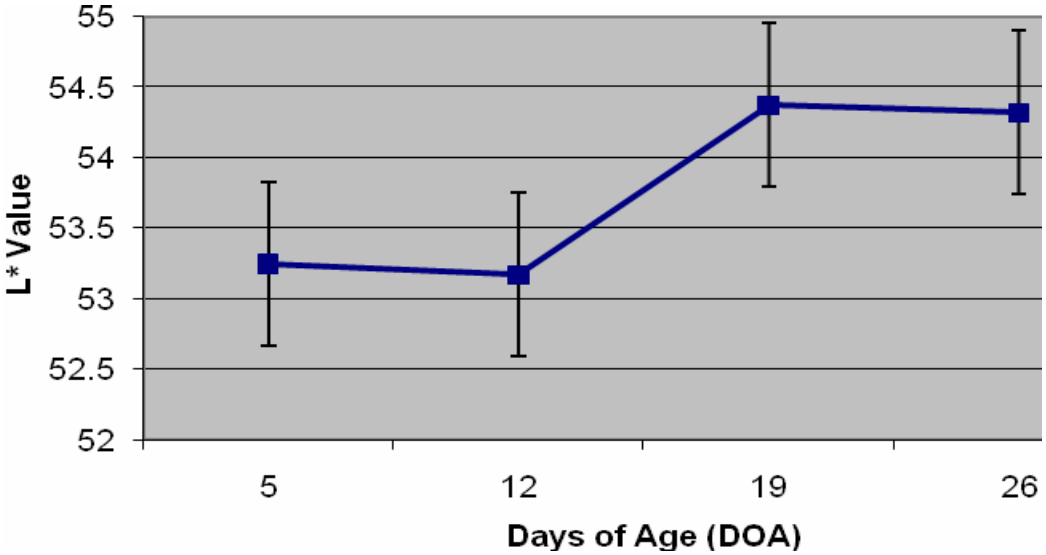

Figure 4-8. L* values change over days of postmortem aging. [1]

Note: [1] Range of 0 to 100 where 0 is absolute black and 100 is absolute white.

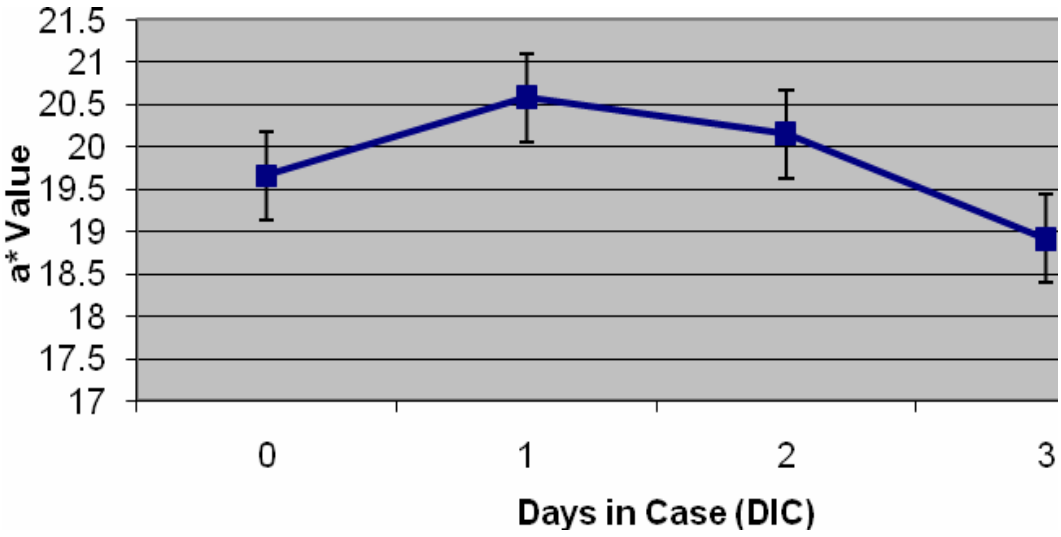

Figure 4-9. a* value change over days in retail case. [1]

Note: [1] Range -60 to 60, with positive numbers being red and negative numbers being green.

CHAPTER 5
EFFECTS OF TOTAL HEME PIGMENTS ON SHELF LIFE STABILITY

Introduction

The concentration and stability of meat pigments are of great importance to all concerned with shelf-life stability. Not only does color become important to retail outlets, but also to merchandisers of meat products. Color stability and acceptability is not only important in the retail sector, but also for food service and institutional industries. According to Hornsey (1956), the assessment of the depth and stability of color which is determined visually and comparisons made at the same time by an expert can provide useful information. However, in order to determine the factors affecting the cause of fading, an objective measurement becomes necessary. The rate of fading meat pigments can only be studied if a fairly rapid estimation is used, in which no further oxidative changes take place during the determination. Although Hornsey conducted experiments using cooked meat products, the methodology he developed can also determine the change in total heme pigment in raw meat products (Hornsey 1956).

Materials and Methods

Experimental Samples

Three of the nine muscles that were identified in the previous chapters as being the most promising from the veal chuck were further evaluated to determine how aging and total pigment content affect shelf life stability. The three muscles include the Infraspinatus, Supraspinatus and the Triceps brachii. These three muscles were selected due to their adequate performance in the sensory and shelf life stability portion of the study.

Aging and Display

Each muscle was randomly assigned to one of four aging periods based on the carcass in which they originated (Table 4-1). After completion of the predetermined aging period, samples

were collected from each of the three muscles to be used as a pre-display hematin sample. The remaining portion of the muscle was placed in a retail display case for three days of display (single tiered flat cases at 7 ± 2° C, with fluorescent lighting of 85 foot candles). After three days of display, muscles were removed from the retail display case and a sample was taken to be used as an ending hematin sample. The samples were packaged in individual sample bags and frozen at -40 ± 2°C until pigment extraction was conducted.

Total Pigment and Heme Iron Procedure

The procedure used was developed by Hornsey (1956) to rapidly extract pigments from cooked cured pork. Due to small samples taken, the procedure was adapted to fit the needs of our project where sample sizes were smaller and less of each reagent was used. The extraction method uses an acetone-acid mixture that is filtered then analyzed with a spectrophotometer. The absorbance reading is then plugged into an equation to determine total pigment (ppm). Aliquots of 2.52 grams of ground sample, free of fat and connective tissue, were placed in a 20 ml homogenizing flask. 5 ml of acetone-acid mixture was added and each sample was homogenized for 30 seconds. After homogenization an additional 5 ml of the acetone-acid mixture was added and samples were placed in a centrifuge for 10 minutes at 2200g. Samples were then filtered and absorbance measurements were taken at 640 nm against reagent blank. To calculate total pigment (Hematin ppm) the absorbance was multiplied by 680 and divided by the sample weight.

Statistical Analysis

Statistical analysis was conducted using the SAS proc mixed procedure. Hematin content for each muscle was the dependent variable explored, with muscle, retail display period and aging period used as independent variables.

Summary of Results and Discussion

Muscle type had an overall effect on total pigments ($P < .05$). Comparing each muscle, the heme pigment content of the Supraspinatus was statistically higher than that of the Infraspinatus and the Triceps brachii ($P<.05$), but the Infraspinatus and the Triceps brachii were similar in hematin content ($P>.05$).

When analyzed by muscle type, the total pigments within each muscle were not significantly different ($P>.05$) after three days of retail display. The amount of total pigments in the samples remained the same after three days of retail display which leads to the conclusion that three days of retail display has no effect on pigment concentration (pigment not purged out).

The only muscle affected by days of post-mortem aging on hematin content was the Infraspinatus. Hematin content was affected between the five and twelve day aging periods with a significant increase ($P<.05$) in total pigments between the first two aging periods. The hematin content of the other two muscles was not affected by days of post-mortem aging.

Conclusion

Although this study did not present a technique useful in determining shelf life stability of muscles from the veal chuck, the Hematin content extracted from these muscles lead to conclusions that are important to the entire study. The first conclusion that can be made is that the carcasses in the study were from a group of calves that were fed a similar diet. According to Miltenburg et al (1992), different levels of dietary iron can affect the amount of total muscle heme pigment. The similarities found among the hematin content of thes muscles from each animal show that the animals were fed similar levels of dietary iron. The total pigment content measured also leads to the conclusion that decreases or increases in hematin have no effect on shelf life stability of the three muscles presented. Although no other research was found that compared hematin content with shelf life stability of fresh veal, the research presented above

concludes that no definitive determination of shelf life stability can be obtained by measuring of total pigments in fresh veal.

CHAPTER 6
CORRELATION BETWEEN MUSCLE COLOR, CARCASS MEASURED COLOR AND TENDERNESS

Introduction

Veal is offered for sale to consumers at generally higher prices than other protein sources. Boleman et al. (1995) demonstrated that consumers are willing to pay for tenderness, and there is a strong correlation between price and tenderness among cuts of beef. The veal industry is similar in a way that prices usually reflect product tenderness as well as consumer acceptability of color. In the beef industry, marbling score is currently used to segregate and price beef carcasses, and has been shown to be related to beef palatability when examined across a wide range of marbling levels (Smith et al., 1984). However, in the veal industry, two different factors are used to grade carcasses. Lean color and degree of feathering and flank fat streaking, instead of marbling scores and maturity scores are used to complete the grading standard for veal carcasses. For beef, there seems to be a relationship between ultimate muscle pH and(or) muscle color and meat tenderness (Purchas, 1990; Jeremiah et al., 1991; Watanabe et al., 1996). This portion of the study was conducted to determine whether objective measures of flank color and Longissimus dorsi color could be used to segregate veal carcasses into merchandising groups (USDA grades), as well as correlating individual muscle color to expected eating satisfaction.

Materials and Methods

Eighteen veal carcasses with USDA Choice quality grade and known slaughter date were randomly selected at two separate commercial veal processors. Before chucks were removed, objective color measurements were taken from the carcass Rectus abdominus (flank area) and longissimus dorsi muscle at the tenth rib from each carcass using using a Minolta CR-310 Chroma meter at 48 hours post-mortem. Veal chucks were taken directly from the fabrication lines at the respective processing plant and then dissected by a professional de-boner to obtain

the following muscles: Complexus (COM), Deep Pectoral (DEP), Infraspinatus (INF), Serratus Ventralis (SEV), Supraspinatus (SUP), and Triceps Brachii (TRB). The muscles were allowed to bloom for 15 minutes and color measurements were taken using a Minolta CR-310 Chroma meter. After color measurements were obtained, each muscle was cut in half to be divided between the University of Florida and the University of Nebraska for further evaluation. Each muscle was vacuum packaged using a roll stock packager and boxed for shipment.

The portion of muscle that was shipped to the University of Nebraska was assigned to an aging regimen where it was stored for one of five aging periods at 3.8 ± 2º C. The aging periods were three, five, ten, seventeen and twenty four days postmortem. After the aging period, the muscles were cooked, cored and sheared according to AMSA (1995) guidelines, and Warner-Bratzler shear force values for each muscle were obtained.

After the data was gathered, shear force values were correlated with flank and longissimus color scores using Pearsons square method to find the relationship between objective color measurements and Warner-Bratzler shear force values. The comparisons were made based upon carcass color measurements as well as color measurements for each individual muscle used in the study.

Summary of Results and Discussion

For individual muscles from the veal chuck, it was found that objective color measurements alone were not sufficient to predict tenderness. For all muscles, excluding the Infraspintaus, b* values had the highest correlation to Warner Bratzler shear force values but the correlation coefficients were low (r values range from -.05 to -.48). Supported by a similar study conducted by Wulf et. al. (1996) where color measurements were used in beef to predict tenderness, it was also found that b* values had the highest correlation with tenderness (R^2 = -.38).

Correlation of carcass color measurements to Warner Bratzler Shear Force values, L* a* b* values showed higher correlation to tenderness than color measurements from individual muscles, but it is not possible to identify one value that correlates color and tenderness. These objective color measurements were more often closely related to muscles from the three and five day aging periods than those of the other three longer aging periods.

Conclusion

This data identified no one color attribute that significantly related to shear values of the muscles from the veal chuck evaluated in this study. Color measurement from the carcass was not related to shear force values of the veal chuck. Although identifying a certain attribute that affects tenderness would be a huge advancement, the measurements obtained in this study were not statistically strong enough to make a definite decision in relating color to tenderness.

CHAPTER 7
OVERALL CONCLUSIONS AND IMPLICATIONS

Preliminary Evaluation of Nine Muscles

Weights and Dimensions

Upon proposal of this study, the chance of finding muscles too small for evaluation was of concern because of the carcass sizes and weights. After dissection of the nine muscles presented in chapter three, it was determined that eight out of the nine muscles removed were of useable size and weight. The only muscle of concern was the Teres major, which was small and did not represent a substantial percentage of carcass weight. The concerns that this muscle would not be feasible to remove grew because dissection of the muscle is tedious and the room for error was small. Although small and difficult to dissect, the positive palatability attributes of this muscle may create value that out weighs the cost of extraction (Table 3-2).

Industry Evaluation

Table 3-3 gives some applicable cooking methods that worked well for each muscle and also gives some insight on the types of further processing that was suggested by the chefs to further enhance the products. It should be noted that the sensory data that was obtained supports the amount of further processing needed for each individual muscle. The most tender muscles (Infraspinatus, Teres major, Complexus) will require minimal processing while the toughest muscles (Splenius, Serratus ventralis, Rhomboideus) will require a more aggressive tenderization method to improve tenderness to a level more acceptable to foodservice. Similar to studies completed on muscles from the beef chuck, some muscles may require more time and expense to create

acceptable palatability attributes, while some can be used in their original form. To fully optimize the value of the less tender muscles, further processing may be needed.

Sensory Evaluation

Sensory evaluation revealed the most-tender muscle of the veal chuck was the Infraspinatus. On a scale of 1-8 with 1 being extremely tough and 8 being extremely tender, the Infraspinatus was evaluated at 6.9 or moderately tender. The Teres Major was found to be not significantly different ($P > .05$) from the Infraspinatus with a tenderness score of 6.8. The toughest muscle in the study was found to be the Rhomboideus which was evaluated at 5.8 on the same 1-8 scale. The Rhomboideus was significantly lower ($P > .05$) in tenderness from all other muscles in the study (Table 3-4).

Table 3-5 depicts the sensory evaluation data for the juiciness of veal muscles. On a scale from 1-8 with 8 being extremely juicy and 1 being extremely dry, it was determined that the Complexus was the juiciest muscle with a sensory evaluation score of 6.5 or moderately juicy. The Supraspinatus was found to be not significantly different ($P > .05$) with a score of 6.3. The driest muscle in the study was found to be the Triceps Brachii with an evaluation score of 5.8. It was discovered that the Infraspinatus and the Splenius were not significantly different ($P > .05$) from the Triceps brachii with scores of 5.9 and 5.8, respectively.

On a scale from 1-8 with 1 being extremely bland and 8 being extremely intense, the Supraspinatus had the most intense beef flavor with a sensory score of 5.1. The Complexus was not significantly different ($P > .05$) with a score of 5.0 or slightly intense. The blandest muscle of the study was the Splenius with a score of 4.0 with no significant difference ($P > .05$) from the Infraspinatus or the Splenius with evaluation scores of 4.5

and 4.3, respectively. Most of these muscles were found to be slightly bland when evaluated for beef flavor (Table 3-6).

Table 3-7 depicts the amount of connective tissue evaluated in each muscle of the study. It should be noted that large visible seams of insoluble connective tissue were removed from the Infraspinatus after dissection and from the Triceps brachii after cooking. On a scale of 1-8 with 8 being no connective tissue detected and 1 being an abundant amount of connective tissue present, the Infraspinatus was found to have the least amount of connective tissue present with a sensory score of 7.3. The Teres major was not significantly different ($P > .05$) from the Infraspinatus or the Triceps brachii with an evaluation score of 7.2. The muscle with the most connective tissue present was the Rhomboideus with a score of 5.8 which was significantly different ($P > .05$) from all other muscles in the study.

Upon completion of sensory evaluation of muscles, no extreme off-flavors were found in any muscle. The off-flavors that appeared most frequently included milky, metallic and grassy. The muscle with the least amount of off-flavor detected on a scale of 1-6 with 1 being extreme off-flavor and 6 being no off-flavor detected was the Triceps Brachii with a sensory score of 5.8. This score was found to be not significantly different ($P > .05$) from the Rhomboideus, Complexus, Splenius, Supraspinatus, Deep pectoral and Serratus ventralis. The muscle with the most extreme off-flavor was the Teres major with a score of 5.5, which was not significantly different from the Deep pectoral, Serratus ventralis or the Infraspinatus (Table 3-8).

After completion of the first phase of the study, it was determined that further evaluation of the muscles was needed. To reduce costs and fully explore the most

promising muscles, six of the nine muscles were selected for the second phase of the study. These muscles were determined to be the most desirable for palatability attributes and tenderness.

Further Evaluation of Six Muscles

Retail Display

For further evaluation, a retail display of the six muscles identified by phase one of the study was conducted. It was found that when placed in a three day retail trial the six muscles in this study behaved the same for overall appearance, subjective color and muscle purge. Post-mortem aging had no significant effect on overall appearance or subjective color evaluation for the six muscles. Muscle discoloration of the Deep Pectoral, Infraspinatus, and Triceps brachii was not effected by post-mortem aging, nor did post-mortem aging have an effect on overall appearance for the three day retail display period for these muscles. However post-mortem aging had a significant effect on objective color values (L*, a*, b*). The greatest impact of post-mortem aging on objective color (L*, a*, b*) values was observed between the five and twelve day post-mortem aging periods. Between these two aging periods the muscles became darker, redder and more yellow. The muscles then retained this color throughout the remaining aging periods (up to 26 days of age). Although there was a significant effect of post-mortem aging on objective color, the overall impact on veal muscle characteristics was small.

Total Pigment

In hopes of finding a way of determining the integrity of muscle color during retail display, three muscles were sampled to determine if the change in color pigments had an effect on retail display acceptability. It was found that muscle type had an overall effect

on total pigments (P<.05). Comparing each muscle, the heme pigment content of the Supraspinatus was statistically different from the Infraspinatus and the Triceps brachii (P<.05), but the Infraspinatus and the Triceps brachii were similar in hematin content (P>.05). When broken down individually, the total pigments within each muscle were not significantly different (P>.05) after three days of retail display. The amount of total pigments in the samples remained the same after three days of retail display which leads to the conclusion that total pigment change during retail display has no effect on shelf-life stability for these three muscles. The only muscle affected by days of post-mortem aging was the Infraspinatus. Hematin content was affected between the five and twelve day aging periods with a significant increase (P<.05) in total pigments between the first two aging periods. The hematin content of the other two muscles was not affected by days of post-mortem aging.

Although this study did not produce conclusions useful for determining retail shelf life stability, the Hematin content extracted from these muscles lead to conclusions that are important to the entire study. The first conclusion that can be made is that the carcasses in the study were from a group of calves that were fed a similar diet. According to Miltenburg et al (1992), different levels of dietary iron can affect the amount of total muscle heme pigment. The similarities found among the hematin content of thes muscles from each animal show that the animals were fed similar levels of dietary iron. The total pigment content measured also leads to the conclusion that decreases or increases in hematin have no effect on shelf life stability of the three muscles presented. Although no other research was found that compared hematin content with shelf life stability of fresh

veal, the research presented above concludes that no definitive determination of shelf life stability can be obtained by measuring of total pigments in fresh veal.

Carcass Color and Tenderness

In industry today, the cost of labor is sky rocketing. To reduce the amount of man hours used in production of meat products, industry is continuously looking for ways to use instruments for grading and carcass selection. In this section of the study, the process of using instrumental color measurements for carcass grading was explored. It was found that carcass color measurements and tenderness were not highly correlated, L* a* b* values were more closely related to tenderness than color measurements from individual muscles, but it was not possible to identify one value that that was highly correlated to tenderness. The objective color measurements were more often closely related to muscles from the three and five day aging periods than those of the other three longer aging periods.

When analyzing the data, no one color attribute was determined to have relationship to tenderness of the muscles from the veal chuck. The data showed that the color measurement that correlates carcass color to tenderness differed for each muscle. In some cases the L* value taken from the flank area was the most correlated with tenderness and other times the a* value taken from the Longissimus muscle was most correlated. Although identifying a certain attribute that affects tenderness would be a huge advancement, the measurements obtained in this study are not statistically strong enough to make a definite decision in relating carcass color measurements in the flank or Longissimus muscle to tenderness.

Value Optimization

Upon completing an evaluation of six muscles from the veal chuck it is evident that the chance for adding value to the veal chuck is prominent. Although complete dissection of these muscles is tedious and somewhat time consuming, industry leaders can take this information and use it as a way to further add value to their product. The main purpose of this project was achieved as the research found muscles that were acceptable and useable and could be a great starting point to merchandising the veal chuck in a way that would be more profitable to the veal industry. Recent work, identical to the work presented here, has been conducted by the University of Florida and the University of Nebraska for over a decade. In an effort to add value to the beef carcass, it was found that to bring attention to the potential use of under-utilized muscles, it must be presented to leaders in the industry both on the supply and retail sides of the business. Evaluation of 39 muscles from the beef chuck and round found a few muscles that offered a more acceptable product at a value price. One of the most impressive and successful steaks found in prior research is the "Flat Iron Steak", in which over 92 million pounds were sold in the U.S. in 2006 (Calkins and Sullivan, 2007). These numbers show that the muscle profiling and value optimization research is useful and successful (Calkins and Sullivan, 2007). For the veal industry to be successful in using this information, industry leaders must take the initiative to further process and de-bone their product. The recent success in the beef industry can be paralleled in the veal industry by simply using more innovative fabrication methods and producing products that consumers demand and are willing to pay for.

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BIOGRAPHICAL SKETCH

Brian Sapp was born in the small town of Avon Park, Florida in 1983. Growing up in the small town of Lake Placid, Florida, Brian learned many things about hard work and life. Working through the years on a flower bulb farm, Brian learned the importance of hard work and dedication, as well as the importance of an education. While attending Lake Placid High School, Brian worked his summers as a welder, fiberglass repairer, caladium bulb farmer and mechanic. Upon graduating in May of 2001, Brian continued his education by attending South Florida Community College, where he would earn his AA degree in May of 2004. Growing up a Gators fan, Brian's ultimate dream was to attend the University of Florida which he achieved in August of 2004. Moving to Gainesville, Florida was a huge change of pace for Brian, but the big city was not too much to keep him from achieving Cum Laude Status upon graduating with his B.S. degree in food and resource economics in May of 2006.

While attending the University of Florida, Brian was a member of the 2005 - 2006 Meat Animal Evaluation Team as well as an active member in the University of Florida Block and Bridle Club where he served as Treasurer for the 2005 - 2006 school years. To spend some free time wisely, Brian took a part time job at the University of Florida Meats Processing Facility, where he would find his passion for processing animals and cutting meat. Upon graduating in 2006, Brian was offered a position as a graduate student in the animal science department at the University of Florida. Knowing that his education was important, Brian took the position in hopes of learning more about meats and meat processing. While attending graduate school, Brian served as a teaching assistant for various meat processing and evaluation classes and also helped coach the 2007 and 2008 meat animal evaluation teams. Upon graduation in August of 2008, Brian will move to

Southwest Georgia to take a position as a meat processing plant manager, in hopes of furthering his education in the real world.