METHODS TO COUNTERACT THE ECONOMICALLY CRITICAL ANTI-QUALITY MEAT CHARACTERISTICS IMPOSED WHEN FEEDING WET DISTILLERS GRAINS TO FINISHING CATTLE

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2008

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May 2010

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ACKNOWLEDGMENTS

I would like to begin by thanking my major professor, Dr. Gretchen Hilton, for giving me the opportunity to stay on at Oklahoma State University and utilize her guidance, support, and friendship throughout the completion of the program. Not only did she give me the opportunity to help with the 2009 Meat Animal Evaluation Team but it is her enthusiasm, competitive drive, and shear passion for the meat industry that she instilled in me, and which truly excites me about being a part of the industry and its betterment in the future. I would like to also thank Dr. Deb VanOverbeke, Dr. Chris Richards, and Dr. J. Brad Morgan for serving on my committee. Not only did Dr. VanOverbeke and Dr. Richards serve as mentors on my project and aided in the statistical analysis, but I also appreciate the project they gave me, in which I had the opportunity to utilize my production background on the live side, as well as my new knowledge in the industry for the meat portion. I express sincere gratitude to Dr. Morgan for his friendship and strong industry ties. His honest support and devotion to future success has given me the opportunity to launch my career at National Beef, Inc., and I greatly appreciate him for that.

Next, I would like to thank my fellow graduate students for the help and support they have given me throughout this strenuous process. Whether it was long trips to Dodge City, KS, cutting and packaging hundreds of samples, multiple weeks of color scoring, TBARS in the lab, or simply a little guidance through SAS and table building, I always knew that someone would be willing to help, thank you so much for that. Also the project may still not be complete if it weren't for the help of Kris Novotny and her lab

assistants. Her guidance through lab procedures and their data entry made the experience much more pleasant.

I must thank my parents, Rick and Terri, and my siblings Tracy, Kevin, Jeffrey, and brother-in-law, Casey, for their continuous support and understanding throughout my college career. Mom and Dad, words can truly not explain the amount of gratitude I have for both the mental and physical guidance you have provided me throughout my rollercoaster ride of life, no matter whether you question my sporadic decision making or not. Tracy, Casey, Kevin, and Jeff, the love and support (which may sometimes be due to our competitiveness) that we provide for each other is not only what has allowed us to be so successful and happy in our lives, but the fact that distance separation can never sever our close relationship is truly a blessing. I would like to thank my best friend, Shannon, for her emotional support throughout the last couple of years, as well as all my other family and close friends who have been a part of this wonderful adventure.

Lastly, I would like to thank my collegiate judging coaches for giving me the opportunity to attend strong agriculture schools and be a part of programs which have helped build the confident and successful person I have become. I don't think I would be where I am today without each person and experience I have been blessed with, thank you all!

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CHAPTER I

INTRODUCTION

The beef industry continues the battle to provide consistent and competitive product. For this reason researchers continue to find ways to produce cattle as economical as possible, while increasing the quality of the product once it makes it to retail cases. The largest factor affecting the beef markets at retail is the amount of product loss due to meat discoloration. A majority of steaks placed in a retail display case are sold before they need to be discounted (Zerby et al., 1999). At the point in which beef products begin to darken, a retailer is forced to do one of three things: 1) discount or mark down the price of the product, 2) convert the product to a new product of lesser value (ex. grinding to hamburger) or 3) discard the product at a 100% loss (Westcott et al., 1997). It has been noticed that once a steak in retail has reached over 10% discoloration it is discounted. Thus, retailers may be more interested in how many hours of acceptable retail display they can gain before 10% of the products in a display case begin to discolor, rather than when the average of all the cuts in the display case is unacceptable (Zerby et al., 1999).

With this in mind, researchers continue to search for ways to increase color stability in lean. Arnold et al. (1992) conducted a study that determined alpha-tocopherol (vitamin E) is effective in extending the color stability of displayed beef. Continual research was conducted, and it was determined that supplementation of 500 IU/hd/d of vitamin E per animal daily for 126 d is sufficient to obtain the color-stabilizing effect of

vitamin E for beef aged 14 d in retail (Liu et al., 1995). This concludes that vitamin E supplementation of beef cattle diets is an effective procedure for enhancing the lipid and color stability of meat products subsequently obtained from animals (Faustman et al., 1998). Today, alpha-tocopherol is supplemented in cattle diets to increase shelf life of meat products.

Although increasing shelf life of the product is extremely important, raising the animal economically, to aid the industry in larger profit returns, is of equal importance. Along with this, economical trends have indicated a larger need for ethanol production to take the burden off of high gas prices for consumers. With a drastic increase in ethanol production and ethanol plants across the nation, corn consumption is greatly impacted. It is estimated that in 2014/15, 23% of the corn produced will go to the production of ethanol (Baker and Zahniser, 2006), and with this use, a by-product, distiller's grains, that is also effective as a feedstuff for producers. Further research concluded that the inclusion of distiller's grains in finishing diets results in higher final body weights, average daily gain, and heavier hot carcass weights (Vander Pol et al., 2006), but can also increase the amount of polyunsaturated fatty acids in the meat resulting in greater lipid oxidation; the chemical change that causes the brown color or metmyoglobin formation in beef (Gill et al., 2008). So, although it may be more economical to feed distiller's grains in finishing diets, it is pertinent to find a way to increase the quality of the final product.

Therefore, the objectives of this study were to determine the impacts of pre-harvest anti-oxidant supplementation on carcass yield and quality grade factors, as well

as the impact of pre and post-harvest management on color stability and consumer acceptability of steaks and ground beef from cattle fed wet distiller's grains.

CHAPTER II

REVIEW OF LITERATURE

MEAT QUALITY: Consumer and Color

Understanding that the average consumer (in 2007) spends $247 annually on both retail and foodservice beef, and over 20% of beef purchased annually is directly from the retail case (beefboard.org), is pertinent in emphasizing the importance of the shelf life of beef products to the industry as a whole. Kropf (1980) explains, in his discussion on Retail Display Conditions on Meat Color, "Color is probably the single greatest appearance factor that determines whether or not a meat cut will be purchased." The bright cherry red color in meat is one of the most important quality attributes influencing consumer's decision to purchase, and extending this time should increase retail stability (Gatellier et al., 2001). Therefore, researchers continue to look into the factors that affect color of beef in retail, such as lighting, temperature, packaging, as well as differences that come directly from the age, sex, breed, and specific muscle cut of the animal.

Display lighting effects could result from: 1) temperature elevation at the meat surface, 2) photochemical effect, and/or 3) differences in light rendition because of different spectral energy distribution patterns (Kropf et al., 1980). Santamaria (1970) demonstrated a temperature elevation of about 7 and 6ºC, at the meat surface; and it has been dually noted that warmer temperature at the muscle surface has

the potential to encourage more rapid discoloration (Kropf et al., 1980). These studies do not include the fluctuation of retail cases due to body heat. In the case of light type and the effect it has on the color rendition of the beef, Fry (1972) found that brighter lean color was found under incandescent light for the first couple of days, but less desirable color was noted after 7 d of display for all light sources used in the study.

In terms of meat storage in the retail case, it was deduced that low storage temperature depressed enzyme activity, minimized color changes, inhibited oxidation and reduced desiccation and drip (Ramsbottom and Koonz, 1941). It is for these reasons that meat retailers want to retard oxidation in meat and keep the myoglobin from turning into metmyoglobin, which, in turn, creates the brown color of the meat. To further emphasize the importance of low temperature stability in a retail case, Snyder and Ayres (1961) report that doubling the rates by increasing the temperature from 0 to 4ºC has a profound effect on oxidative reaction rates.

PACKAGING: Meat Retail

Packaging of products can also have a large impact on case stability. The primary function of a meat package is to present the product to the customer in the most attractive manner possible and at the same time protect the product from physical damage, microbial deterioration and chemical change (Mills and Urbin, 1960). Results from studies comparing packaging films are largely affected by gas and moisture permeability (Kropf, 1980). Multiple authors (Kropf, 1971, Sandberg, 1970; Doordan et al., 1969, Sacharow 1974) recommend that meat be stored in oxygen permeable film that will allow meat to maintain its bright cherry red color, whether being sold fresh or frozen.

Another method of preserving the product at retail is vacuum packaging. Dean and Ball (1958) advocated the marketing of red meat in vacuum packages, although they were concerned about the color darkening with a slow return to a brighter color (blooming). When meat is vacuum packaged, the oxygen molecule is removed from the porphorin ring, bringing it back to deoxymyoglobin and ultimately changing the color back to a purplish-red. It is believed that retail of red meat in this purple-red condition requires consumer education and promotion (Kropf, 1980). Grobbel et al. (2008) found that vacuum-packaged steaks were the most consistent in display color throughout 7 d of display and only changed from bright purplish-red or pink to dull purplish-red or pink for the entire display period, however, many consumers found the purplish-red color of vacuum packaged meat undesirable regardless of the consistent color display. This explains why other means of packaging are continuously considered.

One approach to extend the shelf life of meat is to use modified atmosphere packaging (MAP) (Renerre, 2000). There are several advantages of MAP, including the use of a centralized location, improved quality control of sanitation, more consistent products and increased marketing flexibility (Jeyamkondan et al., 2000; Kropf, 2004). High oxygen pressure significantly retards the undesirable formation of metmyoglobin (Gatellier et al., 2001) resulting in a bright desirable red color (Behrends et al., 2003; Seyfert et al., 2005). Unfortunately, this high oxygen level can promote oxidation particularly of lipids as membrane phospholipids are particularly susceptible to oxidation process, which cause the rapid development of meat rancidity (Gatellier et al., 2001).

MEAT COLOR: Muscle Pigment and Oxidation

The most important sensory property by which consumers judge meat quality is product appearance because it strongly influences the consumer's purchase decision (Faustman and Cassens, 1990). A bright cherry red color is important in retail sales of fresh beef (Hood and Riordan, 1973), and the stability of pigments in meat is highly variable and is governed by a variety of factors (Faustman and Cassens, 1990). The color of meat depends on many factors, such as: concentration of haeminic pigments and particularly of myoglobin, the physical characteristics of the meat, essentially pH, and the chemical state of these pigments (Gatellier et al., 2001). When the pH of the carcass falls in different ranges, the color of the meat can be drastically affected. Meat that has a pH of approximately 5.3-5.7 will be bright cherry red in color; meat that remains at a pH of 6.0-6.5, will be dark in color (dark cutter). Differences in color because of pH can cause the carcass to be discounted before it reaches the fabrication floor.

The two main pigments in meat are hemoglobin and myoglobin. Hemoglobin is a large molecule located in blood that remains a purple color until exposed to oxygen; oxygen causes the color to change to red (Westcott, 1997). The main heme protein responsible for meat color is myoglobin (Faustman and Cassens, 1990), a protein that reacts differently under the ferrous or ferric chemical states. The heme prosthetic group of myoglobin is composed of an iron atom which is bound within a protoporphorin ring by four of the iron atom's six coordination sites (Lehninger, 1982). These heme porphorin rings have five occupied binding sites and one free binding site; the molecule that binds to the sixth binding site, changes the chemical make-up and the color aspect of the meat. Ferrous heme iron which lacks a sixth ligand is called deoxymyoglobin (Faustman and Cassens, 1990) and appears purplish-red in color. Once exposed to air

myoglobin combines with oxygen to form bright red oxymyoglobin which is thought to indicate freshness (or blooming) and considered attractive to the consumer (Gatellier et al., 2001). With time, discoloration results from conversion of oxymyoglobin to metmyoglobin which is brown and unattractive (Renerre, 1990). This change in color occurs due to oxymyoglobin oxidizing which converts the heme iron to the ferric state in which a water molecule takes the place of the oxygen molecule. The muscle myoglobin content of meat-producing animals increases with increased red fiber content, and with increased animal age (Lawrie, 1985). Any other increase in discoloration of the meat, turning to a darker brown or green, can be due to further oxidation or chemical change of the lean.

OXIDATION: Processes in Meat

Oxidation in meat occurs when the heme protein, oxymyoglobin, is subjected to oxygen for an extended period of time, ultimately changing the chemical structure to undesired proteins such as metmyoglobin or choleglobin (when a hydrogen peroxide molecule takes the place of the water molecule, making the meat green in color). There are many catalysts for oxidation which ultimately affect the case life of a product, some examples are: diet, retail case temperature, pH, packaging types, and microorganisms (Westcott, 1997). Oxidation of polyunsaturated fatty acids not only causes the rapid development of meat rancidity, but also affects the color, the nutritional quality and the texture of beef (Kanner, 1994). Due to oxidation's negative economic impact on meat quality, research to reduce or prevent oxidation is continuous.

DISTILLER'S GRAINS: Industry, Feedlot Performance, and Meat Quality

The production of ethanol in the U.S. has increased drastically due to the high demand for alternative fuel sources. The estimated amount of ethanol in 2010, is close to 7 billion gallons, 3.3 billion gallons more than produced in 2005; indicating that over 23% of the corn produced will go to ethanol production (Baker and Zahniser, 2006), creating an abundance of distiller's grain by-products. Stock et al. (2000) stated that, "Distiller's grains, the by-products of dry milling processes, offer a low cost and effective protein energy source that is currently used in feedlot rations." This, combined with consumer preference for wholesome, high quality beef being the focal point of the beef industry, indicates that it is imperative we gain knowledge on the effect of feeding distiller's grains on beef quality and sensory traits (Roeber et al., 2005). Therefore, studies began in 2002, to determine the impact that feeding distiller's grains may have on livestock production. It was previously reported that replacement of 40% of dry-rolled corn with wet corn distiller's grain increased average daily gain and feed efficiency relative to steers fed dry-rolled corn only (Larsen et al., 1993). These experiments suggest wet corn distiller's grain contains approximately 40% more energy for grain than dry-rolled corn (Al-Suwaiegh et al., 2002). So, trials were conducted to determine the impact distiller's grains have on feedlot performance of steers and short term lactation performance on dairy cows.

Focusing on the meat animal trial, 60 red angus steers were fed corn based diets supplemented with wet corn or sorghum DG and Rumensin (to decrease the chance of acidosis). The average dry matter intake of cattle fed the corn based control diets and diets containing wet distiller's grains were similar, complementing the previous reports in which the inclusion level of wet distiller's grains was between 25 and 50% (Firkins et al.,

1985; Ham et al., 1994). Compared with steers fed the control diet, steers fed diets containing wet distiller's grain gained 10.1% faster ($P < 0.01$) and were 8.5% more efficient ($P < 0.01$) (Al-Suwaiegh et al., 2002). Carcasses of cattle fed the distiller's grains included heavier hot carcass weights and higher yielding carcasses without sacrificing the ribeye size or quality grade. The conclusion of this trial indicated that the replacement of dry rolled corn with distiller's grains improved feed efficiency and carcass potential, indicating the importance for further research in this field.

Due to the growing interest in processing corn for ethanol production and the increased production of distiller's grains, Roeber et al. (2005) conducted a study on the effects of feeding dry or wet distiller's grains to Holstein steers to find its effects on meat quality and sensory attributes. Strip loins were collected and put into overwrapped, styrofoam trays and placed under 807 to 1614 lux deluxe warm-white fluorescent lights to mimic retail display. Steaks were then monitored at 6 h intervals initially, and then 12 h intervals both subjectively and objectively. Some steaks were put through a Warner-Bratzler shear force test to determine tenderness, and the remainders were used in a sensory trial where they were evaluated for their tenderness, juiciness, and flavor. Results of this study indicated that including distiller's grains in cattle finishing diets at high (40 to 50% of dietary dry matter) inclusion rates may have a negative effect on color stability of strip loins during retail display (Roeber et al., 2005). Conversely, distiller's grains could be included in the finishing diets of steers at a low to moderate inclusion level (10 to 25% of dietary dry matter) to maintain, or even enhance, shelf life of steaks in the retail case, without affecting cooked beef palatability (Roeber et al., 2005).

Understanding that feeding distiller's grain will increase feedlot performance, it is important to know what inclusion levels (on a dry matter basis) will impact feed efficiency without hindering input costs. Vander Pol et al. (2006) conducted a trial on 360 large framed steers to determine how the inclusion levels of 30% wet distiller's grains would affect cattle on 6 different corn diets, which were: whole corn (WCO), dry rolled corn (DRC), dry rolled/high moisture corn fed at a 1:1 ratio dry matter basis (DRC:HMC), high moisture corn (HMC), steam-flaked corn (SFC), and fine-ground corn (Vander Pol et al., 2006). Cattle whose diets consisted of DRC and 30% wet distiller's grain had higher carcass weights and calculated yield grades when compared to cattle who were on HMC and 30% wet distiller's grain, which provided better feed conversions and higher marbling scores (Vander Pol et al., 2006). Overall, it was concluded that wet distiller's grain is an excellent feed ingredient for finishing diets, especially when combined with dry-rolled or high moisture corn (Vander Pol et al., 2006).

After these initial trials, Vander Pol et al. (2007) continued several other studies to increase the understanding of different levels of distiller's grains and their effect on different feed processing methods. The trial that compared the modified dry by-product, called Dakota Bran cake, to dry distiller's grain supported recent studies (Vander Pol et al., 2006) that show the use of distiller's grains will increase feed to gain ratios, as well as improve feedlot performance when compared to other concentrated diets alone. The trial based on different inclusion levels of the distiller's grains as well as different methods of corn processing also supported past Vander Pol et al. (2006) research, proving that not only were optimal hot carcass weights, final body weights and average daily gain seen with the dry-rolled corn supplemented with 40% wet distiller's grains, but a greater

performance response to wet distiller's grain inclusion in diet based on less intensely processed grain may render them an economically attractive alternative to diets based on more intensely processed grain (Vander Pol et al., 2007). Although the feedlot performance and hot carcass weight is enhanced by inclusion of distiller's grain, sensory attributes are slightly reduced due to increase lipid oxidation. Koger et al. (2004) found that distiller's grain supplementation increased unsaturated fat content of the diet, which can subsequently escape rumen biohydrogenation and become incorporated into the phospholipid fraction of muscle tissue, thus increasing the possibilities of lipid oxidation and subsequent off-flavors. So, Jenschke et al. (2007) completed a trial to understand how different levels of wet distiller's grains (0, 10, 20, 30, 40, 50%) affected sensory attributes. The liver-like off-flavor occurred in a quadratic pattern, where liver-like off-flavor notes were observed most frequently in the 0 and 10% wet distiller's grain diets, while steaks from animals fed with 30 and 50% wet distiller's grain diets had the lowest incidence of liver-like off-flavor (Jenschke et al., 2007). This proves that wet distiller's grain offer cattle feeders a cost-effective means to finish cattle with minimal effects on meat palatability (Jenschke et al., 2007). To add to this, a study done by Buckner et al. (2007) also supplemented distiller's grain into diets with corn concentrates to determine the optimum level of inclusion. This trial indicated that cattle fed 30% and 40% wet distiller's grains gained faster and had heavier body weights than those fed 0%, 10%, 20%, and 50%. This, along with other studies indicates that 30% to 40% inclusion of distiller's grain by-product should be considered for optimal feedlot and carcass benefits, without sacrificing any economical loss.

Gill et al. (2008) went into detail about the effect that distiller's grain supplementation, whether it be with corn based dry or wet distiller's grains or with sorghum based dry or wet distiller's grains, had on all sensory attributes. This trial indicated there was a decrease in visual color scores for cattle fed on both treatments, and it was noted that this gradual decrease in objective color evaluation was expected due to meat color deterioration caused by lipid oxidation (Gill et al., 2008). Although this study found no distinct differences in fatty acid composition or saturated fatty acids for both slaughter groups, it did show that cattle fed dry distiller's grains, from both treatment types, had higher concentrations of polyunsaturated fatty acids than those steaks from cattle fed wet distiller's grains, which may have lead to the greater lipid oxidation and discoloration (Gill et al., 2008). This supports the fact that feeding distiller's grains may have a positive impact on feed efficiency and carcass weight (Vander Pol et al., 2006), without sacrificing tenderness, juiciness, and flavor; however it can decrease shelf life due to the increase in lipid oxidation from dry distiller's grains.

It is important to note that distiller's grain supplementation can increase feedlot performance and carcass weight, while increasing in fat thickness and yield grade without hindering marbling or ribeye size. The best supplementation combination is wet distiller's grains with a combination of either dry-rolled corn or high-moisture corn. Unfortunately, some combinations can increase lipid oxidation which in turn decreases retail display time by turning the meat brown sooner, and there has yet to be research done for improvements of these implications.

VITAMIN E: A Review

Of the many ways that there are to increase shelf life of meat in retail display, one of the most important occurs antemortem; this is the inclusion of alpha-tocopherol (vitamin E) supplementation in the diet. The most biopotent vitamin E compound is d-alpha-tocopherol (Pryor, 1996). The common function that underpins the diverse application of vitamin E (alpha-tocopherol) is mainly its ability to function as an antioxidant in biological systems and play the primary role in neutralization of free radicals, thus preventing the degradation of phospholipids (McCay and King, 1980). This occurs because the chromanol ring of alpha-tocopherol is located among the polar head groups of the phospholipids, and the phytol side chain interactions in the interior of the membrane (Gomez-Fernandez et al., 1989; Kagan, 1989). This specific localization of alpha-tocopherol in the membrane and the molecule's lateral mobility allow it to function very efficiently to protect highly oxidizable polyunsaturated fatty acids from peroxidation be reactive oxygen species produced by adjacent membrane-bound enzymes (McCay and King, 1980; Gomez-Fernandez et al., 1989). Previous research, such as Buckley et al. (1989) found that 10 IU of vitamin E supplementation improved the oxidative stability of swine mitochondria and microsomal fractions. Faustman et al. (1989) found lipid oxidation decreased in fresh or frozen meat from animals that were supplemented with vitamin E; these results direct continued research on the effects that vitamin E has on beef color.

VITAMIN E: Feedlot Performance and Meat Quality

One of the primary functions of vitamin E is to maintain and protect biological membranes from oxidative damage (Rice and Kenefy, 1988). Unsaturated fatty acids in mitochondrial and microsomal membranes are thought to be the origins of free radicals

that initiate lipid oxidation (Rice and Kenefy, 1988). Higher concentrations of alpha-tocopherol in mitochondria and microcosms may provide greater protection against the initiation of oxidation that can affect the entire muscle cell (Arnold et al., 1993). Many researchers (Arnold et al., 1993; Faustman et al., 1998; Sherbeck et al., 1995) have confirmed that dietary vitamin E supplementation during cattle feeding improves objective measures of muscle color and reduces metmyoglobin formation during subsequent retail display (Ahola et al., 2008). As a lipid soluble vitamin, alpha-tocopherol partitions into biomembranes and as its concentration increases with dietary supplementation, so does the protection of membranal unsaturated fatty acids against oxidation (Liu et al., 1995). The standard form of vitamin E for supplementation in a beef feedyard is dl (racemic) alpha-tocopherol acetate (Liu et al., 1995).

Arnold et al. (1992) conducted the first of his multiple trials to determine whether vitamin E supplementation is effective in Holstein and crossbred steers for improving feedlot performance, carcass characteristics, and meat color stability during display. Three different experiments were conducted supplementing cattle being fed high concentrate diets, with different levels of vitamin E. The level of vitamin E in these trials ranged from 300 IU/hd/d for 266 d, to 1,200 IU/hd/d for 36 d. The different intake and day ratios had different effects on shelf life extension. The cattle that were fed lower levels for longer periods of time had retail shelf life extension of 2.5 d, whereas cattle that were fed high amounts of vitamin E for a short period of time were able to extend shelf life up to 4.8 d (Arnold et al., 1992). These experiments provided initial evidence of the potential usefulness of providing cattle with supra-requirement levels of vitamin E to enhance the retail product (Arnold et al., 1992).

After it was officially established that supplementing diets of feedlot steers with vitamin E has been effective in extending the stability of color and lipids in displayed fresh meat from Holstein or crossbred beef steers for several days (Faustman et al., 1989; Arnold et al., 1992), Arnold decided to extend research on the actual length of time vitamin E should be supplemented, as well as shelf life extension and how vitamin E works on the subcellular components of beef. Six different levels of supplementation were given to Holstein steers: 0 IU/hd/d, 2000 IU/hd/d, 5.8 IU/hd/d, 8.6 IU/hd/d, 5.6 IU/hd/d for 126 d and then none through 266 d, or none for 126 d and 8.6 IU/hd/d through 266 d. Arnold et al. (1993) deducted from this study that the critical concentration of alpha-tocopherol that was necessary to achieve maximum protection against oxidation in retail-displayed *longissimus lumborum* that was aged for 7 d after slaughter was approximately 3.3 ug/g, which meant supplementing the animal 1,840 IU/hd/d for 3 mo. In general, the greater the amount of vitamin E fed and(or) the longer the supplementation, the higher the tissue concentration of alpha-tocopherol (Arnold et al., 1993).

Due to the focus of vitamin E supplementation effects on the *longissimus lumborum*, Chan et al. (1996) decided to research its affect on multiple muscles. Reports, such as O'Keeffe and Hood (1982) stated that the color stability of beef muscles followed the order of *longissimus*, *gluteus*, and *psoas* and that the differences are due primarily to differences in oxygen consumption rate and indicated that color stability is muscle dependant. In this, Chan et al. (1996) found that whole muscle discoloration started with the *psoas*, then the *gluteus*, and finally the *longissimus lumborum*. These results compare closely to those of Arnold et al. (1993) that indicated that the *gluteus* will discolor faster

than the *longissimus*. In all, the vitamin E supplementation increased the oxymyoglobin stability, color stability, and visual acceptance by panelist without affecting microbial load (Chan et al., 1996).

To date, studies concerned with vitamin E supplementation to improve meat quality have focused on lipid oxidation, color stability, and moisture retention (Faustman et al., 1998). The bright red appearance of beef is due to oxymyoglobin, a ferrous heme pigment that oxidizes to brown metmyoglobin (Faustman et al., 1998). The rate of oxymyoglobin oxidation is dependant of a variety of factors (Faustman and Cassens, 1990; Renerre, 1990). Alpha-tocopherol seems to exert its color stabilizing effect by indirectly delaying oxymyoglobin oxidation via direct inhibition of lipid oxidation (Faustman et al., 1998), putting the main focus of supplementing vitamin E on extending retail shelf life. Liu et al. (1996) conducted a study on 72 Holstein steers to determine the lightness (L*), retention of redness (a*), yellowness (b*), color saturation (chroma), and proportions of redness and yellowness (hue angle) of fresh beef and to compare color display lives based on color coordinates with estimates based on reflectance spectrophotometry and the method of Arnold et al. (1992). This showed that increments in dietary vitamin E supplementation delayed loss of redness, delayed increase in the vector angle, and delayed loss of color saturation in three major muscles of the beef carcass during simulated retail display (Liu et al., 1996). Ultimately, muscle alpha-tocopherol accumulation resulting from dietary supplementation caused retention of redness, and color saturation decreased yellowness of the longissimus, indicating that a high level of vitamin E supplementation was necessary to detect an improvement in color display life (Liu et al., 1996). In a review by Faustman et al. (1998), it is stated that,

"Vitamin E supplementation of beef cattle diets is an effective procedure for enhancing lipid and color stability of meat products subsequently obtained from animals."

In several other studies, color stability amongst such things as retail stability of multiple muscles, color stability of fresh, frozen, and vacuum packaged beef, and color stability among different levels of vitamin E supplementation was examined. Of the beef stored fresh, frozen, and vacuum packaged, the vitamin E supplementation showed the meat had less ($P < 0.05$) metmyoglobin formation compared to un-supplemented beef after 7 d in retail display (Lynch et al., 1999). This study also concluded that increased alpha-tocopherol levels in different muscle tissues appears to be an effective means for improving the color and oxidative stability of fresh, frozen and vacuum packaged beef cuts (Lynch et al., 1999) which supports previous data (Faustman et al., 1989; Arnold et al., 1993). The multiple muscle study had meats that were color monitored in a retail display and packaged in either a polystyrene retail tray on a soaker pad and over-wrapped with an oxygen permeable plasticized polyvinyl chloride packaging film or packed in nylon and polyethylene chubs. This study provided that vitamin E supplementation helps delay the deterioration of fresh beef color during simulated retail display, especially for ground beef that was stored in a chub for an extended period of time (Zerby et al., 1999). The trial where cattle were fed 0 IU/hd/d, 500 IU/hd/d, and 1000 IU/hd/d for the last 100 d on feed, not only indicated that amount of alpha-tocopherol in animals' muscles depends on dietary history relative to intake of forage verses grain supplementation, but also that dietary supplementation of alpha-tocopherol should be at 1,000 IU/hd/d to ensure desired retail case life extension in beef (Roeber et al., 2001). The summation of this is noted best by Zerby et al. (1999), when he explains, "Vitamin E supplementation

can be used as part of a retail grocer's management strategy to decrease losses associated with discounted and discarded fresh beef products resulting from discoloration before the allotted 'sell by' date."

Conclusion

Meat quality will continue to be a constant concern in the livestock industry. Researchers will continue to search for economical ways to raise livestock, while still maintaining the highest quality product in the retail case. Past research suggests that the inclusion of distiller's grain in cattle diets may aid feeders in extra performance and feed to gain conversion. This combined with the supplementation of alpha-tocopherol (vitamin E) may help to extend shelf life for consumers while also having more total product for the industry. Therefore, research on the combination of distiller's grain and vitamin E in finishing diets for at least 100 d pre-harvest is suggested.

CHAPTER III

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ABSTRACT

The objective of this study was to determine the impact that pre-harvest anti-oxidant supplementation to cattle fed wet distiller's grains has on not only carcass yield and quality grade, but also color stability and consumer acceptability. Two hundred and forty crossbred steers were fed 35% wet distiller's grains with the supplementation of four different levels of vitamin E: 0 IU/hd/d (CON), 125 IU/hd/d, 250 IU/hd/d, and 500 IU/hd/d for 97 d. Chuck rolls (n = 69) and strip loins (n = 185) were collected and processed on 4 d and 7 d, post harvest. Chucks were ground and separated into 0.23 kg samples. Strip loins were faced and cut into 2.54 cm steaks and packaged in either polyvinyl chloride overwrapped (PVC) package, a vacuum package, or modified atmosphere packages (MAP), for further color, alpha-tocopherol, Thiobarbituric Acid Reactive Substance (TBAR), tenderness and palatability analysis, and proximate analysis. Color was measured objectively using a HunterLab Miniscan XE, subjectively by a trained color panel, and a consumer panel was utilized to indicate which treatments impacted retail acceptability and purchase decisions. Warner-Bratzler Shear Force (WBSF) measurements were used for objective tenderness, and a trained panel assessed subjective tenderness and palatability. Instrumental color measurements revealed little

difference for ground beef in both PVC and MAP packages, but diets with 500 IU/hd/d and 250 IU/hd/d inclusion levels of vitamin E showed significant ($P < 0.05$) increases in redness and yellowness retention in steaks. Subjective color evaluation for strip steaks indicated that higher levels of vitamin E were more likely to maintain color stability ($P < 0.01$), overall acceptability, and consumer purchase preference, while decreasing % discoloration ($P < 0.0001$). No significant differences were observed for objective tenderness and sensory attributes of strip steaks, and there was no difference in protein, fat, or moisture percent of ground beef. Lipid oxidation analysis indicated that steaks packaged in PVC for 7 d and MAP for 1 d, 3 d, and 7 d, and ground beef in MAP and PVC for 0 and 7 d of retail display, required higher inclusion levels of vitamin E (500 IU/hd/d and 250 IU/hd/d) to remain below the 2.28 mg malonaldehyde/kg threshold. Ultimately, 500 IU/hd/d of vitamin E should be supplemented to beef distiller's grain base diets and products packaged in MAP to maximize retail shelf life retention.

INTRODUCTION

One of the greatest factors that impact beef retail markets is the amount of profit loss due to meat discoloration. At the point in which beef products begin to darken, a retailer is forced to do one of three things: 1) discount or mark down the price of the product, 2) convert the product to a new product of lesser value (ex. grinding to hamburger), or 3) discard the product at a 100% loss (Westcott et al., 1997). Thus, retailers may be more interested in how many hours of acceptable retail display they can gain before 10% of the products in a display case begin to discolor, rather than when the average of all the cuts in the display case is unacceptable (Zerby et al., 1999).

Therefore, studies have been conducted to increase color stability in lean. Not only did Arnold et al. (1992) determine that alpha-tocopherol (vitamin E) is effective in extending the color stability of displayed beef, but Faustman et al. (1998) confirmed that vitamin E supplementation of beef cattle diets is an effective procedure for enhancing the lipid and color stability of meat products subsequently obtained from animals.

As important as color stability is to retailers, raising cattle economically is of equal importance to producers. It is estimated that in 2010, 23% of the corn produced will go to the production of ethanol (Baker and Zahniser, 2006), and with this comes a by-product, distiller's grain, a feedstuff available to producers at a more economical price than corn. Research on the inclusion of distiller's grains in finishing diets indicates an increase in final body weight, average daily gain, and heavier carcass weight. However, inclusion of distiller's grains can increase the amount of polyunsaturated fatty acids, resulting in greater lipid oxidation; the chemical change that causes the brown color in beef (Gill et al., 2008).

The objectives of this study were to determine the impacts of pre-harvest vitamin E supplementation on carcass yield and quality grade factors, as well as the impact of pre and post-harvest management on color stability and consumer acceptability of steaks and ground beef from cattle fed wet distiller's grains.

MATERIALS AND METHODS

Dietary Treatments

Two hundred and forty crossbred steers were fed at Oklahoma Panhandle State University's extension and research feedlot facility to evaluate animal performance in response to feeding a base diet of dry rolled corn (55% on a dry matter basis) and 35% wet distiller's grain (on a dry matter basis), with the supplementation of vitamin E. The steers were allotted to one of four vitamin E supplementation treatment groups (6 pens per treatment, 10 steers per pen): 0 IU/hd/d the control group (CON); 125 IU/hd/d, 250 IU/hd/d; and 500 IU/hd/d for 97 d.

Harvest and Data Collection

The steers were shipped to a commercial processing facility in Dodge City, KS, over two different slaughter dates (harvest group 1 processed on July 27, 2009, n = 80; harvest group 2 processed on August 17, 2009, n = 125), resulting from the difference in final body weight over the 6 different weight blocks. On the day of harvest, trained Oklahoma State University personnel completed tag transfer and collected hot carcass weights (HCW). After a 36 h chill, and approximately 15 min bloom time, the same personnel collected all carcass data on the grade chain, including: marbling score and ribeye area (REA) at the 12th and 13 rib interface, kidney, pelvic, and heart (KPH) fat percentage; fat thickness (FT); and lean and skeletal maturity. All USDA Quality and Yield grades (QG/YG) were calculated according to the data collected.

Strip Loin and Chuck Collection

Immediately following data collection, carcasses were railed into the sales cooler onto one of two grade rails (Choice or Select), to allow for tagging of strip loins and

chucks. Approximately 60% of the carcasses were graded USDA Choice by a USDA grader, and the other 40% graded USDA Select. Chuck rolls were only collected from carcasses in the initial harvest group. A total of 69 chuck rolls were collected from the right side of each carcass (17 CON; 16, 125 IU/hd/day; 19, 250 IU/hd/day; 17, 500 IU/hd/day). All strip loins from the right side of each carcass were tagged over both harvest dates and a total of 185 loins were collected (53 CON; 45, 125 IU/hd/day, 46, 250 IU/hd/day; 41, 500 IU/hd/day). All products were fabricated according to Institutional Meat Purchase Specifications (IMPS; USDA, 1996), where chucks were fabricated according to the guidelines for IMPS #116A and strip loins for IMPS #180 with a purchaser specified option (PSO) of 2.5 cm x 0 cm, and vacuum packaged at the plant. Once the product was vacuum packaged it was then immediately shipped to Oklahoma State University's Food and Agricultural Products Center (FAPC) for further processing.

Chuck Roll Preparation

Chuck rolls (n = 69) were aged 4 d postmortem at 2ºC, and then removed from the vacuum packaged and ground. Five 0.23 kg samples of finely ground product were collected and separated into different packages. One sample was placed in a styrofoam tray with a soaker pad and overwrapped with a polyvinyl chloride (PVC) film for retail display, one sample was placed in a vacuum package and frozen immediately for thiobarbituric acid (TBARS) testing and placed in a freezer at -20ºC, and one sample was placed in a whirl package for protein, fat, and moisture analysis and also frozen at -20ºC. The final two samples were placed in plastic trays with a soaker pad and sealed in a high oxygen (HiO2) modified atmosphere package (MAP, approximately 75% O2 and 25% CO2). The modified atmosphere packages were placed in dark storage at 2ºC for 7 d

before retail display, while PVC packages were immediately objectively color scored with a HunterLab Miniscan XE spectrophotometer and placed under retail lighting.

Strip Loin Preparation

After aging strip loins for 7 d postmortem at 2ºC, strips (n = 185) were removed from their vacuum packages. Strip loins were then faced on the anterior end and six 2.54 cm steaks were subsequently cut. The face steak was vacuum packaged and immediately frozen at -20ºC for further analysis of α-tocopherol levels. The first steak was divided in half allowing for half the steak to be vacuum packaged frozen at -20ºC for pre-display TBARS testing, and the other half placed in a MAP package and placed under retail display at 14 d postmortem for TBARS testing after 72 h in display. The second steak was placed in a Styrofoam package with a soaker pad and over-wrapped with PVC film. This steak was then objectively color scored using a HunterLab Miniscan XE spectrophotometer and immediately placed under retail lighting. The third steak was selected for Warner-Bratzler shear force analysis (WBSF), placed in a MAP package and aged in dark storage at 2ºC for an additional 7 d before being placed under retail lighting for 72 h. After this time period, steaks were vacuum packaged and frozen at -20ºC. The final three steaks were placed in MAP packages and designated to one of three display periods: MAP 1 d retail display, MAP 3 d retail display, and MAP 7 d retail display. All MAP packages were placed in dark storage at 2ºC for an additional 7 d postmortem to simulate commercial transportation. All MAP 1 d was immediately removed from dark storage, placed in a vacuum package and frozen at -20ºC for later TBARS analysis. The MAP 3 d packages were kept under retail lighting for 72 h before being vacuum packaged and frozen at -20ºC for sensory analysis. The final MAP 7 d package was

held under retail lighting for subjective color score for 156 h before being vacuum packaged and frozen at -20ºC for final TBARS analysis.

Simulated Retail Display

Products designated for retail display were placed in a room designed to simulate retail conditions. The room contained multiple shelving units from which 121.9 cm Phillips Deluxe Warm White Fluorescent lights were hung, exposing the surface of the meat to continuous light at 807 - 1,614 lux, for the entire period of retail display. The room was maintained at a temperature of 4ºC ± 1ºC.

Objective Color Evaluation

The objective color of each steak was measured with a HunterLab Miniscan XE spectrophotometer equipped with a 6 mm aperture (HunterLab Associates Inc., Reston, VA) to determine color coordinate values for L* (brightness: 0 = black and 100 = white), a* (redness/greenness: positive values = red and negative values = green), and b* (yellowness/blueness: positive values = yellow and negative values = blue); in accordance with the procedures of the Commission Internationale de I'Eclairage (CIE, 1976). Each time color was measured, three readings were taken from different places on the surface exposed to continuous light to obtain average L*, a*, and b* values. Objective color measurements for PVC packaged steaks were taken at 0 h, 12 h, 60 h, 108 h, and 156 h, and PVC packaged ground beef measurements were taken at 0 h, 72 h, and 156 h. For MAP package objective measurement, steak packages were sacrificed at 12 h, 72 h and 156 h, and ground beef packages were sacrificed at 0 h and 156 h for evaluation.

Subjective Color Measurement

A six member panel of trained Oklahoma State University personnel was selected to subjectively color score all products for a 7 d period at 12 h intervals. All panelists were required to obtain a passing score using Munsell color tiles (Gretamacbeth, New Windsor, NY) prior to serving on the panel. Each panelist evaluated both the ground beef and strip steaks for muscle color, percent surface discoloration (% metmyoglobin), and overall acceptability. Muscle color was evaluated on an 8-point scale, where half point increments were accepted (1 = very bright red or pinkish red, and 8 = tan to brown), discoloration was scored using a 7-point scale (1 = no discoloration or 0%, and 7 = total discoloration or 100%), and overall acceptability was depicted using an 8-point scale (8 = extremely desirable/acceptable, and 1 = extremely undesirable/unacceptable).

Consumer Color Measurement

Four groups of both male and female consumer panelists, whose educational background spans from high school graduate to advanced college degrees, with an annual household income level that spans from $10,000 to over $100,000 dollars, and purchase beef an average of once a week to once a year, participated on color evaluation panels for both PVC packaged steaks (15 panelists for harvest group 1 and 16 panelists for harvest group 2) and MAP packaged steaks (13 panelist for harvest group 1 and 18 for harvest group 2). Steaks were placed in groups of four (for harvest group 1, n = 18, and for harvest group 2, n = 25), containing one randomly selected representative steak from each of the four treatments. Evaluating muscle color only, panelist were asked to choose one steak from each group that they would most likely purchase (it was requested that one steak be selected from each group for each aging period), and place an X through any steaks they deemed unacceptable for retail display. Steak evaluation by consumer

panelist was done at 72 h and 144 h in retail display. Each steak's overall acceptability for each aging period was averaged (0 = steak was neither chosen for purchase nor deemed unacceptable, 1 = steak was chosen for purchase, and 2 = steak was deemed unacceptable) for a final acceptability value.

Warner-Bratzler Shear Force

Steaks designated for objective tenderness were removed from the freezer and allowed to thaw at 4ºC for 24 h, prior to cooking. The steaks were then cooked on an impingement oven (XLT Ovens, Model 3240TS2, BOFI, Wichita, KS) to an internal temperature of 70ºC. Once steaks were cooked, they were then chilled at 4ºC for another 24 h period. To determine WBSF, 6 cores (1.27 cm in diameter) were taken from each steak parallel to the muscle fiber orientation. Cores were sheared once using an Instron Universal Testing Machine (model 4502; Instron Corp., Canton, MA) with a Warner-Bratzler head, at a speed of 200 mm/min. Peak force (kg) of the cores was recorded using an IBM PS2 (Model 55SX) equipped with software supplied by the Instron Corporation. Peak WBSF values of the six cores were averaged for a final tenderness value.

Sensory Evaluation

Steaks designated for sensory evaluation were removed from the freezer, assigned a random number, and allowed to thaw at 4ºC for 24 h prior to cooking. All steaks were cooked using the same method as described for WBSF. Following cooking, steaks were cut into 1 cm x 1 cm x 2.54 cm samples. Samples were placed into plastic cups which maintained a number corresponding to that designated to the steaks at the time of

tempering. Cups were then placed into individual warmers with heat pads to keep samples warm throughout the evaluation session.

The panel was made up of eight Oklahoma State University personnel who were trained in accordance with the "Guidelines for training and testing judges for sensory analysis of meat quality" (Cross et al., 1978). Sessions were held in a temperature and light controlled room in which panelists were randomly seated at individual booths and served under red lights to avoid visual bias. Twelve samples were served at each session in a random order. Up to four sessions were held a day, two in the morning and two in the afternoon, and each session was separated by at least a 10 min break. Panelists were also supplied with distilled, deionized water and unsalted crackers for palate cleansing between samples. Steaks were evaluated for initial and sustained juiciness (8 = extremely juicy, 1= extremely dry), initial and overall tenderness (8 = extremely tender, 1 = extremely tough), and amount of connective tissue (8 = none, 1 = abundant). If off-flavors were detected then they were recorded in a comment column, but there was no scale and no specific attributes were evaluated.

Thiobarbituric Acid Reactive Substance (TBAR)

Product designated for one of the multiple sampling periods for TBAR testing were removed from the freezer and allowed to thaw for 24 h at 4ºC before lipid peroxidation was performed by a modified method of Buege and Aust (1978). A 10 g sample was removed from each steak and placed in a Waring blender (model 51BL31, Waring, Torrington, CT) to be homogenized with 30 ml of deionized water. That sample was then transferred into a disposable test tube and centrifuged at 3000 rpm and 2ºC for 10 min. Then, 2 ml of the supernatant was extracted and combined in a disposable glass

test tube with 4 ml thiobarbituric acid/trichloroacetic acid (TBA/TCA) and 100 µl of butylated hydrixyanisol (BHA). The combination was then vortexed before allowing it to sit in a boiling water bath for 15 min to develop color and then placed in a cold water bath for 10 min to allow the sample to cool. Once complete, the mixtures were centrifuged again at 3000 rpm and 2ºC for 10 min. The absorbance of these supernatants was analyzed at 531 nm in comparison to standards developed each day. The average of the two supernatants, per sample, was used for statistical analysis.

Proximate Analysis

Samples for proximate analysis were stored in whirl packages and allowed to thaw using the methods previously mentioned for WBSF. Once samples were thawed, they were powder homogenized with the use of a Waring blender (model 51BL31, Waring, Torrington, CT) and two, 1 to 3 gm samples, were secured in filter paper (Whatman #41, 15 cm) with a smooth paper clip. Secured samples were then placed in a 102ºC oven for 24 h, weighing both before and after heating (sample, paper, and clip). Once the samples were removed and allowed to cool, for approximately 45 min, they were placed in a soxhlet unit where heated petroleum ether drips through the sample for a 24 h period, extracting fat. Samples were then dried for approximately 20 min before being placed in a desiccator to cool. Once cool, samples were reweighed for final lipid content (AOAC, 1990 procedures). Weights taken before and after initial heating were averaged and used to determine a final moisture content value, whereas final weight after ether extraction and drying were averaged for a final lipid content value. Samples were analyzed for protein by using the combustion method procedures of the AOAC (1990).

Statistical Analysis

Data for both steaks and ground beef were analyzed using the mixed procedure of SAS (SAS Inst. Inc., Cary, NC) as a completely randomized split plot design with carcass as the experimental unit and strip loin or chuck being the split plot. The Analysis of Variance (ANOVA) model was used to analyze carcass data, WBSF, sensory, TBAR, objective color attributes, subjective color attributes, consumer color attributes, and proximate analysis, where treatment was the fixed effect, strip/chuck identification was the random effect. All color data were analyzed by package type. The ANOVA model for PVC and MAP samples for subjective and objective color attributes were analyzed using time as a repeated measure, where strip/chuck identification was the subject and treatment remained the fixed effect. Interactions were observed for all models and when significant ($\alpha = 0.05$) least square means were computed and statistically separated by pair wise t-test (PDIFF option of SAS).

RESULTS AND DISCUSSION

Carcass Data

Results of supplementation effects on carcass characteristics are presented in Table 3.1. There was no evident difference in carcass characteristics among all treatment groups ($P < 0.05$). This is supported by Arnold et al. (1992) who also recognized that vitamin E supplementation neither affects feedlot performance or carcass characteristics and quality and yield grades ($P < 0.1$). Although it seems as though all carcass traits favor the higher inclusion levels of supplementation, there were still no differences found for HCW, YG, REA, KPH, or marbling score.

Color Evaluation

Subjective color evaluation of MAP packaged steaks can be found in Tables 3.2 through 3.4. An evident difference in color throughout almost the entire retail display period was detected ($P < 0.05$). At 0 h panelist recorded that only the CON diet showed a significant difference in color, whereas 12 h through 60 h, diets of 500 IU/hd/d and 250 IU/hd/d were the same and CON and 125 IU/hd/d were different ($P < 0.01$). After this point, color remained relatively the same, in respect to the previous 60 hours. At 156 h 500 IU/hd/d was recorded significantly higher than 250 IU/hd/d in terms of color, and this treatment was also significantly different than 125 IU/hd/d and the CON ($P < 0.01$).

Discoloration and overall acceptability of steaks in MAP packages were similar in the fact that, although after 36 h in retail display, there is a distinct difference between the higher levels of supplementation (500 IU/hd/d and 250 IU/hd/d) and the lower levels (125 IU/hd/d and CON) ($P < 0.0001$) (Table 3.3 and 3.4). These results correspond to those of Arnold et al. (1993) which reported that, in general, the greater the amount of vitamin E fed and(or) the longer the supplementation, the longer the meat will last in retail display.

Differences in PVC overwrapped steaks for color didn't become apparent until approximately 72 h in the retail display ($P < 0.001$) (Table 3.2). In terms of discoloration (Table 3.3), the PVC overwrapped steaks stayed fairly consistent until 144 h in display. At that point the diets providing more vitamin E (500 IU/hd/d and 250 IU/hd/d) had a distinctly lower amount of discoloration than the diets with lower amounts of vitamin E (125 IU/hd/d and CON) ($P < 0.05$). Least squares means (Table 3.4) indicate that panelist thought PVC packaged steaks, as a whole, were deemed slightly undesirable after 120 h in retail display ($P = 0.08$).

Steaks packaged in both MAP and PVC stayed consistent in terms of color for the duration of retail display. At 108 h, PVC packaged strips were all considered as slightly discolored (1 – 19%), whereas MAP packaged strips weren't all deemed slightly discolored until 120 h. Zerby et al. (1999) reported that at more than 10% discoloration, in retail, meat should be discounted. This suggests that MAP packaging may be preferred for retention of product in the retail display.

Ground beef in MAP packages remained consistent in terms of darkening (Table 3.5) until 156 h of retail display at which there became a significant difference between the supplementation level of 500 IU/hd/d and the lower levels of vitamin E ($P = 0.03$). After approximately 84 h in display, discoloration and overall acceptability of ground beef (Tables 3.5 and 3.6) between the higher levels of vitamin E in the diet (500 IU/hd/d and 250 IU/hd/d) and the lower levels of supplementation (125 IU/hd/d and CON) were significantly different ($P < 0.05$). Ground beef in PVC overwrap packages (Tables 3.5, 3.6, and 3.7) resulted in some differences during retail display ($P < 0.05$) but at 156 hour, no differences were reported for muscle color, discoloration, or overall acceptability among treatment groups.

Instrumental color evaluation of strip steaks measured no significant differences among dietary treatment for L* values, for both MAP and PVC overwrap packaged steaks (Table 3.8) throughout the entire retail display period. Table 3.8 proves that, with the exception of 12 h of PVC overwrapped steaks in which no differences were found at that time, a* measurements for MAP packaged ($P < 0.01$) and PVC packaged steaks ($P < 0.05$) were significantly different throughout the extent of retail display. These results indicate that higher levels of vitamin E supplementation in the diet (500 IU/hd/d and 250

IU/hd/d) retains redness in the beef for a longer period when compared to lower levels of supplementation (125 IU/hd/d and CON). All b* measurements for MAP packaged strip steaks, and those at 60 h and 156 h of PVC overwrapped packaged steaks were significantly higher for treatment levels of 500 IU/hd/d and 250 IU/hd/d than those for treatment levels 125 IU/hd/d and CON. These records suggest that higher levels of vitamin E supplementation in a distiller's grains based diet, enhances retention of yellowness during the retail display period. Aside from vector angle, these results correspond with those of Liu et al. (1996) who declared that muscle alpha-tocopherol accumulation from dietary supplementation causes retention of redness, and yellowness of the longissimus, indicating that a high level of vitamin E supplementation is necessary to detect an improvement in color display life.

Instrumental analysis of ground beef provided no significant difference for L* and b* measurements for both MAP and PVC overwrap packages at 0 and 156 h (Table 3.9). The recorded a* values for 156 h MAP package and 0 and 72 h PVC packaged ground beef indicated a significant difference at $P < 0.05$. These data indicated that supplemental level 500 IU/hd/d enhances the retention of redness in ground beef than that of the lower levels of supplemented vitamin E. Differences among objective measurement values were not significant to suggest that vitamin E supplementation increase retail shelf life in ground beef.

Consumer evaluations of muscle color for strip steaks in both MAP and PVC overwrap packages indicated that dietary treatment had an effect on retail selection of product (Table 3.10). Although differences were not observed for PVC overwrapped packages on 3 d of evaluation, it was evident that higher levels of vitamin E

supplementation (500 IU/hd/d and 250 IU/hd/d) in a distiller's grain based diet for 7 d PVC and 3 and 7 d MAP packaged product was more apt to entice consumers to purchase or deem the steaks acceptable for retention in the retail display. This panel was based strictly off of muscle color and amount of discoloration, concluding that higher amounts of vitamin E in distiller's grain based diets is suggested for consumer acceptance throughout the duration of retail display.

Sensory Attributes

Objective measurements and subjective tenderness evaluations are presented in Table 3.11 and generally show no differences among treatment groups in juiciness, tenderness, and amount of connective tissue ($P < 0.05$). All steaks used for these measurements were stored in MAP packages and therefore no package interactions were evaluated. Warner-Bratzler shear force values were on average 3.83 ± 0.1units among all treatments, which still remains lower than the suggested consumer threshold of 3.9 to 4.6 kg, the threshold for "slightly tender" beef, as reported by Shackelford et al. (1991). These results are supported by multiple other authors (Arnold et al., 1992; Koger et al., 2004; and Brandt et al., 1992) who failed to detect differences in WBSF among different inclusion levels of vitamin E or distiller's grains as well. These objective measurements are supported by the results of the trained panel as well. Although overall tenderness was consistently numerically higher for those diets with an inclusion level of 225 IU/hd/d and 500 IU/hd/d vitamin E, no differences were detected ($P < 0.05$). Like reported by Roeber et al. (2005), Arnold et al. (1992), and Gill et al. (2008) there were no differences in juiciness and connective tissue among different treatment levels. These data suggest that

different inclusion levels of vitamin E in a distiller's grain based diet will not affect sensory attributes.

Thiobarbituric Acid Reactive Substance

Least square means for TBAR measurements in strip steaks are presented in Table 3.12. Dietary treatment did not have an effect on lipid oxidation as indicated by the TBAR concentrations in steaks that were vacuum packaged on absolute 0 d ($P < 0.05$). Those steaks that were packaged in PVC overwrap and MAP packages, though, measured significant differences in lipid oxidation for 7 d in PVC ($P < 0.05$), and 1 d, 3 d, and 7 d in MAP ($P < 0.01$). It is also evident that those steaks in MAP packages oxidize at a faster rate under retail display conditions than those in PVC overwrap packages. Campo et al. (2006) indicated that a TBAR value of 2.28 mg/kg is the limiting threshold for consumer acceptability of oxidation and that after this measurement rancidity overpowers the beef flavor, in terms of sensory attributes. This study indicates that steaks from dietary treatments CON and 125 IU/hd/d, in MAP packages, surpass this threshold at 7 d in a retail display, and would be deemed unacceptable. Steaks from all other aging periods and packaging methods, though, remain below this threshold.

Dietary treatment did have an effect on lipid oxidation as indicated by the TBAR concentrations of ground beef vacuum packaged on absolute 0 d, and the product in PVC overwrap and MAP packages which were placed under simulated retail display conditions for 7 days (Table 3.13). For 0 d, the higher supplementation of vitamin E in the diets proved to have higher amounts of lipid oxidation when compared to the diets of 125 IU/hd/d and CON ($P < 0.01$). Throughout the duration in retail display, though, the higher levels of vitamin E in the diet oxidized at a slower rate, maintaining a lower

amount of oxidation. These significant differences suggest that 500 IU/hd/d will maintain a lower amount of lipid oxidation in ground beef when compared to diets supplemented with lower amounts of vitamin E ($P < 0.01$).

Proximate Analysis- ground beef

Least square means for the amount of fat, moisture, and protein measured in the ground beef, among treatment groups can be found in Table 3.14. Due to the fact that fabrication was done at the plant, to meet IMPS specification #116A, amount of external fat was not altered before grinding. Therefore, the amount of fat in the mixture may vary due to differences in consistency. The amount of fat ranged from 7.03 to 23.07%, the amount of moisture ranged from 60.47 to 74.37%, and the amount of protein ranged from 13.56 to 24.14%. Although the data suggests that higher amounts of vitamin E in the diet tend to increase the amount of moisture and decrease the amount of fat and protein, no significant differences were detected for % fat, moisture and protein among the different treatment groups ($P < 0.05$).

CONCLUSION

Results of this study indicate that the inclusion of different levels of vitamin E in a distiller's grain based diet will not have an effect on carcass characteristics, sensory attributes, or protein, fat and moisture content of beef. This study does indicate that to maximize retail shelf life and decrease lipid oxidation, the critical level of supplementation is 500 IU/hd/d of vitamin E in a 35% wet distiller's grain based diet (dry matter basis) for at least 97 d prior to harvest. It is evident that higher levels of vitamin E supplementation in the diet aid in the maintenance of shelf stability for MAP and PVC packaged strip steaks by sustaining muscle color and overall acceptability while

decreasing percent discoloration by decreasing the rate at which of lipid oxidation occurs throughout a 156 h period. In consideration to package type, MAP seemed to maintain discoloration for a longer period, indicating it would be the preferred package for longer aging periods. Instrumental color measurements also prove that although brightness is not improved, higher levels of dietary vitamin E maintain redness and yellowness of steaks for a longer period of time. It is apparent that higher levels of vitamin E in the diet decrease lipid oxidation in ground beef, yet it has little effect on shelf stability and objective color measurements. Ultimately, the inclusion of vitamin E in distiller's grain based diets for beef cattle, and beef processed for retail in MAP packages, should maximize retail shelf life and decrease the occurrence of profit loss due to lipid oxidation and discoloration.

Table 3.1. Least squares means for carcass data[1]

	Treatments				*P*-Value	
	Control	125 IU/HD/D	250 IU/HD/D	500 IU/HD/D	SEM	Trt
Carcass						
[2]HCW, kg	399.62	394.42	400.57	408.41	6.30	0.48
Yield Grade	1.41	1.38	1.45	1.45	0.07	0.80
[3]REA, cm^2	91.46	92.04	95.65	95.65	2.60	0.68
[4]KPH, %	2.28	2.32	2.48	2.48	0.07	0.80
[5]Marbling Score	43.77	42.10	43.42	43.42	0.96	0.45

[1]n = 204
[2]Hot carcass weight.
[3]Rib-eye area.
[4]Kidney, pelvic, and heart fat.
[5]Marbling score: 10 = practically devoid, 20 = traces, 30 = slight, 40 = small, 50 = modest, 60 = moderate.

Table 3.2. Least squares means for muscle color scores given to [1]MPA and [2]PVC packaged strip loin steaks (n = 185) throughout a 7 d period in the retail display case.[3]

	Treatments			
	Control	125 IU/HD/D	250 IU/HD/D	500 IU/HD/D
MAP Package				
0H	3.31[b]	3.14[a]	2.97[a]	2.98[a]
12 H	3.51[b]	3.48[b]	3.25[a]	3.24[a]
24 H	3.62[b]	3.60[b]	3.32[a]	3.33[a]
36 H	3.75[b]	3.79[b]	3.49[a]	3.45[a]
48 H	4.02[b]	4.17[b]	3.76[a]	3.58[a]
60 H	4.46[b]	4.17[b]	3.83[a]	3.66[a]
72 H	4.64[b]	4.51[b]	4.21[a]	3.91[a]
84 H	4.68[b]	4.62[b]	4.17[a]	4.09[a]
96 H	5.35[c]	4.82[b]	4.23[a]	4.06[a]
108 H	4.96[b]	5.21[b]	4.45[a]	4.29[a]
120 H	5.41[b]	5.35[b]	4.84[a]	4.65[a]
132 H	5.79[b]	5.47[b]	4.98[a]	4.73[a]
144 H	5.84	5.69	5.72	5.08
156 H	6.17[c]	5.92[c]	5.54[b]	5.14[a]
PVC Package				
0H	3.24	3.22	3.11	3.14
12 H	3.29	3.25	3.12	3.20
24 H	3.41	3.39	3.28	3.28
36 H	3.54	3.53	3.39	3.52
48 H	3.85	3.80	3.62	3.68
60 H	4.05	4.05	3.85	3.89
72 H	4.14[b]	4.11[b]	3.84[a]	3.85[a]
84 H	4.29[b]	4.22[b]	4.00[a]	4.02[a]
96 H	4.53[b]	4.47[b]	4.21[a]	4.22[a]
108 H	4.78[b]	4.61[b]	4.27[a]	4.32[a]
120 H	5.00[b]	4.88[b]	4.47[a]	4.52[a]
132 H	5.26[b]	5.08[b]	4.68[a]	4.62[a]
144 H	5.55[b]	5.36[b]	5.03[a]	4.86[a]
156 H	6.04[b]	5.83[a]	5.53[a]	5.32[a]

[abc]Means in the same row without a common superscript are different ($P < 0.05$).
[1]Modified atmosphere package.
[2]Polyvinyl chloride overwrapped package.
[3] Muscle color was measured on an 8-point scale (1 = very bright red or pinkish red, and 8 = tan to brown).

Table 3.3. Least squares means for percent muscle discoloration values given to [1]MAP and [2]PVC packaged strip loin steaks (n = 185) throughout a 7 d period in the retail display case.[3]

	Treatments			
	Control	125 IU/HD/D	250 IU/HD/D	500 IU/HD/D
MAP Package				
0H	1.04	1.04	1.03	1.04
12 H	1.02	1.05	1.02	1.03
24 H	1.04	1.08	1.02	1.03
36 H	1.10	1.16	1.02	1.06
48 H	1.26[a]	1.33[b]	1.05[a]	1.18[a]
60 H	1.46[b]	1.53[b]	1.16[a]	1.23[a]
72 H	1.42[b]	1.28[b]	2.07[a]	2.02[a]
84 H	2.42[b]	2.33[b]	1.36[a]	1.43[a]
96 H	3.22[b]	2.95[b]	1.61[a]	1.61[a]
108 H	3.76[b]	3.40[b]	1.93[a]	1.79[a]
120 H	4.42[b]	4.07[b]	2.53[a]	2.17[a]
132 H	4.78[b]	4.60[b]	2.85[a]	2.31[a]
144 H	5.05[c]	4.86[c]	3.18[b]	2.42[a]
156 H	5.43[c]	5.31[c]	4.00[b]	2.71[a]
PVC Package				
0H	1.00	1.00	1.00	1.00
12 H	1.05	1.03	1.03	1.03
24 H	1.08	1.09	1.14	1.11
36 H	1.22	1.23	1.21	1.25
48 H	1.26	1.30	1.29	1.29
60 H	1.39	1.46	1.38	1.41
72 H	1.54	1.53	1.47	1.50
84 H	1.63	1.61	1.53	1.60
96 H	1.89	1.78	1.69	1.77
108 H	2.42	2.40	2.22	2.26
120 H	2.53	2.41	2.33	2.25
132 H	3.00	2.79	2.91	2.59
144 H	3.42[b]	3.28[b]	3.33[b]	2.75[a]
156 H	1.81	1.74	2.73	3.73

[abc]Means in the same row without a common superscript are different ($P < 0.05$).
[1]Modified atmosphere package.
[2]Polyvinyl chloride overwrapped package.
[3] All % muscle discoloration was measured on a 7-point scale (1 = no discoloration or 0 %, and 7 = total discoloration or 100%).

Table 3.4. Least squares means for overall acceptability values given to [1]MAP and [2]PVC packaged strip loin steaks (n = 185) throughout a 7 d period in the retail display case.[3]

	Treatments			
	Control	125 IU/HD/D	250 IU/HD/D	500 IU/HD/D
MAP Package				
0H	6.98[b]	6.97[b]	7.14[a]	7.11[a]
12 H	6.73[b]	6.68[b]	6.94[a]	6.88[a]
24 H	6.26[b]	6.36[b]	6.62[a]	6.58[a]
36 H	6.10[b]	6.04[b]	6.43[a]	6.42[a]
48 H	5.97[b]	5.84[b]	6.29[a]	6.51[a]
60 H	5.51[b]	5.49[b]	6.17[a]	6.20[a]
72 H	4.50[b]	4.61[b]	5.66[a]	5.66[a]
84 H	4.17[b]	4.28[b]	5.51[a]	5.57[a]
96 H	3.56[b]	6.69[b]	5.31[a]	5.46[a]
108 H	3.16[b]	3.33[b]	4.96[a]	4.99[a]
120 H	2.73[b]	2.76[b]	4.20[a]	4.70[a]
132 H	2.28[c]	2.36[c]	3.84[b]	4.43[a]
144 H	2.02[c]	2.16[c]	3.38[b]	4.16[a]
156 H	1.81[c]	1.74[c]	2.73[b]	3.73[a]
PVC Package				
0H	6.86	6.77	6.88	6.83
12 H	6.89	6.82	7.01	6.83
24 H	6.51	6.44	6.61	6.71
36 H	6.32	6.19	6.40	6.24
48 H	6.01	5.96	6.18	6.04
60 H	5.81	5.75	6.02	5.83
72 H	5.84[b]	5.76[b]	6.12[a]	6.01[a]
84 H	5.59	5.64	5.95	5.80
96 H	5.18[b]	5.30[b]	5.65[a]	5.56[a]
108 H	4.75[b]	4.97[b]	5.40[a]	5.28[a]
120 H	4.31	4.57	4.68	4.90
132 H	3.18[b]	3.51[b]	3.98[a]	4.21[a]
144 H	2.52[b]	2.85[b]	3.23[a]	3.60[a]
156 H	2.13[b]	2.30[b]	2.62[a]	2.86[a]

[abc]Means in the same row without a common superscript are different ($P < 0.05$).
[1]Modified atmosphere package.
[2]Polyvinyl chloride overwrapped package.
[3] Overall acceptability was measured on an 8-point scale (8 = extremely desirable/acceptable, and 1 = extremely undesirable/unacceptable).

Table 3.5. Least squares means for muscle color scores given to [1]MAP and [2]PVC packaged ground beef (n = 69) throughout a 7 d period in the retail display case.[3]

	Treatments			
	Control	125 IU/HD/D	250 IU/HD/D	500 IU/HD/D
MAP Package				
0H	2.14	2.24	2.25	2.22
12 H	2.61	2.68	2.88	2.81
24 H	2.76	2.82	2.85	2.94
36 H	3.08	3.19	3.23	3.30
48 H	3.46	3.61	6.62	6.57
60 H	3.74	4.03	4.13	4.00
72 H	3.90[b]	4.41[a]	4.63[a]	4.28[a]
84 H	4.32	4.77	4.70	4.42
96 H	4.84	5.33	5.07	4.91
108 H	5.26	5.59	5.24	5.01
120 H	5.60	5.92	5.68	5.29
132 H	5.94	6.22	5.91	5.37
144 H	6.07	6.36	5.99	5.52
156 H	6.31[b]	6.56[b]	5.97[a]	5.50[a]
PVC Package				
0H	1.81	1.74	2.01	2.07
12 H	2.21[b]	2.18[b]	2.58[a]	2.57[a]
24 H	2.19	2.54	2.62	2.66
36 H	2.77	2.64	2.89	2.89
48 H	2.75[b]	2.81[b]	3.03[a]	3.22[a]
60 H	3.42	2.88	3.25	3.17
72 H	3.16	3.18	3.51	3.38
84 H	3.46	3.46	3.61	3.54
96 H	3.56	3.58	3.63	3.60
108 H	4.01	4.22	4.25	4.17
120 H	4.67	5.07	4.94	4.63
132 H	5.00	5.63	5.23	5.11
144 H	5.55	6.12	5.52	5.28
156 H	5.94	6.71	6.14	5.79

[abc]Means in the same row without a common superscript are different ($P < 0.05$).
[1]Modified atmosphere package.
[2]Polyvinyl chloride overwrapped package.
[3] Muscle color was measured on an 8-point scale (1 = very bright red or pinkish red, and 8 = tan to brown).

Table 3.6. Least squares means for percent muscle discoloration values given to [1]MAP and [2]PVC packaged ground beef (n =69) throughout a 7 d period in the retail display case.[3]

	Treatments			
	Control	125 IU/HD/D	250 IU/HD/D	500 IU/HD/D
MAP Package				
0H	1	1	1	1
12 H	1	1	1	1
24 H	1	1	1	1
36 H	1.01	1.01	1.06	1.02
48 H	1.23	1.31	1.37	1.35
60 H	1.44	1.57	1.72	1.36
72 H	1.82	2.11	2.02	1.58
84 H	2.19	2.72	2.36	1.79
96 H	2.89[a]	3.43[b]	2.95[a]	2.04[a]
108 H	3.46[b]	3.94[c]	3.18[b]	2.32[a]
120 H	3.85[b]	4.30[c]	3.51[b]	2.52[a]
132 H	4.31[c]	4.73[c]	3.88[b]	2.76[a]
144 H	4.65[c]	4.85[c]	4.12[b]	2.92[a]
156 H	5.18[c]	5.23[c]	4.61[b]	3.15[a]
PVC Package				
0H	1.44	1.48	1.51	1.45
12 H	1.66	1.77	1.93	1.82
24 H	1.75	1.78	1.93	2.01
36 H	1.81	1.80	1.99	2.07
48 H	1.85	1.84	2.24	2.02
60 H	1.92[b]	1.82[b]	2.14[a]	2.13[a]
72 H	1.95	1.90	2.11	2.07
84 H	2.28	2.48	2.34	2.26
96 H	2.21	2.46	2.33	2.30
108 H	2.56	3.29	2.57	2.58
120 H	3.52[b]	4.43[c]	3.66[b]	2.82[a]
132 H	4.03[b]	5.01[c]	4.30[b]	3.26[a]
144 H	4.40[b]	5.40[c]	4.73[b]	3.85[a]
156 H	4.82	5.25	5.95	4.82

[abc]Means in the same row without a common superscript are different ($P < 0.05$).

[1]Modified atmosphere package.

[2]Polyvinyl chloride overwrapped package.

[3] All % muscle discoloration was measured on a 7-point scale (1 = no discoloration or 0 %, and 7 = total discoloration or 100%).

Table 3.7. Least squares means for overall acceptability values given to [1]MAP and [2]PVC packaged ground beef (n = 69) throughout a 7 d period in the retail display case.[3]

	Treatments			
	Control	125 IU/HD/D	250 IU/HD/D	500 IU/HD/D
MAP Package				
0H	7.47	7.42	7.37	7.37
12 H	7.36	7.22	7.17	7.15
24 H	7.53	7.38	7.41	7.38
36 H	7.32	7.13	7.18	7.21
48 H	7.06	6.83	6.83	6.85
60 H	6.00[a]	5.67[b]	5.38[b]	5.83[a]
72 H	5.32[a]	4.62[b]	4.56[b]	5.33[a]
84 H	4.82[a]	4.08[b]	4.30[b]	4.92[a]
96 H	4.13[a]	3.27[b]	3.90[b]	4.46[a]
108 H	3.58[b]	2.80[c]	3.68[b]	4.23[a]
120 H	3.24[b]	2.51[c]	3.38[b]	4.13[a]
132 H	2.79[b]	2.33[c]	3.03[b]	3.84[a]
144 H	2.57[b]	2.10[b]	2.87[b]	3.66[a]
156 H	2.25[b]	2.01[b]	2.61[b]	3.39[a]
PVC Package				
0H	7.50	7.42	7.31	7.36
12 H	7.02	7.01	6.70	6.79
24 H	6.91	6.81	6.70	6.49
36 H	6.58	6.66	6.36	6.23
48 H	6.52[b]	6.45[b]	6.23[b]	5.98[a]
60 H	6.17	6.14	5.72	5.67
72 H	5.80	5.88	5.48	5.42
84 H	5.30	5.11	5.19	5.30
96 H	4.89	4.69	4.80	4.78
108 H	4.33	3.72	4.32	4.38
120 H	3.59[b]	2.62[c]	3.34[b]	4.01[a]
132 H	3.00[a]	2.03[b]	2.75[b]	3.37[a]
144 H	2.56	1.83	2.43	2.91
156 H	2.13	1.29	1.96	2.17

[abc]Means in the same row without a common superscript are different ($P < 0.05$).
[1]Modified atmosphere package.
[2]Polyvinyl chloride overwrapped package.
[3] Overall acceptability was measured on an 8-point scale (8 = extremely desirable/acceptable, and 1 = extremely undesirable/unacceptable).

Table 3.8. Least squares means for the L*A*B* values of [1]MAP and [2]PVC packaged strip loins (n = 185) throughout a 7 d period in the retail display case.[3]

	Treatments			
	Control	125 IU/HD/D	250 IU/HD/D	500 IU/HD/D
L*				
[1]MAP 12 H	41.61	41.96	41.99	43.23
MAP 60 H	42.61	42.48	42.93	43.28
MAP 156 H	45.69	45.11	43.87	43.38
[2]PVC 0 H	37.71	37.58	37.86	38.05
PVC 12 H	38.03	38.16	38.30	38.52
PVC 60 H	38.02	38.15	38.26	38.71
PVC 108 H	38.54	38.73	38.70	38.87
PVC 156 H	38.37	39.05	39.06	39.07
A*				
MAP 12 H	23.15	23.46	24.08	24.05
MAP 60 H	18.49	19.04	20.79	20.63
MAP 156 H	8.88	8.71	2.92	16.38
PVC 0 H	23.14	23.08	22.99	22.27
PVC 12 H	23.26	23.09	23.61	23.18
PVC 60 H	20.61	20.69	22.02	21.43
PVC 108 H	15.10	16.06	16.26	17.44
PVC 156 H	12.69	15.50	17.33	17.31
B*				
MAP 12 H	18.77[b]	19.05[a]	19.23[a]	19.36[a]
MAP 60 H	16.56[b]	16.86[b]	17.64[a]	17.72[a]
MAP 156 H	14.51[c]	14.50[c]	15.06[b]	16.22[a]
PVC 0 H	19.07	19.07	18.74	18.58
PVC 12 H	19.32	19.32	19.68	19.38
PVC 60 H	18.18[a]	18.33[a]	19.16[b]	18.64[a]
PVC 108 H	15.95	16.50	16.59	16.84
PVC 156 H	15.15[b]	16.27[a]	16.96[a]	16.83[a]

[abc]Means in the same row without a common superscript are different ($P < 0.05$).
[1]Modified atmosphere package.
[2]Polyvinyl chloride overwrapped package.
[3] The L* values were used to measure brightness (brightness: 0 = black and 100 = white). The a* values were used to measure redness/greenness (redness/greenness: positive values = red and negative values = green). The b* values were used to measure yellowness/blueness (yellowness/blueness: positive values = yellow and negative values = blue).

Table 3.9. Least squares means for the L*A*B* values of [1]MAP and [2]PVC packaged ground beef (n = 69) throughout a 7 d period in the retail display case.[3]

	Treatments			
	Control	125 IU/HD/D	250 IU/HD/D	500 IU/HD/D
L*				
[1]MAP 12 H	39.87	41.19	40.20	39.39
MAP 156 H	38.24	36.92	37.58	36.65
[2]PVC 0 H	48.55	48.33	46.96	46.77
PVC 72 H	46.19	46.45	45.06	44.08
PVC 156 H	40.20	41.29	40.03	39.45
A*				
MAP 12 H	22.98	22.33	23.03	22.77
MAP 156 H	12.23[b]	12.09[b]	12.83[b]	15.78[a]
PVC 0 H	24.06[b]	23.56[c]	24.96[b]	25.09[a]
PVC 72 H	11.78[b]	9.90[c]	11.81[b]	13.60[a]
PVC 156 H	21.97	22.45	22.42	23.07
B*				
MAP 12 H	19.62	19.41	19.69	19.39
MAP 156 H	15.05	14.71	15.30[a]	15.75
PVC 0 H	18.78	18.16	18.76	18.36
PVC 72 H	13.62[a]	12.50[b]	13.55[a]	13.96[a]
PVC 156 H	19.11	19.48	19.29	19.58

[ab]Means in the same row without a common superscript are different ($P < 0.05$).
[1]Modified atmosphere package.
[2]Polyvinyl chloride overwrapped package.
[3] The L* values were used to measure brightness (brightness: 0 = black and 100 = white). The a* values were used to measure redness/greenness (redness/greenness: positive values = red and negative values = green). The b* values were used to measure yellowness/blueness (yellowness/blueness: positive values = yellow and negative values = blue).

Table 3.10. Least squares means for consumer color evaluation[1]

	Treatments				*P*-Value	
	Control	125 IU/HD/D	250 IU/HD/D	500 IU/HD/D	[1]SEM	Trt
[2]PVC Package,						
D 3	0.7055	0.7228	0.7539	0.6650	0.04	0.58
D 7	1.5451[b]	1.4851[b]	1.4301[ab]	1.2914[a]	0.05	< 0.01
[1]MAP Package,						
D 3	1.0573[b]	1.0640[ab]	0.7891[a]	0.8867[a]	0.06	< 0.01
D 7	1.6259[b]	1.6620[b]	1.6571[a]	1.2243[a]	0.07	< 0.01

[1]Mean values for consumer color scores: 0 = steak was neither chosen for purchase nor deemed unacceptable, 1 = steak was chosen for purchase, and 2 = steak was deemed unacceptable.
[2]Polyvinyl chloride overwrapped package.
[3]Modified atmosphere package.
[ab]Means in the same row without a common superscript are different ($P < 0.05$).

Table 3.11. Least squares means for objective tenderness (n = 185) and sensory attributes (n = 185) of [1]MAP packaged strip steaks that remained under retail display for 72 h.

	Treatments				*P*-Value	
	Control	125 IU/HD/D	250 IU/HD/D	500 IU/HD/D	SEM	Trt
Juiciness						
Initial	4.92	4.87	4.97	5.1026	0.07	0.16
Sustained	5.38	5.32	5.49	5.55	0.07	0.09
Tenderness						
Initial	5.71	5.69	5.76	5.89	0.10	0.52
Overall	5.69	5.63	5.72	5.83	0.10	0.59
Connective						
Tissue	5.78	5.69	5.84	5.91	0.09	0.41
[2]WBSF, kg	3.91	3.74	3.77	3.90	0.11	0.61

[1]Modified atmosphere package.
[2]Warner-Bratzler Shear Force (n = 185) after 72 h in retail display.

Table 3.12. Least squares means for thiobarbituric acid substances in strip loins (n = 185) (TBAR, mg of malonaldehyde/kg of beef), evaluated pre-display and 7 d of retail display for [1]PVC packages, and 1 d, 3 d, and 7 d for [2]MAP packages.

	Treatments					*P*-Value
	Control	125 IU/HD/D	250 IU/HD/D	500 IU/HD/D	[1]SEM	Trt
Vacuum package						
Absolute d 0	0.3676	0.3709	0.3158	0.3142	0.03	0.55
PVC Package						
D 7	1.0311[b]	0.9990[b]	0.7909[ab]	0.5699[a]	0.10	0.10
MAP Package						
D 1	1.1758[b]	1.2106[b]	0.8481[a]	0.6490[a]	0.07	< 0.01
D 3	2.3400[c]	2.2220[c]	1.6909[b]	1.3396[a]	0.09	< 0.01
D 7	3.1023[c]	3.0881[c]	2.2912[b]	1.6610[a]	0.11	< 0.01

[1]Polyvinyl chloride overwrapped package.
[2]Modified atmosphere package.
[abc]Means in the same row without a common superscript are different ($P < 0.05$).

Table 3.13. Least squares means for thiobarbituric acid substances (TBAR, mg of malonaldehyde/kg of beef), evaluated pre-display and d 7 of retail display for ground beef.

	Treatments				*P*-Value	
	Control	125 IU/HD/D	250 IU/HD/D	500 IU/HD/D	SEM	Trt
Vacuum package						
Absolute d 0	0.3417[c]	0.4958[b]	0.8131[a]	0.6011[a]	0.07	< 0.01
[1]PVC Package						
D 7	2.7490[b]	2.4462[b]	2.2853[b]	0.9512[a]	0.25	< 0.01
[2]MAP Package						
D 7	1.2092[b]	1.1023[b]	0.9449[b]	0.4804[a]	0.13	< 0.01

[abc]Means in the same row without a common superscript are different ($P < 0.05$).
[1]Polyvinyl chloride overwrapped package.
[2]Modified atmosphere package.

Table 3.14. Least squares means for the amount of fat, protein, and moisture in the ground beef

	Treatments				*P*-Value	
	Control	125 IU/HD/D	250 IU/HD/D	500 IU/HD/D	[1]SEM	Trt
D 0						
Moisture	66.99	67.10	67.19	67.81	0.66	0.83
Fat	15.89	16.07	15.63	15.10	0.86	0.87
Protein	18.41	18.35	18.36	18.10	0.52	0.97

[1]Standard error of the mean.

CHAPTER IV.

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Master of Science

Thesis: METHODS TO COUNTERACT THE ECONOMICALLY CRITICAL ANTI-QUALITY MEAT CHARACTERISTICS IMPOSED WHEN FEEDING WET DISTILLERS GRAINS TO FINISHING CATTLE

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Title of Study: METHODS TO COUNTERACT THE ECONOMICALLY CRITICAL ANTI-QUALITY MEAT CHARACTERISTICS IMPOSED WHEN FEEDING WET DISTILLERS GRAIN TO FINISHING CATTLE

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Scope and Method of Study: Due to the increase in distiller's grain by-products being used in beef finishing diets, and the anti-quality meat characteristics it causes in the beef, it is important to find a way to decrease lipid oxidation in this product and increase retail shelf life. The objectives of this study was to determine the impact that pre-harvest anti-oxidant supplementation to cattle fed wet distiller's grains has on not only carcass yield and quality grade, but also color stability and consumer acceptability. Two hundred and forty crossbred steers were fed 35% wet distiller's grains with the supplementation of four different levels of vitamin E: fine ground corn (CON), 125 IU/hd/d, 250 IU/hd/d, and 500 IU/hd/d. Chuck rolls (n = 69) and strip loins (n = 185) were collected and processed on 3 d and 7 d, respectively. Chucks were ground and separated into 0.23 kg samples and strip loins were faced and cut into 2.54 cm steaks and packaged in either polyvinyl chloride overwrapped (PVC) package, a vacuum package, a whirl package, or modified atmosphere packages (MAP), for further color, alpha-tocopherol, Thiobarbituric Acid Reactive Substance (TBAR), tenderness and palatability analysis, and proximate analysis.

Findings and Conclusions: Results of this study indicate that the inclusion of different levels of vitamin E in a distiller's grain based diet will not have an effect on carcass characteristics, sensory attributes, or protein, fat and moisture content of beef. This study does indicate that to maximize retail shelf life and decrease lipid oxidation, the critical concentration of supplementation is 500 IU/hd/d of vitamin E in a 35% distiller's grain based diet (dry matter basis) for at least 97 d prior to harvest. It is evident that higher levels of vitamin E inclusions in the diet aid in the maintenance of shelf stability for MAP and PVC packaged strip steaks by sustaining muscle color and overall acceptability while decreasing percent discoloration by decreasing the rate at which of lipid oxidation occurs throughout a 156 h period. In consideration to package type, MAP seemed to maintain discoloration for a longer period, indicating it would be the preferred package for longer aging periods. Instrumental color measurements also prove that although brightness is not improved, higher levels of dietary vitamin E maintains redness and yellowness of steaks for a longer period of time. It is apparent that higher levels of vitamin E in the diet decrease lipid oxidation in ground beef, yet it has little effect on shelf stability and objective color measurements.

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