

**An Analysis of Quality of Non-Traditional Beef Grind Material versus Traditional Beef
Grind Material for Ground Beef Products**

by

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Abstract

An experiment was conducted to evaluate quality differences between traditional and non-traditional grind materials. Three traditional grind sources (T) were compared with seven non-traditional grind sources (N): 7% fat (T1), 11% fat (T2), 16% fat (T3), and 6% fat (N1), 8% fat, (N2), 11% fat (N3), 20% fat (N4), 21% fat (N5), 28% fat (N6) and 29% fat (N7). Additionally, these grind materials were then classified into one of four grind types: Traditional (TR), Quality Grade (QG), Niche (NI) or Breed Specific (BS) for further analysis. All grinds were then packaged in overwrapped foam trays (OW), clear chubs (CH), or overwrapped foam trays in a low oxygen modified atmosphere bag (MAP). Retail display was immediately conducted for 5 d on OW, CH was stored in dark storage for 3 d and MAP was stored in dark storage for 11 d and then placed in retail display for 5 d to simulate industry practices for each respective packaging treatment. Starting on the day packages were placed on display (d 0), 3 packages from each grind/package treatment were removed and frozen for further lab analysis. Also starting on d 0, 5 packages from each package/grind treatment were selected at random and color was evaluated daily with a Hunter Miniscan XE Plus. After completion of the retail display period, the frozen packages were thawed and samples were taken from each for evaluation of oxidative rancidity using TBARS and for Sensory evaluation of initial juiciness (IJ), sustained juiciness (SJ), cohesiveness (CO), beef flavor (BF), off flavor (OF), and cook loss (CL). Data were analyzed using the PROC GLM procedure of SAS. Between grinds, L^* tended to increase with fat percentage and a^* tended to decrease with the increase in fat percentage. No trends were seen in a^* values relating to grinds. Between packaging, all treatments were different for L^* , a^* and b^* ($P < 0.05$). For days of display, all L^* values were not

different ($P>0.05$) until d 3 of retail display. For days on display, a^* values were different ($P<0.0001$) and b^* values all days were different ($P<0.05$) except d 2 and d 3 ($P=0.06$). Two of the highest percentage fat grinds, N5 and N7 had the greatest TBARS values but were not different ($P=0.28$) and the least TBARS value was N4, however this was not different than N3, N1, T1, T3 ($P>0.05$). Days 4 and 5 had the greatest values for TBARS (1.7 and 1.5 TBARS value, respectively), but were not different ($P>0.05$). Day 3 (1.3 TBARS value) was not different than d 5 ($P=0.33$), and d 0 to d 3 were not different ($P>0.05$). Between grinds, differences were seen ($P<0.05$) in all sensory attributes. Between package types, OW and CH had greater IJ ($P<0.05$) than MAP, while the inverse was true for OF values. CH had greater SJ ($P<0.05$) than MAP, with OW not being different than either. CH had greater CO ($P<0.05$) than MAP and OW which were not different ($P>0.05$). All BF values were different ($P<0.05$), with CH being greatest then OW and MAP, respectively. No differences were seen among packages for CL. For display day, d 0 and 3 were different ($P<0.05$) than day d 4 and 5, but neither were different than d 2 for IJ. D 0, 2, and 3 had greater values for SJ ($P<0.05$) than d 5, but none were different ($P>0.05$) from d 4. D 0 and 3 were different ($P<0.05$) but neither were different than d 2, 3, and 4 for CO. BF was lessened from d 0 to d 5 with d 5 being less ($P<0.05$) than d 0, 2, and 3. Additionally, OF was greater ($P<0.05$) at d 5 than d 0 and 2. Data indicates that factors in each grind beyond fat content as well as package and display time play roles in ground beef color stability, lipid oxidation and sensory characteristics.

Differences are also shown when comparing grind types. For Thiobarbituric Acid Reactive Substances (TBARS) BS had the greatest value followed by QG then NI and finally TR, all of which were different ($P<0.05$). In regards to color, BS showed the greatest L^* value followed by TR, QG, and finally NI, respectively. QG and TR were not different ($P>0.05$), but all others were significantly different ($P<0.05$). B^* values were greatest for QG and TR ($P>0.05$), which were greater ($P<0.05$) than BS and NI. The later were not different from one another ($P>0.05$). Additionally there were significant ($P<0.05$) interactions of grind type by day and by packaging type for both a^* and b^* . For

sensory traits, differences also existed. For IJ, TR, QG, and BS were not different ($P>0.05$) and juiciest, followed by NI which was not different ($P>0.05$) than QG and BS. TR, QG, and BS were also not different ($P>0.05$) and greatest for SJ. These were again followed by NI, which was not different than BS ($P>0.05$). BS and NI ($P>0.05$) were most cohesive, followed by QG which was not different ($P>0.05$) than NI. Finally TR was least cohesive, but not different ($P>0.05$) than QG. Beef flavor and off flavor were inverses. BS, QG, and TR had greatest beef flavor and least off flavor and not different from one another ($P>0.05$). NI has the greatest off flavor and least beef flavor. This shows differences do exist between traditional and non-traditional grind types.

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I. INTRODUCTION

Historically, ground beef has been marketed by fat content, but now branded beef programs have become a very popular way to add value to beef. Over 75 of these branded programs now exist, with the oldest being Certified Angus Beef which was initially released in 1978 (USDA, 2012). Some of these programs are associated with USDA Quality Grades as well as other qualifications, while others insinuate a production system in which the cattle were raised. Extensive research has been done on the effect of marbling (one of the key qualifications in USDA Quality Grading) on palatability in whole muscle cuts, yet little has been done to suggest that quality grade impacts nor if any of these branded programs truly represent differences in ground beef palatability.

Marbling is a good indication of overall palatability in loin cuts (McBee, 1967). Additionally, Marbling is one of the major factors involved in the determination of USDA Quality Grade (USDA, 1997), therefore branding programs with a quality grade requirement should be at least equal in quality to there associated quality grade.

The 2011 National Beef Quality Audit (NCBA, 2011) indicated that consumers are confused by terminology in regards to quality. Research has shown consumers that self identify as having low familiarity to the product they are purchasing show a 0.75 correlation between branding of the product to expected eating quality (Bredahl, 2004). Branding, in this case, could both be seen as certification programs, in-store brands, or possibly USDA Quality Grades if they are shown on the package as was the brand created in the Bredahl (2004) study. This indicates that consumers rely heavily on cues from branding when determining quality of beef they intend to purchase. As stated previously, these brands or quality grades are good indicators of quality in whole muscle cuts, but little research has been done to evaluate ground beef from these brands and how they differ from traditional ground beef.

The objective of this study is to examine ground beef from traditional and non-traditional (branded) grind materials to determine if differences exist that differ from what is expected based on fat percentage. It is hypothesized that differences in sensory characteristics, shelf life and color stability between these grind materials should follow a similar pattern as seen in previous studies of fat percentage in ground beef.

II. REVIEW OF LITERATURE

Consumer Willingness to Pay for Beef

Ground beef is typically marketed based on fat percentage, and lean ground beef is more valuable (Lusk et al., 2009). In recent years, though, a decline in beef demand has forced the beef industry to significantly change marketing programs (Campiche et al., 2004). One marketing tactic, branded programs, has grown to include over 75 branded programs (USDA, 2012). The oldest is Certified Angus Beef which was initially released in 1978 (USDA, 2012). These branding programs include a wide variety of claims from natural to some indication of quality to location of production (USDA, 2012).

To assess the successfulness of many branded programs, numerous consumer surveys and studies have been published. Loureiro et al. (2003) surveyed consumers in Colorado about their willingness to pay for Country-of-Origin labeling. This survey was conducted in several grocery stores in Boulder, Denver and Fort Collins. These consumers indicated that they would pay 38%-58% premiums for products labeled “U.S. Certified Steak” or “U.S. Certified Hamburger”.

Consumers studied in Canada would pay greater premiums for quality than they would pay for products branded as being produced in Canada (Froehlich et al., 2009). Consumers in this study were offered four hypothetical brands developed to represent local, natural, guaranteed tender, and Angus derived beef. Using a Becker-DeGroot-Marschak experimental auction, consumers purchased the brands perceived to impart greater quality at an average premium \$0.11-0.12 higher than the brand associated with origin. This seems to indicate consumers will not pay equal premiums for domestic products of inferior quality and that products claiming country of origin must also meet quality expectations.

Additionally, Lyford et al. (2010) surveyed consumers about their willingness to pay for quality beef. Across most demographics, including gender, income, family size and profession, as well as meat consumption frequency, consumers were willing to pay premiums for higher quality beef. The only exception being that as people aged, their willingness to pay decreased. Other studies have concluded that consumers are willing to pay for quality (Lusk et al., 1999).

Another study was conducted by Boleman et al. (1997) to determine consumer perceptions of beef top loin steaks of known shear force and to evaluate how buying trends were altered by tenderness and price variations. The center steak of each strip loin was evaluated for tenderness by Warner-Bratzler Shear force and the remaining steaks from the loin were assigned a colored package: Tender-Red, Intermediate-White, and Tough-Blue. Forty-two families were used in this 3 phase study. During the first phase, families were sent steaks from each of the three color packages to evaluate. In the second phase, steaks were available for sale in a retail case at an equal price. In the final phase a \$1.10/kg difference in price placed between groups. In this phase, families were informed of shear force values of each color and sold steaks on the phone. 94.6% of families purchased the guaranteed tender steaks at a \$1.10/kg premium.

Consumers have also been surveyed about their desire to purchase meat produced in an organic or natural manner. Napolitano et al. (2010) indicate that organic products remain limited by high production costs and therefore high prices, but since consumer willingness to pay for these products is largely driven by information rather than sensory characteristics, consumers will pay for them even at the high premiums.

Grannis et al. (2000) examined the willingness to pay for locally-produced, natural ground beef and steaks in the Intermountain West as well as the importance of several production methods to consumers. Twenty-two hundred primary grocery shoppers in Colorado, New Mexico

and Utah were surveyed via mail with just over 60% responding to the survey. “No use of Hormones” ranked as the most important production characteristic in both the ground beef and steak categories followed by antibiotics. 38% of consumers were willing to pay a 10% premium for natural steak and 67% were willing to pay a 12% premium for natural ground beef. Additionally, consumers that had previously purchased natural beef were more willing to pay premiums associated with natural branding. This study used the terms Natural and Organic interchangeably, so it is possible that two groups of consumers were grouped together.

This is echoed by Lusk et al. (2002), who reported that consumers would be willing to pay a 17% premium for beef from cattle grown without the use of growth promoting implants and a 10.6% premium for beef from cattle not fed genetic modified corn. 85% of consumers in that study also desired mandatory labeling of products of these production practices, if no cost was added. Other studies agree that consumers will pay premiums for a natural label (Campiche et al., 2004).

Thilmany et al. (2005) performed a cluster analysis of consumers in Colorado and the marketing segments for various natural beef products. This analysis identified that there are multiple segments of the consumer population likely to purchase natural beef and these segments are motivated by different factors. These groups were identified and clustered by statistical analysis of their perceptions and responses. Five clusters were created: Quality Seekers, Health and Natural Consumers, Moderate Consumers, Empathic Value Seekers, and Price Conscience Consumers. Quality Seekers and Health and Natural Consumers were much more willing to pay for all natural, local beef products followed by Moderate Consumers.

Beriain et al. (2009) compared consumer sensory acceptance, purchase intention, and willingness to pay for U.S. Choice and Prime beef as well as Spanish beef from yearling bulls on

consumers in Spain. Consumers were tested at three levels: blind, with knowledge of production system and fat content, and with knowledge of origin, fat content and production system.

Consumers given full information showed greater intent to purchase the Spanish beef even with lower sensory acceptance. This seems to contradict findings by Froehlich et al. (2009). This might partial be explained by the difference in cultures between the countries in which these studies were conducted.

Umberger et al. (2002) surveyed consumers as to whether they preferred domestically grown grain-finished beef or imported grass-finished beef of equal quality. Respondents were grouped into three categories: grain preferring, grass preferring or indifferent. While 62% of respondents were willing to pay a \$1.61/lb. premium for U.S. grain-finished beef, 23% were willing to pay a \$1.36/lb. premium for the grass-finished beef. Those respondents categorized into a group preferring one or the other were willing to pay premiums for their preference.

While it is clear that consumers are willing to pay for quality and, in some cases, a more natural product, what is even more evident is that consumers will pay for their preferences. However as consumer preferences change, the quality of the product must be assessed.

Effect of Production System on Ground Beef

Many of the branded beef programs have some association with a particular production system. Many of these production systems can potentially play a role in beef quality.

One of the more popular alternative production systems is the forage finishing system. French et al. (2000) performed an experiment to evaluate the differences in fatty acid composition of steers offered grass, grass silage and concentrate-based diets. Their data indicate that cattle fed forages have higher levels of polyunsaturated fatty acids as well as higher levels of conjugated linoleic acid. Multiple studies have confirmed that forage diets create higher levels of

polyunsaturated fatty acids (Larick et al., 1989; French et al., 2002; Baublits et al., 2006; Realini et al., 2004) and conjugated linoleic acid (Leheska et al., 2008; Poulson et al., 2004)

Additionally, it has been reported that beef from cattle fed grass silage have increased color stability and decreased lipid oxidation than those fed corn silage (O'Sullivan et al., 2002). Mandell et al. (1998) also showed that beef from cattle fed Alfalfa silage have increased off flavor and decreased beef flavor. Baublits et al. (2006) reported this same increase in off flavor in cattle fed forage diets as compared to those supplemented.

Due to the ethanol production in the U.S., distillers grains has become a popular feed stuff. Koger et al. (2010) supplemented steers with either 0%, 20% or 40% dried distillers grains to determine its influence on meat quality. Their data show that beef from cattle fed distillers grains contains higher concentrations of polyunsaturated fatty acids and at 40% inclusion TBARS values are increased. Biological type of cattle has been shown by Baublits et al. (2006) not to have an effect on fatty acid profile or sensory characteristics.

Length of feed period has also been shown to have little affect on fatty acid profile (Rule et al., 1997).

Dietary supplements can also be used to affect beef quality. Vitamin E supplementation to beef cattle increase α -tocopherol in skeletal muscle, which acts as an antioxidant slowing the discoloration of fresh meat and suppressing lipid oxidation (Liu et al., 1995). Postmortem addition of Vitamin C can retard pigment oxidation in both grain and grass finished cattle, but does not suppress lipid oxidation in grass finished cattle (Realini et al., 2004). Raines et al. (2009) also show that ground beef from dairy cattle as well as beef cattle were equal in color stability.

Growth Promoting hormones are great concern of consumers (Lusk et al., 2002; Grannis et al., 2000). Cranwell et al. (1996) used Trenbolone Acetate and Testosterone propionate with Estradiol Benzoate implants on mature cow to evaluate meat quality effects. They showed that these implants both increased palatability of steaks from mature cows. Additionally, Zilpaterol hydrochloride, a β -agonist used in feedlot cattle, was shown to lower TBARS values in beef after 7 days of dark storage and was equal to controls for instrumental color and discoloration.

Lipid Oxidation

The oxidation of lipids and the associated changes are a major cause of muscle food quality deterioration (Ladikos et al., 1989). These oxidative changes in lipids primarily involve autoxidation reactions accompanied by secondary oxidative and non-oxidative reactions, but the initiation stage of this autoxidation is the subject of much research and is regarded generally as uncertain (Gray et al., 1992).

Initiation of autoxidation by spontaneous abstraction of hydrogen from organic material with molecular oxygen requires a large amount of activation energy and the direct addition of oxygen to a double bond to generate hydroperoxide compounds is prevented by the spin conservation rule (Kanner et al., 1992; Baron et al., 2002).

Iron initiates lipid oxidation by generating free radicals that can then abstract a proton from unsaturated fatty acids (Baron et al., 2002). Additionally, enzymes such as flavoenzyme, cytochrome-P450 reductase, lipoxygenase, xanthine oxidase, and cyclooxygenase have been shown to catalyze the formation of hydroperoxides (Kanner et al., 1992). This initiation step ultimately produces hydroperoxides which can then undergo changes and deterioration with the radicals (Fernandez et al., 1997)

Heavy metals, such as nonheme iron, exert a prooxidative effect on lipid oxidation through the catalytic decomposition of hydroperoxides to free radicals (Rhee et al., 1987). Decker et al. (1989) demonstrated that Ferritin, an iron storage protein found in the liver, spleen and skeletal muscle, could also play a role in the catalysis of oxidation. This ultimately results in the formation of carbonyl compounds, malonaldehyde, hydrocarbons, or fluorescent products (Gray et al., 1992). Malonaldehyde is toxic to living cells (Addis, 1986).

Measurement of lipid oxidation can be done either by measuring the primary products (hydroperoxides) or the secondary products with one of the most frequently used assay is the 2-thiobarbituric acid reactive substances assay(Gray et al., 1992). Addis (1986) demonstrated that the TBARS method vastly overestimates malonaldehyde levels, but is still a useful measurement of lipid oxidation. Gray et al. (1992) suggests that when presenting data for this assay it should simply be referred to as TBARS value in place of ppm malonaldehyde.

Effect of Fat in Ground Beef

Troutt et al. (1992) performed an experiment to compare the chemical, physical, and sensory characteristics of ground beef with fat percentage of 5 to 30 percent. Using lean cow knuckles and 90% fat beef trimmings, they created grinds of 5, 10, 15, 20, 25, and 30 percent fat and used these to make patties for evaluation. Patties were cooked to two endpoint internal temperatures of 71°C and 77°C, then evaluated. Their data indicated an increase in Moisture, Moisture Release, and Juiciness as fat percentage increased. Beef Flavor was largely unaffected by fat content, as well as cohesiveness.

Berry (1992) conducted a similar trial. Grinds of 0, 4, 8, 12, 16, and 20 percent fat were created, but were cooked to a similar cook loss. This resulted in similar percentages of fat in the cooked product as the raw product. This data agrees with Troutt et al. (1992). As fat percentage

decreases so does juiciness, but in contrast Berry (1992) indicates that tenderness and flavor also decline as fat percentage decreases.

Most studies agree with the above examples that ground beef containing a higher percentage fat will also be scored higher in sensory evaluation of juiciness (Berry et al., 1984; Berry 1994; Cross et al., 1980; Miller et al., 1993). Some studies also agree with Berry (1992) that fat percentage and flavor are highly correlated (Berry, 1993; Berry, 1994; Miller et al., 1993), while others agree with Troutt et al. (1992) that flavor is not dependent on fat content (Cross et al., 1980).

Flavor results from the combination of tastes and odors derived from a variety of volatile compounds and over half of the volatiles identified in cooked meat result from lipids (Brewer, 2012). Morrissey et al. (1998) indicates that lipid oxidation is more prone to occur in meat contain higher percentages of unsaturated fatty acids. Many studies and reviews agree with this concept (Ladikos et al., 1990; Baron et al., 2002; Gray et al., 1992).

Cannell et al. (1989) performed an experiment to evaluate the fatty acid composition of ground beef at various fat percentages using beef top rounds as a lean source and plates as a fat source. They showed that fatty acid profile changes very little due to grind formulation or cooking. Houben et al. (2000) data showing no difference in TBARS values across a 10 day retail display between low and high fat ground beef samples is then expected when considering the previous statements.

Effect of Packaging

When processing meat for retail sale, packaging must be taken into account. Consumers have an expectation to buy meat that appears fresh, while retailers and processors would prefer a product with an extended shelf life. Different packaging treatments, such as overwrapped

polystyrene trays, vacuum packages and modified atmosphere packaging, have the ability to address these issues.

Modified atmosphere packaging (MAP) is packaging in which the product is placed in a defined atmosphere of gases. Beef packaged in High Oxygen (>70%) MAP has been shown to maintain its fresh meat color longer when compared to beef packaged in an anaerobic environment, but also had higher TBARS values which are an indicator of lipid oxidation (Kim et al., 2010; Jayasingh et al., 2002). Similarly, data from Cayuela et al. (2004) demonstrates that TBARS values were higher for High Oxygen MAP than both vacuum packaged pork loins and pork loins overwrapped with oxygen-permeable film, but that no significant difference in redness occurred. This could be contributed to the lower levels of myoglobin found in pork, resulting in less color change from oxymyoglobin to deoxymyoglobin.

In an experiment performed by Zakrys et al. (2008), various levels of oxygen were included in MAP of beef muscles. In this study, five packaging treatments consisting of 20% CO₂, either 0, 10, 20, 50, or 80% O₂, and the remainder N₂ were evaluated for Lipid Oxidation, Color Stability and Sensory Preference. This research indicated that lowering oxygen content below 20% significantly lowers TBARS values in extended storage times. Results from Jakobsen et al. (1999) agree with findings from Zakrys et al. (2008) that at 20% oxygen TBARS values were lowered, but the results also indicate that these lower levels of oxygen also create lower a* values, or a less red appearance.

Additional research has been performed to evaluate MAP with the complete removal of oxygen as compared to vacuum packaging and 10% O₂ MAP (Sørheim et al., 1996). Sensory color evaluation indicated that MAP including 10% O₂ showed greater color after storage (greater being more grey/tan) and greater discoloration after storage than all other treatments in

pork loin sections. These studies appear to indicate that using low oxygen (20% or less oxygen) MAP would increase shelf life, but decreases the fresh meat color consumers have come to expect.

Lund et al. (2007) attempted to solve this problem by adding an antioxidant to the meat in the package. In their research, they found that by adding antioxidants such as L-Ascorbic Acid with Sodium Citrate and Rosemary Extract to meat in high oxygen MAP they could lower TBARS values to the level of low oxygen MAP while maintaining the color advantage held by high oxygen MAP.

Additional research has been conducted to evaluate the effect of carbon monoxide (CO) on low oxygen MAP. Luño et al. (2000) evaluated the use of MAP with atmospheres containing 24% O₂ with either 0.1, 0.25, 0.5, 0.75, or 1% CO and compared them to a 70% O₂ atmosphere using beef steaks. This data showed that low oxygen MAP including CO at 0.5-0.75% is equal in color stability and a* color while also having lower TBARS values across storage than high oxygen MAP. Similarly, Wilkinson et al. (2006) show that low oxygen MAP with CO maintains the same shelf life with the MAP including CO providing improved color in pork.

Sørheim et al. (1999) evaluated the use of low oxygen with carbon monoxide and high oxygen MAP in ground beef, beef steak and pork chops in regards to color and odor at two storage temperatures of 4°C and 8°C. All three meats were packed in these two treatments as well as clipped chub bags for ground beef, vacuum packaging for steaks and a MAP of 60% CO₂/40 N₂ for the pork chops. CO MAP, Chub bags and Vacuum packaging all performed similarly in time of off-odor detection in beef and in pork CO MAP had the longest time before off-odor detection followed by the no oxygen MAP then high oxygen MAP. Both visual and instrumental color scores were redder for the CO MAP regardless of product or storage temperature.

Luño et al. (1998) examined color stability of both ground beef and loin steaks packaged in MAP gas mixtures of 70% O₂ without NO, 70% O₂ with 1% NO and 24% O₂ with 1% NO. Ground beef and loin steaks packaged in MAP with NO had greater color stability beyond 12 and 15 days, respectively, than the packaging treatments that did not contain NO.

Low oxygen MAP with CO also performs well when compared to overwrap and vacuum packaging. It has shown the same resistance to lipid oxidation as vacuum packaging (John et al., 2004) with the same acceptable color as traditional overwrapped meat (John et al., 2004; Hunt et al., 2004) while maintaining this color longer (Ho et al., 2003).

It has also been show in beef steaks that high oxygen MAP decreases overall palatability (Clausen et al., 2008; Lagerstedt et al., 2011) and that the inclusion of CO does not change palatability when compared to high oxygen MAP (Stetzer et al., 2007).

In a consumer study, Carpenter et al. (2001) reported that consumers prefer the traditionally overwrapped meat to both vacuum packaged and MAP. This research also showed that consumers did not allow decisions at purchase to bias there perception of the product at cooking, so they speculate that in time consumers could grow to accept MAP once they have seen if it has equal quality to overwrap.

Conclusion

Production systems and proper formulation of ground beef products can produce a product that meets consumer expectations of quality more efficiently. Through the use of packaging technologies, quality of these products can be sustained across a longer shelf life.

Additionally, consumers have shown they are willing to pay for added quality. They have also shown a demand for beef produced more naturally. Some of the branded programs now

being marketed have taken advantage of these premiums. No research has been done to indicate these programs offer any added quality beyond that of any other ground beef products of equal fat content.

Therefore, the objective of this study is to compare seven of these branded ground beef products to traditional ground beef sources on fatty acid composition, shelf life and sensory characteristics to determine if any of these branded programs offer quality different than their traditional grind counterparts of similar fat content.

III. An Analysis of Quality of Non-Traditional Beef Grind Material Versus Traditional Beef Grind Material for Ground Beef Products

Abstract

An experiment was conducted to evaluate quality differences between traditional and non-traditional grind materials. Three traditional grind sources (T) were compared with seven non-traditional grind sources (N): 7% fat (T1), 11% fat (T2), 16% fat (T3), and 6% fat (N1), 8% fat, (N2), 11% fat (N3), 20% fat (N4), 21% fat (N5), 28% fat (N6) and 29% fat (N7). All grinds were then packaged in overwrapped foam trays (OW), clear chubs (CH), or overwrapped foam trays in a low oxygen modified atmosphere bag (MAP). Retail display was immediately conducted for 5 d on OW, CH was stored in dark storage for 3 d and MAP was stored in dark storage for 11 d and then placed in retail display for 5 d to simulate industry practices for each respective packaging treatment. Starting on the day packages were placed on display (d 0), 3 packages from each grind/package treatment were removed and frozen for further lab analysis. Also starting on d 0, 5 packages from each package/grind treatment were selected at random and color was evaluated daily with a Hunter Miniscan XE Plus. After completion of the retail display period, the frozen packages were thawed and samples were taken from each for evaluation of oxidative rancidity using TBARS and for Sensory evaluation of initial juiciness (IJ), sustained juiciness (SJ), cohesiveness (CO), beef flavor (BF), off flavor (OF), and cook loss (CL). Data were analyzed using the PROC GLM procedure of SAS. Between grinds, L* tended to increase with fat percentage and a* tended to decrease with the increase in fat percentage. No trends were seen in a* values relating to grinds. Between packaging, all treatments were different for L*, a* and b* ($P < 0.05$). For days of display, all L* values were not different ($P > 0.05$) until d 3 of retail display. For days on display, a* values were different ($P < 0.0001$) and b* values all days were different ($P < 0.05$) except d 2 and d 3 ($P = 0.06$). Two of the highest percentage fat grinds, N5 and

N7 had the greatest TBARS values but were not different ($P=0.28$) and the least TBARS value was N4, however this was not different than N3, N1, T1, T3 ($P>0.05$). Days 4 and 5 had the greatest values for TBARS (1.7 and 1.5 TBARS value, respectively), but were not different ($P>0.05$). Day 3 (1.3 TBARS value) was not different than d 5 ($P=0.33$), and d 0 to d 3 were not different ($P>0.05$). Between grinds, differences were seen ($P<0.05$) in all sensory attributes. Between package types, OW and CH had greater IJ ($P<0.05$) than MAP, while the inverse was true for OF values. CH had greater SJ ($P<0.05$) than MAP, with OW not being different than either. CH had greater CO ($P<0.05$) than MAP and OW which were not different ($P>0.05$). All BF values were different ($P<0.05$), with CH being greatest then OW and MAP, respectively. No differences were seen among packages for CL. For display day, d 0 and 3 were different ($P<0.05$) than day d 4 and 5, but neither were different than d 2 for IJ. D 0, 2, and 3 had greater values for SJ ($P<0.05$) than d 5, but none were different ($P>0.05$) from d 4. D 0 and 3 were different ($P<0.05$) but neither were different than d 2, 3, and 4 for CO. BF was lessened from d 0 to d 5 with d 5 being less ($P<0.05$) than d 0, 2, and 3. Additionally, OF was greater ($P<0.05$) at d 5 than d 0 and 2. Data indicates that factors in each grind beyond fat content as well as package and display time play roles in ground beef color stability, lipid oxidation and sensory characteristics.

Materials and Methods

Ground Beef Materials

Ground beef from ten different grind sources were shipped to Cargill Meat Solutions' Research and Development Center (Wichita, KS) for evaluation. Three of the grinds were from traditional beef grind materials and the remaining seven were from non-traditional or branded grind materials. All grinds were finely ground prior to arrival.

Traditional Grind Material 1 (T1) was a grind material labeled as 19 percent fat ground chuck. The beef arrived in a finely ground form, packaged into approximately 4.54 kg chubs.

Traditional Grind Material 2 (T2) was a grind material labeled as 14 percent fat ground round. The beef arrived in a finely ground form, packaged into approximately 4.54 kg chubs.

Traditional Grind Material 3 (T3) was a grind material labeled as 7 percent fat ground beef. The beef arrived in a finely ground form, packaged into approximately 4.54 kg chubs.

Non-Traditional Grind Material 1 (N1) was a grind material labeled as 19 percent fat. This ground beef must have come from beef carcasses with a minimum marbling score of modest, maturity A, medium or fine marbling texture, Ribeye Area of 10.0 to 16.0 in², Hot Carcass Weight of less than 1000 pounds, Fat Thickness of less than 1.0 inch, Moderately Thick or thicker muscling, and no hump exceeding 2 inches as well as having at least 51 percent black hide with no dairy influence. The beef arrived in a finely ground form, packaged into approximately 4.54 kg chubs.

Non-Traditional Grind Material 2 (N2) was a grind material labeled as 14 percent fat. This ground beef must have come from beef carcasses with a minimum marbling score of modest, maturity B or younger, medium or fine marbling texture, Moderately Thick or thicker muscling, and no hump exceeding 2 inches. The beef arrived in a finely ground form, packaged into approximately 4.54 kg chubs.

Non-Traditional Grind Material 3 (N3) was a grind material with an unspecified fat percentage. This ground beef came from fed-cattle of Wagyu parentage. The beef arrived in a finely ground form, packaged into approximately 4.54 kg chubs.

Non-Traditional Grind Material 4 (N4) was a grind material with an unspecified fat percentage. This ground beef came from carcasses of maturity B or younger with a marbling score Slightly Abundant or higher. The beef arrived in a finely ground form, packaged into approximately 4.54 kg chubs.

Non-Traditional Grind Material 5 (N5) was a grind material labeled as 10 percent fat. This ground beef was taken from carcasses of cattle strictly finished on high forage diets. The beef arrived in a finely ground form, packaged into approximately 18.16 kg vacuum sealed bags.

Non-Traditional Grind Material 6 (N6) was a grind material with an unspecified fat percentage. This ground beef was taken from carcasses of cull Wagyu breeding bulls. The beef arrived in a finely ground form, packaged into approximately 4.54 kg chubs.

Non-Traditional Grind Material 7 (N7) arrived in a finely ground form, packaged into approximately 4.54 kg chubs. This grind material was labeled as a natural product.

Packaging

After arriving at Cargill, the ground beef was stored overnight and processed into retail packaging the next day. Grind N3 and N4 were slightly frozen upon arrival, but thawed overnight. Each grind was packaged in to three packaging treatments: 0.45 kg loaves on traditional 2S Styrofoam trays (Cryovac, Duncan, SC) with absorbent diapers and overwrapped with oxygen-permeable polyvinyl chloride film (O₂ transmission = 23,250 mL/m²/24 h, 72 gauge), 0.45 kg loaves on traditional overwrapped 2S Styrofoam trays in a modified atmosphere shipping bag, and 0.45 kg of meat stuffed into clear chubs.

All grind materials were packaged with a Vemag Vacuum Stuffer (Vemag Maschinenbau GmbH, Verden, Germany) using a stuffing horn for the chubs and a grinder/portioning head (Vemag Maschinenbau GmbH, Verden, Germany) for the foam trays. The Vemag was set to extrude 4.54 kg of meat at a time. Chubs were placed directly on to the stuffing horn and filled tightly to minimize air in the package, then clipped with a staple. When enough chubs were made for a grind, the grinder/portioning head was attached. Loaves were extruded onto a moving conveyor belt and shaped into 5”x8”x2” loaves with plastic paddles, then placed on to 2S foam

trays and overwrapped using a Minipack Ministretch (Minipack America, Inc., Orange, CA) . Between each grind material, approximately 6 to 10 kg of meat was passed through each attachment to clear the remnants of the previous grind material.

After packaging, half of the overwrapped foam trays were placed into storage bags along with Multisorb CR20 Oxygen Scavenger (Multisorb Technologies, Buffalo, NY). Using a Fresh Vac Modified Atmosphere Machine (CVP System, Inc., Downers Grove, IL), air was then vacuumed out and flushed with an industry standard low oxygen gas mix, (approximately 0.4% CO, 30% CO₂, 60% N₂).

Storage and Retail Display

Traditional Overwrapped Foam Trays were then immediately placed on retail display after packaging in a Hussman retail display case (Hussman, Bridgton, MO). Packages were displayed for five days and every day, starting on day 0, three packages were removed from display and frozen for later analysis. Additionally, 5 packages were selected at random and scanned with a Hunter Miniscan XE Plus (Hunter Lab, Reston, VA) starting on day 0 and rescanned every 24 hours. After five days of display, these 5 packages were frozen for later analysis.

Chubs were held for three days in dark storage to simulate shipping then placed on retail display. Packages were displayed for five days and every day, starting on day 0, three packages were removed from display and frozen for later analysis. Additionally, 5 packages were selected at random and scanned with a Hunter Miniscan XE Plus (Hunter Lab, Reston, VA) starting on day 0 and rescanned every 24 hours. After five days of display, these 5 packages were frozen for later analysis.

Overwrapped Foam Trays in the modified atmosphere storage bags were placed in individual plastic trays to prevent crushing of the bags. These trays were placed in dark storage for three days then moved to normal storage for an additional seven days to simulate average shipping and storage of retail ground beef. After storage, packages were placed on retail display. Packages were displayed for five days and every day, starting on day 0, three packages were removed from display and frozen for later analysis. Additionally, 5 packages were selected at random and scanned with a Hunter Miniscan XE Plus (Hunter Lab, Reston, VA) starting on day 0 and rescanned every 24 hours. After five days of display, these 5 packages were frozen for later analysis.

Processing

After freezing, samples were then placed in insulated boxes with dry ice shipped to the Lambert-Powell Meats Laboratory at Auburn University (Auburn, AL) and were immediately unboxed and stored at -23°C . Samples were then thawed for 24 hours at $4^{\circ}\text{C} \pm 2^{\circ}\text{C}$.

Once thawed, each sample was removed from its retail package and placed in a 20.3 x 38.1 cm 3 mil High Barrier Nylon/Ethylene Vinyl Alcohol/Polyethylene Vacuum pouch (Cryovac, Duncan, SC) and mixed thoroughly by hand. From these bags approximately 50 grams was removed and placed in a 50 mL plastic conical tube (VWR, Radnor, PA) for analysis in the laboratory in Upchurch Hall and two portions weighing at least 114 grams each were placed into 15.2 x 20.3 cm 3 mil High Barrier Nylon/Ethylene Vinyl Alcohol/Polyethylene Vacuum pouches (Cryovac, Duncan, SC) and labeled for later sensory evaluation. After portioning, the remaining sample in the 20.3 x 38.1 cm vacuum pouch and both sensory portions were vacuum sealed at 98% vacuum with an Ultravac UV2100-C (Koch Equipment LLC., Kansas City, MO) and frozen at approximately -23°C . This was repeated for each sample.

Thiobarbituric Acid Reactive Substances

Immediately after all samples were processed, the thawed meat samples in the vortex tubes were transported to Upchurch Hall and analysis began. A modified Buege and Aust (1978) procedure for Thiobarbituric Acid Reactive Substances (TBARS) was used to measure the levels of malondialdehyde in each kg of meat.

A standard was first created to create a regression equation for the prediction of malondialdehyde levels. First a stock solution of 0.1 mL of 1,1,3,3-tetraethoxypropane (TEP) and 100 mL deionized water was created and then diluted to 1:2.96 with additional deionized water. A 10% butylated hydroxyanisole (BHA) solution was also made by dissolving 10g BHA into 100 mL of 90% Ethanol. Seven tubes were then labeled 0 through 6 with 4 mL of the BHA solution were then added to each tube. The TEP working solution was then added to each tube starting with 0 mL in tube 0, then 0.01 mL, 0.02 mL, 0.04 mL, 0.06 mL, 0.08 mL, and 0.1 mL to tubes 1, 2, 3, 4, 5, and 6, respectively. Deionized water was then added to each tube to reach a final total volume of 6 mL. These tubes were heated in a 95°C water bath for 15 minutes, then cooled in a 20°C water bath for ten minutes.

To measure absorbance, 200 µL of each of the resulting solutions were pipetted in duplicate into a 96 well microtiter plate (Greiner Bio-one, Frickenhausen, Germany) and read using a Multiskan EX (Thermo Fisher Scientific, Waltham, MA, USA) absorbance reader at 540 nm.

To determine TBARS on each meat sample, 5 grams of each meat sample was weighed and placed in an additional vortex tube with 15 mL of de-ionized water. After 5 grams was removed from the original sample, the remainder was placed into the freezer for later analysis. The vortex tube was then sealed and vortexed for 20 seconds, homogenizing the mixture. Tubes

were then centrifuged for 10 minutes at 1850 g using a Beckman Coulter Allegra X-15 R (Beckman Coulter, Inc., Brea, CA, USA) swinging bucket rotor.

From the centrifuged tube, 2 mL of the supernatant was removed and placed in a test tube with a pipette. 4 mL was then added of a 15% trichloroacetic acid (TCA) and 20 μ M Thiobarbituric Acid (TBA) as well as 100 μ L of a 10% BHA solution. This mixture was then vortexed and heated in a 95°C water bath for 15 minutes. Test tubes were cooled in a water bath at 20°C for 10 minutes then centrifuged at 1850 g for 10 minutes.

To measure absorbance, 200 μ L of the resulting supernatant was pipetted in duplicate into a 96 well microtiter plate (Greiner Bio-one, Frickenhausen, Germany) and read using a Multiskan EX (Thermo Fisher Scientific, Waltham, MA, USA) absorbance reader at 540 nm.

Fatty Acid Composition

All fatty acid standards were purchased through Nu-Chek Prep Inc., Elysian, Minnesota, except Hexanes (J.T. Baker, Phillipsburg, New Jersey), MeOH (Fisher Scientific, Fair Lawn, New Jersey), KOH (Sigma-Aldrich, St. Louis, Missouri), and Supelco standard fatty acid methyl ester (FAME) mixture (47885-U) (Supelco, Bellefonte, Pennsylvania).

Frozen samples were thawed to room temperature. Samples were uniformly distributed by grinding for 10 to 15 s in a room-temperature coffee bean grinder (Mr. Coffee Inc., Cleveland, Ohio). 1.0 g of meat was placed into a 16 \times 125 mm screw-cap Pyrex culture tube (Corning Laboratory Science Company, New York) to which 1.0 mL of the C13:0 internal standard (0.5 mg of C13:0/mL of MeOH), 0.7 mL of 10 N KOH in water, and 5.3 mL of MeOH were added. The tube was incubated in a 55°C water bath for 1.5 h with vigorous hand-shaking every 20 min to properly permeate, dissolve, and hydrolyze the sample. After cooling below room temperature in a cold tap water bath, 0.58 mL of 24 N H₂SO₄ in water was added. The tube was mixed by

inversion and with precipitated K_2SO_4 present was incubated again in a $55^\circ C$ water bath for 1.5 h with hand-shaking every 20 min.

After FAME synthesis, the tube was cooled in a cold tap water bath. Three milliliters of hexane was added, and the tube was mixed for 5 min on a vortex. The tube was then centrifuged for 5 min in a Beckman-Coulter Allegra X-15R centrifuge, and the hexane layer, containing the FAME, was removed and placed into a 2ml GC vial. The vial was capped and placed at $-20^\circ C$ until GC analysis.

The fatty acid composition of the FAME was determined by capillary GC on a SP-2560, $100m \times 0.25 \text{ mm} \times 0.20 \text{ }\mu\text{m}$ capillary column (Supelco) installed on a Shimadzu 2014 gas chromatograph equipped with a Shimadzu AOC-20i auto injector, a flame ionization detector, and split injection. The initial oven temperature was $140^\circ C$, held for 5 minutes, subsequently increased to $240^\circ C$ at a rate of $4^\circ C \text{ min}^{-1}$, and then held for 20 minutes. Helium was used as the carrier gas at a flow rate of $0.5 \text{ mL}_{\text{min}}^{-1}$, and the column head pressure was 280 kPa. Both the injector and the detector were set at $260^\circ C$. The split ratio was 30:1. Fatty acids were identified by comparing their retention times with FAME standards purchased from Supelco.

Crude Fat Percentage-Proximate Analysis

Meat samples from the display day 0 and traditional overwrap packages of all ten grinds were used for proximate analysis. Each sample was run in duplicate. These samples represented the meat that was frozen before any storage or display occurred. These samples were the previously frozen samples not used during TBARS analysis.

Each sample was ground to a fine powder. 5 grams of each sample was weighed out and placed in an aluminum pan and dried in the Cenco Forced Convection Oven (Central Scientific

Company, Chicago, IL) at 100C for 16 to 18 hours. Pans were then removed from the drying oven and placed in a desiccator to cool for ½ hour. Each pan was then weighed and recorded.

After completion of drying, nonabsorbent cotton was placed in the pan to cover the sample. The sample pans were then weighed and recorded to measure the amount of cotton added. A boiling flask was filled 2/3 full of petroleum ether and 3 boiling chips were added. Samples were then placed in the Soxtec System HT 1043 Extraction Unit (Gerber Instruments AG, Switzerland), 6 at a time following the AOAC guidelines for this machine.

After extraction was completed, samples were placed under fume hood for approximately 1 hour to allow all of the petroleum ether to evaporate. Samples were dried in the drying oven for 1 hour at 100C, then placed in a desiccator to cool. After cooling, the samples were weighed and crude fat percentage was calculated.

Trained Sensory Panel

A trained sensory panel was formed to evaluate the ground beef samples for initial juiciness, sustained juiciness, cohesiveness, beef flavor intensity, and off flavor according to guidelines by AMSA (1995).

Training

Each trait was rated on an 8 point hedonic scale (1= extremely dry, extremely crumbly, extremely bland, no off flavor to 8= extremely juicy, extremely cohesive, extremely intense beef, and extreme off flavor). Panelists were trained prior to the beginning of testing. Initial juiciness was defined as the amount of juice excreted by the beef sample during the initial bite. If any juice was present, then a score must be given of at least 5. If no juice was present, the sample could not be scored any higher than 4. Sustained juiciness was defined as the juiciness of the sample after

20 chews. If any juice was present, then a score must be given of at least 5. If no juice was present, the sample could not be scored any higher than 4.

Cohesiveness was defined as how the product held its form during chewing. An 8 was simulated in training with chewing gum. A score of 4 was simulated with dried plums. 1 was simulated with cornbread.

Beef flavor was simulated using one beef bouillon cube (Ach Food Companies, Inc., Memphis, TN) dissolved into one cup of water. An 8 on the beef flavor scale would be equivalent to this liquid and a 1 would be the complete absence of beef flavor.

Sample Preparation

From each of the three replicates, 114 grams of each grind/day/package was thoroughly hand mixed a large mixing bowl. Two-113 g patties were weighted out and formed into patties using a patty press. A large hypodermic needle was used to insert a copper constantan thermocouple wire attached to a hand-held Omega data logger HH309A 34 (Omega, Stamford, CT) temperature recorder into the geometric center of each patty.

Calphalon Removable Plate Grill (Calphalon, Perrysburg, OH) clamshell style contact grills were preheated to 163°C and patties were placed on the grills. Internal temperatures were monitored closely using thermocouples. Once the patties reached an internal temperature of 70°C, they were removed from the grill. The thermocouples were removed slowly and temperature was monitored during removal to ensure internal temperature of 70°C was reached. Patties were then allowed to rest for 10 minutes before portioning.

After resting, each patty was portioned into 8 equal sections. One section from each patty in the grind/day/package was then placed into a 2 ounce cup with a lid and labeled with a random three digit code. Samples were then placed in a warming oven until testing began.

Testing

Testing was conducted no more than twice daily. Morning sessions were held at 10 A.M. and afternoon sessions were held at 2 P.M. to allow for adequate time between meals and testing. Panelists were placed into individual testing booths under red light. Panelists were then served samples one at a time until all samples for that session were completed. For each sample, panelists were to chew a minimum of 20 times then expectorate each sample after completing evaluation. Between samples, panelists were given unsalted crackers and their choice of apple juice or water to cleanse their palate. Panelists were not asked to sample more than 12 samples at any given session to reduce fatigue. Panelists were instructed to score each sample on an 8 point hedonic scale for initial juiciness, sustained juiciness, cohesiveness, beef flavor intensity, and off flavor.

Statistical Analysis

Statistical analysis was performed with the mixed procedure of SAS (SAS Inst. Inc., Cary, NC). Type-3 tests of fixed effects were performed for all variables. Grind product, packaging treatment and day of storage were fixed effects. Least squares means for protected F-tests ($P < 0.05$) were separated by using least significant differences (LSD, $P < 0.05$).

Results and Discussion

Color

In this study, grind materials were compared by fat percentage measured using proximate analysis. Fat percentages can be matched with their grind source in Table 11. Table 1 lists the means of the colorimetric values L^* , a^* , and b^* for each grind. The greatest L^* values were the 16.3% fat traditional grind material, the 11.4% fat traditional grind material, the 19.3% and 29.0% fat non-traditional grind materials (50.1, 49.47, 49.41, and 49.73, respectively; $P > 0.05$).

These were followed by the 21.3% fat non-traditional grind material, with an L* value of 48.25, then the 28.4% fat non-traditional grind material with an L* value of 47.52. The 9.6% fat traditional grind material came next at 44.55 with the 10.5% fat non-traditional grind material following. Finally, the 8.1% and the 6.2% fat non-traditional grind materials had the least L* values, at 39.94 and 39.61 respectively ($P>0.05$). It was hypothesized that greater fat percentages would equal greater L* values as the increasing amount of fat would create a lighter color than smaller amounts of fat. The traditional grinds followed this trend closely. While the 6.2% and 8.1% fat non-traditional grind materials did have the smallest L* values, the remaining non-traditional grind materials varied in L* values in a manner that did not follow this trend.

When evaluating a* measurements, the 8.1% and 10.5% fat non-traditional grind materials had the greatest, most red, values at 19.21 and 18.76 respectively which were not different ($P>0.05$). The 21.3% and 29.0% fat non-traditional grind materials had the least a* values at 10.95 and 11.10 respectively. Amongst the traditional grind materials, the 9.6% fat material displayed the greatest a* value at 16.98, followed by the 16.3% fat material at 14.70 and, finally, the 11.4% fat material at 13.75. A* values did not follow the hypothesized trend that as fat percentage increased, a* values would decrease because of the lesser amount of lean red tissue in those materials. Neither the traditional nor the non-traditional grind materials fit this idea.

Regarding b* values, the 19.3% fat non-traditional grind material showed the greatest value of 19.27 with the 6.2% fat non-traditional grind material having the least value of 17.17. The 9.6% and 16.3% fat grind materials were not different ($P>0.05$) and displayed the greatest b* values among the traditional grinds with values of 18.83 and 18.72, respectively, followed by the 11.4% fat grind material with a value of 18.48 which was not different than the 16.3% fat grind material.

Overall, color values did not trend with the fat content in each grind as hypothesized. Differences in these color measurements could be associated with differences in the fiber type, quality grade, production practice, or other factors in each grind material beyond fat percentage.

Colorimetric values for the packaging treatments are shown in Table 2. The MAP packaging displayed the greatest L*, a* and b* values at 47.27, 17.81 and 19.68 respectively. This was followed by the OW packaging with L*, a* and b* values of 45.53, 15.29 and 18.62 respectively. Finally, the CH packaging displayed the least L*, a* and b* values of 45.13, 11.53 and 16.91 respectively. All packaging treatments were different ($P < 0.05$) for each colorimetric value. These results were expected as the MAP packaging had an atmosphere consisting of 0.4% CO, 30% CO₂, 60% N₂ in an outer bag for the dark storage period with each tray overwrapped in an oxygen-permeable film (O₂ transmission = 23,250 mL/m²/24 h, 72 gauge) whereas the OW had an O₂ environment and was displayed immediately after wrapping with the same oxygen-permeable film. Carbon monoxide in the MAP packaging binds to myoglobin in the meat, reducing the rate of oxidation due to the lack of oxygen while maintaining the fresh meat color. The chub had an anaerobic atmosphere, so lesser colorimetric values were expected over the MAP and OW. This anaerobic environment removes the oxygen needed to bind to myoglobin to create oxymyoglobin. In this state, deoxymyoglobin is produced showing a more purple color.

Additionally, a day of display effect was measured and the colorimetric values are displayed in Table 3. For L*, d 5 had the greatest value at 46.70. The least L* values were d 0, 1, 2 and 3 with 45.55, 45.53, 45.76, and 46.02 respectively ($P > 0.05$). D 4 was not different than d 3 ($P > 0.05$), but was greater than previous days with an L* value of 46.18. When looking at a* and b*, both lessened from d 0 through d 5 with d 0 having the greatest a* and b* values of 21.30 and 20.49, respectively, and d 5 having the least values of 9.78 and 16.52, respectively. These results

were expected. As oxidation of both lipids and myoglobin occurs overtime, color is impacted negatively.

There was a grind product by packaging treatment interaction ($P < 0.05$) (Figure 1) for a^* . A^* values decreased as fat percentage increased in the non-traditional grind materials across packaging treatments. There were two exceptions to this trend. The first being the 6.2% non-traditional grind material which was a grind material taken from carcasses of grass-fed cattle. The second was the 28.40% fat non-traditional grind material. This material was exclusively taken from carcasses of mature bulls and therefore likely had a greater volume of myoglobin in the muscle fibers generating a different lean color (Seideman, et al., 1986).

An interaction was seen with packaging treatment and day of display ($P < 0.05$) for a^* values (Figure 2) and b^* values (Figure 3). Over each packaging treatment, a^* and b^* values decreased. The lowest of the a^* and b^* values were seen within the CH packing treatment with the OW having the greatest a^* and b^* values overall. MAP and OW showed similar a^* values at d 0, but the MAP lessened at a faster rate and to a ultimately lesser value than the OW. This sharper decline is likely due to the older age of the MAP products at the time of display due to the storage time. Once removed from the modified atmosphere, they deteriorated quickly.

Shelf life – Thiobarbituric Acid Reactive Substances

Thiobarbituric Acid Reactive Substances (TBARS) are an indication of the lipid oxidation of a sample. As the level of lipid oxidation increases in a sample, the TBARS value increase. The greatest TBARS value was detected in the 21.3% and 29.0% fat non-traditional grind materials with levels of 2.49 and 2.29, respectively which were not different from one another ($P > 0.05$). The least TBARS value was in the 19.3% fat non-traditional grind material with 0.66 mgs. Additionally when looking at the traditional grind materials, the 11.4% fat material had the greatest TBARS value at 1.41, with the 9.6% and 16.3% being lesser and not different from one another ($P > 0.05$) at 0.86 and 0.74, respectively. It was hypothesized that as fat

percentage increased, so would the amount of lipid oxidation and, in turn, TBARS values. This did not hold true. Also, the grind materials with the greatest TBARS values were frozen prior to arrival at the research facility, possibly altering the ultimate lipid oxidation which occurred.

The MAP had the greatest TBARS values with 1.73 mgs/kg meat ($P < 0.05$), followed by OW and then CH (1.28 and 0.90 respectively) for packaging treatment averaged over the grind products and days of display (Table 5). MAP packaged materials were much older than both OW and CH, leading to increased oxidation once removed from the modified atmosphere. The anaerobic environment presented in the CH packaging method

There was also a days of display effect. D 0, 1, 2 and 3 lesser TBARS values and were not different ($P > 0.05$) and d 4 and 5 had greater TBARS values and were not different ($P > 0.05$) from one another or from d 3 (Table 6).

There was a packaging treatment by grind product interaction ($P < 0.05$) for TBARS values (Figure 4). The highest levels of TBARS were the 21.30% and 29.00% fat non-traditional grind product (3.76 and 3.30 respectively) in MAP packaging. The least TBARS values was the 19.30% fat non-traditional grind product packaged in CH (0.47). The anaerobic atmosphere of the CH packaging allowed for less oxidation overall. While some high fat grind materials did have TBARS values across package types, this did not hold true for across all grinds indicating that there were more effects on lipid oxidation than just fat percentage alone.

Flavor Profile – Sensory Evaluation

Campo et al. (2006) showed that as TBARS values reach 2.28 mg MDA/kg meat, rancid off-flavor exceeds beef flavor in ground beef samples. Because of this, any samples measured at or greater than 2.0 mg MDA/kg meat were not prepared for sensory evaluation. Additionally, because of the lack of differences seen in MDA levels from d 0, 1, 2 and 3, all d 1 samples were eliminated from the sensory evaluation to reduce the number of overall samples tested and fatigue of the testers.

Means for sensory evaluation and cook loss of grind materials are displayed in Table 7. For initial juiciness, the 9.6% and 16.3% fat traditional grind materials and the 19.3%, 21.3% and 28.4% fat non-traditional grind materials were not different from one another ($P>0.05$) and scored the juiciest at 5.04, 4.98, 5.01, 4.94 and 4.88 respectively. At a score of 4.34, the 10.5% fat non-traditional grind material was seen to have the least initial juiciness. Sustained juiciness followed the same trends for most and least juicy grind materials with slightly lesser values.

Cohesiveness is defined as the ability of a product to maintain its bolus during mastication. The grind materials with the greatest cohesiveness values (greatest ability to maintain its bolus during mastication with the least amount of crumbling) were the 29.0% and 21.3% fat non-traditional fat grind materials with scores of 5.0 and 4.62, respectively, which were not different than one another ($P>0.05$). The 9.6% and 11.4% fat traditional grind materials and the 10.5% and 19.3% fat non-traditional grind materials were perceived to be the least cohesive and crumble the most. These products were not different from one another ($P>0.05$), with cohesiveness scores of 4.18, 4.23, 4.39 and 4.19, respectively. When evaluating the traditional grind materials alone, cohesiveness values tended to increase with fat percentage increase, but the non-traditional grind materials did not follow this same trend. This suggests other factors are involved in cohesiveness other than fat percentage.

Little difference in beef flavor intensity was perceived by sensory panelists all but one of the grind materials. The grind materials with the greatest scores for beef flavor were the 8.1%, 19.3% and 28.4% non-traditional grind materials and the 9.6% and 11.4% fat traditional grind materials (4.60, 4.75, 4.81, 4.61 and 4.60, respectively), which were not different from one another ($P>0.05$). The grind material perceived to have the least intense beef flavor was the 6.2% fat non-traditional grind material, with a score of 2.92. When looking at the nine greatest values for beef flavor intensity, only 0.63 points separated the greatest and least intense scores. The 6.2% fat non-traditional grind material was 1.26 points lesser than the next grind material greater.

Off flavor intensity was perceived in an inverse fashion. The 6.2% fat non-traditional grind material scored the most intense in off flavor at 4.84. The 9.6% and 11.4% fat traditional grind materials and the 8.1%, 10.5%, 19.3% and 28.4% fat non-traditional grind materials scored as the least intense in off flavor with scores of 1.50, 1.54, 1.56, 1.65, 1.29 and 1.46, respectively. These least intense off flavor grind materials were not different from one another ($P>0.05$).

The 6.2% fat non-traditional grind material was a material taken from carcasses of cattle finished on a forage-based diet. Because of this, a greater level of “grassy” off flavor was detected by the sensory panelists, contributing to the greater off flavor intensity scores and possibly the lesser beef flavor intensity scores.

Sensory evaluation data by packaging treatment is displayed in Table 8. CH and OW packaging had the greatest initial juiciness scores at 4.94 and 4.84, respectively. These were not different ($P>0.05$) and were followed by the MAP at 4.65. For sustained juiciness, CH was greatest at 4.70 and MAP was least at 4.38 ($P<0.05$). OW was not different than either CH or MAP ($P>0.05$) at 4.56. CH packaging was perceived to have the greatest cohesiveness with a score of 4.77, while MAP and OW were the more crumbly packaging treatments with scores of 4.35 and 4.30, respectively (which were not different from one another; $P>0.05$). CH was perceived to have the greatest beef flavor intensity at 4.65, followed by OW with an intensity score of 4.38 then MAP at 4.04, all of which were different ($P<0.05$). The MAP (2.38) was perceived to have a greater ($P<0.05$) off flavor than CH or OW (1.84 and 1.93, respectively) which were not different ($P>0.05$). The anaerobic environment of the chub packaging slowed the detrimental effects of retail display on the grind materials within, leading to more desirable sensory attributes.

The length of retail display showed some impact on sensory characteristics (Table 9). Initial juiciness was greatest on d 0 and 2 (4.90 and 4.96, respectively), which were not different ($P>0.05$), and least on d 4 and 5 (4.66 and 4.65, respectively), which were not different ($P>0.05$).

Day 3 was not different ($P < .05$) than any other day at 4.88. Day 0, 2 and 3 were the greatest in regards to sustained juiciness at 4.68, 4.62 and 4.62, respectively ($P < 0.05$). Day 5 had the least sustained juiciness at 4.37, and d 4 was not different ($P > 0.05$) than any other display day. Day 0 was the most cohesive at 4.52 and d 5 the least at 4.32 ($P < 0.05$). Day 2, 3 and 4 were not different than either d 0 or 5 ($P > 0.05$). Beef flavor intensity decreased as display day increased, with d 0, 2 and 3 being the greatest and not different ($P > 0.05$) at 4.52, 4.45, and 4.37, respectively. Day 5 was the least intense beef flavor 4.13 and d 4 was not different ($P > 0.05$) than any other display day at 4.31. Off flavor intensity increased with display day. Day 0 and 2 were the least intense in off flavor ($P > 0.05$) at 1.84 and 1.95, respectively. The most intense off flavors were perceived on d 5 at 2.32. Day 3 and 4 were not different than d 0, 2 or 5 ($P > 0.05$).

Cook loss was also evaluated on grind materials during sensory evaluation. Means of cook loss by grind material are shown in Table 7. The greatest cook loss was measured in the 29.0% and 28.4% non-traditional grind materials ($P > 0.05$) at 40.03% and 39.42%, respectively. No difference ($P > 0.05$) was observed in cook loss across packaging treatments (Table 8). Cook loss was greatest on d 5 of retail display at 33.45% with d 3 having the least cook loss at 31.77% ($P < 0.05$). Neither d 5 nor 3 were different than d 0, 2 or 4 ($P > 0.05$).

There was an interaction of packaging treatment and grind material ($P < 0.5$) on off flavor and for packaging treatment by day of storage (Figure 5). The 6.2% fat non-traditional grind material was the greatest in off flavor intensity across all packaging treatments. Even after removing that grind material, there appears to be no clear trend involving fat percentage and packaging treatment, indicating that other variables have greater impact on off flavor development.

Fatty Acid – Gas Chromatography (GC)

Fatty acid profiles of each grind material differed substantially, due possibly to production system and practices used to create each grind material (Table 10). The 9.6%

traditional grind material had the greatest percentages of ($P>0.05$) C22 and C20:5n3 fatty acids. The 11.4% fat traditional grind material had the greatest percentages of ($P>0.05$) C8 and C10 fatty acids. The 28.4% non-traditional grind material had the greatest percentages of ($P>0.05$) C14, C18:1n9-trans, C18:2n6-trans, C18:2n6-cis fatty acids and the greatest percentage ($P>0.05$) of total n6 fatty acids. The 19.3% fat non-traditional grind material had the greatest percentage ($P<0.05$) of C17, C17:1, C20, C18:3n6 and C20:2 fatty acids. The 21.3% fat non-traditional grind material had the greatest percentage ($P<0.05$) of C15:1 and C18:1n9-cis fatty acids. The 6.2% fat non-traditional grind material had the greatest percentage ($P<0.05$) of C20:1, C18:3n3 and C20:4n6 fatty acids. The greatest percentage of C16:1 was in the 29.0% fat non-traditional material.

The greatest percentages ($P>0.05$) of saturated fatty acids were in the 9.6% traditional grind material at 63.97%, however this was not different ($P>0.05$) than 11.4% fat traditional grind or 19.3% fat non-traditional grind (66.70% and 66.05%, respectively). The least percentage ($P>0.05$) of saturated fatty acids was in the 8.1% and 29.0% fat non-traditional grind materials (25.28 and 29.92%, respectively). The greatest percentages ($P<0.05$) of monounsaturated fatty acids were in the 16.3% traditional grind material and the 8.1% and 29.0% fat non-traditional grind materials at 68.77%, 69.72% and 68.35%, respectively (which were not different; $P>0.05$). The least percentage of monounsaturated fatty acids was in the 9.6% fat traditional grind material at 25.39%. This was not different ($P>0.05$) than the 11.4% fat traditional grind material or the 19.3% non-traditional grind material which were 28.70% and 27.34%, respectively, and not different than one another ($P>0.05$).

The greatest percentage of polyunsaturated fatty acids were in the 6.2%, 19.3% and 28.4% fat non-traditional grind materials (7.71, 6.61 and 7.53%, respectively) which were not different than one another ($P>0.05$). The least percentage of polyunsaturated fatty acids was in

the 16.3% fat traditional grind (3.23%), this was not different ($P>0.05$) than the 10.5% or 29.0% fat non-traditional grind materials (4.22 and 3.73%, respectively).

The highest ratios of polyunsaturated fatty acids to saturated fatty acids were in the 6.2% and 8.1% fat non-traditional grind materials (0.22 and 0.20, respectively). The lowest ratios were 9.6% and 11.4% fat traditional grind materials and 10.5% fat non-traditional grind material (0.08, 0.07 and 0.07, respectively). The greatest percentage of n6 fatty acids were found in the 28.4% non-traditional grind material (6.37%) and the greatest percentage of n3 fatty acids were in the 11.4% fat traditional grind material and 6.2% fat non-traditional grind material (2.37 and 2.42%, respectively) however, these percentages were not different than the 9.6% fat traditional grind material.

Production system may account for some of the differences in the fatty acid profiles, as the 6.2% non-traditional grind material are taken from carcasses of cattle that are fed forage-based diets prior to slaughter and the 28.4% fat non-traditional grind material is taken from carcasses of mature breeding bulls that likely spent a majority of their lives on forage-based feeding programs. The remaining grind materials came from carcasses of cattle that were fed traditional feedlot diets and differences in these materials can not be explained with the information available in this study.

Implications

Some factors appear to play a large role in shelf life, color stability and sensory characteristics other than fat content. Additional research should be conducted to identify these factors. The 19.3% fat non-traditional grind material appeared to be superior in many respects, even to grinds of similar fat content. Factors such as genetics of cattle, cattle sex and age, feeding programs, production systems, quality grade, and others should be evaluated in ground beef at the different levels of these factors at the same fat percentage or different fat percentages within one

level of the factor with all other factors being equalized could help identify the relationship of each to fat content.

IV. An Analysis of Quality of Non-Traditional Beef Grind Material Types versus Traditional Grind Material Types for Ground Beef Products

Abstract

An experiment was conducted to evaluate quality differences between traditional and non-traditional grind materials. Three traditional grind sources (T) were compared with seven non-traditional grind sources (N): 7% fat (T1), 11% fat (T2), 16% fat (T3), and 6% fat (N1), 8% fat (N2), 11% fat (N3), 20% fat (N4), 21% fat (N5), 28% fat (N6) and 29% fat (N7). These grind materials were then classified into one of four grind types using the data from the previous chapter: Traditional (TR), Quality Grade (QG), Niche (NI) or Breed Specific (BS). All grinds were then packaged in overwrapped foam trays (OW), clear chubs (CH), or overwrapped foam trays in a low oxygen modified atmosphere bag (MAP). Retail display was immediately conducted for 5 d on OW, CH was stored in dark storage for 3 d and MAP was stored in dark storage for 11 d and then placed in retail display for 5 d to simulate industry practices for each respective packaging treatment. Starting on the day packages were placed on display (d 0), 3 packages from each grind/package treatment were removed and frozen for further lab analysis. Also starting on d 0, 5 packages from each package/grind treatment were selected at random and color was evaluated daily with a Hunter Miniscan XE Plus. After completion of the retail display period, the frozen packages were thawed and samples were taken from each for evaluation of oxidative rancidity using TBARS and for Sensory evaluation of initial juiciness (IJ), sustained juiciness (SJ), cohesiveness (CO), beef flavor (BF), off flavor (OF), and cook loss (CL). Data were analyzed using the PROC GLM procedure of SAS.

For Thiobarbituric Acid Reactive Substances (TBARS) BS had the greatest value followed by QG then NI and finally TR, all of which were different ($P < 0.05$). In regards to color, BS showed the greatest L^* value followed by TR, QG, and finally NI, respectively. QG and TR

were not different ($P>0.05$), but all others were significantly different ($P<0.05$). B^* values were greatest for QG and TR ($P>0.05$), which were greater ($P<0.05$) than BS and NI. The later were not different from one another ($P>0.05$). Additionally there were significant ($P<0.05$) interactions of grind type by day and by packaging type for both a^* and b^* . For sensory traits, differences also existed. For IJ, TR, QG, and BS were not different ($P>0.05$) and juiciest, followed by NI which was not different ($P>0.05$) than QG and BS. TR, QG, and BS were also not different ($P>0.05$) and greatest for SJ. These were again followed by NI, which was not different than BS ($P>0.05$). BS and NI ($P>0.05$) were most cohesive, followed by QG which was not different ($P>0.05$) than NI. Finally TR was least cohesive, but not different ($P>0.05$) than QG. Beef flavor and off flavor were inverses. BS, QG, and TR had greatest beef flavor and least off flavor and not different from one another ($P>0.05$). NI has the greatest off flavor and least beef flavor. This shows differences do exist between traditional and non-traditional grind types.

Materials and Methods

Ground Beef Materials

Ground beef from ten different grind sources were shipped to Cargill Meat Solutions' Research and Development Center (Wichita, KS) for evaluation. Three of the grinds were from traditional beef grind materials and the remaining seven were from non-traditional or branded grind materials. All grinds were finely ground prior to arrival.

Traditional Grind Material 1 (T1) was a grind material labeled as 19 percent fat ground chuck. The beef arrived in a finely ground form, packaged into approximately 4.54 kg chubs.

Traditional Grind Material 2 (T2) was a grind material labeled as 14 percent fat ground round. The beef arrived in a finely ground form, packaged into approximately 4.54 kg chubs.

Traditional Grind Material 3 (T3) was a grind material labeled as 7 percent fat ground beef. The beef arrived in a finely ground form, packaged into approximately 4.54 kg chubs.

Non-Traditional Grind Material 1 (N1) was a grind material labeled as 19 percent fat. This ground beef must have come from beef carcasses with a minimum marbling score of modest, maturity A, medium or fine marbling texture, Ribeye Area of 10.0 to 16.0 in², Hot Carcass Weight of less than 1000 pounds, Fat Thickness of less than 1.0 inch, Moderately Thick or thicker muscling, and no hump exceeding 2 inches as well as having at least 51 percent black hide with no dairy influence. The beef arrived in a finely ground form, packaged into approximately 4.54 kg chubs.

Non-Traditional Grind Material 2 (N2) was a grind material labeled as 14 percent fat. This ground beef must have come from beef carcasses with a minimum marbling score of modest, maturity B or younger, medium or fine marbling texture, Moderately Thick or thicker muscling, and no hump exceeding 2 inches. The beef arrived in a finely ground form, packaged into approximately 4.54 kg chubs.

Non-Traditional Grind Material 3 (N3) was a grind material with an unspecified fat percentage. This ground beef came from fed-cattle of Wagyu parentage. The beef arrived in a finely ground form, packaged into approximately 4.54 kg chubs.

Non-Traditional Grind Material 4 (N4) was a grind material with an unspecified fat percentage. This ground beef came from carcasses of maturity B or younger with a marbling score Slightly Abundant or higher. The beef arrived in a finely ground form, packaged into approximately 4.54 kg chubs.

Non-Traditional Grind Material 5 (N5) was a grind material labeled as 10 percent fat. This ground beef was taken from carcasses of cattle strictly finished on high forage diets. The beef arrived in a finely ground form, packaged into approximately 18.16 kg vacuum sealed bags.

Non-Traditional Grind Material 6 (N6) was a grind material with an unspecified fat percentage. This ground beef was taken from carcasses of cull Wagyu breeding bulls. The beef arrived in a finely ground form, packaged into approximately 4.54 kg chubs.

Non-Traditional Grind Material 7 (N7) arrived in a finely ground form, packaged into approximately 4.54 kg chubs. This grind material was labeled as a natural product.

Grinds were grouped into four type categories: Traditional, Quality Grade, Niche, and Breed Specific. These groups were selected to represent branded products currently on the market. This was done using the data from the previous chapter to create like groups.

The traditional (TR) type consisted of Traditional Grinds 1, 2, and 3. These grinds are consistent with the commodity ground beef currently found in the market place and represent three common fat percentages of commodity ground beef.

The Quality Grade (QG) type consisted of Non-Traditional Grinds 1, 2, and 4. These grinds represent commonly found branded programs that require a minimum USDA Quality Grade to enter the branding program. These grinds were selected at fat levels comparable the form in which they are marketed.

The Niche (NI) type consisted of Non-Traditional Grinds 5 and 7. This type was created to represent niche grinds such as “grass-fed”, “organic” or some other production system. These grinds were selected at fat levels comparable the form in which they are marketed.

The Breed-Specific (BS) type consisted of Non-Traditional Grinds 3 and 6. This type was created to represent that specify a breed in the branding. Beef from carcasses that met the criteria to fall under a specific Wagyu program were chosen to differentiate from the other breed-specific branded programs, which could also fall under the Quality Grade type. These grinds were selected at fat levels comparable the form in which they are marketed.

Packaging

After arriving at Cargill, the ground beef was stored overnight and processed into retail packaging the next day. Grind N3 and N4 were slightly frozen upon arrival, but thawed overnight. Each grind was packaged in to three packaging treatments: 0.45 kg loaves on traditional 2S Styrofoam trays (Cryovac, Duncan, SC) with absorbent diapers and overwrapped with oxygen-permeable polyvinyl chloride film (O₂ transmission = 23,250 mL/m²/24 h, 72 gauge), 0.45 kg loaves on traditional overwrapped 2S Styrofoam trays in a modified atmosphere shipping bag, and 0.45 kg of meat stuffed into clear chubs.

All grind materials were packaged with a Vemag Vacuum Stuffer (Vemag Maschinenbau GmbH, Verden, Germany) using a stuffing horn for the chubs and a grinder/portioning head (Vemag Maschinenbau GmbH, Verden, Germany) for the foam trays. The Vemag was set to extrude 4.54 kg of meat at a time. Chubs were placed directly on to the stuffing horn and filled tightly to minimize air in the package, then clipped with a staple. When enough chubs were made for a grind, the grinder/portioning head was attached. Loaves were extruded onto a moving conveyor belt and shaped into 5"x8"x2" loaves with plastic paddles, then placed on to 2S foam trays and overwrapped using a Minipack Ministretch (Minipack America, Inc., Orange, CA) . Between each grind material, approximately 6 to 10 kg of meat was passed through each attachment to clear the remnants of the previous grind material.

After packaging, half of the overwrapped foam trays were placed into storage bags along with Multisorb CR20 Oxygen Scavenger (Multisorb Technologies, Buffalo, NY). Using a Fresh Vac Modified Atmosphere Machine (CVP System, Inc., Downers Grove, IL), air was then vacuumed out and flushed with an industry standard low oxygen gas mix, (approximately 0.4% CO, 30% CO₂, 60% N₂).

Storage and Retail Display

Traditional Overwrapped Foam Trays were then immediately placed on retail display after packaging in a Hussman retail display case (Hussman, Bridgton, MO). Packages were displayed for five days and every day, starting on day 0, three packages were removed from display and frozen for later analysis. Additionally, 5 packages were selected at random and scanned with a Hunter Miniscan XE Plus (Hunter Lab, Reston, VA) starting on day 0 and rescanned every 24 hours. After five days of display, these 5 packages were frozen for later analysis.

Chubs were held for three days in dark storage to simulate shipping then placed on retail display. Packages were displayed for five days and every day, starting on day 0, three packages were removed from display and frozen for later analysis. Additionally, 5 packages were selected at random and scanned with a Hunter Miniscan XE Plus (Hunter Lab, Reston, VA) starting on day 0 and rescanned every 24 hours. After five days of display, these 5 packages were frozen for later analysis.

Overwrapped Foam Trays in the modified atmosphere storage bags were placed in individual plastic trays to prevent crushing of the bags. These trays were placed in dark storage for three days then moved to normal storage for an additional seven days to simulate average shipping and storage of retail ground beef. After storage, packages were placed on retail display.

Packages were displayed for five days and every day, starting on day 0, three packages were removed from display and frozen for later analysis. Additionally, 5 packages were selected at random and scanned with a Hunter Miniscan XE Plus (Hunter Lab, Reston, VA) starting on day 0 and rescanned every 24 hours. After five days of display, these 5 packages were frozen for later analysis.

Processing

After freezing, samples were then placed in insulated boxes with dry ice shipped to the Lambert-Powell Meats Laboratory at Auburn University (Auburn, AL) and were immediately unboxed and stored at -23°C. Samples were then thawed for 24 hours at 4°C ± 2°C.

Once thawed, each sample was removed from its retail package and placed in a 20.3 x 38.1 cm 3 mil High Barrier Nylon/Ethylene Vinyl Alcohol/Polyethylene Vacuum pouch (Cryovac, Duncan, SC) and mixed thoroughly by hand. From these bags approximately 50 grams was removed and placed in a 50 mL plastic conical tube (VWR, Radnor, PA) for analysis in the laboratory in Upchurch Hall and two portions weighing at least 114 grams each were placed into 15.2 x 20.3 cm 3 mil High Barrier Nylon/Ethylene Vinyl Alcohol/Polyethylene Vacuum pouches (Cryovac, Duncan, SC) and labeled for later sensory evaluation. After portioning, the remaining sample in the 20.3 x 38.1 cm vacuum pouch and both sensory portions were vacuum sealed at 98% vacuum with an Ultravac UV2100-C (Koch Equipment LLC., Kansas City, MO) and frozen at approximately -23°C. This was repeated for each sample.

Thiobarbituric Acid Reactive Substances

Immediately after all samples were processed, the thawed meat samples in the vortex tubes were transported to Upchurch Hall and analysis began. A modified Buege and Aust (1978)

procedure for Thiobarbituric Acid Reactive Substances (TBARS) was used to measure the levels of malondialdehyde in each kg of meat.

A standard was first created to create a regression equation for the prediction of malondialdehyde levels. First a stock solution of 0.1 mL of 1,1,3,3-tetraethoxypropane (TEP) and 100 mL deionized water was created and then diluted to 1:2.96 with additional deionized water. A 10% butylated hydroxyanisole (BHA) solution was also made by dissolving 10g BHA into 100 mL of 90% Ethanol. Seven tubes were then labeled 0 through 6 with 4 mL of the BHA solution were then added to each tube. The TEP working solution was then added to each tube starting with 0 mL in tube 0, then 0.01 mL, 0.02 mL, 0.04 mL, 0.06 mL, 0.08 mL, and 0.1 mL to tubes 1, 2, 3, 4, 5, and 6, respectively. Deionized water was then added to each tube to reach a final total volume of 6 mL. These tubes were heated in a 95°C water bath for 15 minutes, then cooled in a 20°C water bath for ten minutes.

To measure absorbance, 200 μ L of each of the resulting solutions were pipetted in duplicate into a 96 well microtiter plate (Greiner Bio-one, Frickenhausen, Germany) and read using a Multiskan EX (Thermo Fisher Scientific, Waltham, MA, USA) absorbance reader at 540 nm.

To determine TBARS on each meat sample, 5 grams of each meat sample was weighed and placed in an additional vortex tube with 15 mL of de-ionized water. After 5 grams was removed from the original sample, the remainder was placed into the freezer for later analysis. The vortex tube was then sealed and vortexed for 20 seconds, homogenizing the mixture. Tubes were then centrifuged for 10 minutes at 1850 g using a Beckman Coulter Allegra X-15 R (Beckman Coulter, Inc., Brea, CA, USA) swinging bucket rotor.

From the centrifuged tube, 2 mL of the supernatant was removed and placed in a test tube with a pipette. 4 mL was then added of a 15% trichloroacetic acid (TCA) and 20 μ M Thiobarbituric Acid (TBA) as well as 100 μ L of a 10% BHA solution. This mixture was then vortexed and heated in a 95°C water bath for 15 minutes. Test tubes were cooled in a water bath at 20°C for 10 minutes then centrifuged at 1850 g for 10 minutes.

To measure absorbance, 200 μ L of the resulting supernatant was pipetted in duplicate into a 96 well microtiter plate (Greiner Bio-one, Frickenhausen, Germany) and read using a Multiskan EX (Thermo Fisher Scientific, Waltham, MA, USA) absorbance reader at 540 nm.

Crude Fat Percentage-Proximate Analysis

Meat samples from the display day 0 and traditional overwrap packages of all ten grinds were used for proximate analysis. Each sample was run in duplicate. These samples represented the meat that was frozen before any storage or display occurred. These samples were the previously frozen samples not used during TBARS analysis.

Each sample was ground to a fine powder. 5 grams of each samples was weighed out and placed in an aluminum pan and dried in the Cenco Forced Convection Oven (Central Scientific Company, Chicago, IL) at 100C for 16 to 18 hours. Pans were then removed from the drying oven and place in a desiccator to cool for ½ hour. Each pan was then weighed and recorded.

After completion of drying, nonabsorbent cotton was placed in the pan to cover the sample. The sample pans were then weighed and recorded to measure the amount of cotton added. A boiling flask was filled 2/3 full of petroleum ether and 3 boiling chips were added. Samples were then placed in the Soxtec System HT 1043 Extraction Unit (Gerber Instruments AG, Switzerland), 6 at a time following the AOAC guidelines for this machine.

After extraction was completed, samples were placed under fume hood for approximately 1 hour to allow all of the petroleum ether to evaporate. Samples were dried in the drying oven for 1 hour at 100C, then placed in a desiccator to cool. After cooling, the samples were weighed and crude fat percentage was calculated.

Trained Sensory Panel

A trained sensory panel was formed to evaluate the ground beef samples for initial juiciness, sustained juiciness, cohesiveness, beef flavor intensity, and off flavor according to guidelines by AMSA (1995).

Training

Each trait was rated on an 8 point hedonic scale (1= extremely dry, extremely crumbly, extremely bland, no off flavor to 8= extremely juicy, extremely cohesive, extremely intense beef, and extreme off flavor). Panelists were trained prior to the beginning of testing. Initial juiciness was defined as the amount of juice excreted by the beef sample during the initial bite. If any juice was present, then a score must be given of at least 5. If no juice was present, the sample could not be scored any higher than 4. Sustained juiciness was defined as the juiciness of the sample after 20 chews. If any juice was present, then a score must be given of at least 5. If no juice was present, the sample could not be scored any higher than 4.

Cohesiveness was defined as how the product held its form during chewing. An 8 was simulated in training with chewing gum. A score of 4 was simulated with dried plums. 1 was simulated with cornbread.

Beef flavor was simulated using one beef bouillon cube (Ach Food Companies, Inc., Memphis, TN) dissolved into one cup of water. An 8 on the beef flavor scale would be equivalent to this liquid and a 1 would be the complete absence of beef flavor.

Sample Preparation

From each of the three replicates, 114 grams of each grind/day/package was thoroughly hand mixed in a large mixing bowl. Two 113 g patties were weighted out and formed into patties using a patty press. A large hypodermic needle was used to insert a copper constantan thermocouple wire attached to a hand-held Omega data logger HH309A 34 (Omega, Stamford, CT) temperature recorder into the geometric center of each patty.

Calphalon Removable Plate Grill (Calphalon, Perrysburg, OH) clamshell style contact grills were preheated to 163°C and patties were placed on the grills. Internal temperatures were monitored closely using thermocouples. Once the patties reached an internal temperature of 70°C, they were removed from the grill. The thermocouples were removed slowly and temperature was monitored during removal to ensure internal temperature of 70°C was reached. Patties were then allowed to rest for 10 minutes before portioning.

After resting, each patty was portioned into 8 equal sections. One section from each patty in the grind/day/package was then placed into a 2 ounce cup with a lid and labeled with a random three digit code. Samples were then placed in a warming oven until testing began.

Testing

Testing was conducted no more than twice daily. Morning sessions were held at 10 A.M. and afternoon sessions were held at 2 P.M. to allow for adequate time between meals and testing. Panelists were placed into individual testing booths under red light. Panelists were then served samples one at a time until all samples for that session were completed. For each sample,

panelists were to chew a minimum of 20 times then expectorate each sample after completing evaluation. Between samples, panelists were given unsalted crackers and their choice of apple juice or water to cleanse their palate. Panelists were not asked to sample more than 12 samples at any given session to reduce fatigue. Panelists were instructed to score each sample on an 8 point hedonic scale for initial juiciness, sustained juiciness, cohesiveness, beef flavor intensity, and off flavor.

Statistical Analysis

Statistical analysis was performed with the mixed procedure of SAS (SAS Inst. Inc., Cary, NC). Type-3 tests of fixed effects were performed for all variables. Grind type, packaging treatment and day of storage were fixed effects. Least squares means for protected F-tests ($P < 0.05$) were separated by using least significant differences (LSD, $P < 0.05$).

Results and Discussion

Proximate Analysis-Grind Types

Proximate Analysis was conducted to evaluate the crude fat percentages of each grind material. This information as well as which grind materials fit into each grind type is presented in Table 11.

Shelf life-Thiobarbituric Acid Reactive Substances

The Thiobarbituric Acid Reactive Substance Assay is a good indicator of lipid oxidation in the sample. TBARS values differed across the ground beef types (Table 12). The BS type had the highest TBARS value (2.01; $P < 0.05$). This was followed by the QG type and the NI type (1.39 and 1.21, respectively) which were not different ($P > 0.05$). Finally the TR type had the lowest TBARS value at 1.00, which was not different than the NI type ($P > 0.05$).

These results indicate that the BS type was significant less stable in terms of lipid oxidation, while the remaining types were much more stable, with the TR type having the lowest numeric value.

There were no significant interactions for TBARS between type, day of display or packaging treatment. Additionally, packaging treatment and day of display effect are not discussed in this chapter as they were discussed at length in the previous chapter.

Color

Colorimetric values between grind types are shown in Table 13. L*, or the degree of lightness, followed a patterned that would be expected when considering the fat percentages of the grind types. The BS type had the greatest L* value, or lightest value, at 48.97, followed by the TR type (48.11), then the QG type (46.17) and finally the NI type at 39.84 (P<0.05). It is noted that the NI grind is the darkest by a great margin, but contains grinds of much lower fat contents than the other types. The remaining types have comparable fat contents and, as expected, are much more similar in L* values. There were no interaction for L* between grind type, day of display or packaging treatment.

There were significant (P<0.05) interactions for both type by packaging treatment (Figure 7) and type by day of display (Figure 8) in regards to a* values. When comparing type by package, each grind type performed differently. The BS type had the greatest a* value in the TR Overwrapped Foam Tray followed by the Chub and Modified Atmosphere Master Bag. This indicates that this grind type could not stand the long storage time associated with the Master Bag treatment, and declined to levels slightly lower than the anaerobic atmosphere of the Chub packaging. The NI grind type had the greatest a* values in the Modified Atmosphere Master Bag and the TR Overwrapped Foam Trays, with the chub being much less. The QG and TR Types performed similarly, with the TR Overwrapped Foam Trays having the greatest values, followed by the Modified Atmosphere Master Bags then the chub. Additionally, when analyzing the type

by day of display, the BS type deteriorated at a faster rate than the other three grinds with TR grind remaining the most stable across display.

Significant ($P < 0.05$) interactions also existed for both type by packaging treatment (Figure 9) and type by day of display (Figure 10) in regards to b^* values. When comparing type by package, each grind type performed differently. Similarly to a^* values, the BS type had the greatest b^* value in the TR Overwrapped Foam Tray followed by the Chub and Modified Atmosphere Master Bag. This seems to strengthen the thought that this grind type could not stand the long storage time associated with the Master Bag treatment. The NI grind type had the greatest b^* values in the Modified Atmosphere Master Bag and the TR Overwrapped Foam Trays, with the Chub being much less. The QG and TR Types performed similarly, with the TR Overwrapped Foam Trays having the greatest values, followed closely by the Modified Atmosphere Master Bags then the Chub. Also similarly to the a^* interaction of type by display time, the BS type deteriorated at a faster rate than the other three grinds with TR grind remaining the most stable across the first three days of display.

These colorimetric values indicate that the TR and QG types behave very similarly in most regards. Additionally, the BS type is much less stable across display time regardless of package, but also does not favor the long storage time of the Master Bag treatment.

Flavor Profile – Sensory Evaluation

Sensory evaluation scores show some differences in grind types (Table 14). For Initial Juiciness TR, QG and BS (4.93, 4.81, and 4.74, respectively) were juiciest and not different ($P > 0.05$). The NI type was least juicy with a score of 4.61, but was not different ($P > 0.05$) than the QG or BS types. Similarly for Sustained Juiciness, TR, QG and BS (4.68, 4.51, and 4.48, respectively) were juiciest and not different ($P > 0.05$), with the NI type being least juicy at 4.27, but not different than the BS type ($P > 0.05$). BS and NI types were the most cohesive (4.63 and

4.55, respectively; $P < 0.05$), followed by the QG type (4.36) which was not different than the NI type ($P > 0.05$), and finally the TR type (4.30) which was not different ($P > 0.05$) than the QG type.

Beef flavor and Off-flavor responded in an inverse fashion. The TR, QG, and BS types had both the greatest beef flavor intensities (4.55, 4.51, and 4.50, respectively) and least off flavor intensities (1.57, 1.70, and 1.77, respectively) and were not different ($P > 0.05$) in either category, while the NI type had the lowest beef flavor (3.72) and greatest off-flavor (3.23) and was different than the other types ($P < 0.05$). This is likely due to the grass-fed grind in the NI type, which showed higher off-flavor values, as described in the previous chapter.

Cook loss also differed among grind types. The BS type had the greatest cook loss at 42.61 percent. The TR and QG types followed at 30.97 and 31.72 percent, respectively, which were not different ($P > 0.05$). The NI type had the least cook loss at 27.62 percent.

This data indicates that little difference exists between the BS, TR, and QG types, while the NI type was inferior in most cases. This is probably due to the combination of the lower fat content and the grass-fed grind material.

Implications

In the commonly marketed forms of these grind types, differences do exist. Traditional and Quality Grade types appeared to perform similarly throughout the study. The BS type also performed similarly to these two grinds in sensory testing, but did not show the color or lipid stability of the other grinds. The Niche grind type might have also been slightly hampered by both its low fat content and grass-fed grind, but is typically marketed in this fashion.

Further research should be done to both expand this study to evaluate other branded programs and to also identify some of the variables that effect sensory properties as well as lipid and color stability within these grind materials and grind types. This might be accomplished by formulating grind types to a designated fat percentage, but as these grinds and programs are currently presented to the consumer differences do exist.

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Appendix A

Thiobarbituric Acid Reactive Substances Assay

Buege, J. A.; Aust, S. D. 1978. Microsomal lipid peroxidation. *Methods in Enzymology*, 52: 302-310.

A. Solutions

1. TCA/TBA stock solution: (15% TCA (w/v) and 20mM (M weight 144.15) reagent in ddH₂O)
 - a. Dissolve 2.88 grams TBA in *warm* ddH₂O
 - b. Add 150 grams TCA and add ddH₂O until total volume equals 1 liter
2. BHA:
 - a. Make 10% solution by dissolving BHA into 90% ethanol
3. TEP Standard: (1×10^{-3} M 1,1,3-Tetra-ethoxypropane in ddH₂O)
 - a. Dilute 0.5 mL TEP with 499.5 mL ddH₂O and dilute again to 1:2.96 ratio (TEP: ddH₂O)

B. Procedure

1. Slice 10 grams of fresh frozen meat and place in blender with 30 mL ddH₂O.
2. Homogenize in blender for 2 minutes
3. Take 2 mL of the homogenate and combine with 4 mL of the TCA/TBA solution and 100 μ L of BHA solution and vortex thoroughly.
4. Heat solution for 15 minutes in boiling water.
5. Cool for 10 minutes in cold water then vortex.
6. Centrifuge for 10 minutes at 2000G
7. Read absorbance of supernatant at 531 nm against blank.

C. Standard Curves

1. Construct TBA standard curve using TEP.

2. Label tubes 0-6, 2 tubes each
3. Add 0, 10, 20 40, 60, 80, and 100 μL of TEP solution to each tube, respectively.
4. Add 4 mL of TBA/TCA solution to each tube and add ddH₂O to bring the total volume of each tube to 6 mL, then vortex.
5. Cool for 10 minutes in cold water then vortex.
6. Read absorbance of supernatant at 531 nm against blank.

Appendix B

Fatty Acid Methyl Esters

O'Fallon, J. V., Busboom, J. R., Nelson, M. L., Gaskins, C. T. 2007. A direct method for fatty acid methyl ester synthesis: Application to wet meat tissues, oils, and feedstuffs. *Journal of Animal Science*, 85:1511-1521.

A. Solutions and Chemicals

- a. Hexane
- b. Methanol (MeOH)
- c. 10 N KOH
- d. 24 N H₂SO₄

B. Direct Fatty Acid Methylation

- a. Mince meat sample and weigh out 1 g
- b. Place 1 g meat into a 16 mL screwtop tube
- c. Add 5.3 mL of MeOH, 0.7 mL of KOH and standard to meat sample in tube. Place cap on tube and place in water bath at 55°C. If waterbath has a shaker attachment, turn shaker attachment on to desired setting. If there is no shaker attachment, vortex samples for 5 s every 20 min. Incubate for 90 min.
- d. After incubation, place samples in cold tap water and allow to cool to below room temperature.
- e. After cooling, add 0.58 mL of 24 N H₂SO₄. Mix tube by inversion and make sure K₂SO₄ precipitate is present. Place tube back in water bath and incubate for 90 min at 55°C. If there is no shaker attachment, vortex samples for 5 s every 20 min.
- f. Repeat step d.
- g. After cooling, add 3 mL of hexane and vortex for 5 min.
- h. Centrifuge tubes for 5 min at 1,500 x g.
- i. Remove hexane layer and place in fatty acid vial.
- j. Place fatty acid vials in freezer until time of analysis

Table 1. LSMEANS of colorimetric values and SEM for traditional and non-traditional grinds.

Fat %	L*	a*	b*
Traditional			
9.6	44.55±0.13 ^e	16.98±0.21 ^b	18.83±0.09 ^{bc}
11.4	49.47±0.13 ^b	13.75±0.21 ^{ef}	18.48±0.09 ^d
16.3	50.19±0.13 ^a	14.70±0.21 ^d	18.72±0.09 ^{cd}
Non-traditional			
6.2	39.61±0.13 ^g	14.18±0.21 ^{de}	17.17±0.09 ^g
8.1	39.94±0.13 ^g	19.21±0.21 ^a	18.90±0.09 ^{bc}
10.5	41.11±0.13 ^f	18.76±0.21 ^a	19.03±0.09 ^b
19.3	49.41±0.13 ^b	15.79±0.21 ^c	19.27±0.09 ^a
21.3	48.25±0.13 ^c	10.95±0.21 ^g	17.68±0.09 ^f
28.4	47.52±0.18 ^d	13.36±0.28 ^f	18.03±0.11 ^e
29.0	49.73±0.13 ^b	11.10±0.21 ^g	17.95±0.09 ^e

^{abc}Means within the common superscripts in the same column are not different (P>0.05).

Table 2. LSMEANS of colorimetric values and SEM for traditional and non-traditional grind products in three different packaging treatments.

Package	L*	a*	b*
Modified Atmosphere	47.27±0.08 ^a	17.81±0.12 ^a	19.68±0.05 ^a
Overwrap	45.53±0.08 ^b	15.29±0.12 ^b	18.62±0.05 ^b
Chub	45.13±0.08 ^c	11.53±0.12 ^c	16.91±0.05 ^c

^{abc}Means within the common superscripts in the same column are not different (P>0.05).

Table 3. LSMEANS of colorimetric values and SEM for traditional and non-traditional grind products over days of storage in retail display.

Day	L*	a*	b*
0	45.55±0.10 ^c	21.30±0.17 ^a	20.49±0.69 ^a
1	45.53±0.10 ^c	17.62±0.17 ^b	19.53±0.69 ^b
2	45.76±0.10 ^c	15.35±0.17 ^c	18.61±0.69 ^c
3	46.02±0.10 ^{bc}	13.69±0.16 ^d	18.34±0.69 ^d
4	46.18±0.10 ^b	11.51±0.17 ^e	16.94±0.69 ^e
5	46.70±0.10 ^a	9.78±0.17 ^f	16.52±0.69 ^f

^{abc}Means within the common superscripts in the same column are not different (P>0.05).

Table 4. LSMEANS of Thiobarbituric Acid Reactive Substances values and SEM for traditional versus non-traditional grinds.

Fat %	MDA mg/kg
Traditional	
9.6	0.86±0.14 ^{cd}
11.4	1.41±0.14 ^b
16.3	0.74±0.14 ^{cd}
Non-traditional	
6.2	0.95±0.14 ^{cd}
8.1	1.47±0.14 ^b
19.3	0.66±0.14 ^d
10.5	1.02±0.14 ^{cd}
21.3	2.49±0.14 ^a
28.4	1.18±0.21 ^{bc}
29.0	2.29±0.14 ^a

^{abc}Means within the common superscripts in the same column are not different (P>0.05).

Table 5. LSMEANS of Thiobarbituric Acid Reactive Substances values and SEM for traditional and non-traditional grind products in three different packaging treatments.

Package	MDA mg/kg
Modified Atmosphere	1.73±0.08 ^a
Overwrap	1.28±0.08 ^b
Chub	0.90±0.08 ^c

^{abc}Means within the common superscripts in the same column are not different (P>0.05).

Table 6. LSMEANS of Thiobarbituric Acid Reactive Substances values and SEM for traditional and non-traditional grind products over days of storage in retail display.

Day	MDA mg/kg
0	1.17±0.11 ^a
1	1.13±0.11 ^a
2	1.06±0.11 ^a
3	1.36±0.11 ^{ab}
4	1.59±0.11 ^b
5	1.52±0.11 ^b

^{abc}Means within the common superscripts in the same column are not different (P>0.05).

Table 7. LSMEANS for sensory evaluation and cook loss and SEM for traditional versus non-traditional grinds.

Fat %	Initial Juiciness	Sustained Juiciness	Cohesiveness	Beef Flavor	Off Flavor	Cook Loss
Traditional						
9.6	5.04±0.11 ^{ab}	4.79±0.10 ^{ab}	4.18±0.10 ^d	4.61±0.10 ^{ab}	1.50±0.15 ^{de}	30.44±0.65 ^d
11.4	4.66±0.11 ^d	4.45±0.11 ^{cd}	4.23±0.11 ^{cd}	4.60±0.10 ^{ab}	1.54±0.16 ^{de}	29.44±0.68 ^{de}
16.3	4.98±0.11 ^{abc}	4.73±0.10 ^{abc}	4.50±0.10 ^{bc}	4.38±0.10 ^{bc}	1.73±0.15 ^{cd}	33.11±0.65 ^c
Non-traditional						
6.2	4.51±0.11 ^{de}	4.29±0.10 ^d	4.58±0.10 ^b	2.92±0.10 ^d	4.84±0.15 ^a	27.54±0.65 ^{ef}
8.1	4.74±0.11 ^d	4.29±0.11 ^d	4.53±0.11 ^{bc}	4.60±0.11 ^{ab}	1.56±0.16 ^{de}	27.75±0.67 ^{ef}
10.5	4.34±0.11 ^e	3.91±0.10 ^e	4.39±0.10 ^{bcd}	4.43±0.10 ^{bc}	1.65±0.15 ^{de}	28.45±0.65 ^e
19.3	5.01±0.11 ^a	4.99±0.10 ^a	4.19±0.10 ^d	4.75±0.10 ^a	1.29±0.15 ^e	32.30±0.65 ^c
21.3	4.94±0.15 ^{abcd}	4.73±0.15 ^{abc}	4.62±0.14 ^{ab}	4.18±0.14 ^c	2.80±0.21 ^b	37.15±0.91 ^b
28.4	4.88±0.15 ^{abcd}	4.70±0.15 ^{abc}	4.58 ±.14 ^{bc}	4.81 ±.14 ^a	1.46 ±.21 ^{de}	39.42 ±.91 ^{ab}
29.0	4.83±0.22 ^{bcd}	4.61±0.14 ^{bcd}	5.0±0.13 ^a	4.30±0.14 ^{bc}	2.19±0.20 ^c	41.03±0.86 ^a

^{abc}Means within the common superscripts in the same column are not different (P>0.05).

An eight-point scale was used for the evaluations of initial and sustained juiciness, cohesiveness, beef flavor, and off flavor (1= extremely dry, extremely crumbly, extremely bland, no off flavor to 8= extremely juicy, extremely cohesive, extremely intense beef, and extreme off flavor).

Table 8. LSMEANS of sensory evaluation and cook loss and SEM for traditional and non-traditional grind products in three different packaging treatments.

Package	Initial Juiciness	Sustained Juiciness	Cohesiveness	Beef Flavor	Off Flavor	Cook Loss
Chub	4.94±0.06 ^a	4.70±0.06 ^a	4.77±0.06 ^a	4.65±0.06 ^a	1.84±0.09 ^b	32.68±0.37
MAP	4.65±0.07 ^b	4.38±0.07 ^b	4.35±0.07 ^b	4.04±0.07 ^c	2.38±0.10 ^a	33.04±0.43
OverWrap	4.84±0.06 ^a	4.56±0.06 ^{ab}	4.30±0.06 ^b	4.38±0.06 ^b	1.93±0.09 ^b	32.28±0.39

^{abc}Means within the common superscripts in the same column are not different ($P>0.05$).

An eight-point scale was used for the evaluations of initial and sustained juiciness, cohesiveness, beef flavor, and off flavor (1= extremely dry, extremely crumbly, extremely bland, no off flavor to 8= extremely juicy, extremely cohesive, extremely intense beef, and extreme off flavor).

Table 9. LSMEANS for sensory evaluation and cook loss and SEM for traditional and non-traditional grind products over days of storage in retail display.

Day	Initial Juiciness	Sustained Juiciness	Cohesiveness	Beef Flavor	Off Flavor	Cook Loss
0	4.90±0.08 ^a	4.68±0.07 ^a	4.52±0.07 ^a	4.52±0.07 ^a	1.84±0.11 ^a	32.60±0.46 ^{ab}
2	4.88±0.09 ^{ab}	4.62±0.08 ^a	4.51±0.08 ^{ab}	4.45±0.08 ^a	1.95±0.12 ^a	32.46±0.53 ^{ab}
3	4.96±0.08 ^a	4.62±0.08 ^a	4.56±0.08 ^{ab}	4.37±0.08 ^a	2.00±0.12 ^{ab}	31.77±0.51 ^b
4	4.66±0.09 ^b	4.46±0.09 ^{ab}	4.44±0.08 ^{ab}	4.31±0.09 ^{ab}	2.15±0.13 ^{ab}	33.02±0.54 ^{ab}
5	4.65±0.08 ^b	4.37±0.08 ^b	4.32±0.08 ^b	4.13±0.08 ^b	2.32±0.12 ^b	33.45±0.50 ^a

^{abc}Means within the common superscripts in the same column are not different (P>0.05).

An eight-point scale was used for the evaluations of initial and sustained juiciness, cohesiveness, beef flavor, and off flavor (1= extremely dry, extremely crumbly, extremely bland, no off flavor to 8= extremely juicy, extremely cohesive, extremely intense beef, and extreme off flavor).

Table 10. LSMEANS for sensory evaluation and cook loss and SEM for traditional versus non-traditional grinds.

Compound	Traditional					Non-traditional					SEM
	9.6	11.4	16.3	6.2	8.1	10.5	19.3	21.3	28.4	29.0	
c8	0.25 ^b	0.53 ^a	0.16 ^{bc}	0.17 ^{bc}	0.19 ^{bc}	0.21 ^b c	0.12 ^{bc}	0.07 ^c	0.03 ^c	0.06 ^c	0.06
c10	0.40 ^b	0.62 ^a	0.26 ^{bc} d	0.20 ^{cd}	0.30 ^{bc}	0.33 ^b c	0.33 ^{bc}	0.16 ^c d	0.19 ^c d	0.10 ^d	0.07
c11	0.26 ^a	0.29 ^a	0.09 ^{bc}	0.20 ^{ab}	0.28 ^a	0.22 ^a b	0.10 ^{bc}	0.08 ^b c	0.12 ^a bc	0.01 ^c	0.06
c12	0.44 ^a b	0.66 ^a	0.35 ^{bc}	0.66 ^a	0.52 ^{ab}	0.30 ^b c	0.38 ^{bc}	0.19 ^c	0.20 ^c	0.21 ^c	0.08
c13	0.40 ^a bc	0.73 ^a	0.14 ^{bc}	0.34 ^{bc}	0.16 ^{bc}	0.46 ^a b	0.19 ^{bc}	0.12 ^b c	0.09 ^b c	0.08 ^{bc}	0.13
c14	5.48 ^b cd	5.85 ^{bc}	5.27 ^{cd} e	4.87 ^{de}	5.08 ^f	4.81 ^e	8.09 ^{de}	3.00 ^e	5.38 ^a	5.90 ^b	0.22
c14:1	2.37 ^b c	2.04 ^{de}	2.09 ^{cd}	2.07 ^{cd}	2.05 ^{de}	1.76 ^e	3.24 ^a	1.31 ^f	2.62 ^b	3.24 ^a	0.11
c15	1.29 ^a bc	1.18 ^{bc} d	1.02 ^d	1.51 ^a	1.04 ^{cd}	0.97 ^d	1.43 ^{ab}	0.26 ^e	0.88 ^d	0.79 ^d	0.09
c15:1	1.08 ^b	0.73 ^b	0.74 ^b	0.76 ^b	1.18 ^b	1.06 ^b	1.04 ^b	4.13 ^a	0.53 ^b	0.47 ^b	0.60
c16	38.79 a	39.79 a	2.55 ^d	22.05 c	0.04 ^d	40.53 a	28.57 b	20.49 c	42.72 a	0.01 ^d	1.21
c16:1	0.1 ^f	0.23 ^f	39.16 ^b	6.69 ^d	40.72 ^b	1.25 ^f	0.10 ^f	4.15 ^e	11.02 c	45.65 ^a	0.80
c17	9.71 ^b	7.31 ^c	7.67 ^c	1.38 ^f	6.89 ^c	5.63 ^d	13.04 a	1.22 ^f	3.87 ^e	12.72 ^a	0.41
c17:1	2.31 ^b c	2.43 ^b	1.99 ^{cd}	1.42 ^{ef}	1.96 ^{cd}	2.27 ^c	3.26 ^a	1.05 ^f	2.43 ^b c	1.58 ^{de}	0.15
c18	1.97 ^b	2.02 ^b	1.60 ^b	2.46 ^b	1.80 ^b	1.56 ^b	2.43 ^b	13.16 a	0.00 ^c	1.71 ^b	0.36
C18:1n9t	0.61 ^d	0.18 ^d	0.89 ^d	7.71 ^b	0.34 ^d	0.34 ^d	0.44 ^d	2.67 ^c	19.56 a	0.03 ^d	0.37
c18:1n9c	17.59 e	21.8 ^{cd}	23.84 ^c	36.92 b	22.38 ^c	23.00 c	18.34 de	42.13 a	0.26 ^f	17.11 ^e	1.34
c18:2n6t	0.03 ^d	0.01 ^d	0.00 ^d	1.03 ^b	0.54 ^c	0.00 ^d	0.03 ^d	0.18 ^c d	1.57 ^a	0.00 ^d	0.13
c18:2n6c	1.14 ^{ef}	0.90 ^{ef}	0.84 ^e	2.35 ^{cd}	2.28 ^d	1.42 ^e	2.91 ^b	2.91 ^b c	4.34 ^a	1.85 ^{de}	0.21
c20	7.59 ^b	5.69 ^d	6.21 ^{cd}	0.08 ^f	6.77 ^c	8.00 ^b	8.84 ^a	0.11 ^f	0.17 ^f	4.30 ^e	0.23
c18:3n6	0.4 ^b	0.14 ^{de}	0.29 ^{bc}	0.23 ^{cd}	0.39 ^{bc}	0.37 ^b	0.62 ^a	0.08 ^e	0.07 ^e	0.24 ^{bc}	0.06

			d	e		c				de	
c20:1	0.06 ^c	0.06 ^c	0.04 ^c	0.61 ^a	0.07 ^c	0.03 ^c	0.03 ^d	0.45 ^b	0.07 ^c	0.01 ^c	0.03
c18:3n3	0.1 ^c	0.08 ^c	0.03 ^c	0.75 ^a	0.03 ^c	0.09 ^c	0.07 ^c	0.42 ^b	0.41 ^b	0.02 ^c	0.05
c21	1.14 ^b	1.01 ^{bc}	1.77 ^a	0.86 ^{bc}	0.83 ^{cd}	0.68 ^d	1.58 ^a	0.15 ^e	1.80 ^a	1.69 ^a	0.10
				d							
c20:2	1.27 ^b	0.66 ^d	0.96 ^c	0.67 ^c	0.56 ^d	0.61 ^d	1.70 ^a	0.17 ^e	0.24 ^e	1.20 ^b	0.09
c22	0.39 ^a	0.18 ^b	0.21 ^b	0.17 ^b	0.16 ^b	0.11 ^b	0.10 ^b	0.07 ^b	0.09 ^b	0.05 ^b	0.06
c20:3n6	0.08 ^b	0.17 ^{ab}	0.10 ^{bc}	0.27 ^a	0.07 ^{bc}	0.14 ^a	0.10 ^{bc}	0.14 ^a	0.27 ^a	0.03 ^c	0.05
	c					bc		bc			
c20:4n6	0.04 ^b	0.09 ^b	0.01 ^b	0.54 ^a	0.02 ^b	0.07 ^b	0.02 ^b	0.03 ^b	0.11 ^b	0.00 ^b	0.04
c20:3n3	0.07 ^c	0.05 ^{cd}	0.02 ^{cd}	0.28 ^a	0.05 ^{cd}	0.11 ^b	0.03 ^{cd}	0.19 ^a	0.01 ^c	0.00 ^d	0.03
	d					c		b	d		
c23	0.99 ^a	0.61 ^c	0.59 ^c	0.22 ^d	1.06 ^{ab}	1.15 ^a	0.82 ^{bc}	0.08 ^d	0.18 ^d	0.21 ^d	0.08
	b										
c22:2	0.24 ^a	0.27 ^a	0.09 ^{cd}	0.2 ^{abc}	0.09 ^{cd}	0.06 ^c	0.11 ^{bc}	0.05 ^d	0.04 ^d	0.03 ^d	0.05
	b					d	d				
c24	0.25 ^a	0.22 ^b	0.11 ^{bc}	0.36 ^a	0.17 ^{bc}	0.04 ^c	0.04 ^c	0.05 ^c	0.07 ^b	0.04 ^c	0.05
	b								c		
c20:5n3	0.36 ^a	0.14 ^b	0.12 ^{bc}	0.10 ^{bc}	0.07 ^{bc}	0.12 ^b	0.12 ^{bc}	0.06 ^b	0.04 ^b	0.01 ^c	0.04
						c		c	c		
c24:1	0.86 ^a	0.94 ^a	0.53 ^{bc}	0.43 ^{cd}	0.59 ^{ab}	0.73 ^a	0.57 ^{bc}	0.19 ^{ef}	0.2d ^{ef}	0.07 ^f	0.13
	b		de	ef	cd	bc	d				
c22:6n3	1.51 ^a	2.10 ^a	0.77 ^{cd}	1.30 ^{bc}	0.90 ^{cd}	1.24 ^b	0.90 ^{cd}	0.43 ^d	0.42 ^d	0.34 ^d	0.21
	b					c					
SFA	69.37	66.70	28.00 ^e	35.53	25.28 ^e	65.02	66.05	39.19	55.79	27.92 ^e	1.55
	a	ab		d	f	b	ab	d	c	f	
MUFA	25.39	28.70	68.77 ^a	56.76	69.72 ^a	30.75	27.34	56.14	36.68	68.35 ^a	1.59
	e	de		b		d	de	b	c		
PUFA	5.24 ^b	4.61 ^{bc}	3.23 ^d	7.71 ^a	5.00 ^b	4.22 ^b	6.61 ^a	4.67 ^b	7.53 ^a	3.73 ^{cd}	0.42
						cd		c			
P/S	0.08 ^c	0.07 ^c	0.12 ^b	0.22 ^a	0.20 ^a	0.07 ^c	0.10 ^b	0.13 ^b	0.14 ^b	0.14 ^b	0.01
n6	1.70 ^d	1.31 ^e	1.24 ^e	4.41 ^b	3.30 ^c	2.00 ^d	3.68 ^{bc}	3.35 ^c	6.37 ^a	2.12 ^d	0.28
	e					e					
n3	2.03 ^a	2.37 ^a	0.95 ^{cd}	2.42 ^a	1.05 ^{cd}	1.55 ^b	1.12 ^{cd}	1.11 ^c	0.88 ^d	0.38 ^e	0.24
	b		e			c		d	e		

^{abc}Means within the common superscripts in the same row are not different (P>0.05).

Table 11. Proximate analysis Fat percentage of each Grind Source and Type

Fat %	Abbreviation	Grind Type
Traditional		
9.6	T3	Traditional (TR)
11.4	T2	Traditional (TR)
16.3	T1	Traditional (TR)
Non-Traditional		
6.2	N5	Niche (NI)
8.1	N7	Niche (NI)
10.5	N2	Quality Grade (QG)
19.3	N1	Quality Grade (QG)
21.3	N4	Quality Grade (QG)
28.4	N6	BS (BS)
29.0	N3	BS (BS)

Table 12. LSMeans TBARS values and SEM for grind types

Grind Type	TBARS
BS	2.01±0.17 ^a
NI	1.21±0.14 ^{b,c}
QG	1.39±0.11 ^b
TR	1.00±0.11 ^c

^{abc}Means within the common superscripts in the same column are not different (P>0.05)

Table 13. LSMeans colorimetric values and SEM for grind types

Grind Type	L*	a*	b*
BS	48.97±0.17 ^a	11.94±0.21 ^c	17.97±0.08 ^b
NI	39.84±0.16 ^d	16.62±0.19 ^a	18.02±0.07 ^b
QG	46.17±0.13 ^c	15.17±0.15 ^b	18.63±0.06 ^a
TR	48.11±0.13 ^b	15.05±0.15 ^b	18.65±0.06 ^a

^{abc}Means within the common superscripts in the same column are not different (P>0.05)

Table 14. LSMeans sensory evaluation scores and SEM for grind types

Grind Type	Initial Juiciness	Sustained Juiciness	Cohesiveness	Beef Flavor	Off Flavor	Cook Loss
BS	4.74±0.15 ^{ab}	4.48±0.16 ^{ab}	4.63±0.12 ^a	4.50±0.017 ^a	1.77±0.28 ^b	42.61±0.91 ^a
NI	4.61±0.08 ^b	4.27±0.09 ^b	4.55±0.07 ^{ab}	3.72±0.10 ^b	3.23±0.16 ^a	27.62±0.51 ^c
QG	4.81±0.07 ^{ab}	4.51±0.08 ^a	4.36±0.06 ^{bc}	4.51±0.09 ^a	1.70±0.14 ^b	31.72±0.46 ^b
TR	4.93±0.07 ^a	4.68±0.07 ^a	4.30±0.06 ^c	4.55±0.08 ^a	1.57±0.13 ^b	30.97±0.42 ^b

^{abc}Means within the common superscripts in the same column are not different (P>0.05)

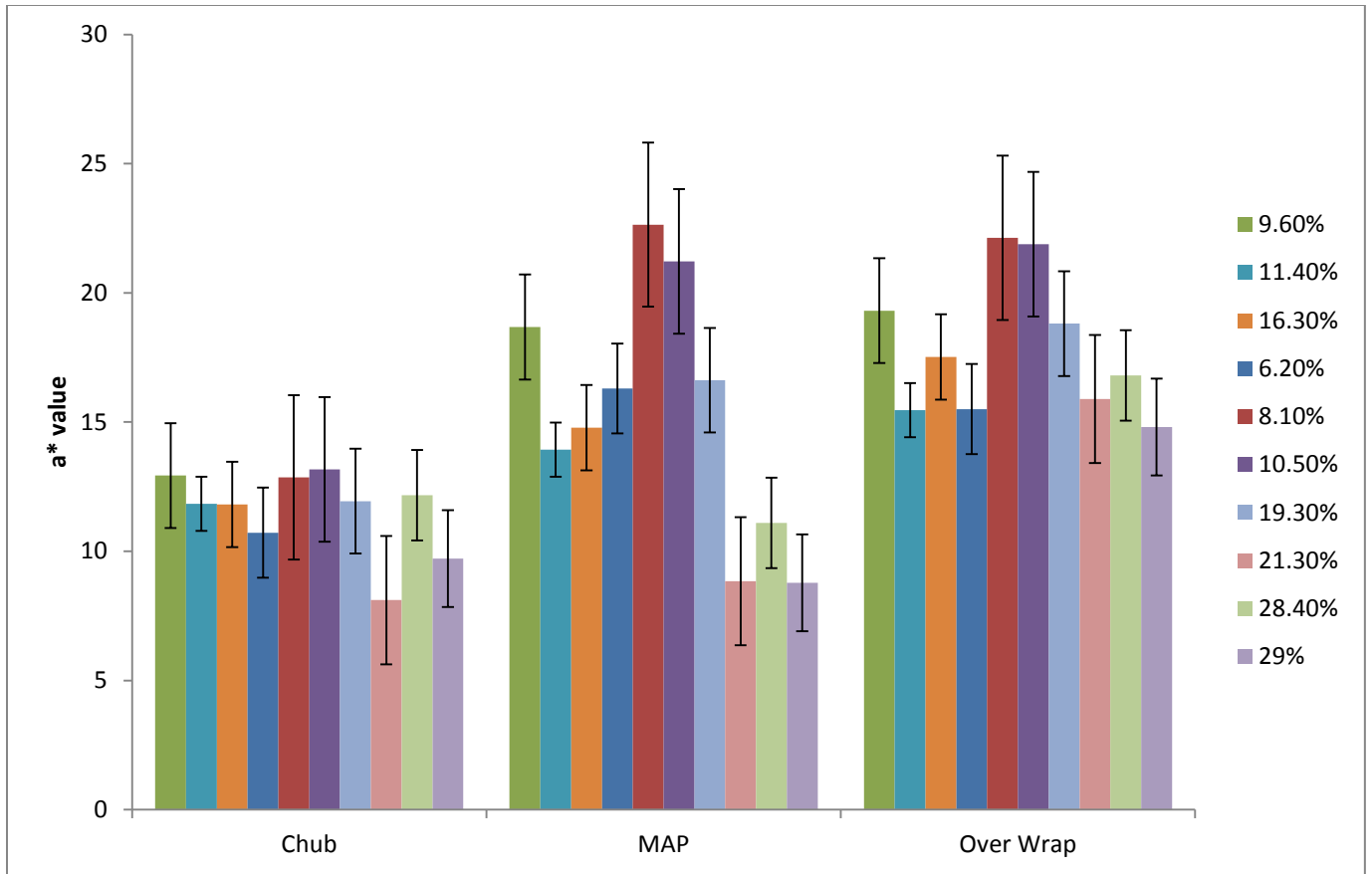


Figure 1. LSMEANS of interaction of grind by packaging on a* values in traditional versus non-traditional grind products.

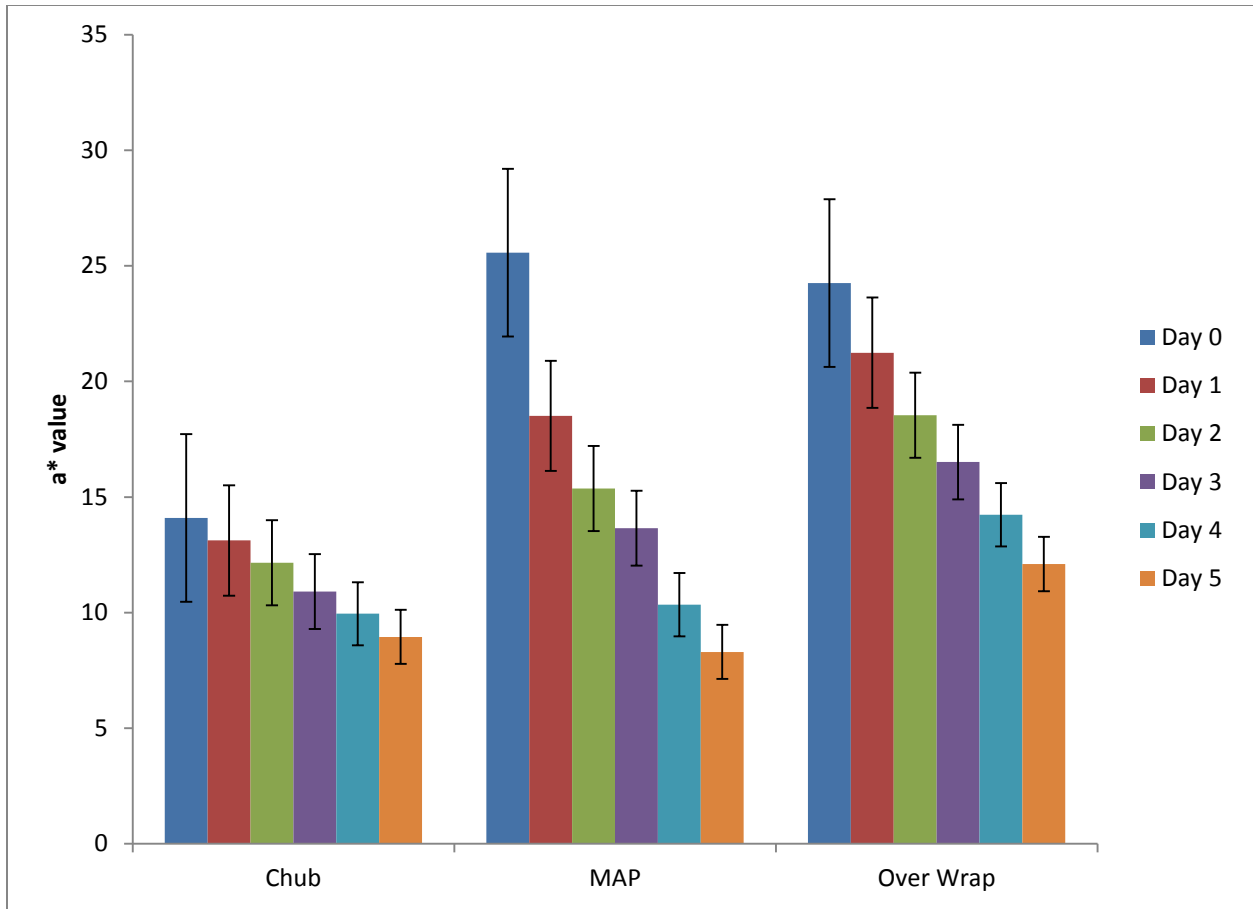


Figure 2. LSMEANS of interaction of grind by packaging on a* values in traditional versus non-traditional grind products.

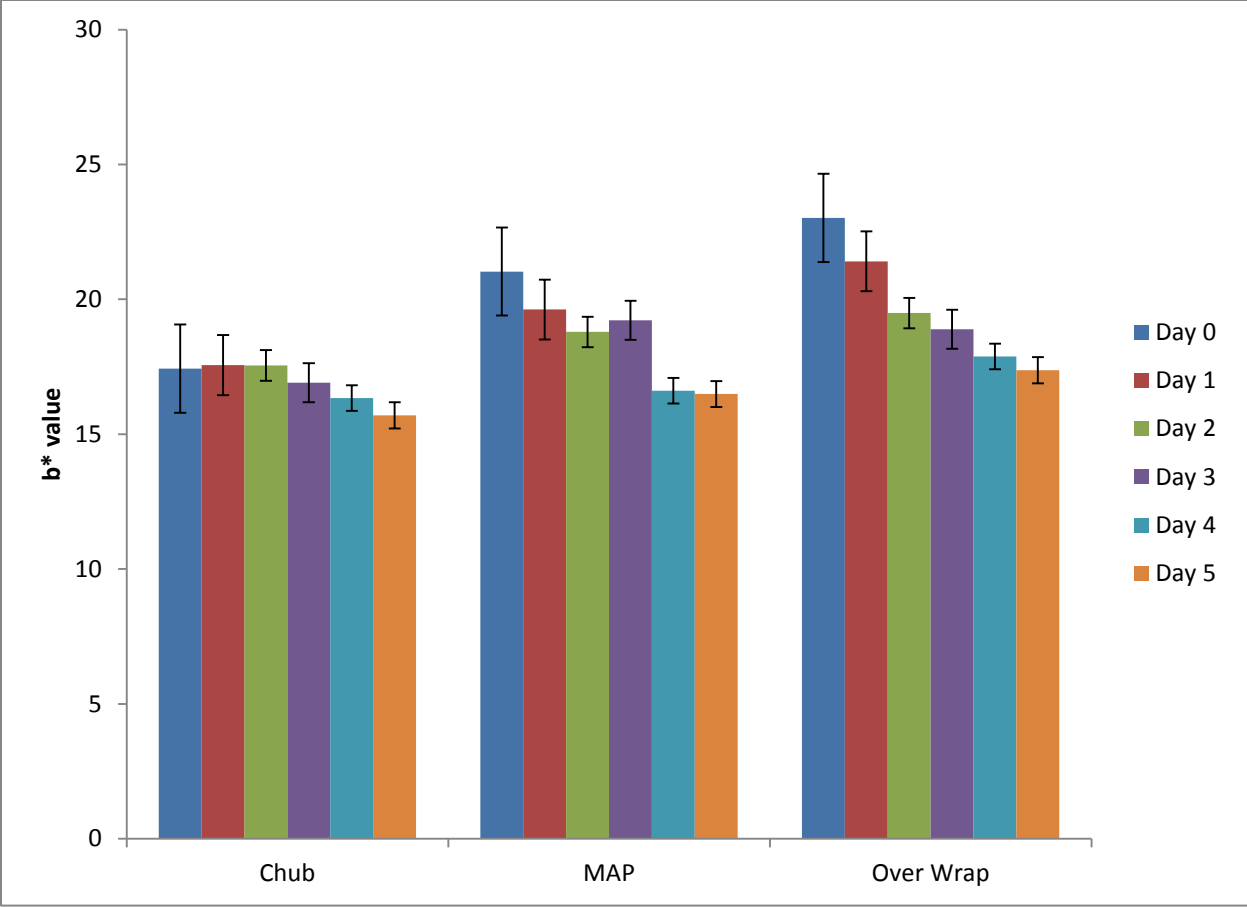


Figure 3. LSMEANS of interaction of day of storage in retail display by packaging on b* values in traditional versus non-traditional grind products.

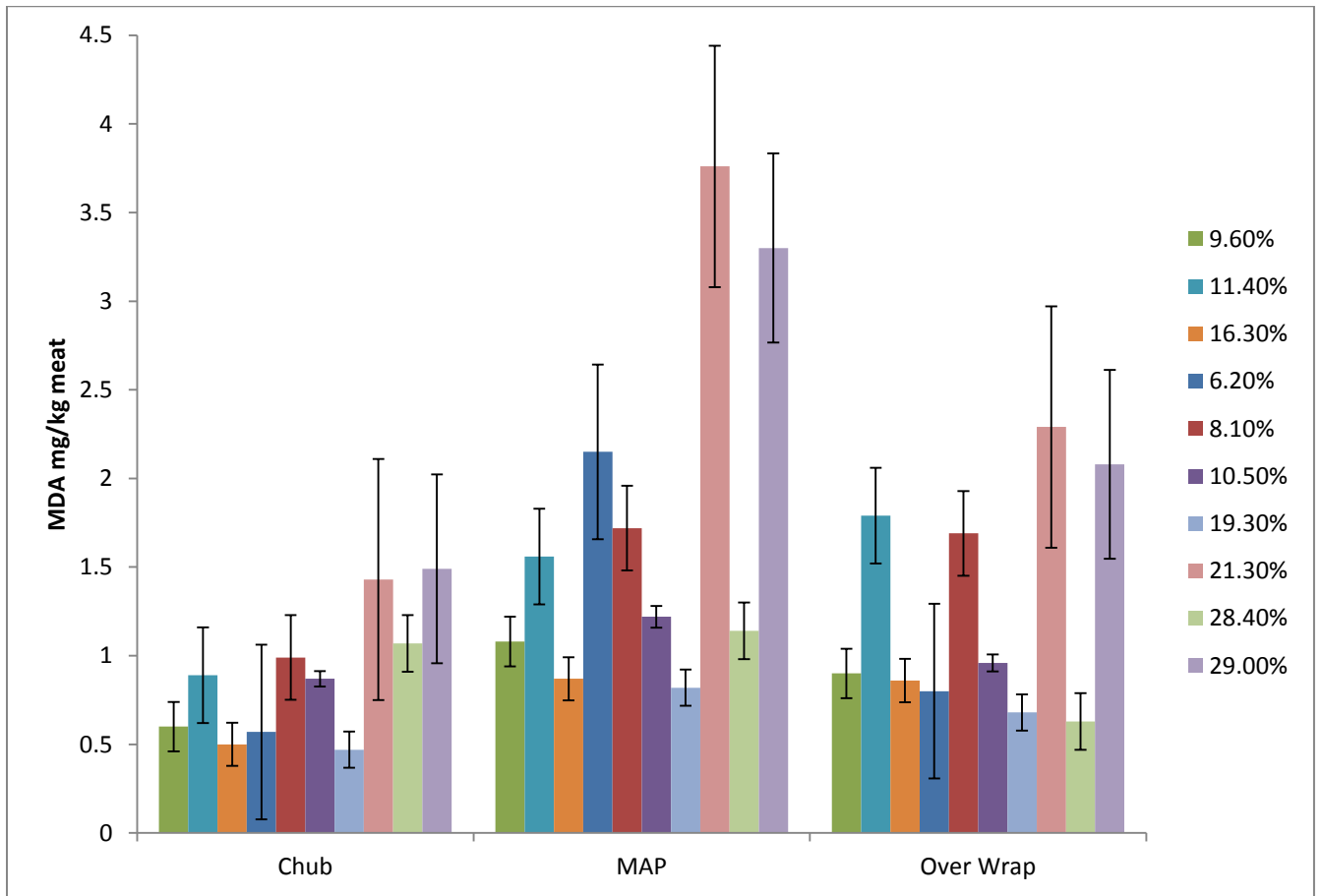


Figure 4. LSMEANS of interaction of packing treatment by grind product on TBARS (mg MDA/kg meat) values in traditional versus non-traditional grind products.

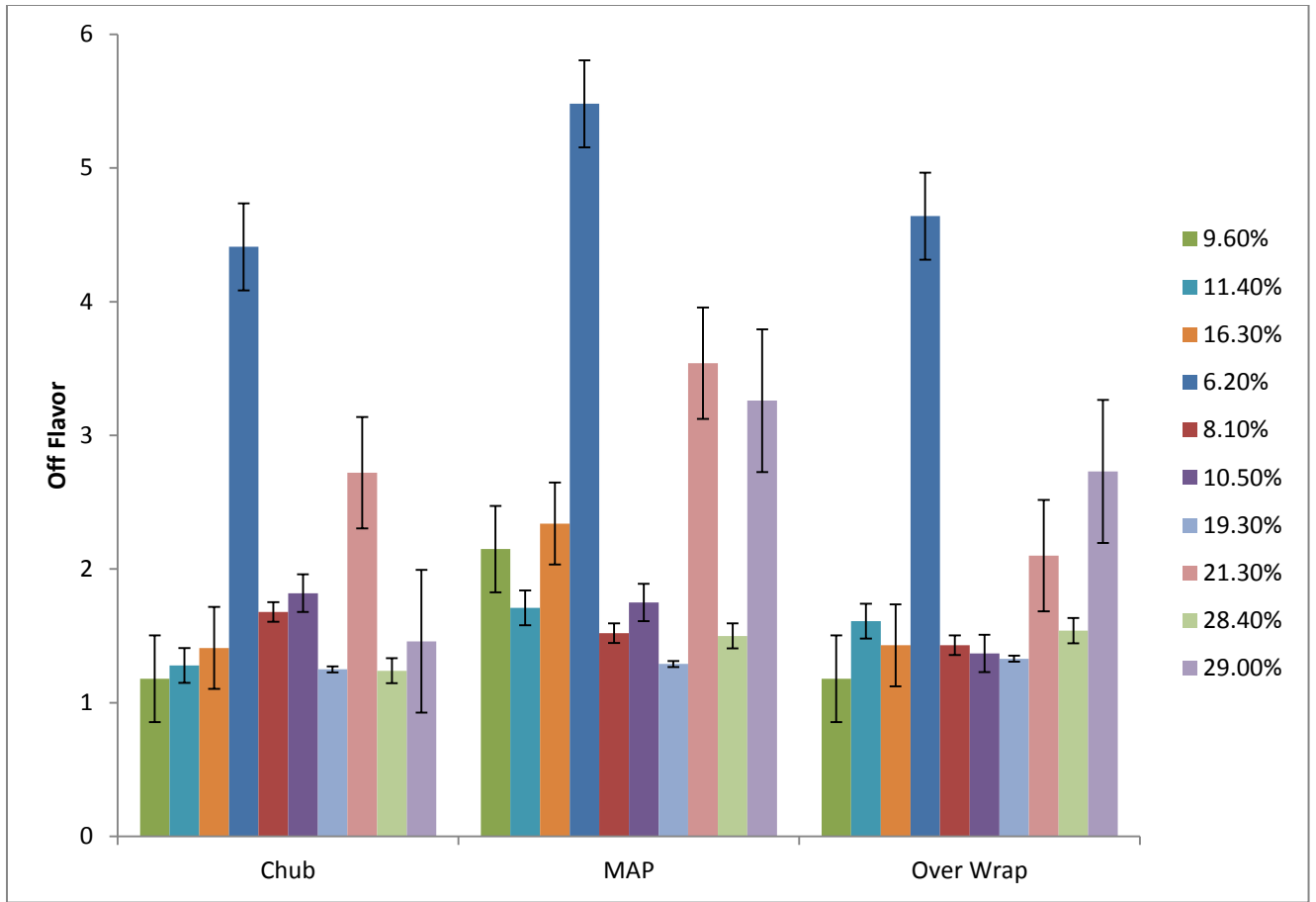


Figure 5. LSMEANS of interaction of packaging treatment by grind product on off flavor as determined by trained sensory panel in traditional versus non-traditional grind products.

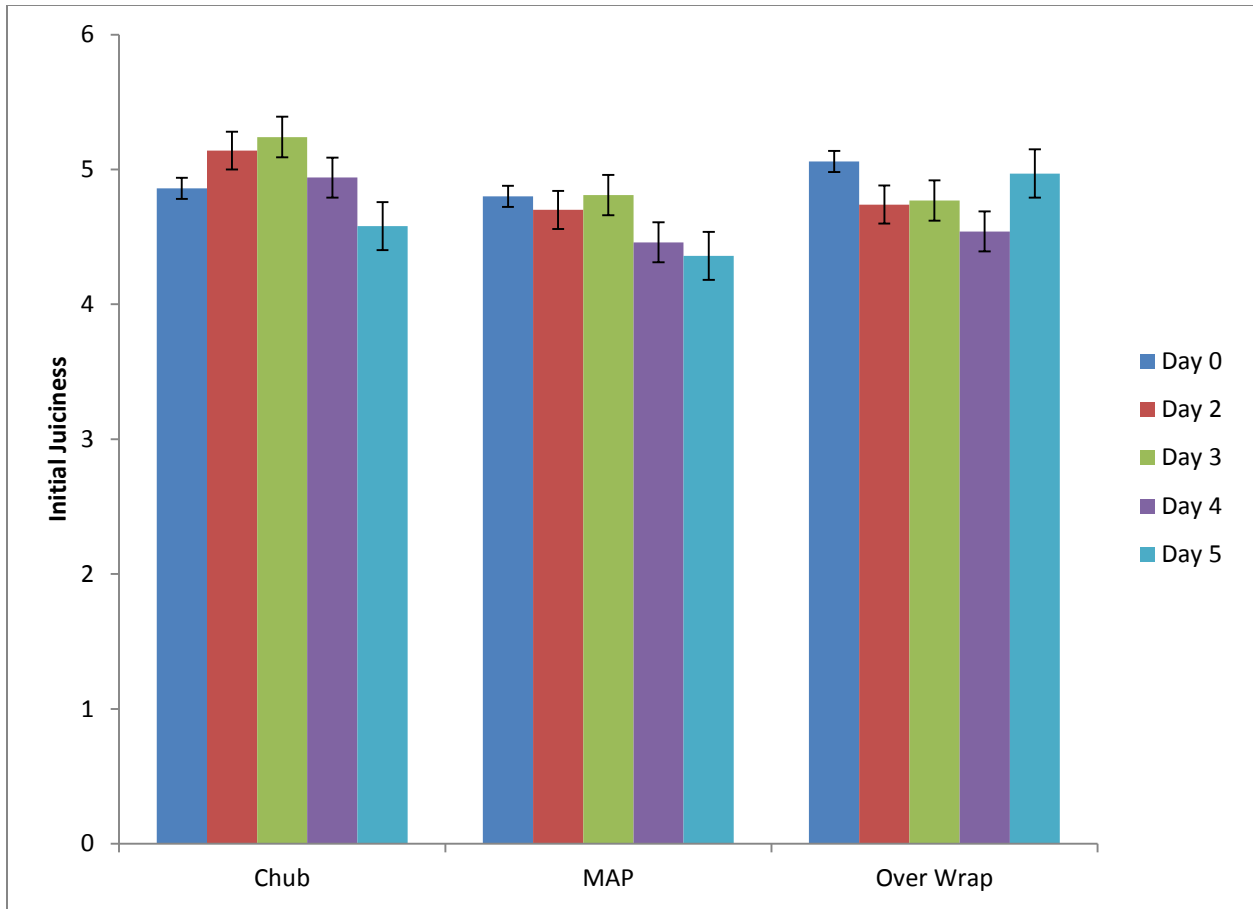


Figure 6. LSMEANS of interaction of day of storage in retail display by packaging on initial juiciness values determined by trained sensory panel in traditional versus non-traditional grind products.

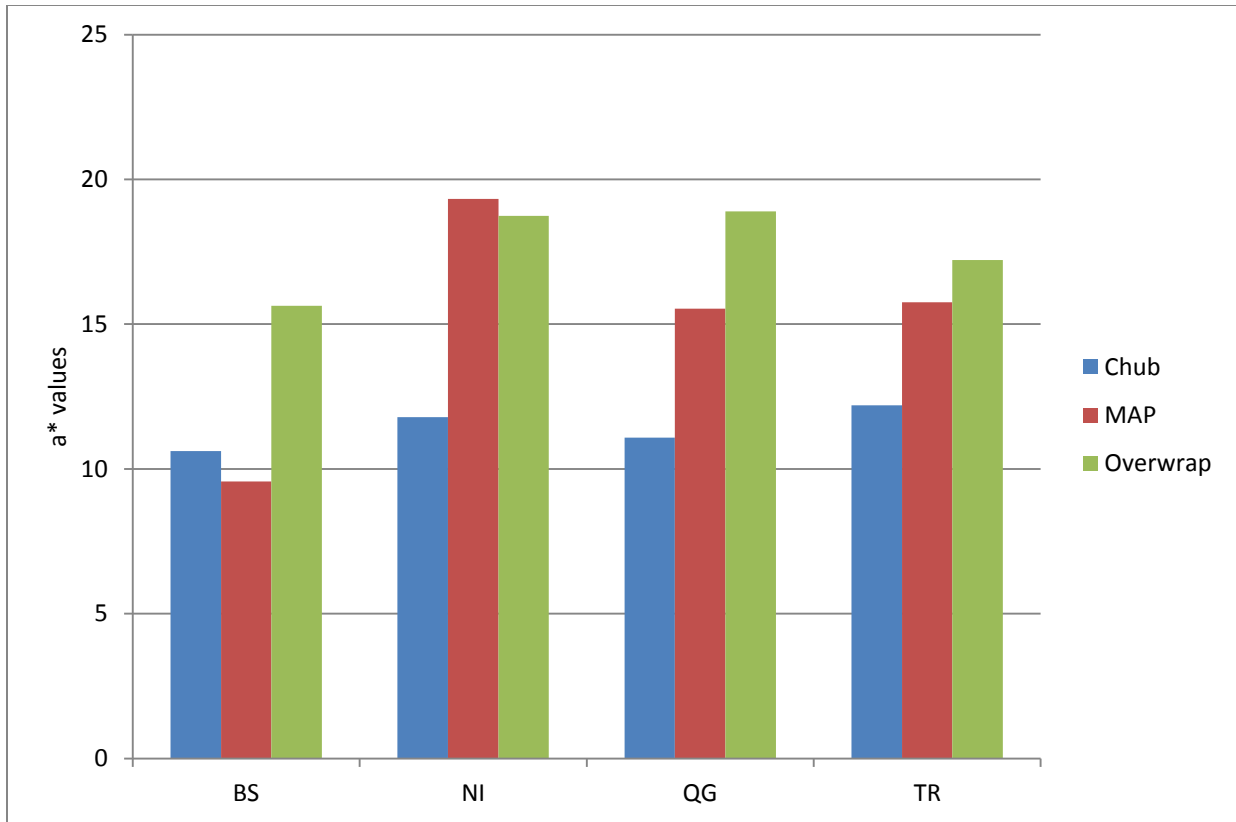


Figure 7. LSMEANS of interaction of grind type by packaging on a* values in traditional versus non-traditional grind types.

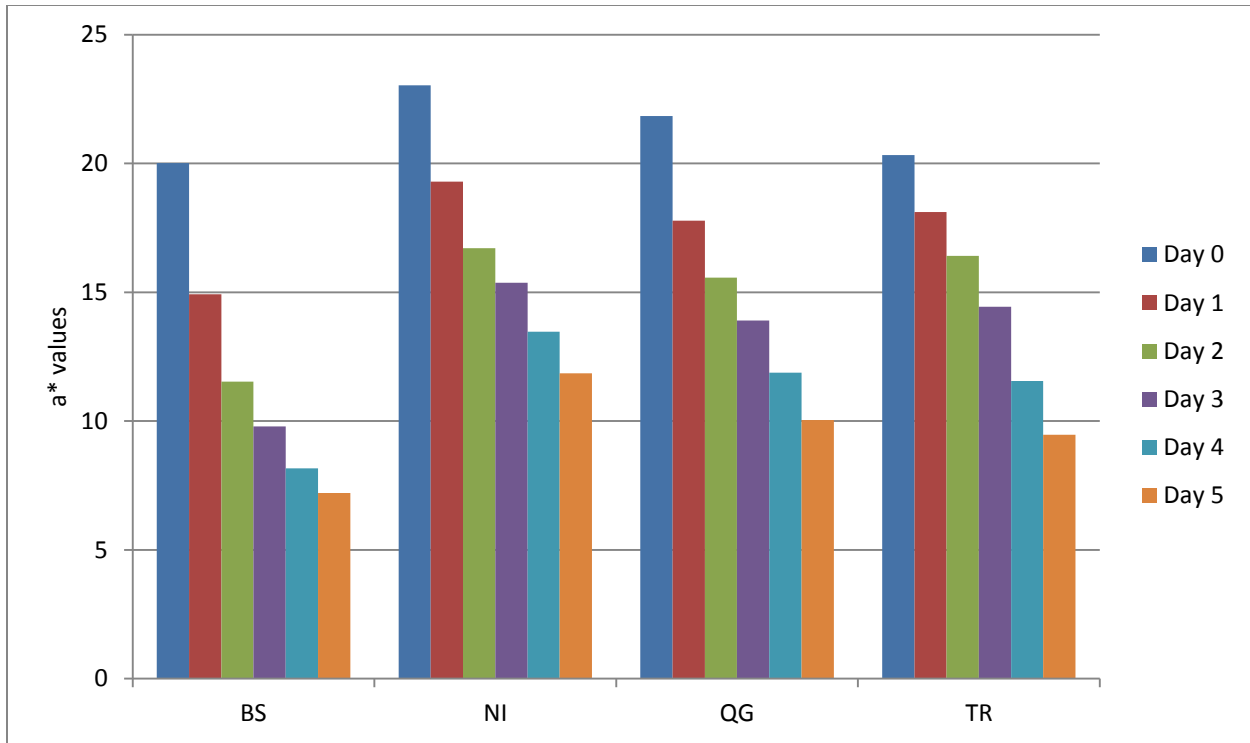


Figure 8. LSMEANS of interaction of grind type by day on a* values in traditional versus non-traditional grind types.

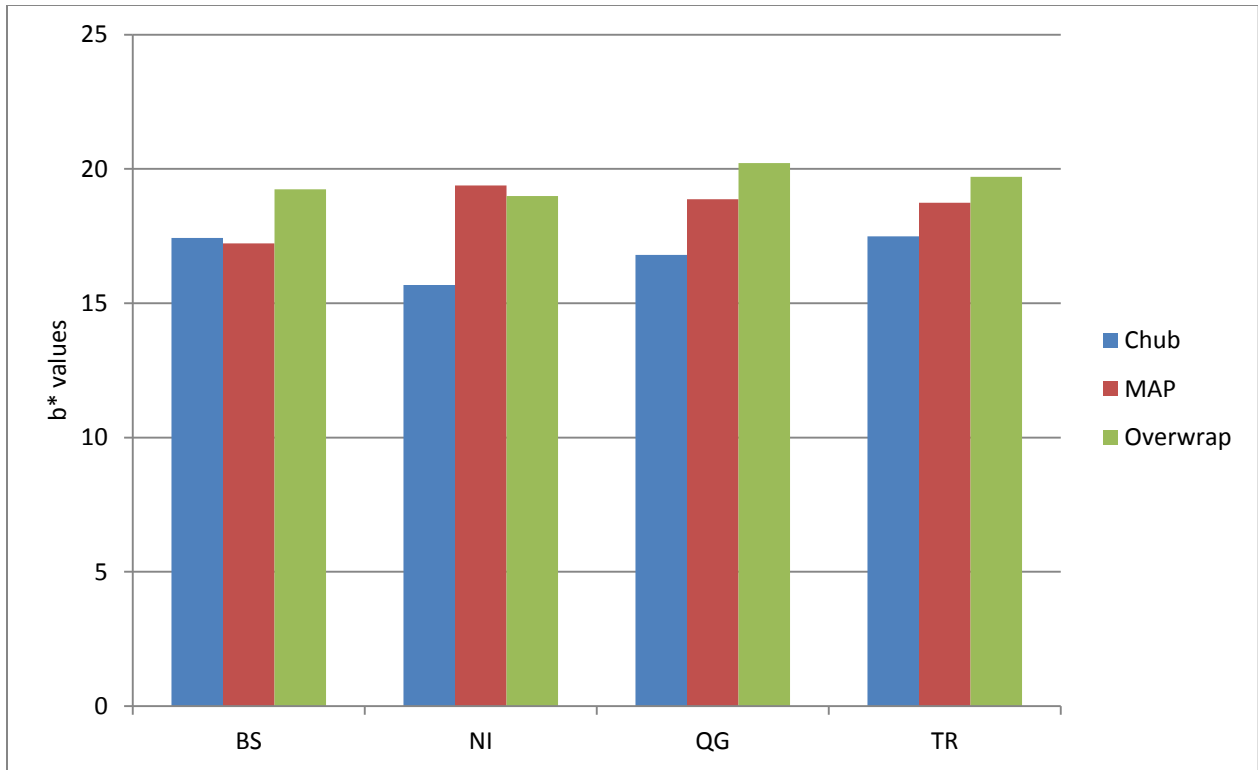


Figure 9. LSMEANS of interaction of grind type by packaging on b* values in traditional versus non-traditional grind types.

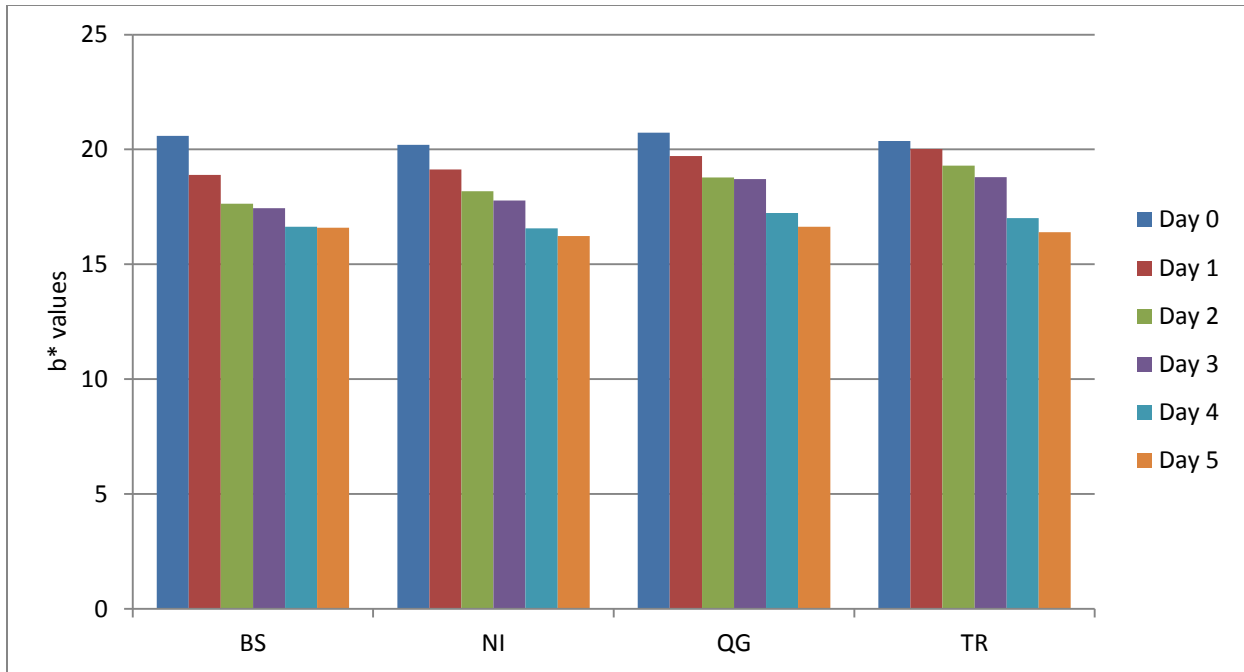


Figure 10. LSMEANS of interaction of grind type by day on b* values in traditional versus non-traditional grind types.