Relationship of an Objective Measure and Consumer Perception of Oxidized Flavor in Ground Beef

by

Megan Christine McMurray

A thesis submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Master of Science

Auburn, Alabama
May 3, 2014

Keywords: Ground Beef, Sensory Evaluation, Lipid Oxidation

Approved by

Christy L. Bratcher, Chair, Associate Professor of Animal Sciences
Luxin Wang, Assistant Professor of Animal Sciences
Manpreet Singh, Assistant Professor of Food Sciences

Abstract

An experiment was conducted to compare the sensory and shelf life characteristics of ground beef with three different fat contents in order to determine if an objective measure is adequate in predicting consumer perception of rancidity in ground beef. Three different grinds, 73/27, 80/20, and 93/7, were packaged in overwrapped foam trays and put on retail display for 6 days. Starting on the day packages were placed on display (d 0), 5 packages from each grind were removed and frozen each day for further lab analysis. Also starting on d 0, 1 packaged from each grind was 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 juiciness (J), cohesiveness (CO), beef flavor (BF), off-flavor (OF), and cook loss (CL). Data were analyzed using the PROC GLM procedure of SAS. L* values were shown to increase with increasing fat percentage while a* values decreased. For days on display, all colorimetric values were found to decline within each grind. The 73/27 grind had the highest TBARS of 0.61, but this was not different from the other two grinds. Days 5 and 6 had the greatest values for TBARS (1.10 and 1.00 TBARS value, respectively), but were not different ($P>0.05$). Days 0 through 4 were not different from one another ($P>0.05$). Between grinds, differences were seen ($P<0.05$) in OF and CO. The 93/7 grind scored the most intense OF at 2.38. With regards to CO, the 73/27 grind had the greatest value of 5.55, but this was not different ($P>0.05$) from the 80/20 grind. No differences ($P>0.05$) in beef flavor were found

among the three grinds. Throughout retail display, differences were also seen ($P<0.05$) in OF, CO, and BF. Days 5 and 6 had the most intense perceived OF but were not different ($P>0.05$) from one another. Day 0 had the least intense OF at 1.69, but was not different ($P>0.05$) than days 1 through 4. D 6 also had the most intense BF at 5.39, but was not different ($P>0.05$) than days 3, 4, or 5. Day 5 had the highest CO value at 5.52 and day 1 the least at 4.96. Days 0, 2, 3, 4, and 6 were not different ($P>0.05$) than either d 1 or 5. There was an interaction of grind and days of display on J and CL. The 73/27 grind had the highest J and CL values followed by the 80/20 and 93/7 grinds. Data indicates that factors beyond fat content play roles in ground beef color stability, lipid oxidation, and sensory characteristics.

TBARS values were correlated with the OF values for each panelist resulting in an r value of 0.29, indicating a low correlation. Another variation of data analysis was performed in which the average of all panelists' OF scores for each grind by day treatment was correlated to the TBARS for each treatment. This resulted in a higher correlation with an r value of 0.85. The TBARS and OF scores were also fitted to a regression and with all data together, the coefficient of determination was smaller ($r^2=0.05$) than compared to the average of all panelists at $r^2=0.72$. This shows TBARS can in some cases be used to predict consumer assessments of rancidity although there are numerous other factors that can influence the correlation.

Acknowledgments

In my time here at Auburn I have been blessed with wonderful opportunities and experiences that I will always treasure. I have also had the great pleasure of meeting so many fantastic people who have helped me along the way, and had the pleasure of gaining numerous friends who I will be forever grateful for.

First I would like to thank God for all His many blessings and for allowing me to be where I am and be the person I am today. I would like to thank my parents, Mark and Lisa, for giving me the opportunity to come to Auburn and follow my dreams, and for supporting, encouraging, and loving me each step of the way. Your faith and love in God and in me have been a huge encouragement, and I could not have asked for a better set of role models. I would also like to thank my grandparents, Garlin and Nancy Stephens and Carl and Mae McMurray, as well as all my other family. You are all such a great blessing in my life, and I thank you for your support and love.

I would like to thank all of the faculty, staff, and students in the Department of Animal Sciences. You not only helped with my research, but also gave me memorable experiences and made my time here so much fun. I would like to thank Dr. Mulvaney for always pushing me to be my best and to pursue graduate school. I would also like to thank Dr. Wang and Dr. Singh for serving on my committee along with supporting and helping me when I needed it. Furthermore, I would like to thank Heidi Finegan, Kayla Blake, and Clint Martin, for giving me a helping hand with my research when I needed it most.

I want to thank Pete Holloway, TJ Mayfield, and Susan Dale from the Meat Lab. You were always available when I needed help or had questions and could always manage to bring a smile to my face no matter what. I also want to thank Barney Wilborn for being such a great teacher and supporter during my time here. Your advice and funny stories always made my day.

I would like to thank Dr. Bratcher for taking me on as a graduate student. I have learned so much in my short time with you, and I will forever be grateful for your support and help in achieving my dreams. I would also like to thank Kim Fisher and Staci DeGeer. You both helped ease my transition in to graduate school and were always there to help, support, and encourage along the way. You have given me so many wonderful memories that I will always cherish, so thank you both for the lifelong friendship.

Finally I want to thank my fiancé, Justin Thomas, for his constant love and support. Being together through long distance has been tough, but I am continually thankful for your patience and encouragement while I accomplish my goals. I am beyond blessed to have you and am looking forward to being your wife.

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I. INTRODUCTION

Ground beef is traditionally marketed in a retail setting based on fat and lean percentage. This is helpful to consumers, as studies have shown that fat content often impacts certain quality characteristics of the meat, and because consumers are becoming more health conscious. Extensive research has been performed to examine how fat percentage affects juiciness, tenderness, flavor intensity, and off-flavor in meat products. This is important as each of the characteristics can affect the palatability and perception of the meat product to consumers.

It has also been reported that oxidation of the fat content can lead to some undesirable meat qualities such as off-flavors (Morrissey et al., 1998). Much research has been conducted on the topic of lipid oxidation, however certain aspects of the complex process remain largely uncertain (Gray et al., 1996; Kanner, 1994; Morrissey et al., 1998). Using products formed from lipid oxidation, researchers can use chemical means to measure the extent of oxidation in a meat product. However, little research has been done to compare these chemical measurements of oxidation to that of sensory panelists' perception of rancidity in meat products.

Sensory evaluation is an important tool in the meat industry as it can help relate the human perception of meat to its quality attributes. Understanding consumer perception can help improve or modify a product as well as determine how well the product will fare in the market. Relating these subjective sensory measurements to objective measurements is a common research topic throughout meat science. However, little research has been conducted to specifically relate an objective measure of oxidation to sensory perception of oxidation and rancid flavor in meat.

The objective of this study is to examine the sensory and shelf life characteristics of ground beef composed of different lean-to-fat ratios to determine an objective measure is sufficient in predicting consumer perception of oxidation in ground beef. It is hypothesized sensory

characteristics, shelf lift, and color stability will deteriorate as fat percentage increases and days of retail display increase.

II. REVIEW OF LITERATURE

A tremendous amount of ground beef is produced and consumed in the United States. Ground beef is sold either by the primal it is ground from (ground chuck, ground round), or it is sold by the lean to fat ratio, with the most common in the market place being 93/7, 90/10, 85/15, and 80/20. Research has been conducted on various characteristics of ground beef, especially lipid oxidation and sensory evaluation (Campo et al., 2006; Greene et al., 1981). However, in order to better understand the relationship between the two, research needs to be performed to correlate what a sensory panelist reports on off-flavor with a subjective measure of lipid oxidation like the thiobarbituric reactive substances assay (TBARS).

Effect of Fat in Ground Beef

Cross et al. (1980) performed an experiment to compare the chemical, physical, and sensory properties of ground beef with fat percentages of 16 to 28 percent. Boneless beef materials were used to create grinds of 16, 20, 24, and 28 percent fat that were then used to make patties for evaluation. Cooking times for the patties were determined based on previous research which reported that cooking time decreased as the intramuscular fat percentage increased because of differences in lean versus fat heat transfers. After evaluation, data indicated greater tenderness and juiciness ratings as fat content increased. Other sensory traits such as beef flavor, mouth coating, and collagen content were largely unaffected by fat content. Cooking loss was also unaffected.

Troutt et al. (1992) carried out a similar test. Grinds of 5, 10, 15, 20, 25, and 30 percent fat were blended using 90% lean beef from lean cow knuckles and fat trim. They were then formed into patties. Patties were cooked on a preheated electric skillet to internal temperatures of 71°C and 77°C

in order to determine cook losses and then evaluated. The data agrees with Cross et al. (1980). Using a trained sensory panel to analyze sensory characteristics, juiciness was found to increase as fat percentage increased, while beef flavor was found to be unaffected by the fat content. However, cooking loss was also found to increase with increasing fat percentage and greater cohesiveness was found in the lower fat patties.

Many studies concur with the above experiments that ground beef composed of a greater fat percentage will also have greater juiciness scores in sensory evaluation (Berry et al., 1984; Berry 1994; Miller et al., 1993). While Cross et al. (1980) and Troutt et al. (1992) both agree that beef flavor is not reliant on fat content, other studies have found fat percentage and flavor are highly correlated (Berry, 1992; Berry, 1993; Berry, 1994; Miller et al., 1993).

Lipids in cooked meat produce volatile compounds that act as primary sources of flavor through the combination of tastes and odors obtained from the volatile compounds (Brewer, 2012). Ladikos et al. (1990) suggest meat with greater percentages of unsaturated fatty acids is more prone to lipid oxidation. Other studies and reviews have yielded the same conclusion that unsaturated fatty acids are linked to the occurrence of lipid oxidation (Gray et al., 1992; Morrissey et al., 1998; Baron et al., 2002).

Based on the previous discussion, it would be expected that as fat percentage increases, the extent and rate of lipid oxidation would also increase. However, a few studies have reported that this is not always the case. Houben et al. (2000) reported data showing no difference in TBARS values across a 10-day retail display between low and high fat ground beef. Tigue (2013) also showed similar data in which the expectation that increasing fat levels would lead to increased lipid oxidation did not hold true. The relationship between fat levels, oxidation, and shelf life continues to be a much-researched area of meat science.

Lipid Oxidation

Lipid oxidation is a main factor that affects the quality and acceptability of meat products (Chaijan, 2008). It is a very complex process in which unsaturated fatty acids react with molecular oxygen through a free radical chain mechanism to form primary products known as peroxides, which is then followed by a series of secondary reactions that lead to the breakdown of the lipid and rancidity development (Ladikos et al., 1990). Autoxidation through the free radical chain mechanism involves an initiation, propagation, and termination stage, with the initiation stage being regarded as uncertain and the topic of much research (Gray et al., 1992).

Lipid molecules are in a singlet spin state, and molecular oxygen is in a triplet spin state, which prevents an interaction leading to initiation of autoxidation by the direct addition of oxygen to a double bond to produce hydroperoxide compounds. Also the spontaneous abstraction of hydrogen from organic material with molecular oxygen needs a large quantity of activation energy, thus being considered unfavorable (Kanner et al., 1992; Gray et al., 1996; Baron et al., 2002).

Transition metals, markedly iron, have been found to be essential in generating free radicals able to abstract a proton from an unsaturated fatty acid (Gray et al., 1996; Kanner et al., 1992; Baron et al., 2002). There are also several enzymes such as flavoenzyme, cytochrome-P450 reductase, lipoxygenase, xanthine oxidase, and cyclooxygenase that have been found to catalyze the development of hydroperoxides (Kanner et al., 1992). Hydroperoxides are the most important and final result of this initiation step, as they proceed on to change and deteriorate with the radicals to cause secondary products such as alkanes, alkenes, aldehydes, ketones, alcohols, esters, and acids (Fernandez et al., 1997; Gray et al., 1992).

One particular secondary oxidation product is malonaldehyde, a highly reactive and toxic product that requires an acid/heat treatment to release it from its bond to other food ingredients (Ulu, 2004; Addis, 1986). While lipid oxidation can be measured using primary products, the oldest and most commonly used test is the 2-thiobarbituric acid reactive substances assay that is based upon the absorbance of a colored complex formed between malonaldehyde and TBA (Gray et al., 1992; Ulu, 2004). Addis (1986) showed that the TBARS method is not adequate to quantify malonaldehyde and therefore should not be reported as ppm malonaldehyde, however since the test is still an effective measurement of lipid oxidation, the term TBARS value should be used.

Fernandez et al. (1997) outlined two other procedures widely used to determine the amount of lipid oxidation in a meat product other than determining the amount of the malonaldehyde content. These include looking at peroxide values, which are intermediate products formed from carbonyl compounds, and determining the hexanal content, which involves measuring the content of a steam distillate and has been linearly correlated with TBA values. Fernandez et al. (1997) also discussed the different analytical techniques when looking specifically at the malonaldehyde content. Ultraviolet spectrophotometry has been successfully applied to the assay of malonaldehyde in distillates from rancid foods. Gas chromatography has also been used and can determine free and bound malonaldehyde concentrations. However, the TBA test still remains the most widely used. Fernandez et al. (1997) and Ulu (2004) both explain the different TBA test procedures that can be used. One method involves directly heating the sample with the TBA solution. However, it is a very time consuming method and is believed to bring on oxidation just from the nature of the test. Another method that can be used is based up on the reaction between the TBA solution and a portion of the distillate. This method has been found to be more sensitive and better for samples containing a

higher fat content . It is also the most widely used TBA procedure. An aqueous acid extraction of the sample prior to a reaction with TBA can also be used as a method and is considered to be the best because the sample is not exposed to heat. It is also considered faster and easier and recommended when a large number of samples may need to be rapidly analyzed. However, impurities can often interfere with the red pigment formation and this extraction method does give lower malonaldehyde numbers than the distillation method. Finally, lipid extraction through evaporation and nitrogen can also be used, resulting in a high TBA number and no interfering substances.

The TBA assay is widely used in meat science literature because studies have found that it often correlates with sensory evaluations of oxidation in meat products (Fernandez et al., 1997). Studies have been conducted to simplify the methodology over the years (Rhee, 1978; Crackel et al., 1988; Raharjo et al., 1992; Ulu, 2004). It is generally used as a "within trial" comparison and with methodology varying across labs, it is difficult to compare values from one manuscript to the next unless the exact same methodology is utilized.

Sensory Evaluation

Since meat is a food, and consumers have a sensory experience when consuming meat, sensory evaluation, or sensory science, is an important tool in meat science research. Sensory evaluation is a science used to evoke, measure, analyze, and interpret human responses to the sensory characteristics of foods (Civille, 1994). Since consumer acceptance ultimately determines the success of a product, consumer sensory evaluation is crucial in comprehending how products can be improved and whether or not they meet consumer expectations (Chambers, 1994). Consumer perceptions of meat are often examined through a quantitative study that evaluates the

intensity/strength of specific attributes such as tenderness, juiciness, color, and flavor (Muñoz, 1998).

Greene et al. (1981) conducted a study to determine if TBARS values could be correlated with consumer perception of oxidized flavor and established as an effective indicator of consumer assessment. Beef semitendenosus muscles were used to form patties that were subsequently stored for varying lengths of time to represent different increments in oxidized flavor intensity. After evaluation, correlations were found between consumers' tastes and TBARS, but were considered low. Oxidized flavor was detected over a broad range of TBARS, which indicated a big variation in the threshold of the consumer panelists.

Campo et al. (2006) performed a related experiment in which the aim was to assess the limiting threshold for the acceptability of oxidation by relating sensory perceptions to TBARS. Steaks from the longissimus dorsi of steers raised on ten different diets were evaluated after being in a simulated retail environment for 0, 4, or 9 days. Oxidation was found to increase throughout display for each of the diets as indicated by a rise in TBARS values. Beef flavor and overall liking decreased throughout display while rancid flavors increased. The data agrees with Greene et al. (1981) as correlations were found between sensory and TBARS values, although the correlations were greater in this study. A TBARS value of 2 was suggested as the limiting point where rancid flavor overwhelms beef flavor, although it was noted that perceptions can vary and thresholds do not necessarily indicate acceptability/rejection.

Conclusion

Fat content in ground beef products can affect the juiciness and flavor of the products while also increasing the susceptibility to lipid oxidation. This lipid oxidation can in turn affect the quality and acceptability of products to consumers. Products can be evaluated using sensory evaluation to better understand consumer expectations while simultaneously helping to improve products.

The relationship of rancidity and flavor is an ongoing investigation. Attempts have been made to relate the human perception of rancidity to chemical measurements, though it has proved to be a difficult task, and much of that research is dated.

Therefore, the objective of this study was to compare the sensory and shelf life characteristics of ground beef with three different fat contents to determine if an objective measure is adequate in predicting consumer perception of rancidity in ground beef.

III. Relationship between an Objective Measure and Consumer Perception of Oxidized Flavor in Ground Beef

Abstract

An experiment was conducted to compare the sensory and shelf life characteristics of ground beef with three different fat contents in order to determine if an objective measure is adequate in predicting consumer perception of rancidity in ground beef. Three different grinds, 73/27, 80/20, and 93/7, were packaged in overwrapped foam trays and put on retail display for 6 days. Starting on d 0, the day packages were placed on display (d 0), 5 packages from each grind were removed and frozen each day for further lab analysis. Also starting on d 0, 1 package from each grind was 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 juiciness (J), cohesiveness (CO), beef flavor (BF), off-flavor (OF), and cook loss (CL). Data were analyzed using the PROC GLM procedure of SAS. L* values were shown to increase with increasing fat percentage while a* values decreased. For days on display, all colorimetric values were found to decline within each grind. The 73/27 grind had the highest TBARS of 0.61, but this was not different from the other two grinds. Days 5 and 6 had the greatest values for TBARS (1.10 and 1.00 TBARS value, respectively), but were not different ($P>0.05$). Days 0 through 4 were not different from one another ($P>0.05$). Between grinds, differences were seen ($P<0.05$) in OF and CO. The 93/7 grind scored the most intense OF at 2.38. With regards to CO, the 73/27 grind had the greatest value of 5.55, but this was not different ($P>0.05$) from the 80/20 grind. No differences ($P>0.05$) in beef flavor were found among the three grinds. Throughout retail display, differences were also seen ($P<0.05$) in OF, CO, and BF. Days 5 and 6 had the most intense perceived OF but were not different ($P>0.05$) from one another. Day 0 had the least intense OF at 1.69, but was not different ($P>0.05$) than days 1 through

4. D 6 also had the most intense BF at 5.39, but was not different (P>0.05) than days 3, 4, or 5. Day 5 had the highest CO value at 5.52 and day 1 the least at 4.96. Days 0, 2, 3, 4, and 6 were not different (P>0.05) than either d 1 or 5. There was an interaction of grind and days of display on J and CL. The 73/27 grind had the highest J and CL values followed by the 80/20 and 93/7 grinds. Data indicates that factors beyond fat content play roles in ground beef color stability, lipid oxidation, and sensory characteristics.

TBARS values were correlated with the OF values for each panelist resulting in an r value of 0.29, indicating a low correlation. Another variation of data analysis was performed in which the average of all panelists' OF scores for each grind by day treatment was correlated to the TBARS for each treatment. This resulted in a higher correlation with an r value of 0.85. The TBARS and OF scores were also fitted to a regression and with all data together, the coefficient of determination was smaller (r^2=0.05) than compared to the average of all panelists at r^2=0.72. This shows TBARS can in some cases be used to predict consumer assessments of rancidity although there are numerous other factors that can influence the correlation.

Materials and Methods

Ground Beef Materials

Ground beef composed of three different fat percentages were shipped to the Lambert-Powell Meats Laboratory at Auburn University (Auburn, AL) for evaluation. The three grinds had similar packaging dates and were all coarsely ground prior to arrival. The three grinds 93/7, 80/20, and 73/27 were packaged into chubs weighing approximately 4.54 kg each.

Packaging

After arriving at Auburn University, the ground beef was stored overnight at 4 ± 2°C and processed into retail packaging the following day. Each grind was finely ground with an Auto Feed Mixer Grinder (Biro Manufacturing Company, Marblehead, OH) and weighed onto traditional 1S Styrofoam trays (Copaco, Columbus, GA) using a bench scale (A&D Weighing, San Jose, CA) in 0.45 kg loves. The packages were then overwrapped with oxygen-permeable polyvinyl chloride film (O2 transmission = 23,250 mL/m2/24 h. 72 gauge) using a floor model stretch film overwrapper (Heat Seal, LLC, Cleveland, OH). Approximately 6 to 10 kg of meat was passed through the grinder between each grind type to clear the remains of the previous grind type.

Retail Display

The foam trays were then immediately placed into the Lambert-Powell Meats Laboratory retail sales display at 4 ± 2°C. Packages were displayed for six days, and every day, starting on day 0, five packages of each grind were removed from display and frozen at -23 ± 2°C for later analysis.

Furthermore, one package of each grind was selected at random and scanned with a Hunter Miniscan XE Plus (Hunter Lab, Reston, VA) starting on day 0 and rescanned every 24 hours.

Processing

From the five packages pulled from display daily of each grind type, three were labeled for sensory evaluation, one was labeled for laboratory analysis, and the last package was labeled as extra and kept frozen for future analysis if needed. Prior to freezing, samples were removed from packaging and sealed in 20.3 x 38.1 cm 3 mil High Barrier Nylon/Ethylene Vinyl Alcohol/Polyethylene Vacuum pouches (Cryovac, Duncan, SC) at 98% vacuum with an Ultravac UV2100-C (Koch Equipment LLC., Kansas City, MO). Samples were transported to the laboratory in Upchurch Hall at Auburn University (Auburn, AL) where the sensory and laboratory samples were thawed for 24 hours at 4 ± 2C.

Once thawed, each laboratory sample was removed from its vacuum package and approximately 50 grams wereremoved and homogenized in a rocket blender (Bella Cucina, Atlanta, GA) and placed in a 50 mL plastic conical tube (VWR, Radnor, PA) for analysis in the laboratory in Upchurch Hall. After thawing the sensory samples, eight patties weighing approximately 119 grams were formed from each grind and day sample and labeled for later sensory evaluation.

Thiobarbituric Acid Reactive Substances

After all samples were processed, the thawed meat samples in the conical tubes were brought to the laboratory in Upchurch Hall and analysis began. A modified Buege and Aust (1978) method for Thiobarbituric Acid Reactive Substances (TBARS) was used to measure the levels of malonaldehyde in each kg of meat.

First a standard was created in order to create a regression equation for the prediction of malonaldehyde levels. A stock solution of 0.1 mL of 1, 1, 3, 3-tetraethoxypropane (TEP) and 100 mL deionized water was created first then diluted to 1:2.96 with additional deionized water. Next a 10% butylated hydrozyanisole (BHA) solution was made by dissolving 10 g BHA into 100 mL of 90% Ethanol. Seven tubes were labeled 0 through 6 and 4 mL of the BHA solution was then added to each tube. The TEP working solution was added to each tube next starting with 0 mL in tube 0, followed by 0.01 mL, 0.02 mL, 0.04 mL, 0.06 mL, 0.08 mL, and 0.1 mL to tubes 1 through 6, respectively. Deionized water added to each tube to reach a final total volume of 6 mL.

To determine TBARS on each meat sample, 5 grams of each sample was weighed and placed in an additional vortex tube containing 15 mL of deionized water. After removing 5 grams, the remainder of the original sample was frozen for later analysis. The vortex tube was sealed and vortexed for 20 seconds in order to homogenize the mixture. All tubes were centrifuged next for 10 minutes at 1850 g using a Beckman Coulter Allegra X-15 R (Beckman Coulter, Inc., Brea, CA) swinging bucket rotor.

Next 2 mL of the supernatant was removed from the centrifuged tube and placed into a test tube using a pipette. Then 4 mL of reagent consisting of 15% trichloroacetic acid (TCA) and 20 μM Thiobarbituric Acid was added along with 100 μL of a 10% BHA solution. This mixture was vortexed then heated in a 95°C water bath for 15 minutes. The test tubes were then cooled in a 20°C water bath for 10 minutes and centrifuged at 1850 g for 10 minutes.

In order to measure absorbance, 200 μL of the resulting supernatant was pipetted in triplicate into a 96 well microtiter plate (Greneir Bio-one, Frickenhausen, Germany) and read using a Multiskan EX (Thermo Fisher Scientific, Waltham, MA) absorbance reader at 540 nm.

Crude Fat Percentage – Proximate Analysis

Meat samples from the display day 0 of all three grinds were used for proximate analysis. Each sample was run in duplicate with the samples representing the meat that was frozen before any display or storage occurred. The previously frozen samples that were not used during TBARS were used for this procedure.

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

Nonabsorbent cotton was placed in the pan after drying to cover the sample. The pans were again weighed and the weights recorded to measure the amount of cotton added. A boiling flask was then filled two-thirds 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) following the AOAC guidelines for the machine.

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

Consumer Sensory Panel

An untrained consumer panel was used to evaluate the ground beef samples for juiciness, cohesiveness, beef flavor intensity, and off-flavor according to guidelines by AMSA (1995).

Sample Preparation

From each grind/day, eight-119 g patties were weighed out and formed into patties using a home kitchen style patty press. A copper constantan thermocouple wire attached to a hand-held Omega data logger HH309A 34 (Omega, Stamford, CT) temperature recorder was inserted into the geometric center of each patty using a large hypodermic needle.

Patties were placed onto Calphalon Removable Plate Grill (Caphalon, Perrysburg, OH) clamshell style contact grills that were preheated to 163°C. Internal temperatures of the patties were closely monitored using the thermocouples. The patties were removed from the grill after reaching an internal temperature of 70°C. The thermocouples were removed slowly while being monitored to ensure that the desired internal temperature was reached. Patties were then left to rest for 10 minutes before being portioned.

Each patty was portioned into 8 equal sections after resting. Two sections from various patties in the grind/day were then placed into a 2-ounce cup with a lid and labeled with a randomly selected three-digit code. All samples were placed in a warming oven until testing began.

Testing

Testing was conducted twice daily for three days. Morning sessions were held starting at 10 A.M. and afternoon sessions were held starting at 2 P.M. to allow for sufficient time between meals and testing. Panelists were seated in individual testing booths under red light. Panelists were then served all the samples in a random sequence and asked to evaluate each sample one at a time. For each sample, panelists were asked to chew a minimum of 10 times then expectorate each sample after completing evaluation. Panelists were provided with unsalted crackers and water and asked to

cleanse their palate between each sample. Panelists were not asked to sample more than 7 samples at any given session to reduce fatigue. Panelists were instructed to evaluate each sample for juiciness, cohesiveness, beef flavor intensity, and off-flavor by placing a mark on a 10 cm line scale. Panelists were also asked to write any specific off-flavors they may have tasted.

Statistical Analysis

Statistical analysis was performed using analysis of variance and mean separations calculated using the General Linear Model (GLM) procedure of SAS 9.2 (SAS Institute, Inc., Cary, NC). Grind and day of storage were main effects. Differences between mean values were evaluated using the Least Squares Means (LSMEANS) procedure. Pearson's rho correlations (PROC CORR) were performed on TBARS and off-flavor.

Results and Discussion

Proximate Analysis

Proximate Analysis was used to validate the crude fat percentages of each grind. Analyzed fat percentages for each grind are shown in Table 1. Fat percentages were found to be within an acceptable range of the values reported from the manufacturer. The 73/27 grind had 27.3 percent fat, while the 80/20 and 93/7 grinds had 20.2 and 7.5 percent fat, respectively.

Color

Table 2 lists the means of the colorimetric values L*, a*, b* for each grind. L* is a measure of the lightness of a sample with 0 being the darkest and 100 being the lightest, a* is a measure of green (-values) to red (+values), and b* is a measure of blue (-values) to yellow (+values). The greatest L* value was the 73/27 grind, followed by the 80/20 and 93/7 grinds (61.39, 57.37, and 49.94, respectively). It was hypothesized that greater fat content would equal greater L* values, as the increasing amount of fat would create a lighter color of the meat than smaller amounts of fat. The three grinds held true to this trend.

With regards to the a* means, the 93/7 grind had the greatest value at 18.84, followed by the 80/20 grind at 18.23, and finally the 73/27 grind at 14.98. The a* values followed the hypothesized trend that suggested a* values would decrease as fat content increases because of the lesser amount of lean red tissue present in the product. When evaluating b* averages, the 80/20 grind had the

greatest value at 20.81 while the 93/7 grind had the lowest value of 18.97. Overall, color values did appear to trend with the fat content in each grind as hypothesized.

Colorimetric values for the grinds over days of storage in retail display are shown in Table 3. Day 0 of the 73/27 grind had the greatest L* value at 63.65, while day 6 of the 93/7 grind had the lowest value at 46.56. Day 0 of the 93/7 grind had the greatest a* value at 27.80 while day 6 of the 73/27 grind had the lowest at 7.28. At 25.19, day 0 of the 80/20 grind had the greatest b* value while day 6 of the 93/7 grind had the lowest value of 15.90. Within each colorimetric value and grind over storage time, a decline can be seen which suggests color deteriorates over time as oxidation occurs causing a negative impact. This data agrees with Zakrys et al. (2008) as well as O'Grady et al. (1998) who both reported that as oxygen levels increased in packaging, lipid oxidation also increased while color stability decreased. Tigue (2013) also found similar results. This data was generated from taking duplicate measurements from a package of each grind on each day. Unfortunately, the values from each individual measurement were not recorded by hand because the colorimeter records and averages the values automatically. At the point of data analysis the data could not be recovered from the colorimeter, therefore there are no standard errors that could be computed with this data set for color.

Shelf life – Thiobarbituric Acid Reactive Substances

Thiobarbituric Acid Reactive Substances (TBARS) are an indication of lipid oxidation of a sample. The TBARS value should increase as the extent of lipid oxidation increases in a sample. The greatest TBARS value was detected in the 73/27 grind, followed by the 93/7 and 80/20 grinds (0.61, 0.58, and 0.53, respectively) with no differences ($P>0.05$) among the grinds as shown in Table 4. It

was hypothesized that as fat percentage increased, so would the extent of lipid oxidation, and therefore, the TBARS values. Multiple replicates of this procedure were performed to validate results and each time, the same results were shown. Tigue (2013) yielded similar results, which showed the data did not follow the hypothesized trend.

There was a days of display effect. Days 0, 1, 2, 3, and 4 TBARS values were not different ($P>0.05$), and days 5 and 6 had the greatest TBARS values and were not different ($P>0.05$) from one another (Table 5). The value increased from 0.35 to 1.10 mg/MDA/kg meat from day 4 to day 5. These results are similar to the data reported by Tigue (2013) who found the highest TBARS values in days 4 and 5 of retail display.

Sensory Evaluation

Means for sensory evaluation and cook loss of grinds are presented in Table 4. A representation of the score sheet can be found in Appendix B. On a 10 cm line scale, for juiciness, cohesiveness, and beef flavor, the higher the number, the more desirable the characteristic. For off flavor intensity, the higher the number, the more off flavor a panelist perceived.

There was a main effect of grind on off flavor and cohesiveness. The 93/7 grind was scored as the most intense in off-flavor at 2.38 followed by the 80/20 grind at 2.19 with no difference ($P>0.05$) between the two. The 73/27 grind scored the least intense off-flavor at 1.82. This data is contrary to Tigue (2013) who reported the opposite to be true, the greater the fat content of traditional grinds, the greater the off-flavor was also. In the case of the current study, the less fat in the meat, the more intense the off flavor score was reported. This could be that the majority of the panelists were accustomed to eating a hamburger with a greater fat percentage and their perception

of an off flavor was that of negative desirability of the lower fat ground beef. However, this conclusion cannot be supported with data collected in this particular research since no consumer preference or demographic data was collected. No differences ($P>0.05$) among the three grinds in beef flavor intensity were apparent to sensory panelists. This concurs with data presented by both Cross et al. (1980) and Tigue (2013) that suggested that fat in ground beef has no effect on beef flavor intensity.

Cohesiveness is defined as the ability of a product to maintain its bolus during chewing as opposed to crumbling. The 73/27 and 80/20 grinds had the greatest cohesiveness values with scores of 5.55 and 5.35, respectively, with no difference ($P>0.05$) between them. The 93/7 grind had the lowest score, indicating cohesiveness values tended to increase with fat percentage and therefore, fat percentage does play a role in cohesiveness of a product. While Tigue (2013) found similar results, this does not agree with the study conducted by Berry et al. (1984), which reported that as fat increased, cohesiveness decreased.

Retail display influenced some sensory characteristics (Table 5). Days 5 and 6 had the most intense perceived off-flavor and were not different ($P>0.05$) from each other with values of 2.78 and 2.76, respectively. Day 0 had the least intense off-flavor at 1.69 and was not different ($P>0.05$) than days 1 through 4. Therefore, from this data, it appears that ground beef can be stored in retail packaging in retail display for up to 4 days before consumers can perceive an increase in off-flavor.

Day 2 had the least intense perceived beef flavor at 4.81, but this was not different ($P>0.05$) than any of the other display days with the exception of day 6 which had the highest beef flavor value at 5.39. Therefore, there is a trend for beef flavor to increase over days of retail display. These findings do not agree with Tigue (2013) who found the opposite to be true in which beef flavor decreased over days of retail display.

Day 5 was the most cohesive at 5.52 and day 1 the least at 4.96. Days 0, 2, 3, 4, and 6 were not different (P>0.05) than either day 1 or 5. With the range being only 0.56 cm, there is a good chance that this data is not indicative of any actual perceived changes in cohesiveness. Tigue (2013) yielded similar results with an even smaller range of 0.24 cm.

There was an interaction of grind and days of display on juiciness (Figure 1). Day 2 of the 73/27 grind had the greatest juiciness value at 6.70 across all the grinds and days, and day 4 of the 93/7 grind had the lowest value at 2.79 (P>0.05). There did appear to be a trend in which the 73/27 grind had greater juiciness scores followed by the 80/20 and 93/7 grinds. This once again may indicate that juiciness is greater in products with higher fat contents. There was also an interaction of grind and days of display on cook loss (Figure 2). Cook loss percentage was greatest for day 3 of the 73/27 grind at 39.29 and lowest for day 6 of the 93/7 grind at 20.59 (P>0.05). There appeared to be the same trend here in which the 73/27 grind had the greatest cook loss percentage followed by the 80/20 and 93/7 grinds. This again indicates that as fat content increase, so does cook loss.

Objective Relationship to Consumer Perception

When the off-flavor data was fitted to a regression equation with the TBARS values for each panelist, the coefficient of determination was very low (Figure 3). With an r^2 value of 0.05, a low relationship was found between off-flavor and TBARS values indicating that TBARS is not an adequate predictor of consumer perception of rancidity in ground beef. Spearman's rho correlation was also conducted using SAS, which resulted in a low r value of 0.29. However, with the data set in entirety, there are a few inherent problems. The panelists did not necessarily come to the sensory booths when the samples were taken right off the grill, as the facilities available did not allow for

this. There were approximately 46 panelists for each grind by day treatment and there are only 6 sensory booths. So, some panelists had to wait, and the samples could have developed a warmed over flavor during the time that they were stored prior to being served. While all panelists performed their analysis within one hour post cooking and all samples were stored in a warming oven, there still could be some development of an off-flavor simply from the storage of cooked beef. The TBARS assay was not performed on each sample that every panelist ate, but instead performed in triplicate on each grind by days of display treatment. To perform a more accurate correlation a simultaneous TBARS assay would need to be conducted with every sample tested by a panelist, that is not however feasible in any lab because of the amount of work that would be necessary. Variability among panelists could also have contributed to this result since no panelists were trained to associate certain stimuli with a descriptive term and therefore all had non-standardized judgments (Greene et al., 1981). While the term "rancid" was often used to describe the samples, other descriptive terms such as "metallic", "grassy", "sour", "old", and "bitter" were used as well. It is clear that panelists were able to identify an off flavor in the samples, though with such a variability in descriptive terms, it is hard to determine whether the panelists were in fact detecting a rancid flavor or some other associated off-flavor instead.

To further investigate the results, another variation of data analysis was also performed. The average score from all panelists of the off-flavor of each grind by day treatment was fitted to a regression equation for TBARS for each grind by day treatment. That data is reported in Figure 4. There was a greater relationship (r^2 value of 0.72) of TBARS to sensory off-flavor when this method was used. In this analysis when the Spearman's rho correlation was conducted using SAS, there was a greater correlation of off-flavor to TBARS with an r=0.85. This data compares with data from Campo et al. (2006) who reported that TBARS were a good predictor of the perception of rancidity

with an r^2 value of 0.84 because the greater the TBARS values, the more rancid the meat was perceived to be in sensory evaluation. Greene et al. (1981) found similar results, although with a broader range of rancidity detection indicating more variation in the results compared to Campo et al. (2006).

Implications

While TBARS is an adequate method to measure oxidation in meat products, the method does not appear to be able to predict consumer assessments of rancidity. This laboratory method is variable between labs and it is often very difficult to repeat even within labs. This assay is a very difficult assay to assess rancidity because it is difficult to "stop" oxidation in time and to quickly generate results. It is also difficult to have repeatability of consumer perception results. In our case, the consumers were skeptical of the ground beef that they were consuming. While they were reassured numerous times that there was nothing wrong with the samples that they were served, it was often a perception in their minds, that was verbalized in many instances, that the samples were somehow tainted and they were looking for an off-flavor. This can be seen in the scatter plot of all data. The off flavor scores ranged from 0 to sometimes over 5 even in the day 0 samples. Further research should be conducted to compare other chemical measurements of rancidity to sensory evaluations in order to determine if there is a more accurate and efficient method to predict consumer perception other than TBARS.

REFERENCES

Addis, P.B. 1986. Occurrence of Lipid Oxidation Products in Foods. Food Chemistry and Toxicology, 24:1021-1030.

AMSA. 1995. Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurements of meat. American Meat Science Association, Chicago, IL.

Baron, C.P., H.J. Anderson. 2002. Myoglobin-Induced Lipid Oxidation: A review. Journal of Agricultural and Food Chemistry, 50:3887-3897.

Berry, B.W. 1992. Low Fat Level Effects on Sensory, Shear, Cooking, and Chemical Properties of Ground Beef Patties. Journal of Food Science, 57:537-542.

Berry, B.W. 1993. Fat Level and Freezing Temperature Affect Sensory, Shear, Cooking and Compositional Properties of Ground Beef Patties. Journal of Food Science, 58:34-37.

Berry, B.W. 1994. Fat Level, High temperature Cooking and Degree of Doneness Affect Sensory, Chemical and Physical Properties of Beef Patties. Journal of Food Science, 59:10-14.

Berry, B.W., K.F. Leddy. 1984. Effects of Fat Level and Cooking Method on Sensory and Textural Properties of Ground Beef Patties. Journal of Food Science, 49:870-875.

Brewer, M.S. 2012. Reducing the fat content in ground beef without sacrificing quality: a review. Meat Science, 91:385-395.

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

Campo, M.M., G.R. Nute, S.I. Hughes, M. Enser, J.D. Wood, R.I. Richardson. 2006. Flavour perception of oxidation in beef. Meat Science, 72:303-311.

Chaijan, M. 2008. Review: Lipid and myoglobin oxidations in muscle foods. Songklanakarin Journal of Science and Technology, 30:47-53.

Chambers, E. IV. 1994. Conducting Consumer Sensory Evaluation Studies. Proc. 47th Reciprocal Meat Conf. p. 27-29.

Civille, G.V. 1994. New Sensory Methods and Sensory Attributes for New Products. Proc. 47th Reciprocal Meat Conf. p. 17-26.

Crackel, R.L., J.I. Gray, A.M. Pearson, A.M. Booren, D.J. Buckley. 1988. Some Further Observations on the TBA Test as an Index of Lipid Oxidation in Meats. Food Chemistry, 28:187-196.

Cross. H.R., B.W. Berry, L.H. Wells. 1980. Effect of Fat Level and Source on the Chemical, Sensory and Cooking Properties of Ground Beef Patties. Journal of Food Science, 45: 791-793.

Fernández, J., J.A. Pérez-Alvarez, J.A. Fernández-Lopéz. 1997. Thiobarbituric acid test for monitoring lipid oxidation in meat. Food Chemistry, 59:345-353.

Gray, J.I., F.J. Monahan. 1992. Measurement of lipid oxidation in meat and meat products. Trends in Food Science & Technology, December 1992.

Gray, J.I., E.A. Gomaa, D.J. Buckley. 1996. Oxidative Quality and Shelf Life of Meats. Meat Science, 43:S111-S123.

Greene, B.E., T.H. Cumuze. 1981. Relationship Between TBA Numbers and Inexperienced Panelists' Assessments of Oxidized Flavor in Cooked Beef. Journal of Food Science, 47:52-58.

Houben, J.H., A. van Dijk, G. Eikelenboom, A.H. Hoving-Bolink. 2000. Effect of dietary vitamin E supplementation, fat level and packaging on color stability and lipid oxidation in minced beef. Meat Science, 55:331-336.

Kanner, J., I. Rosenthal. 1992. An Assessment of Lipid Oxidation in Foods,report. Pure and Applied Chemistry, 64:1959-1964.

Ladikos, D., V. Lougovois. 1990. Lipid Oxidation in Muscle Foods: A Review. Food Chemistry, 35:295-314.

Miller, M.F., M.K. Anderson, C.B. Ramsey, J.O. Reagan. 1993. Physical and Sensory Characteristics of Low Fat Ground Beef Patties. Journal of Food Science, 58:461-463.

Morrissey, P.A., P.J.A. Sheehy, K. Galvin, J.P. Kerry, D.J. Buckley. 1998. Lipid Stability in Meat and Meat Products. Meat Science, 49:73-86.

Munoz, A.M. 1998. Consumer Perceptions of Meat. Understanding These Results Through Descriptive Analysis. Meat Science. 49:S287-S295.

O'Grady, M.N., F.J. Monahan, J. Bailey, P. Allen, D.J. Buckley, M.G. Keane. 1998. Colour-stabilising effect of muscle vitamin E in minced beef stored in high oxygen packs. Meat Science, 50:73-80.

Raharjo, S., J.N. Sofos, G.R. Schmidt. 1992. Improved Speed, Specificity, and Limit of Determination of an Aqueous Acid-Extraction Thiobarbituric Acid-C18 Method for Measuring Lipid-Peroxidation in Beef. Journal of Agricultural and Food Chemistry, 40:2182-2185.

Rhee, K.S. 1978. Minimization of Further Lipid Peroxidation in Distillation 2-thiobarbituric acid test of Fish and Meat. Journal of Food Science, 43:1776-1778.

Tigue, D.A. 2013. An Analysis of Quality of Non-Traditional Beef Grind Material versus Traditional Beef Grind Material for Ground Beef Products. M.S. Thesis. Auburn University: U.S.A.

Troutt, E.S., M.C. Hunt, D.E. Johnson, J.R. Claus, C.L. Kastner, D.H. Kropf, S. Stroda. 1992. Chemical, Physical, and Sensory Characterization of Ground Beef containing 5 to 30 Percent Fat. Journal of Food Science, 57:25-29.

Ulu, H. 2004. Evaluation of three 2-thiobarbituric acid methods for the measurement of lipid oxidation in various meats and meat products. Meat Science, 67:683-687.

Zakrys, P.I., S.A. Hogan, M.G. O'Sullivan, P. Allen, J.P. Kerry. 2008. Effects of oxygen concentration on the sensory evaluation and quality indicators of beef muscle packed under modified atmosphere. Meat Science, 79:648-655.

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 ddH20)
    a. Dissolve 2.88 grams TBA in *warm* ddH20
    b. Add 150 grams TCA and add ddH20 until total volume equals 1 liter
2. BHA:
    a. Make 10% solution by dissolving BHA into 90% ethanol
3. TEP Standard: (1x10-3 M 1,1,3-Tetra-ethoxypropanein ddH20)
    a. Dilute 0.5 mL TEP with 499.5 mL ddH20 and dilute again to 1:2.96 ratio (TEP: ddH20)

B. Procedure

1. Slice 10 grams of fresh frozen meat and place in blender with 30 mL ddH20.
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 µL 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 ddH20 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

GROUND BEEF CONSUMER SENSORY EVALUATION FORM
ID #:_____ Date:_____ Time:_____

Juiciness

Extremely Juicy Extremely Dry

Cohesiveness

Extremely Cohesive Extremely Crumbly

Beef Flavor Intensity

Extremely Intense Extremely Bland

Off-flavor Intensity

Extremely Intense No Off-flavor

Comments:
Please record any identification of off-flavor or any other comments here.

Table 1. Proximate Analysis of fat percentage for grind.

Fat %	Grind
7.5	93/7
20.2	80/20
27.3	73/27

Table 2. Means of colorimetric values for grinds.

Grind	L*	a*	b*
73/27	61.39	14.98	20.44
80/20	57.37	18.23	20.81
93/7	49.94	18.84	18.97

Table 3. Means of colorimetric values for grinds over days of storage in retail display.

Grind		L*	a*	b*
73/27				
	0	63.65	23.29	24.97
	1	61.64	19.45	22.87
	2	59.97	17.43	21.55
	3	60.83	15.32	20.07
	4	61.21	11.98	18.68
	5	61.09	10.06	18.13
	6	61.64	7.28	17.00
80/20				
	0	60.13	25.05	25.19
	1	56.03	22.38	23.35
	2	57.48	18.27	20.65
	3	56.74	18.66	21.04
	4	58.43	16.22	19.18
	5	55.66	15.35	18.98
	6	57.03	11.91	17.42
93/7				
	0	54.24	27.80	23.10
	1	50.26	24.36	22.01
	2	50.76	21.49	20.25
	3	49.94	18.07	17.00
	4	49.97	15.46	16.99
	5	47.84	13.17	17.05
	6	46.56	10.87	15.90

Table 4. LSMEANS for sensory evaluation, TBARS, and cook loss and SEM for grinds.

Grind	Juiciness	Off-Flavor	Beef Flavor	Cohesiveness	TBARS	Cook Loss
73/27	5.97±0.12[a]	1.82±0.10[b]	5.10±0.12	5.55±0.12[a]	0.61±0.11	35.06±0.33[a]
80/20	4.88±0.13[b]	2.19±0.11[a]	5.00±0.13	5.35±0.13[a]	0.53±0.11	31.20±0.33[b]
93/7	3.57±0.13[c]	2.38±0.11[a]	5.01±0.13	4.95±0.13[b]	0.58±0.11	22.88±0.33[c]

[abc]Means within the common superscripts in the same column are not different (P>0.05).
A 10 cm line scale was used for the evaluations of juiciness, off-flavor, beef flavor, and cohesiveness (left = extremely dry, no off-flavor, extremely bland, extremely crumbly to right = extremely juicy, extreme intense off-flavor, extreme intense beef flavor, and extremely cohesive).

Table 5. LSMEANS for sensory evaluation, TBARS, and cook loss and SEM for grind over days of storage in retail display.

Day	Juiciness	Off-Flavor	Beef Flavor	Cohesiveness	TBARS	Cook Loss
0	4.73±0.20[a]	1.69±0.17[b]	4.88±0.20[ab]	5.21±0.20[ab]	0.31±0.16[b]	29.85±0.51[abc]
1	5.23±0.19[a]	1.90±0.16[b]	4.84±0.20[b]	4.96±0.19[b]	0.44±0.16[b]	28.47±0.51[c]
2	4.77±0.18[a]	1.92±0.16[b]	4.81±0.19[b]	5.34±0.18[ab]	0.44±0.16[b]	29.92±0.51[ab]
3	4.12±0.19[b]	1.93±0.17[b]	5.05±0.20[ab]	5.12±0.19[ab]	0.38±0.16[b]	30.72±0.51[a]
4	4.80±0.19[a]	1.91±0.16[b]	5.20±0.19[ab]	5.46±0.19[ab]	0.35±0.16[b]	30.51±0.51[a]
5	4.81±0.20[a]	2.78±0.17[a]	5.11±0.20[ab]	5.52±0.20[a]	1.10±0.16[a]	28.78±0.51[bc]
6	5.17±0.19[a]	2.76±0.17[a]	5.39±0.20[a]	5.39±0.20[ab]	1.00±0.16[a]	29.74±0.51[abc]

[abc]Means within the common superscripts in the same column are not different (P>0.05).
A 10 cm line scale was used for the evaluations of juiciness, off-flavor, beef flavor, and cohesiveness (left = extremely dry, no off-flavor, extremely bland, extremely crumbly to right = extremely juicy, extreme intense off-flavor, extreme intense beef flavor, and extremely cohesive).

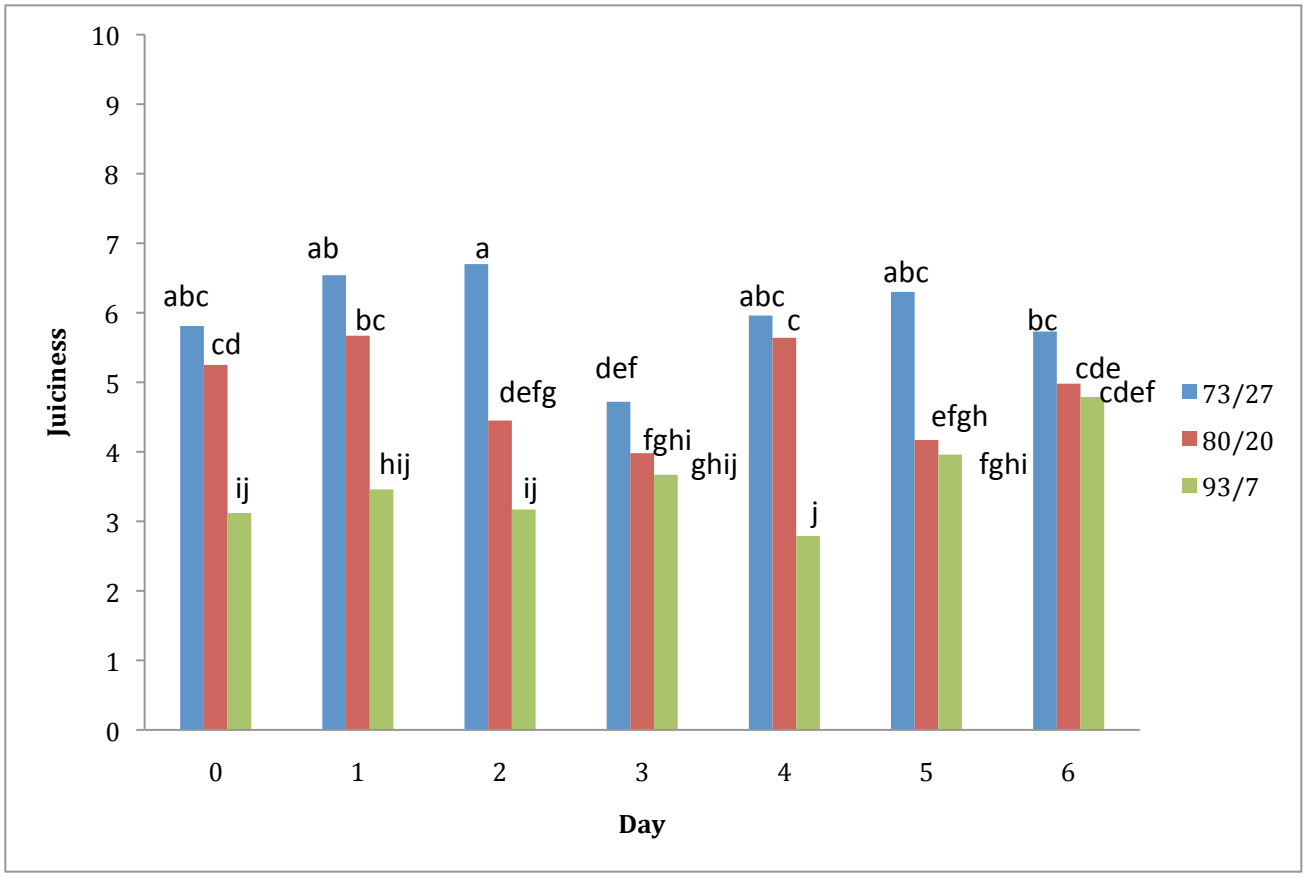

Figure 1. LSMEANS of interaction of grind and days of display on juiciness scores.
[abc]Means within the common superscripts are not different (P>0.05).

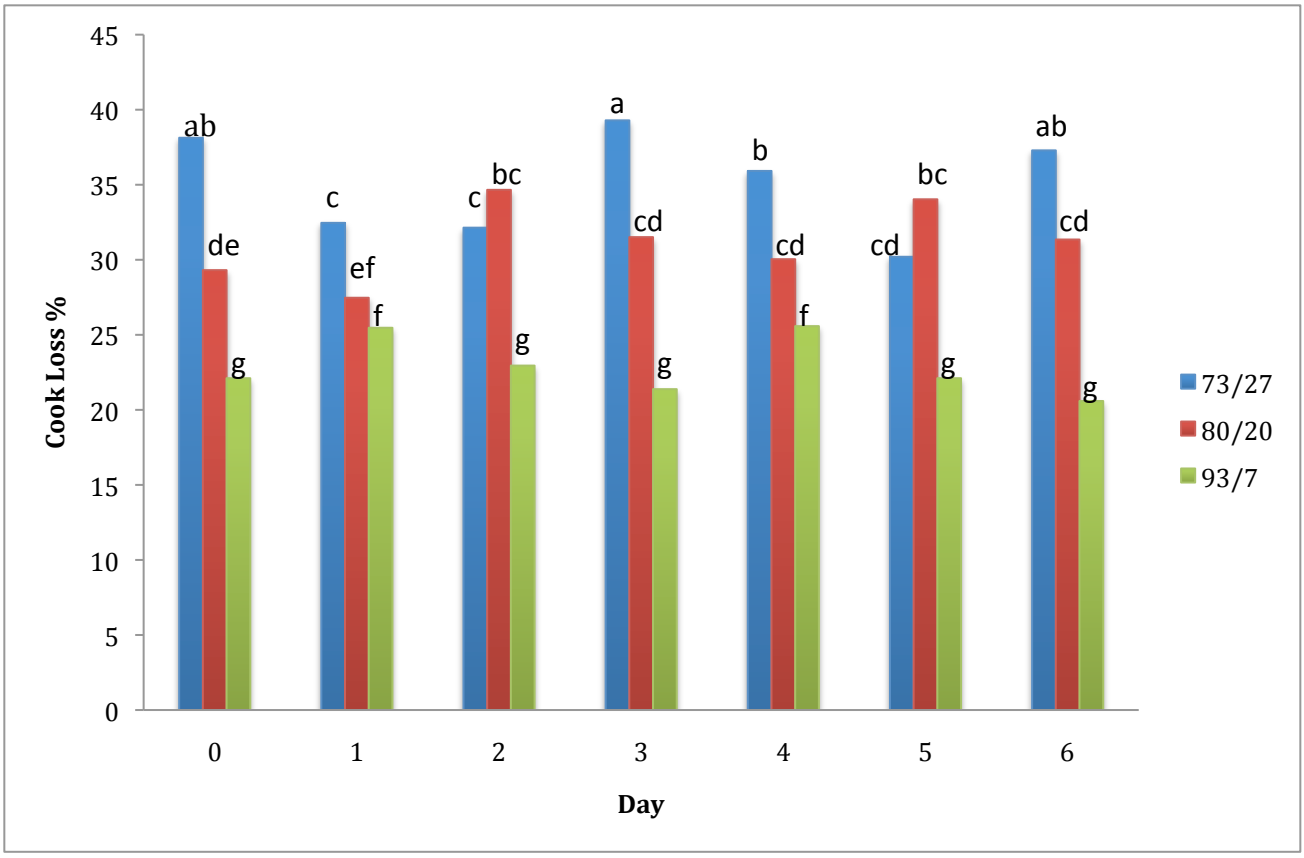

Figure 2. LSMEANS of interaction of grind and days of display on cook loss percentage.
[abc]Means within the common superscripts are not different (P>0.05).

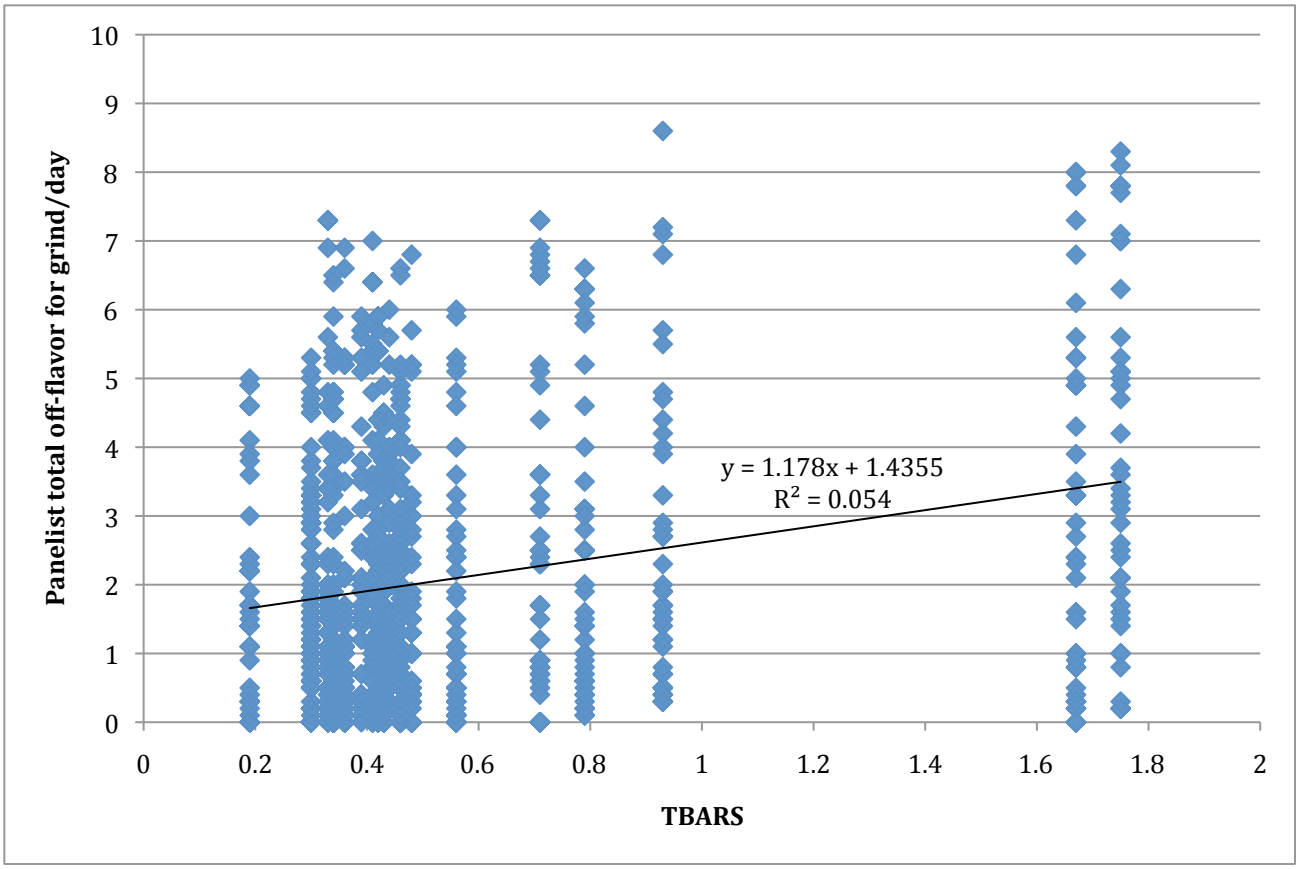

Figure 3. Regression of TBARS with total panelist off-flavor for each grind and day treatment.

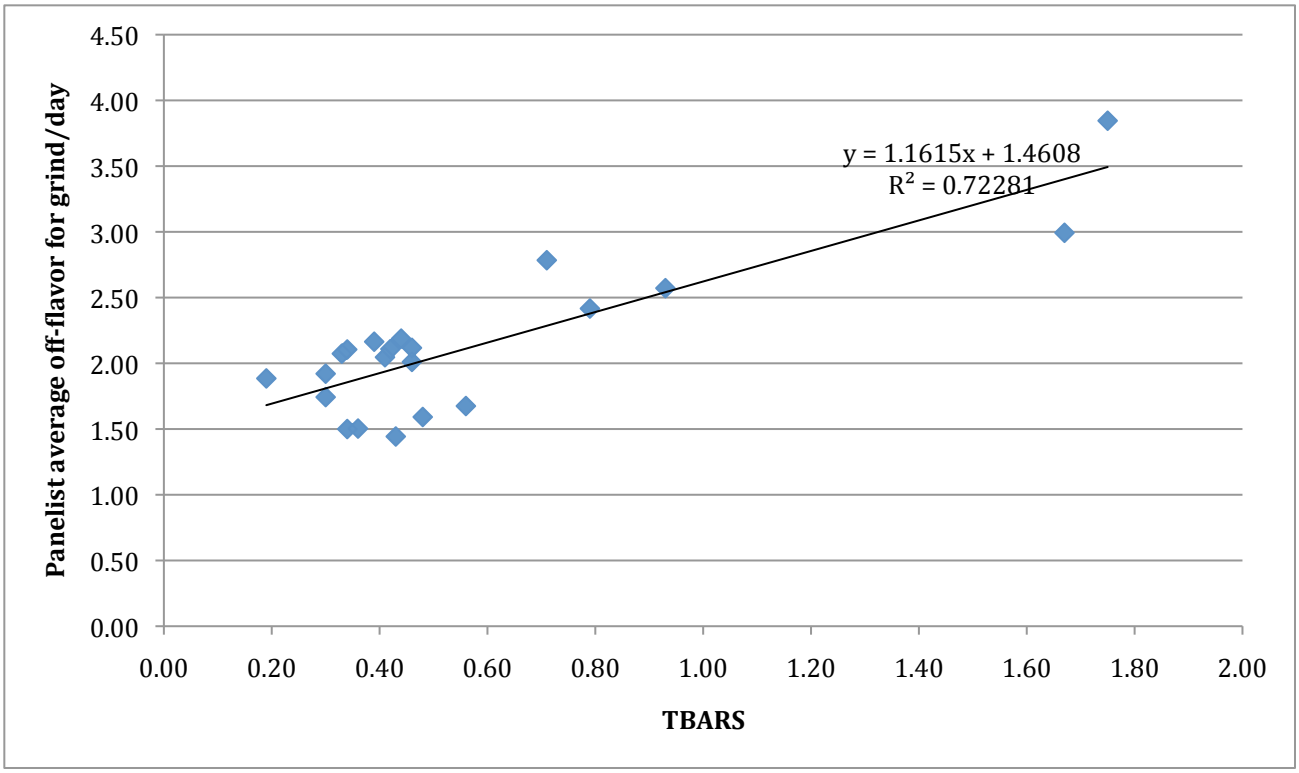

Figure 4. Regression of TBARS with average panelist off-flavor for each grind and day treatment.