RELATIONSHIP BETWEEN DESCRIPTIVE FLAVOR AND TEXTURE ATTRIBUTES AND CONSUMER ACCEPTANCE IN GROUND BEEF PATTIES

A Thesis

by

BLYTHE AUTUMN BEAVERS

Submitted to the Office of Graduate and Professional Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Chair of Committee,	Rhonda K. Miller
Co-Chair of Committee,	Christopher R. Kerth
Committee Member,	Leonardo Lombardini
Head of Department,	G Cliff Lamb

August 2017

Major Subject: Animal Science

ABSTRACT

Ground beef is one of the most widely consumed beef commodities; emerging trends in the industry are utilizing different formulations and grind treatments to affect flavor and texture attributes in ground beef patties. In this study, sixteen treatments were utilized, including four meat sources (chuck, regular, sirloin, round), two fat percentages (10 and 20%), and two grind treatments (6.4 mm grind and bowl chopped) to better understand trained descriptive beef flavor and texture attributes, volatile flavor aroma compounds, and consumer attitudes and preferences in ground beef. Meat sources arrived as subprimals and were trimmed of all external fat before formulating. Patties were formed with a patty maker using a 2.54 cm mold.

Meat source by fat interactions were significant for beef identity, brown, roasted, bloody/serumy, umami, salty, and particle size ($P < 0.05$). Bowl-chopped patties were higher in hardness, and springiness scores compared to 6.4 mm ground patties, while 6.4 mm ground patties were higher in umami and particle size ($P < 0.05$) compared to bowl-chopped patties. Meat source affected bitter, cardboard, fat-like, liver-like, sour, sour milk/sour dairy, hardness, and springiness flavor and texture attributes ($P < 0.05$).

Consumers (n = 314) from four cities across the United States liked ground beef patties ground to a 6.4 mm grind size better than bowl-chopped patties for all attributes ($P < 0.05$). Flavor liking and texture liking were impacted by meat source, while only texture liking was impacted by fat level ($P < 0.05$). A grind by fat interaction existed for overall cooked appearance liking, overall liking, and flavor liking, while a meat source by fat interaction only existed for flavor liking among consumers.

Volatile aromatic compounds were most impacted by grind treatment. 2,5-dimethyl-pyrazine, 3-ethyl-2,5-dimethyl-pyrazine, trimethyl-pyrazine, 2-ethyl-5-methyl-pyrazine, and 2-ethyl-6-methyl-pyrazine were all higher in ground beef patties ground to a 6.4 mm grind size ($P < 0.05$) compared to bowl chopped patties. A meat source by grind interaction existed only for hexanal, and a grind by fat interaction existed only for acetic acid and 2-ethyl-3,5-dimethyl-pyrazine. Flavor and consumer acceptability of ground beef can be improved by optimizing grind, lean source, and fat level.

DEDICATION

This thesis and graduate degree are dedicated to my incredible parents. Without their emotional, spiritual, and financial support these past two years wouldn't have been possible. Thanks for always believing in me, loving me, and encouraging me at every step along the way. 'Have I not commanded you? Be strong and courageous. Do not be afraid; do not be discourage, for the Lord your God will be with you wherever you go' Joshua 1:9.

ACKNOWLEDGEMENTS

I would like to first thank the Beef Checkoff, without their financial support this project would not have bee possible.

I would like to thank my advisor and co-chair, Dr. Rhonda Miller for seeing potential in a struggling undergraduate student and providing me with a chance to see what I was always capable of. This opportunity has shown me that my grades do not define me, but with a strong work ethic and willingness to learn that I am capable of anything. This opportunity has shaped me dramatically.

I would like to thank my co-chair Dr. Chris Kerth for his patience with my many questions, for his willingness to always walk me through anything I struggled with, and for always being real with me. I would also like to thank my committee member Dr. Leonardo Lombardini who agreed to stay as a member of my committee despite my project taking a complete 180. His commitment to staying on as a supportive member of my graduate committee and willingness to open himself up to a new topic have not gone unnoticed, and for this I am very grateful to him.

I would like to thank Kayley Wall, Ale Ochoa, Wade Hanson, Anderson Cabral, Hillary Martinez, Melissa Bamsey, Alex Maxwell, Hannah Laird, Fergie, Shannon, Cassie, Emily, Andrew, Paige, Marley, and Greg. Without this great team, this project would not have been possible. A special shout out goes to Hillary, Anderson, Alex, and Hannah for traveling across the United States with me and for all of the memories we made chasing waterfalls and peeling off our blackheads with facemasks.

I would like to thank my family and friends who have stuck by me through thick and thin these past two years. My support network is what gave me the confidence to pursue my dreams. Lastly, I would like to thank my best friend and my biggest supporter for always loving me and believing in me, even when I didn't believe in myself. Austin, I can't wait for our forever.

CONTRIBUTORS AND FUNDING SOURCES

Contributors

This work was supervised by a thesis committee consisting of Dr. Rhonda Miller [advisor – co-chair] and Dr. Chris Kerth [co-chair] of the Department of Animal Science and Dr. Leonardo Lombardini of the Department of Horticulture.

Collaborators to this project include Dr. Koushik Adhikari of the University of Georgia Griffin, and Dr. Edgar Chambers of Kansas State University.

The data analyzed for Chapter III was provided by Professor Dr. Rhonda Miller.

Funding Sources

Graduate research assistantship was supported through funding provided by the Beef Checkoff. Research was partially funded by The Beef Checkoff under grant number 40787780020.

NOMENCLATURE

CLT	Central Location Test
cm	centimeter
GC/MS/O	chromatograph/mass spectrophotometer system with olfactory
h	hour/s
HUT	Home Use Test
IMPS	Institutional Meat Purchase Specifications
mm	Millimeter
SPME	Solid-Phase Micro-Extraction
USDA	United States Department of Agriculture
WBSF	Warner-Bratzler Shear Force

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

INTRODUCTION

Ground beef comprises between 50 and 60% of the beef consumed in the United States and is manufactured from beef trimmings from either commodity, grain-fed beef or lean trimmings from older, mature cows and bulls. Source of raw material is used to affect final lipid content and the subsequent flavor of the final product. Additionally, ground beef is commonly consumed at home and in the foodservice industry and cooking and preparation varies. Emerging restaurant concepts that focus on ground beef (Five Guys, Smash Burger, etc.) vary in ground beef formulation, grinding procedures and cooking methods, which impacts beef flavor through how heat transfers through ground beef. Beef flavor is comprised principally from aromas generated either by thermal lipid degradation or by Maillard browning reactions. Flavor is incredibly important to the long-term success of beef products and serves as the "guard rails" to beef quality. Sitz and others (2005) found that flavor was the most important factor affecting consumers' buying habits and preferences when tenderness was held constant. Additionally, Huffman et al. (1996) reported that flavor had the strongest relationship (r = 0.67) to overall steak palatability ratings when consumers prepared steaks at home. Recent research conducted by our team has shown that beef flavor is more closely related to overall consumer liking than beef tenderness and juiciness. While it is well understood that as marbling increases in steaks, flavor and overall acceptability increases (Berry and Leddy, 1990; Kerth and Miller, 2015), fat content in ground beef has also been shown to affect flavor (Blackmon et al., 2015).

It is apparent that multiple factors impact flavor in ground beef. Phase I research has been conducted to understand the effects of final grind (chopped, 9.5 mm and 6.4 mm final grind), forming (hand and machine), fat/source content (20% and 5% lipid from commodity and mature beef), patty thickness (6.4 mm and 2.54 cm), cooking (steam and dry heat), and holding (steam table holding for 0, 1 and 3 h) on beef flavor as measured by trained descriptive attribute panels using the Beef Lexicon (Adhikari et al., 2011). Two sensory panels, one at Kansas State University and one at Texas A&M University, were used to test flavor differences due to the aforementioned treatments. Phase II of this research used the data from the trained panel in Phase I to determine ground beef treatments that have the greatest impact on beef flavor. Sixteen treatments were used in Phase II. These 16 treatments were used in a consumer central location test to understand consumer perceptions of ground beef and to provide an understanding of consumer perception of ground beef in foodservice. Trained sensory evaluation and volatile chemical aromatics were determined on ground beef from these same 16 treatments to understand the relationships between consumer, trained sensory and chemical flavor attributes.

CHAPTER II

LITERATURE REVIEW

Biological Response to Flavor

Flavor is determined through a complex combination of detection using gustatory sensory cells, trigeminal nerves, and the olfactory bulb (Kerth and Miller, 2015). The tongue contains numerous taste buds, each possessing taste receptor cells (or gustatory cells), which can detect bitter, sweet, salty, sour, and umami to varying levels of intensity (Imafidon et al., 1994; Kerth and Miller, 2015; Mattes, 2009). While bitter, sweet, sour, and salty are generally accepted basic tastes, the addition of umami to the basic tastes has been controversial as many consider it to be extremely mild even at high concentrations (Lindemann et al., 2002). It has been well documented that adenylyl cyclase-generated cAMP and PLCBeta-2-generated IP_3 are responsible for tasting sweetness and epithelial-type sodium channel transduction mechanisms are responsible for tasting salty (Gilbertson et al., 2000; Kerth and Miller, 2015; Lindemann et al., 2002). It is further known that proton concentration is responsible for tasting sour, gustducin from chemosensory cell organs in the gut and most taste receptor cells on the tongue are responsible for tasting bitter, and L-glutamate is responsible for tasting umami (Gilbertson et al., 2000; Kerth and Miller, 2015; Lindemann et al., 2002).

The overall perception of flavor is believed to be derived from a combination of taste and odor (Delwiche, 2004). The presence of simply an odor may be enough to trigger a flavor response, but this phenomenon is not true in the presence of just flavor for an odor response (Delwiche, 2004). Furthermore, the trigeminal senses are responsible for the ability to feel coolness, astringency, warming and other sensations that contribute to overall sensory evaluation of a product (Kerth and Miller, 2015).

Aroma compounds are detected through the olfactory bulb, and the determination of compounds and reactions responsible for "meaty" flavors and aromas are critical to gain a comprehensive understanding of the complexity of beef flavor (McLeod, 1994). Both inherent compounds and interaction products in meat contribute to the overall impression of flavor and aroma. Interactions between non-volatile precursors (including amino acids, peptides, reducing sugars, vitamins, nucleotides and unsaturated fatty acids) produce volatile products that develop into various meat flavors and aromas (Melton, 1999). Water-soluble precursors include free sugars, sugar phosphates, nucleotide-bounded sugars, free amino acids, peptides, and nucleotides (Mottram, 1998). Indications have been made that water-insoluble components of meat possess a roast beef type flavor, while water-soluble portions possess an intense flavor that is not characteristic of meat (Batzer et al., 1960). These combinations of odor, taste, and sensations are all important in the ultimate experience that occurs when a product is consumed.

Beef Flavor

While the biological response to flavor describes the ability to taste, understanding the specific factors and reactions that contribute to these responses will help to better understand the overall complexity of flavor. Sensory evaluation is one way to attempt to understand how products differ in flavor and aroma. Different sensory tests, such as discriminative, descriptive, and consumer testing can be utilized depending on the desired outcome. Discriminative testing is used to determine what overall differences and/or specific attributes (such as crunchy, sweet, etc.), if any, exist between samples (Meilgaard et al., 2007). Descriptive attribute sensory testing utilizes many quantitative tools such as the Spectrum Scale developed by Gail Civille, that uses a 0 to 15 intensity scale (Meilgaard et al., 2007). Individual attributes can be defined and references developed for consistent anchoring along the scale. These attributes can be further segmented into a 'lexicon' for a specific product, which is a list of terms used as a training tool so that panels across the world can identify the attributes and evaluate products similarly (Meilgaard et al., 2007).

In 2011, the current and most comprehensive and functional beef flavor lexicon was produced by collaborators at Kansas State University and Texas A&M University (Adhikari et al., 2011). During the development of the lexicon, 38 terms were observed across samples, of which 12 were present in almost every sample and are considered major beef attributes. The major beef attributes include beef identity, brown/roasted, bloody/serumy, metallic, fat-like, overall sweet, overall sour, and the five basic tastes (Adhikari et al., 2011). These attributes are used to identify flavor differences in beef as a quantifiable measurement.

Many antemortem and postmortem factors affect the development of meat flavor (Imafidon et al., 1994). These factors include animal age, sex, fat level or composition; carcass handling; cook method and types; levels of volatile and non-volatile compounds; and storage conditions (Imafidon et al., 1994; Kerth and Miller, 2015; Melton, 1999). A more mild, metallic, and serumy-type aroma is found in raw meat, and ribonucleotides have been shown to play an important role in the flavor of meat due to their ability to maximize meaty flavors and suppress some negative attributes, such as sulfury and bitter (Imafidon et al., 1994; Kosowska et al., 2017). Raw meat possesses a plethora of both volatile and non-volatile compounds responsible for the development of meat flavor (Kosowska et al., 2017). It is also important to note that the development of 'meaty' or 'beefy' flavors, as well as an increase in the production of volatile compounds, both require heating of the sample (Delwiche, 2004; Kerth and Miller, 2015).

These sensory attributes allow for the identification of both positive and negative flavor contributors. One unique flavor present in beef, which can be positive or negative depending on personal preference, is 'grassy'. Traditional beef is derived from grain-finished animals but there is consumer demand for cattle finished on forage. Some attributes generally perceived as negative are present in these forage-finished animals including grassy/gamey off-flavors, darker colored lean, and yellowish fat which lowers desirability (Cox et al., 2006). Some off flavors are inherent, deriving from either the lean source or the fat source, and other flavors are produced from a series of reactions that occur throughout the cooking process. Understanding the fundamental flavors and where they are derived from can provide a comprehensive understanding when determining why differences exist across samples and treatments.

Sensory Differences Across Muscles

Ground beef patties made with lean collected from brisket, plate, and flank subprimals have been shown to each possess unique lipid and Maillard-derived volatiles (Blackmon et al., 2015; Kerth et al., 2015). These volatiles indicate that the lean from each of these muscles possesses differences, and not just preparation plays a role in flavor or aroma changes. A study by Seggern et al. (2005) profiled 39 muscles from the beef chuck and round on physical and chemical properties in order to develop a database to be used in the production of value-added products. Variations were identified in all traits across muscles, with quality grade having the biggest effect, which validates the inherent variation across muscles within a carcass (Seggern et al., 2005).

A study by Jenschke et al. (2008) focused on identifying differences in tenderness within two major muscles of the knuckle, if the knuckle was removed intact before the round was cut. Warner-Bratzler shear force (WBSF) and muscle fiber tenderness descriptive sensory analysis on the *rectus femoris* and v*astus lateralis* showed that while the distal regions of these muscles had statistically higher WBSF and sensory tenderness than the proximal regions, the distal regions were still considered tender (Jenschke, 2008). This shows that these cuts could be further fabricated as sirloin instead of as beef round sirloin tip center roast as the differences are small, which would result in an overall increase in carcass value (Jenschke, 2008). While this study did not directly focus on the impact of flavor, it highlighted the affects of tenderness across muscles, which could ultimately impact the eating experience for a consumer.

In a study by Cleveland et al. (2014), combinations of chuck rolls and knuckle subprimals in Premium Choice and Select quality grades were formulated into ground beef patties at different fat percentages. Sensory analysis was performed on the samples and while very few differences were detected across quality grades, patties produced with Premium Choice subprimals with a high percentage of knuckles resulted in lower hardness and gumminess values as measured instrumentally.

While muscle variations in flavor and aroma have been shown to help differentiate them, sometimes the presence of off-flavors further contributes to variation. Hodgen et al. (2007) investigated the ability to identify volatile compounds present in different concentrations between normal beef round and chuck muscle samples, and round and chuck muscle beef samples known to possess a liver-like off-flavor. Liver-like samples possessed an additional four volatile peaks when compared to normal samples, and the majority of compounds with a higher prevalence in liver-like samples are known to be associated with lipid oxidation (Hodgen et al., 2007). Overall, it seems that a combination of compounds play a role in the presence of off-flavors as differences were detected between liver-like and normal beef samples from the chuck and round (Hodgen et al., 2007).

A study by Meisinger et al. (2006) further examined the flavor differences between the beef chuck and round, looking closely at the prevalence of off-flavors and liver-like flavors. The *infraspinatus* (from the chuck) had a lower prevalence of off-flavors and scored high across tender and juicy ratings, while the v*astus lateralis* (from the round) had the highest prevalence of off-flavors and scored lowest across tenderness and juiciness ratings (James, 2008; Meisinger et al., 2006). Additionally, if one muscle from a carcass possessed off-flavors, most other muscles from the carcass also possessed off-flavors. This suggests that liver-like, if present in one muscle, likely affects the entire carcass (Meisinger et al., 2006). Data from this study also indicated that liver-like tends to be more overwhelming than other off-flavors and has the capability to subdue more subtle off-flavors (Meisinger et al., 2006). A study by James and Calkins (2008) found that when comparing muscle flavor with consumers from the round and chuck, the t*eres major* typically resulted in an unacceptable score in off-flavor intensity.

Jenschke et al. (2008) noted that off-flavors varied between feedlots, and conducted a study that focused on the prevalence of liver-like off-flavors in cooked beef from five different feedlots. This is consistent with the suggestions from Meisinger et al. (2006) that pre-slaughter factors affected the presence of off-flavors in the entire carcass. Apart from just off-flavor prevalence, it is clear that positive flavor as well as tenderness and juiciness also vary across muscles.

Maillard Reaction and Lipid Thermal Degradation

Meat flavor is produced from thermal exposure during the cooking process (Kosowska et al., 2017; Mottram, 1998). Non-volatile components of lean and fatty tissue react during heating and produce a variety of flavors and aromas that play a role in the characteristic flavors of meat (Mottram, 1998). There are two main reactions that are largely responsible for the 'meat' flavor and aroma produced during the cooking process: the Maillard reaction and lipid thermal degradation (Kosowska et al., 2017; Mottram, 1998). Aliphatic hydrocarbons, aldehydes, ketones, alcohols, carboxylic acids, ketones, and esters are examples of volatile compounds produced during cooking as a result of lipid thermal degradation (Elmore et al., 1999; Mottram, 1998), while volatiles formed during the Maillard reaction include heterocyclic nitrogen and sulfur compounds (Elmore et al., 1999).

The Maillard reaction occurs from the interaction of amino compounds and reducing sugars, and is the result of high-temperature, dry-heat cookery in beef (Kerth and Miller, 2015; Mottram, 1998). In fact, most heterocyclic compounds reported for cooked meats are a result of high-temperature, dry-heat cookery, including roasted, grilled, or fried meats (Melton, 1999). Main volatiles produced from cooked beef include octanal, nonanal, methanethiol, and methional (Kosowska et al., 2017). The breakdown of proteins when surrounded by reducing sugars present in beef results in the main Maillard reaction products (Kerth and Miller, 2015).

The Maillard reaction is a complex series of main and intermediate reactions resulting in different variations throughout the cooking process (Hodge, 1953). The reaction begins with a sugar and an amino acid coming together and producing either an Amadori rearrangement product or a Heyns rearrangement product (Jousse et al., 2002; MacLeod, 1994; Mottram, 2007). The initial sugar may also immediately degrade without ever reacting with the amino acid; this would happen if a product is cooked at a high temperature resulting in a caramelization reaction (Jousse et al., 2002). The second stage of the Maillard reaction focuses on the Amadori and Heyns rearrangement products. These products can either cyclize, which would produce pyrrole or pyridine compounds, or the products might cleave and create rearranged sugars that possess the initial sugar chain and return the initial amino acid (Jousse et al., 2002; Mottram, 2007). The third stage of the reaction involves the rearranged sugars cyclizing into furan or furfural compounds (Jousse et al., 2002). Alternatively, the sugars may break apart further into carbonyls, which may later recombine to produce the furan or furfural compounds (Jousse et al., 2002; Mottam, 2007). The last stage of the Maillard reaction involves further reactions from the carbonyl compounds (Jousse et al., 2002). If these compounds do not recombine to produce furans, they may react with the amine group from the initial amino acid and undergo Strecker degradation (Jousse et al., 2002; Mottram, 1998). Strecker degradation produces two main intermediates: Strecker aldehydes and pyrazines (Jousse et al., 2002). All of these final compound groups formed (pyrroles, furans, carbonyls, Strecker aldehydes, and pyrazines) ultimately contribute to the development of melanoidins and flavor (Jousse et al., 2002; Kerth and Miller, 2015; Mottram, 2007).

Lipid thermal degradation, as described by Kerth and Miller (2015), refers to the breakdown of neutral and polar lipids due to the shift in energy stabilization, as a result of applying low and slow heat. When the glycerol backbone is broken apart from the fatty acid branches, aldehydes, ketones, and others are produced and result in the simplest products of lipid thermal degradation (Kerth and Miller, 2015). More than half of the volatiles produced in cooked meat are lipid volatiles (Brewer, 2012). It is believed that lipid degradation products may prevent the development of certain flavor compounds produced by the Maillard reaction (MacLeod, 1994).

It is possible for lipid and Maillard compounds to interact, but these interactions result in mild volatiles compared to the intensity of each primary reaction (Kerth and Miller, 2015). When lipids oxidize, the by-products can enter the Maillard reaction and produce volatiles that could not have been produced by a lean meat product (Melton, 1999). It is largely the phospholipids, rather than the triacylglycerols, that contribute fatty acids capable of reacting with the Maillard reaction (Melton, 1999). These interactions of Maillard and lipid degradation products have been confirmed and provide a mechanism, which enables both interaction products to be controlled by the cooking process (Elmore et al., 1999).

Fatty Acids

The lipid portion of meat is known to be responsible for the production of various flavor compounds, including species-specific volatile components that further contribute to the development of flavor upon heating of lipid-soluble compounds

(Hornstein et al., 1960; Kosowska et al., 2017; Melton, 1999; Mottram, 1998). Over time, oxidation reactions can lead to the production of negative or off-flavors, but during the cooking process this reaction is expedited (Ladikos and Lougovois, 1990; Mottram, 1998). The amount of unsaturated fatty acids present in lipids doesn't directly correlate to quantity of volatiles produced during oxidation (Melton, 1999). This pathway typically has a negative outcome, but when expedited through the cooking processes results in truly desirable and unique sensory attributes.

Lipid content also plays a critical role in how overall flavor is perceived in a product. An article by Delwiche (2004) discussed the concept of how changing the lipid content in a product alters the texture and slows down the diffusion of compounds (flavor release) of both fat-soluble and water-soluble components, which could influence how people perceive the attributes of the product. Delwiche (2004) explained further that while the fat itself was not specifically interacting with taste and smell compounds, the lipid content present influenced how compounds within the product interacted with each other and subsequently altered the perceived flavor (Delwiche, 2004).

Legako et al. (2015) examined whether USDA quality grades and cooking would influence fatty acid composition and new beef flavor precursors. The most prominent fatty acids in beef are oleic acid (18:1), myristoleic acid (14:1), and palmitic acid (16:0; Legako et al., 2015), with oleic making up 35% of fatty acid composition in beef (Elmore et al., 1999). Increased total fatty acid concentration has been correlated with increased overall fat content (Legako et al., 2015).

Monounsaturated fatty acids and saturated fatty acids were more prevalent due to high-concentrate feeding of beef (Legako et al., 2015). Legako et al. (2015) showed cooking strongly affected changes in monounsaturated fatty acids, and resulted in thermal oxidation of polyunsaturated fatty acids (Legako, 2015). Jenschke et al. (2007) attempted to identify which fatty acids played a role in the development of off-flavors present in beef. This research identified unsaturated fatty acids (20:3) as well as saturated fatty acids (15:0) that played important roles in the presence of liver-like off-flavors (Jenschke et al., 2007).

Although they are typically associated with adverse flavors, humans have been shown to be sensitive to free fatty acids at various chain lengths and saturation types (Mattes, 2009). Even as an indicator flavor that something is no longer fresh, this finding shows that these fatty acids do in fact possess an inherent ‘flavor’ (Mattes, 2009). In a study by Blackmon et al. (2015), the effects of various fat levels and lean sources on overall fatty acid and flavor contributions were observed. Patties made with brisket and plate lean scored higher for fat-like, and as fat level was increased within patties both fat-like and green hay-like increased as well (Blackmon et al., 2015). Linoleic acid was shown to reduce intensity of beef identity, myristoleic acid decreased the intensity of salty, and stearic acid increased the intensity of umami, overall sweet, sweet, and heated oil (Blackmon et al., 2015). Patties made with various lean sources resulted in unique lipid- and Maillard-derived volatiles, but patties with higher fat percentages were shown to potentially interfere with the development of lipid- and Maillard-derived volatiles (Blackmon et al., 2015). A study by Kerth et al. (2015) found that stearic acid (18:0) was lower in brisket patties compared to patties made with chuck and flank lean. Percentage of total saturated fatty acids was found to be higher for patties which utilized flank fat compared to those made from round fat (Kerth et al., 2015). It is notable to identify that understanding the impact of oleic acid is important due to its tendency to positively impact beef flavor (Kerth et al., 2015).

Lipid Contributions to Flavor

Ground beef is one of the most widely consumed beef products in the United States, and fat content plays a critical role in overall acceptability (Cleveland et al., 2014). Many researchers believe that "fatty" should be considered as the sixth basic taste due to tactile, olfactory, and potentially taste properties it contributes to food (Mattes, 2009). It has been noted that while ground beef products can range in fat content from 30% to 5% or less, overall palatability decreases as the fat percentage falls below 10% (Cleveland et al., 2014).

While ground beef patties with higher fat sometimes experience more cook loss, it is noted that when fat percentage decreases from 20% to 4% that initial tenderness decreases, but when cooked to medium, the final tenderness of each are similar (Berry, 1984, 1994). Patties with 20% fat also scored higher in beef flavor intensity despite the degree of doneness it was cooked to when compared to the 4% fat patty (Berry, 1994). Lean ground beef has low levels of palatability due to the lack of fat in the formula (Brewer, 2012; Miller et al., 1993). Miller et al. (1993) explored ways to enhance the palatability of lean ground beef through the addition of water and phosphates. The addition of water and phosphate to lean ground beef aided in moisture retention during cooking; high fat patties and water added patties revealed no difference across juiciness, cohesiveness, texture, flavor, overall palatability, and incidence of off flavor when evaluated by the sensory panel (Miller et al., 1993). Based on these initial results, lean ground beef patties with less than 10% fat with water or phosphates added could potentially rate similarly to higher-fat ground beef formulations in overall palatability (Miller et al., 1993). Despite these findings, the current USDA regulations do not allow for added water or phosphates in either ground beef or hamburger meat (USDA, 2016). Currently, to be marketed as ground beef or hamburger meat there can be no added ingredients.

When flavors of ground beef patties formulated to various fat percentages were evaluated, low-fat patties tended to have more metallic and general off-flavors when compared to higher-fat patties (Berry, 1992). Higher percentages of lean in ground beef contribute to the presence of off-flavors (Berry, 1992). It was also determined that 5% or less fat in ground beef might not be enough to mask the presence of off-flavors, and patties less than 8% show reduced scores for consumer acceptability (Berry, 1992). Although consumers say they want a lower fat product, in blind tastings the scores reveal that these products have poor flavor and lower overall acceptability.

Juiciness of patties appear correlated to fat percentage, as seen in a study by Cross et al. (1980) in which patties containing 28% fat scored significantly higher in juiciness than patties containing 16% and 20% fat. Another study comparing various fat levels found moistness, firmness, and cohesiveness of mass were all correlated to fat content (Troutt et al., 1992). When low-percent-fat patties were compared to high-fat patties, it was found that lower-fat patties had darker colors, less cook loss, denser/firmer patty, longer cook time, and less juiciness compared to the higher-fat patties (Troutt et al., 1992). The visual appearance, flavor, and texture of low-fat patties as compared to higher-fat patties do not possess the same consumer acceptability. Consumers appear to like everything about higher-fat patties except for the fat content itself, but removing the fat decreases acceptability overall.

Influences of Texture

In a review article by Brewer (2012), texture was defined as the combination of three kinesthetic sensory characteristics, including those perceived prior to mastication, during mastication, and after mastication. Grinding meat offers the unique opportunity to disguise differences in tenderness, but caution should still be taken as muscle source and overall quality still play a role in the sensory evaluation of ground beef products (Cleveland et al., 2014). In a study by Cross et al. (1978), the ability of mechanical devices to evaluate cooked ground beef patties effectively when compared to human evaluations was examined. For this study, patties were cooked and cut into four equal sections for mechanical evaluation (Cross et al., 1978). Single blade shear area under the curve and circular blade shear scores were both highly correlated with tenderness and connective tissue amounts in sensory scores and therefore acceptable means of evaluating ground beef texture attributes that correlate to sensory panel data (Cross et al., 1978).

In a review article by Brewer (2012), it was determined that a possible way to increase palatability in lower-fat patties, when compared to higher-fat patties, was to grind the product through a 4.76 mm plate rather than a 3.18 mm plate. The finer grind and the higher amount of lean present resulted in more protein extraction and subsequently, a more tightly bound patty which negatively affected texture. A study by Randall and Larmond (1977) looked at the effect of grinding versus flake-cutting on hamburger patties. Some benefits of flake-cutting included potential texture improvement, better binding abilities, decreased cook loss, and better breakdown of negative texture attributes (Randall and Larmond, 1977). When these two methods were compared, panelists found ground meat had a finer texture, increased tenderness, were less rubbery, were juicier, and greasier when compared to the flake-cut patties (Randall and Larmond, 1977). While flake-cut patties had desirable functional qualities, the textural effect resulted in tough, firm, and dry descriptions from the panelists (Randall and Larmond, 1977). Texture and cooking method of ground beef products can drastically affect its overall acceptability.

Berry (1984) found that connective tissue was easier to identify in patties at 14% fat compared to patties containing 19% and 24% fat. Higher fat content can potentially mask textural variability. Patties with increased fat percentages had lower cohesiveness, increased softness, and decreased patty density; this phenomenon may be because fat replaces muscle, the texture becomes softer (Berry, 1984). Utilizing fat content to improve texture is a positive way to ensure that minor lean inconsistencies don't interfere with the overall acceptability and promotes positive 'beefy' flavors.

The Cooking Process

The cooking process contributes to the development of flavor through the Maillard reaction and lipid degradation, but it contributes in more ways to overall acceptability. Cooking ground beef patties contributes to structural changes and protein denaturation, which ultimately plays a role in the inherent change of shape that occurs during cooking of the patties (Pan and Singh, 2001). In an observation by Pan and Singh (2001), they found that upon cooking of ground beef patties, both the total fat and the percent fat composition were reduced. The cooking process resulted in evaporation of the ground beef patties that contributed to meat shrinkage both by weight and by thickness (Pan and Singh, 2001). High-fat-content patties appeared to have higher cook loss because of the visible fat remaining in the pan after cooking, however low fat patties also experience high cook loss that was less noticeable as it was lost as water that evaporated out of the pan (Cross et al., 1980). Ultimately, high-fat patties still experience more cook loss, but it is often not as dramatic of a difference as it is perceived to be. This rate of cook loss began to decrease once temperatures hit 70°C, but past 75°C it began to increase again with water loss as high as 30% and fat loss at 40% or more (Pan and Singh, 2001). It has been found that when patties are formulated at 4% and 20% fat, lower-fat patties had a higher cook yield and better fat retention, and higher-fat patties had more fat loss during cooking (Berry, 1994; Cross et al., 1980).

In 1993, the USDA released requirements for cooked, uncured meat products that finalized recommendations from a 1988 proposal. In these recommendations, internal end temperatures of uncured meat products was established as 71.1°C for consumers, while 68.3°C (holding at least for 16 seconds) was listed for food service establishments (USDA, 1993). Having temperature requirements for doneness of ground beef is important because consumers interpret internal color as degree of doneness, which is neither accurate nor consistent. In a study by Brewer et al. (1999), pH of meat was affected by the ability of the product to visually brown. Pinkness within a sample could be due to formation of pink hemochrome, incomplete myoglobin denaturation during the cooking process, or a high pH (>6.0; Berry, 1994; Brewer et al., 1999). Brewer concluded that internal temperatures of patties should be determined with a thermometer and not based on visual assessment (Brewer et al., 1999).

Low-fat patties lose palatability when cooked to well done at which point their juiciness and beef flavor intensity suffer (Berry, 1994). This poses a challenge because based on work done by Berry (1992), low-fat patties were considered palatable when cooked to medium but ultimately would result in a food safety risk (Berry, 1994). A study conducted by Berry (1992) found that when comparing fat percentages across ground beef patties, the lower-fat patties tended to experience a greater decrease in moisture as the patty was cooked. When the panel evaluated these patties, panelists found that upon initially biting into these patties that juices were released, but past the first bite the juiciness was gone and the sample seemed dry (Berry, 1992).

Consumer Responses

Understanding consumer expectations and responses is easily the key to producing a successful product, however a wide variety of factors contribute to what each consumer considers acceptable. In a study by Savell et al. (1987), consumers had different marbling preferences based on the region in which they lived, and juiciness, tenderness, and flavor trained sensory panel scores correlated to consumer preferences. Statistical tools, such as multivariate analysis, have enabled sensory scientists to better understand relationships between trained panel descriptive attributes, consumer liking, chemical components, and volatile aromatics and how they are related to each other (Kerth and Miller, 2015). In a study by Miller et al. (2014), relationships between consumer and trained panel data were evaluated; overall consumer liking showed a positive relationship to beef identity, brown/roasted, fat-like, umami and overall sweet. While it has been observed that flavor, juiciness, and tenderness are the three main driving factors for consumer liking in beef, flavor has proven to be slightly more important than the other two (Kerth and Miller, 2015).

In a study by Cox et al. (2006), a variety of tests were performed to determine consumer acceptance of grain- and forage-finished animals. In a retail setting consumers rated flavor, overall palatability, and price higher, however when they were able to take the meat home and prepare it themselves they did not differentiate between the two treatments (Cox et al., 2006). When observed across three southeastern US states in the retail study, there was a significant acceptance of grain-finished animals over forage-finished, with only an average of 34% of consumers choosing forage-finished as their preference (Cox et al., 2006). It is believed that the ability for consumers to prepare food according to their own manner, and at a time of their choosing during a home use test may play a role in overall acceptability of a product (Boutrolle et al., 2007; Cox et al., 2006). Environment and context of evaluation plays a key role in consumer acceptance of a product, especially since a home use test can be a social experience and a central location test is individual (Boutrolle et al., 2007).

In a study by Sveinsdottir et al. (2010) central location test (CLT) versus home use testing (HUT) evaluations were compared. Consumers evaluated fish, which they took home for the HUT in a raw state (Sveinsdottir et al., 2010). They found that when consumers were given the freedom to cook the fish in any manner in the HUT, it influenced the overall evaluation of the product when compared to consistent preparation during the CLT (Sveinsdottir et al., 2010). Consumers not only scored samples differently between HUT and CLT settings, but it also appeared that CLT testing had a higher discriminating power compared to the more natural setting of a HUT, especially when the product being tested was typically consumed as part of a family meal (Boutrolle et al., 2005; Sveinsdottir et al., 2010). During a CLT test, consumers rated samples lower in overall liking scores compared to when they could freely prepare the samples to their liking (Boutrolle et al., 2005; Sosa et al., 2008; Sveinsdottir et al., 2010). This may be because during a CLT test, consumers are more concentrated on the evaluation when compared to the HUT (Sosa et al., 2008).

In a study that specifically compared the effects of central location testing and home use testing on overall consumer acceptability, it was noted if any differences were visibly present in a product, these differences would more clearly be identified in the home use portion when they took home samples which were not prepared (Griffin and Stauffer, 1990). In a central location test, samples arrived to the consumer already prepared and controlled in order to minimize potential bias about what they would be evaluating (Griffin and Stauffer, 1990). When a product went home with the consumer, control now existed with the consumer over the preparation and the evaluation (Griffin and Stauffer, 1990). Inherent variations occured across consumers, which could result in very different reactions to the product, and subsequently poor relationships across the test methods (Griffin and Stauffer, 1990).

The whole goal of utilizing either a central location test or a home use test is to understand what a consumer likes and doesn't like about a product. The ability to provide a consumer with a tender product consistently both at home and in a restaurant setting is something sought after, especially since it is reported that 51% of consumers consider tenderness their most desired attribute (Huffman et al., 1996). Consumers also have different expectations when they go out to eat versus when they eat at home, and it is important for restaurants to understand not only how tender their consumers like their steaks, but also what their tenderness acceptability threshold is (Huffman et al., 1996). In a study by Huffman et al. (1996), it was determined that based on WBSF values, consumer expectations for tenderness at home fell between 4.8-5.6 kg while at a restaurant they expected tenderness values of 4.4-5.2 kg (Huffman et al., 1996). This study identified that a WBSF value of 4.1 kg (consistent with a 6 on the 1 to 9 hedonic scale) would result in 98% of consumer acceptability for both in home and at restaurants (Huffman et al., 1996). This study provides a good example of utilizing in-home data to understand consumer expectations at a restaurant.

Ultimately, eating quality to consumers involves focus on tenderness, juiciness, and flavor (Brewer, 2012; Legako, 2016). While both tenderness and flavor are considered important, flavor is considered to be the most complex due to the significant amount of contributors that play a role in its development (Legako, 2016). 'Liking factors' are typically evaluated by untrained panelists or consumers (Legako, 2016). While consumers say that they prefer lower fat ground beef, this is not always consistent with consumer research. In order to provide consumers with palatable, high-quality, and low-fat ground beef patties, emphasis on cooking method must be made as well as maximization of the remaining fat in terms of flavor to create this balance (Brewer, 2012). It has been shown that consumers are willing to pay a premium for an extra lean product under the assumption that it will experience less cook loss, which is not necessarily true (Cross et al., 1980). A study by Corbin et al. (2015) looked at strip loin steaks with various levels of marbling and found that a correlation existed between fat content and consumer responses. This finding was consistent with those of Legako et al. (2016) who found that fat content plays a role in the perception of beef flavor attributes. Consumer flavor liking and overall liking were positively correlated to beef identity, brown/roasted, fat-like, and umami (Legako et al., 2016).

Various studies have revealed that consumers do not perceive beef to be comparable to lower-fat meats, such as chicken, in terms of health concerns (Resurreccion, 2004). In fact, the major variables that affect purchasing habits of beef include an increase in health concerns, shift in demographics, desire for convenience, and changes in price (Resurreccion, 2004). It has also been shown that consumers determine quality based on visual appearance of a product, primarily bright red colored lean and low amounts of visible fat (Font-i-Furnols and Guerrero, 2014; Resurreccion, 2004).

In a study to understand how demographics played a role in ground beef purchases, Berry and Hasty (1982) found that younger consumers considered price the most important factors and older consumers considered color most important when making purchasing decisions. Across age, income, and marital status, there were differences in the selection of ground beef especially in terms of fat percentage (Berry and Hasty, 1982). Additionally, households with a higher income tended to purchase larger quantities of ground beef at a lower fat percentage per visit to the grocery store when compared to lower-income households (Berry and Hasty, 1982). Along with demographics, many psychological factors play a role in our purchasing decisions such as attitudes, beliefs, and expectations (Font-i-Furnols and Guerrero, 2014). These psychological factors result in some interesting choices when purchasing.

Often consumers have an opinion about various concerns surrounding animal welfare, but when it comes time to make a purchase they often don't think about it; this is a phenomenon referred to as 'Directed or Intentional Forgetting' (Font-i-Furnols and Guerrero, 2014). Consumers are not willing to compromise eating quality for potential health benefits in food products (Font-i-Furnols and Guerrero, 2014). Having a thorough understanding of how beef flavors, including lean and fat contributors, heating reactions, texture, and cooking each play a role in quality is crucial when understanding consumer acceptability of products. Without understanding the components that contribute to the end product, there will be a lack of understanding when trying to correlate these contributors to why consumers consume and purchase certain products.

Factors influencing ground beef flavor have been widely researched including focuses on lean source and lipid levels, as well as cooking influences from the Maillard reaction and lipid degradation. Ground beef texture influences have been studied, but on a smaller scale comparatively. Despite ground beef being one of the most widely-consumed beef products, flavor and texture interactions between meat source, lipid levels, and grind treatments have not been widely studied. This study is unique from others that have been performed because it is one of the first to utilize the full lexicon when describing differences in flavor. Understanding flavor and texture attributes, volatile flavor aromatic compounds, and consumer reactions to ground beef patties through formulation interactions is the next step in ground beef research. We hypothesize that flavor and consumer acceptability of ground beef can be improved by optimizing grind method, lean source, and fat level.

CHAPTER III

MATERIALS AND METHODS

Sample Selection and Preparation

Beef round sirloin tip (knuckle) peeled (IMPS 167A; NAMP 2004), outside round flats (IMPS 171B; NAMP 2004), chuck shoulder clods (IMPS 114; NAMP 2004), 80/20 coarse ground beef (IMPS 136; NAMP 2004), and 50/50 beef trim were all purchased from Ruffino Meats in Bryan, TX. A supplemental supply of beef trim and knuckles were purchased from Sam Kane Beef Processors in Corpus Christi, TX. Knuckles, bottom round flats, and clods were trimmed of all visible fat and connective tissue on the external surface. Each primal was then cubed into chunks and coarse ground (12.7 mm plate) using a grinder (Meat Grinder Model 1056, Biro Manufacturing Company, Marblehead, OH) and mixed in a gondola to ensure a homogenous source.

Three random samples from each coarse ground batch (knuckles, bottom round flats, clod hearts, and 50/50 trim) were taken to determine starting fat percentage of each source. Samples of about 50 to 100g were homogenized in a food processor. Three samples of about 4g from each source were utilized to get a representative reading. The Moisture/Solids Analyzer (Smart System[5] Moisture/Solids Analyzer, CEM Corporation, Matthews, NC) was set (Load Method #3) to “0 to 30 Beef” or “30 to 65 Beef” depending on estimated fat percentage of sample to be run. The system was tared. A 4g homogenized sample was spread in an even, thin square across one pad using a spatula. A second pad was placed on top of the sample and pressed together and evaluated for moisture. The sample was then placed into the fat analyzer (SMART Trac Fat Analysis System, CEM Corporation, Matthews, NC). After three readings for each source were taken, fat and moisture percentages were averaged and utilized when calculating for 10 and 20% final fat content for the four meat sources. A Pearson square was utilized to calculate how much lean source and how much trim were needed for fat percentages for each batch.

The regular 80/20 treatments arrived in coarse ground chubs and was utilized as received. The regular 90/10 treatments were formulated by utilizing knuckles as the lean source and Regular 80/20 as the fat source. Chuck 80/20 and 90/10 treatments were formulated by utilizing clods as the lean source and 50/50 trim as the fat source. Round 80/20 and 90/10 treatments were formulated by utilizing bottom round flats as the lean source and 50/50 trim as the fat source. Sirloin 80/20 and 90/10 treatments were formulated by utilizing knuckles as the lean source and 50/50 trim as the fat source. Once the eight initial treatments were formulated, three representative samples were taken, homogenized and run through the fat analyzer as a verification step. If samples came back within 2% of the target fat percentage then the batch was ready for further processing, if it was more than ± 2% the sample was reformulated until the target fat percentage was obtained.

Once all eight sources were validated by the fat analyzer, each batch was split into two groups. One group was run through the grinder plate (6.4 mm), and the other group was bowl chopped (Model K64 Vacuum Cutter, Seydelmann, Stuttgart, Germany) for six revolutions at high speed (6,000 RPM) as determined based on preliminary testing. This resulted in 16 final treatments: Regular 80/20, 6.4 mm grind; Regular 80/20 bowl chopped; Regular 90/10, 6.4 mm grind; Regular 90/10 bowl chopped; Chuck 80/20, 6.4 mm grind; Chuck 80/20 bowl chopped; Chuck 90/10, 6.4 mm grind; Chuck 90/10 bowl chopped; Round 80/20, 6.4 mm grind; Round 80/20 bowl chopped; Round 90/10, 6.4 mm grind; Round 90/10 bowl chopped; Sirloin 80/20, 6.4 mm grind; Sirloin 80/20 bowl chopped; Sirloin 90/10, 6.4 mm grind; and Sirloin 90/10 bowl chopped.

Patties for each treatment were formed with a patty maker (Supermodel 54 Food Portioning Machine, Hollymatic Corporation, Countryside, IL) with a 2.54 cm plate. Patties were randomly assigned to trained panel testing, central location testing, GC, or chemical testing. The number of patties needed from each treatment was predetermined through a randomization process. Once patties were labeled they were placed with patty paper on top and bottom in a single layer on trays, placed in a -40°C freezer and crust frozen for 20 min, and then vacuum packaged. Patties designated for consumer sensory evaluation/central location testing in Griffin GA, Manhattan KS, Portland OR, and State College PA; cooked chemical flavor volatile analysis/GC; and raw chemical fat/moisture testing were placed into bags (B2470, Cryovac Sealed Air Corporation, Duncan, SC) with an oxygen transmission rate of 3 to 6 cc at 4°C (m^2, 24 h at 4°C, 0% RH) and a water vapor transmission rate of 0.5 to 0.6 g at 38°C (100% RH, 0.6 m^2, 24 h) and individually sealed. Patties designated for trained panel were placed into bags (B6620, Cryovac Sealed Air Corporation, Duncan, SC) with an oxygen transmission rate of 3 to 6 cc at 4°C ([1cm^3{STP}/{m^2, 24hr, atm}] @ 0% RH) and a water vapor transmission rate of 0.4 to 0.5 g at 37.7°C (100% RH, [g/{100 in^2 – 24 hrs}]) and five patties were sealed for each "sample" to be served to the trained panel. Three bags of five patties were collected from each treatment across three replicates, which were created by new orders of raw materials for three consecutive weeks.

Immediately after packaging, samples were taken to a -40°C freezer until frozen solid and then moved to a -23°C freezer where they were sorted by test and city and placed into labeled boxes until time of testing. These procedures were repeated for three weeks, with new shipments of meat arriving each week in order to produce three representative replicates (n = 48; 4 meat sources x 2 fat percentages x 2 grinds x 3 replicates). All testing was conducted within 6 months of processing.

Expert, Trained Descriptive Beef Flavor Analysis

Patties were evaluated by an expert trained beef flavor descriptive attribute panel that helped develop and validate the beef lexicon (Adhikari et al., 2011). This panel was retrained for 16 d using the beef lexicon leading up to testing. Panelist training and testing was approved by IRB protocol IRB2016-0420M. Beef flavor attributes were measured using the Beef Lexicon (0 = none and 15 = extremely intense; Appendix A, Table 1). Approximately 24 h prior to testing, samples were removed from the freezer and placed on racks in a single layer in order to thaw in a cooler (4°C). One hour prior to testing, patties were organized by cook order on the trays, removed from their vacuum packaged bags and patty paper, and raw weights (g) were taken. Patty trays were then covered with saran wrap and held in the cooler until time to cook. Prior to cooking, five temperature readings of the surface of the grill were taken using an infrared temperature reader (MS6530H Infrared Thermometer, Commercial Electric Products Corporation, Cleveland, OH) with a target temperature of 163°C. Raw temperatures and time put on the grill were recorded, along with end temperature, time off the grill, and final cook weights (APPENDIX C). After patties came off the grill and were weighed, they were wrapped in foil and placed in a holding oven (Model 750-TH-II, Alto-Shaam, Menomonee Falls, WI) for no longer than 20 min, until served.

Panelists were provided with a warm-up sample to calibrate each sensory day. The warm-up was individually evaluated by each panelist and then discussed. Panelists came to consensus for all attributes prior to testing. Eight random samples over the course of a two-hour session were evaluated each sensory day. Samples were cooked on a commercial flat top grill (2.54-cm-thick flat top Star Max 536TGF 91.44cm Countertop Electric Griddle with Snap Action Thermostatic Controls [Star International Holdings Inc. Company, St. Louis, MO]) with a flip temperature at 35°C to an end temperature of 71°C. Internal temperatures were monitored using thermocouple probes (Model SCPSS-040U-6, Type T, 0.040 sheath diameter, 15.2-cm-length ungrounded junction thermocouple, Omega Engineering, Stamford, CT) by probing into the geometric center of the patty periodically throughout cooking and were displayed using a thermometer (Omega HH501BT Type T, Omega Engineering, Stanford, CT). Each sample was served on a clear, plastic plate (clear 15.9 cm plastic plates premium quality, Members Mark, Sam's Club, Bentonville, AR) marked with a random three-digit code. Samples consisted of half of a patty each, and panelists were given a new clear plastic fork and clear plastic knife to evaluate each sample.

Each panelist's station consisted of three palate cleansers: double-distilled deionized water, sparkling water, and saltless saltines. Each panelist was given a tablet (iPad Air 1, Apple Inc., Cupertino, CA) to record their individual data using an electronic spreadsheet (Microsoft Excel, One Drive, Microsoft Corporation, Redmond WA), and samples were evaluated independently. The trained panel for each sample evaluated 51 flavor and texture attributes as defined in Table 1.

Consumer Location Evaluation

Consumers (n = 80) were randomly selected in each of four cities (Griffin, GA; Manhattan, KS; Portland, OR; State College, PA) so that geographical areas represented the Southeast, the Midwest, the east coast, and the west coast. In each city, four consumer sessions with 20 consumers were conducted. Consumers were selected to be representative of their respective geographic region with an attempt to evenly distribute across demographics. One individual research institution located in each of the four cities mentioned above was responsible for recruiting 80 consumer panelists who passed a pre-screener. The pre-screener guaranteed that consumers were over the age of 18 and consumed ground beef as a part of their regular diet.

One week before each central location test, patties were organized and packed on dry ice into insulated Styrofoam coolers and shipped overnight to the testing facility where they were held in freezers (-10°C) prior to testing. Approximately 24 h prior to each central location test, patties were removed from the freezer and placed on trays or racks in a single layer to thaw in a cooler (2 to 4°C). Two hours prior to the start of each session, patties were organized by cook order on the trays, removed from their vacuum-packaged bags and patty paper, and raw weights (g) were taken. Patty trays were then covered with saran wrap and held in the cooler until time to cook. At the beginning of each session, five temperature readings were taken using an infrared temperature reader (MS6530H Infrared Thermometer, Commercial Electric Products Corporation, Cleveland, OH) of the surface of the grill with a target temperature of 163°C. Samples were cooked beginning one hour prior to the start of the panel time. Raw temperatures and time placed on the grill were recorded, along with end temperatures, time off the grill, and final cook weights (APPENDIX C). After patties were removed from the grill, they were weighed, wrapped in foil, and placed in a holding oven until time to serve.

On the day of evaluation, consumer panelists were asked to fill out and sign an informed consent form (APPENDIX C). Consumer testing and consent forms were approved by IRB, protocol number IRB2016-0420M. Once consumers entered the testing room and were seated, they were presented with a packet containing testing procedures, palate cleansers of distilled water and saltless saltine crackers, demographic ballot, and eight individual sample ballots (APPENDIX C). Consumer demographic questions included: gender, age, ethnicity, household income, household population, employment level, protein sources consumed and location consumed, frequency of protein consumption, preferred cooking method for ground beef, degree of doneness desired for ground beef, type of ground beef typically purchased, desired fat percentage of ground beef, and types of cuisines consumed (Table 7). Cooked appearance, overall, overall flavor, and overall texture liking were included on each sample ballot utilizing 9-point hedonic scales. "Please write any words that describe what you LIKE about this meat patty" and "Please write any words that describe what you DISLIKE about this meat patty" open-ended questions were also included on each ballot.

Consumer panelists were provided with eight random samples over the course of a one-hour session. Samples were cooked on a commercial flat-top grill to an end temperature of 71°C, with a flip temperature at 35°C. Internal temperatures were monitored using thermocouple probes (Model SCPSS-040U-6, Type T, 0.040 Sheath Diameter, 15.24 cm length Ungrounded Junction Thermocouple, Omega Engineering, Stamford, CT) by probing into the geometric center of the patty periodically throughout cooking and were displayed using a thermometer (Omega HH501BT Type T, Omega Engineering, Stanford, CT). Each sample was served on a clear, plastic plate (clear 15.88 cm plastic plates premium quality, Members Mark, Sam's Club, Bentonville, AR) marked with a random three-digit code. Samples consisted of half of a patty each, and consumers were given a new clear plastic fork and clear plastic knife to evaluate each sample. Each patty was split into two equal halves and a half of a patty was served to one consumer. Treatments for consumer evaluation were evenly distributed across all consumers in each city, with each consumer evaluating eight total treatments.

At the completion of each session, four randomly-selected consumers were asked to participate in one-on-one interviews to determine driving factors and attitudes towards ground beef flavor and purchasing habits. Interviews lasted for approximately 15 minutes, and the script is defined in Appendix C.

Cook Beef Volatile Flavor Evaluation

Sample Collection

Samples for volatile analysis evaluation using gas chromatograph/mass spectrophotometer system with olfactory (GC/MS/O) were cooked in Griffin, GA. Since evaluation samples were half patties and were consumed by two panelists, GC patties were cooked side-by-side with consumer patties of the same treatment and treated as duplicates.

The GC patties were stored, shipped, thawed and cooked as described for CLT patties. After GC patties came off the grill, they were weighed, half the patty was wrapped in foil with a tag, and frozen in liquid nitrogen. Samples were shipped to Texas A&M University on dry ice and then stored in an -80°C freezer. One hundred and forty-four patties were collected for volatile analysis.

Sample Evaluation

Volatiles were evaluated using the Aroma Trax gas chromatograph/mass spectrophotometer system with dual sniff ports for characterization of aromatics (MicroAnalytics-Aromatrax, Round Rock, TX). This technology provided the opportunity to separate individual volatile compounds, identify their chemical structure and characterize the aroma/flavor associated with the compound. Samples were removed from the -80°C freezer, placed in glass jars (473 mL), weighed, and topped with a Teflon lid under the metal screw-top to avoid off-aromas. Samples were then set in a water bath at 60°C and thawed for one hour. The headspace was collected with a solid-phase micro-extraction (SPME) portable field sampler (Supelco 504831, 75 µm Carboxen/polydimethylsiloxane, Sigma-Aldrich, St. Louis, MO). The headspace above each meat sample in the glass jar was collected for a total of 2 h in the 60°C water bath. Upon completion of collection, the SPME was injected in the injection port of the GC where the sample was desorbed at 280°C. The sample was then loaded onto the multi-dimensional gas chromatograph into the first column (30m X 0.53mm ID/ BPX5 [5% phenyl polysilphenylene-siloxane] X 0.5 µm, SGE Analytical Sciences, Austin, TX). The temperature started at 40°C and increased at a rate of 7°C/minute until reaching 260°C. Upon passing through the first column, compounds were sent to the second column ([30m X 0.53mm ID; BP20- Polyethylene Glycol] X 0.50 µm, SGE Analytical Sciences, Austin, TX). The gas chromatography column then split into three different columns at a three-way valve with one going to the mass spectrometer (Agilient Technologies 5975 Series MSD, Santa Clara, CA) and two going to two humidified sniff ports with glass nose pieces heated to 115°C. The sniff ports and software for determining flavor and aroma were part of the AromaTrax program (MicroAnalytics-Aromatrax, Round Rock, TX). Panelists were trained to accurately use the Aromatrax software. For samples collected with a SPME that were not to be used for immediate evaluation, the SPME was wrapped in foil and held in an -80°C freezer until evaluation.

Statistical Analyses

The trained panel descriptive flavor attributes, CLT sensory attributes and the volatile compounds were analyzed using the general linear models procedure in SAS (v9.3, SAS Institute, Cary, NC) with a predetermined alpha of 5%. For trained panel results, data were averaged across panelists, order was defined as a random variable, and replicate was included in the model as a fixed effect. A full model was calculated where main effects of grind type, meat source, fat level and their two-way interactions were included. A final model used main effects of grind type, meat source, fat level and significant ($P < 0.05$) two-way interactions. Consumer sensory and volatile aromatic data were analyzed similarly. Least squares means were calculated and differences between least squares means were determined using the pdiff function when differences were significance ($P < 0.05$) in the Analysis of Variance table. Principal component analysis (PCA) and partial least squares regression (PLS) was conducted using XLSTAT (v2013, Addinsoft, New York, NY). Data were presented in bi-plots.

CHAPTER IV

RESULTS AND DISCUSSION

Expert, Trained Descriptive Beef Flavor Analysis

The ground beef flavor attributes, definitions, and reference standards (Adhikari et al., 2011) as well as the ground beef texture attributes (AMSA, 1983) are included in Table 1. Descriptive sensory attributes were evaluated using 0 to 15 scales where 0 = none and 15 = extremely intense. Attributes that were not present included animal hair, apricot, asparagus, barnyard, beet, chemical, chocolate/cocoa, cumin, dairy, fishy, floral, green haylike, leather, nutty, painty, rancid, smoky wood, soapy, sour aromatics, and spoiled-putrid.

Slight differences in burnt flavor descriptive attribute across meat source by grind ($P = 0.03$) and meat source by fat ($P = 0.03$) interactions were reported (Table 2). Ground beef patties manufactured from the round and ground to a 6.4 mm grind size had more ($P < 0.05$) burnt flavor than regular bowl chopped, round bowl chopped, or chuck 6.4 mm. Additionally, sirloin ground beef patties with 20% lipid and round ground beef patties with 10% lipid had more ($P < 0.05$) burnt flavor than regular and sirloin ground beef patties with 10% lipid. The development of burnt flavor can be attributed to the Maillard reaction (Ames, 1992) and contributes to the characteristic meaty aroma of cooked beef (McLeod, 1994). The Maillard reaction is a type of non-enzymatic browning and occurs when a carbonyl compound and a compound possessing an amino acid react (Ames, 1992). In the case of meat, this amino acid is present in the lean portion, which could explain why meat source was present in both significant interactions. It should also be noted that even though meat source may be a driver of the development of burnt flavor through the Maillard reaction, its interactions with grind treatment and lipid level also play a role.

Levels for green flavor were 0.2 or less, and while there was a meat by grind interaction ($P = 0.02$; Table 3) values were low and most likely not detectable. In a study by Blackmon et al. (2015), they also detected very low, but significant, difference in green hay-like flavors across meat source. This indicates that certain meat sources may have a higher prevalence of green flavor, but depending on fat percentage the detection could be masked.

Slight differences in overall sweet across meat source by fat ($P = 0.05$) and grind by fat ($P = 0.04$) interactions were found (Table 4). Sirloin and chuck ground beef patties with 20% lipid had more overall sweet flavor than round ground beef patties with 10% lipid, which tended to have the lowest prevalence of overall sweet flavor. Additionally, ground beef patties with 20% lipid and ground to a 6.4 mm grind size tended to have more overall sweet flavor when compared to ground beef patties at 10% lipid and ground to a 6.4 mm grind size, which tended to have the lowest prevalence of overall sweet flavor. Although differences were statistically significant, they were minimal overall. These results indicate that higher fat percentages (20%) have a higher prevalence of overall sweet flavors and lean source also may contribute, but one grind type does not promote any more sweetness than the other. A study by Legako et al. (2016) noted that as quality grades increased so did the presence of overall sweet, which agrees with the conclusion from this study.

Differences in beef identity (*P* < 0.0001), brown (*P* = 0.02), roasted (*P* < 0.0001), bloody/serumy (*P* = 0.01), umami (*P* = 0.03), salty (*P* = 0.006), and particle size (*P* = 0.02) across meat source by fat interactions are present in Table 5. Ground beef patties manufactured from sirloin with 20% lipid were higher (*P* < 0.05) in beef identity, brown, and roasted compared to sirloin ground beef patties with 10% lipid which scored the lowest in prevalence of beef identity, brown, and roasted flavors. As the sirloin patties were made from knuckles, which have sometimes been shown to be less flavorful than other sirloin cuts (Jeremiah et al., 2003; King et al., 2009), the addition of added lipid from beef fat source most likely resulted in increased levels of these attributes. Round ground beef patties with 10% and 20% lipid and sirloin ground beef patties with 20% lipid were lower in bloody/serumy flavor (*P* = 0.01) compared to regular ground beef patties at 10% and 20% lipid and sirloin ground beef patties at 10% lipid which were higher in bloody/serumy flavor. These results imply that lean from the round is inherently lower in bloody/serumy while regular beef (which is from a combination of cuts) is inherently higher in bloody/sermuy despite fat percentage. These results differ from those of Meisinger et al. (2006) who compared flavor across muscles from the round and chuck and found no differences for the attribute bloody across muscle type. Regular ground beef patties with 10% and 20% lipid and sirloin ground beef patties with 10% lipid were lower in umami flavor (*P* = 0.03) compared to round, sirloin, and chuck ground beef patties at 20%, which were higher in umami flavor. As differences were less than 0.3, differences in salty were most likely not important. Although it wouldn't be expected that meat source and lipid level would affect particle size, round ground beef patties with 10% lipid had a smaller particle size ($P = 0.02$) compared to regular ground beef patties at 20% lipid which was larger than all in particle size.

Grind treatment did not affect flavor attributes, except for medicinal ($P = 0.04$) (Table 6) and umami flavor ($P = 0.0005$; Table 5). For umami, 6.4 mm ground beef patties scored higher than bowl chopped patties. Bowl-chopped patties had a slightly smaller particle size ($P = 0.0004$; Table 5), were harder (P < 0.0001; Table 6), and were springier ($P < 0.0001$; Table 6) than 6.4 mm-ground beef patties. These results are consistent with those of Randall et al. (1977) who compared flake-cut patties ground to a 6.4 mm grind size. They found that the ground meat was more tender and less rubbery when compared to the flake cut patties (Randall et al., 1977). A difference in the two studies is that Randall et al. (1977) found that the ground meat was juicier and a finer grind when compared to flake-cut meat, but in this study there was no significant differences ($P > 0.05$) in juiciness or cohesiveness of mass identified between grind treatments.

Meat source affected bitter ($P = 0.01$), cardboard ($P = 0.04$), fat-like ($P = 0.02$), liver-like ($P = 0.04$), sour ($P < 0.0001$), and sour milk/sour dairy ($P = 0.005$) flavor attributes as well as hardness ($P = 0.007$) and springiness ($P = 0.009$) texture attributes (Table 6). Regular ground beef patties rated lower (P < 0.05) for bitter than round and sirloin patties, lower (P < 0.05) in cardboardy compared to sirloin patties, higher (P < 0.05) in fat-like than chuck patties, and lower (P < 0.05) for liver-like and sour than round patties. Regular ground beef patties also were harder than chuck patties, and springier than all other meat sources. Sirloin ground beef patties scored higher (P < 0.05) in cardboard than regular and chuck patties, lower (P < 0.05) for sour and sour milk/sour dairy compared to all other meat sources, and were not different from the other attributes for fat-like or livery favor aromatics. Chuck ground beef patties scored lower for cardboard compared to sirloin patties, higher for fat-like compared to round patties, lower for sour and sour milk/sour dairy compared to round patties, and were not different for bitter or liver-like flavor aromatics. Ground beef patties made from the round were higher (P < 0.05) in liver-like than regular ground beef, and were higher ($P < 0.05$) in sour and sour milk/sour dairy flavor attributes compared to all other meat sources. This finding is similar to that of Meisinger et al. (2006) where they found the V. *lateralis* had the most intense off flavor (in this case liver-like), and scored among the highest in sour.

Fat level had the most significant affect on flavor attributes. Ground beef patties containing 10% lipid were higher in bitter ($P = 0.002$), cardboardy ($P = 0.0002$), liver-like ($P < 0.0001$), sour ($P < 0.0001$), sour milk/sour dairy ($P = 0.01$) compared to 20% lipid patties. Ground beef patties containing 20% lipid were higher in buttery ($P < 0.0001$), fat-like ($P < 0.0001$), heated oil ($P < 0.0001$), smoky charcoal ($P = 0.01$), and sweet ($P = 0.005$) flavor attributes and were juicier ($P = 0.0001$) compared to 10% lipid patties (Table 6). In a study by Blackmon et al. (2015), differences were found across fat percentage and lean source for fat-like. This is similar to the findings of this study in which both lean source ($P = 0.02$) and fat percentage ($P < 0.0001$) affected the level of fat-like in ground beef patties. Berry (1994) found that there was a higher incidence of sour or acid flavor in patties at 4% fat when compared to patties at 20% fat. This result was mirrored in the present study where 10% fat patties were higher for both sour ($P < 0.0001$) and sour milk/sour dairy ($P = 0.01$) when compared to 20% fat patties. Typically, increased fat-level has been shown to increase tenderness of ground beef (Berry, 1984), but this was not seen in the present study, as hardness was not significant for fat- level ($P = 0.49$). Troutt et al. (1992) found that fat-level significantly affected moistness, juiciness, beef flavor intensity, firmness, and cohesiveness of mass in ground beef patties. This study found that fat-level affected juiciness with 20% fat patties being juicier. An interaction for meat by fat was reported for beef flavor identity. Unlike other studies that found higher-fat patties were higher in beef flavor identity (Troutt et al., 1992), low-fat patties were not consistently lower in beef identity flavor and high-fat patties were not higher in beef identity flavor. As Troutt et al. (1992) did not define references used for beef flavor, beef flavor identity may have been measured differently.

Consumer Demographics

Consumer demographics (n = 314) are reported in Table 7. Slightly more females (57.8%) participated in the study compared to males and the majority of participants (98.1%) fell in the 21 - 65 age range with a slightly heavier representation of the 26 - 35 age range (30.9%). The majority of consumers represented Caucasian (non-Hispanic) ethnicity (77.7%), followed by Asian/Pacific Islanders (8.6%) and

African-American (6.1%). Household incomes were fairly evenly distributed with 25.3% falling in the $25,001 - $49,999 group and 26.6% falling in the $50,000 - $74, 999 group, and roughly 15% - 17% for all other income brackets. Household size was represented by a majority of two-person households (40.9%), followed by three-person (21.1%), and one-person (16.6%) households. Most consumers surveyed were full-time employed (69.8%).

When asked about proteins consumed at home, over 80% of consumers reported consuming chicken, beef (steaks), ground beef, pork, fish, and eggs. The top three proteins consumed at home included chicken (97.8%), eggs (96.3%), and ground beef (95.2%). When asked about proteins consumed away from home or at restaurants, over 80% of consumers reported consuming chicken, beef (steaks), ground beef, fish, and eggs. The top proteins consumed away from home included chicken (94.9%), ground beef (91.2), eggs (88.2%), and beef (steaks; 87.2%).

Consumers were asked to report how many times a week they consumed each protein source. The majority of consumers reported consuming beef (steaks) 1 to 2 times per week (76.8%), followed by 3 to 4 times per week (14.4%). For ground beef consumption, the majority of consumers reported eating 1 to 2 times per week (69.5%) followed by 3 t0 4 times per week (24.1%). For pork consumption, consumers reported 1 to 2 times per week (77.4%) followed by 0 times per week (12.8%). For lamb consumption, the majority of consumers reported 0 times per week (75.5%) followed by 1 to 2 times (23.8%). For chicken consumption, the majority of consumers consumed chicken either 1 to 2 times per week (43.2%) or 3 to 4 times per week (41.9%). For fish consumption, the majority of consumers reported eating fish 1 to 2 time per week (72.0%) followed by 0 times per week (16.9%). Finally, for soy-based products, consumers reported eating soy-based products 0 times per week (57.0%) followed by 1 to 2 times per week (36.4%).

Consumers were asked what methods were preferred when cooking ground beef. The majority of consumers preferred to pan-fry/skillet on the stove (83.0%) or grilling outside (73.1%). Some consumers oven bake (34.6%) or stir-fry (30.1%), and even fewer used an electric appliance (George Forman Grill; 18.6%), oven broiling (16.4%), or microwave (7.4%).

When asked for preference on degree of doneness, the majority of consumers responded with medium-well (30.1%), followed closely by medium (28.7%). Few consumers preferred the extremes with only 1.2% reported for rare and 4.9% for very well done.

When asked about ground beef purchasing habits, the majority of consumers responded with a tendency to buy traditional beef at the retail store (74.9%). About a quarter of consumers typically purchase grass-fed ground beef (22.5%), followed by consumers who typically purchase organic (17.0%). When consumers were asked what fat level they typically purchased, the top two percentages were 10% (30.1%) and 15% (30.7%) with some consumers purchasing 7% (21.7%) and 20% (18.1%) fat level. Finally, when asked about type of ground beef typically purchased, consumers responded with an overwhelming majority for ground beef (69.8%), followed by ground chuck (30.2%), and ground sirloin (16.1%).

Consumers were asked what types of cuisines they liked to purchase. Over 80% reported enjoying American, Chinese, Barbeque, Mexican/Spanish, and Italian cuisines. Lebanese, Indian, French, and Greek were among the lowest typically consumed. These results indicate that consumers in this study purchased ground beef and were an acceptable population to test the effects of ground beef fat level, meat source and grind size.

Consumer Perception of Ground Beef Patties

Consumer liking scores are reported in Table 8. Meat source did not affect consumer cooked appearance liking ($P = 0.15$) or overall liking ($P = 0.06$). Flavor liking was higher ($P = 0.01$) for chuck ground beef patties compared to all other meat sources. Texture liking was higher ($P = 0.004$) for chuck and sirloin ground beef patties compared to regular patties.

Ground beef patties with a 6.4 mm grind size was more desirable for cooked appearance liking ($P < 0.0001$), overall liking ($P < 0.0001$), flavor liking ($P < 0.0001$), and texture liking ($P < 0.0001$) when compared to bowl chopped ground beef patties. In a study by Randall et al. (1977), flake-cut and 6.4 mm grind patties were compared. They found that the 6.4 mm grind size patties were more acceptable. Consumers commented that the flake-cut patties were tough and dry, firm, and pressed too tight. Randall et al. (1977) related that these texture effects were due to increased binding and cohesive properties that result from the flake-cutting process. As fat level increased, texture liking increased ($P = 0.01$). Fat level did not affect consumer cooked appearance liking (*P* = 0.15), overall liking (*P* = 0.06), or flavor liking (*P* = 0.48).

The grind by fat interaction was significant for cooked appearance liking (*P* = 0.008), overall liking (*P* = 0.02), and flavor liking (*P* = 0.01). Ground beef patties ground to a 6.4 mm grind size with 10% lipid had a more desirable cooked appearance liking and were most highly liked, bowl chopped samples with 10% lipid were liked least (*P* < 0.05). For overall liking, ground beef patties that were bowl chopped with 10% lipid were lowest (*P* < 0.05), while the 10 and 20% lipid treatments ground to a 6.4 mm grind size were liked the most (*P* < 0.05). For flavor liking, bowl chopped patties were not liked as well (*P* < 0.05) as ground patties. The meat source by fat interaction was significant for flavor liking (*P* = 0.03; data not presented). Regular 20% lipid ground beef patties rated lowest in flavor liking compared to chuck ground beef patties at 10% and 20% lipid. Cooked appearance liking, overall liking and texture liking were not significant (*P* > 0.05) for the meat source by fat interaction.

Word clouds were produced using the like and dislike open-ended consumer liking questions. Figures 1 to 6 show the consumer responses separated by meat source, grind type, and fat level. The larger a word appears, the more frequently it was used as a response. For meat source, the most commonly used words for liking were flavor, good, texture, and juicy (Figures 1, 2, 3, 4) and for dislike words were little, chewy, dry, flavor, and texture. Consumers used more terms to describe what they did not like about the meat source than to describe what they like (Figures 1, 2, 3, 4). More words appear large on the disliking word clouds when compared to the liking word clouds.

For liking and dislike terms associated with fat percentage, flavor, good, and texture were dominant for both 10% and 20% liking (Figure 5). However, dry was by far the most used descriptor for 10% (Figure 5). When looking at the 20% fat dislike figure, many words are similar in size and no one descriptor was dominant (Figure 5). Finally, when comparing grind method like and dislike terms, both 6.4 mm grind size and bowl chopped patties had flavor and good as positive descriptors (Figures 6). As for dislike descriptors, the most commonly used for both grind methods were dry, flavor, and chewy (Figures 6). For all treatments including meat source, fat percentage, and grind method, consumers typically used more descriptors when discussing what they disliked in a sample compared to what they liked about a sample. Across all the word clouds, flavor most consistently influenced whether or not a consumer liked a sample.

Trained Descriptive Flavor Panel and Consumer Perception of Ground Beef Relationships

A partial least squares regression biplot for consumer liking sensory attributes and trained meat descriptive attributes is defined in Figure 7 to understand the relationships between sensory and consumer liking attributes. The first factor (t1) segmented mainly for flavor descriptor attributes with positive flavor on the right of the axis, and negative flavor on the left. Umami, fat-like, beef flavor identity, salt, roasted, brown, cooked milk, initial juiciness, and heated oil were considered to be positive flavor attributes, and are closely related to consumer liking attributes. A loose cluster exists in the top right quadrant which groups consumer liking attributes closely with cooked milk flavor and the chuck 6.4 mm 10% lipid ground beef patty treatment. This cluster represents attributes that were positively affected by both flavor and texture, and also reveals that the chuck 6.4 mm 10% lipid treatment was most closely associated with consumer liking. A closer clustering of attributes exists in the bottom right quadrant which groups together many of the major beef flavor attributes. The chuck bowl chopped 20% lipid treatment was correlated closely to these beef flavor attributes. This quadrant captures attributes that were positively related to flavor, but negatively related to texture.

The second factor (t2) segmented mainly for texture attributes with positive texture above the axis and negative texture below the axis. In the lower left quadrant, a loose cluster existed including springiness, burnt, and hardness descriptive attributes as well as chuck bowl chopped 10% lipid ground beef patties. This cluster represents negative flavor and negative texture attributes and also highlights the attributes least liked by consumers. Consumers did not like patties that tasted burnt or were springy or hard, and least liked the chuck bowl chopped 10% lipid treatment. In the upper left quadrant, a cluster surrounding metallic, warmed-over, cohesiveness of mass, and sirloin bowl chopped 10% patties existed. This quadrant represents attributes that had negative flavor but positive texture. This indicated that consumers did not like patties that tasted metallic, bloody/serumy, or warmed over, and that ground beef patties with more cohesiveness of mass tended to negatively impact flavor. As attributes appeared closer to an axis they had less impact on variation.

Addressing the PLS as a whole, bowl chopped patties tended to be disliked as most appear on the left side of the plot. Lipid percentage was not consistently related to consumer and descriptive sensory attributes. It was apparent that meat source and grind type affected sensory attributes. Bowl chopping tended to negatively affect texture attributes and consumer liking. Chuck ground beef tended to be liked as long as it was either bowl chopped with 20% lipid or ground to 6.4 mm with 10% lipid. Increasing the lipid from 10 to 20% appeared to improve consumer liking for bowl chopped chuck ground beef patties. Similar results were reported for round ground beef.

Cooked Ground Beef Volatile Evaluation

Grind by fat interactions existed for acetic acid ($P = 0.01$; Table 9) and 2-ethyl-3,5-dimethyl- pyrazine ($P = 0.04$). Acetic acid has an inherent sour, vinegar aroma (Kerth and Miller, 2015) and was higher ($P < 0.05$) in ground beef patties with 20% lipid ground to 6.4 mm compared to all other grind by fat interactions. 2-Ethyl-3,5-dimethyl- pyrazine tends to produce roasty, caramel-like, burnt and earthy aromas (Cerny and Grosch, 1992) that was found to be higher in 20% lipid ground beef patties ground to 6.4 mm grind size compared to 10% lipid patties ground to a 6.4 mm grind. This indicates that lower-fat may contribute to fewer Maillard products since pyrazines are most commonly the result of Maillard reactions. Interestingly, bowl chopped patties at 20% lipid had similar levels of pyrazine to the bowl chopped patties at 10% lipid indicating that bowl chopping alters texture (as previously reported) and also affects the development of Maillard reaction intermediate.

A meat by grind interaction existed for hexanal ($P = 0.02$) which is a compound known to be a product of lipid oxidation (Mottram, 2007; Table 10). Hexanal is known to produce grassy or green aromas (Kerth and Miller, 2015) and was higher ($P < 0.05$) in 6.4 mm grind regular and round patties compared to round ground beef patties that were bowl chopped. Lipid oxidation is catalyzed by iron and heat. These results indicate that bowl chopped round ground beef patties may have been less susceptible to lipid oxidation due to texture affects reported in Figure 7.

Meat source did not affect (P > 0.05) volatile compounds except for 2-(hexyloxy)-ethanol where chuck had a higher prevalence ($P = 0.005$) when compared to the other meat sources (Table 11). Grind type had the most significant affect on volatile compounds. Ground beef patties ground to a 6.4 mm grind size were higher than bowl-chopped patties in benzeneacetaldehyde ($P = 0.02$) known to produce a sweet, floral, honey, rosy aroma (Kerth and Miller, 2015); 2-5-dimethyl-pyrazine ($P = 0.002$) which produces a musty, potato, and cocoa aroma (Kerth and Miller, 2015); 3-ethyl-2,5-dimethyl-pyrazine ($P = 0.009$) which produces a peanut, caramel, coffee, popcorn-like aroma (Kerth and Miller, 2015); trimethyl-pyrazine ($P = 0.01$) which produces a raw, potato, musty aroma (Kerth and Miller, 2015); 2-ethyl-5-methyl-pyrazine ($P = 0.03$) which produces a coffee/nutty aroma (Kerth and Miller, 2015); and 2-ethyl-6-methyl-pyrazine ($P = 0.02$) which produces a roasted hazelnut aroma

(Winter, 1975; Table 11). Pyrazines and pyrroles are formed during the Maillard reaction from intermediate reactions including from Amadori rearrangement products, Heyns rearrangement products, or via the Strecker degradation mechanism (Jousse et al., 2002). Pyrroles most commonly come from the Amadori rearrangement products and pyrazines from the Strecker degradation (Jousse et al., 2002).

Fat level affected benzaldehyde ($P = 0.006$), nonenal ($P = 0.005$), and 1-(1H-pyrrol-2-yl)- ethanone ($P = 0.002$; Table 11). Benzaldehyde was higher in 10% lipid samples and is known to produce almond, nutty, and woody aromas (Kerth and Miller, 2015). Nonenal was higher in 20% lipid samples and is known to produce a melon or cucumber aroma (Kerth and Miller, 2015). Aldehydes can be produced through either the Maillard reaction or lipid degradation (Kerth and Miller, 2015). They are produced from the breakdown of fatty acids through the removal of the glycerol backbone in lipid degradation, and from the decarboxylation and deamination of amino acids in the Maillard reaction (Kerth and Miller, 2015). Aldehydes derived from the oxidation of unsaturated fatty acids are key in determining exactly which intermediate (heterocyclic compounds) are formed throughout the Maillard reaction (Melton, 1999). It can be inferred that these aldehdyes are the indicator compounds which determined the Maillard reaction and lipid degradation products. 1-(1H-pyrrol-2-yl)-ethanone is a pyrrole and was found to be higher in 10% lipid samples; it is also known to produce warm, nutty, and ethereal aromas (Burdock, 2010).

Maillard compounds, including aldehydes, pyrroles, and pyrazines, are known to produce roasted, browned, meaty, and caramelized aromas (Kerth and Miller, 2015). In fact, heterocyclic compounds, including pyrroles and pyrazines, are typically associated with high heat cookery (Melton, 1999). Many of the significant compounds in this study fall into one of these compound groups and produce characteristic aromas of the Maillard reaction. It is safe to assume that many of the significant volatile compounds present in this study were produced during the cooking process.

Volatile Aromatic Compounds and Consumer Perception of Ground Beef Relationships

A partial least squares regression biplot for consumer sensory attributes and volatile aromatic compounds is presented in Figure 8. This figure helps show the relationships between the volatile compounds and consumer liking attributes. The first factor (t1) segmented mainly for volatile compounds that contributed to flavor with aromatics that positively impacted flavor on the right of the axis, and aromatics that negatively impacted flavor on the left. The consumer attributes all clustered closely together. A cluster exists in the upper right quadrant with decanal, tetradecanal, and nonenal (all aldehydes), 2-heptanone and 3-hydroxy-2-butanone (both ketones), chuck 6.4 mm 20% lipid and sirloin 6.4 mm 20% lipid treatments. This cluster is closely related to consumer liking and positively impacted flavor and texture. A large cluster formed in the bottom right quadrant surrounding round ground beef patties at 20% lipid ground to a 6.4 mm grind size and four aldehydes (heptanal, pentanal, octanal, and butanal, 3-methyl-), two ketones (2-propanone and 2-butanone), and four pyrazines (trimethyl-pyrazine; 2-ethyl-6-methyl-pyrazine; 2,5-dimethyl-pyrazine; 2-ethyl-5-methyl-pyrazine). This cluster indicated that these volatile compounds positively impacted flavor, but negatively impacted texture.

The second factor (t2) segmented mainly for volatile compounds that impacted texture with aromatics that positively impacted texture above the axis and aromatics that negatively impacted texture below the axis. A cluster formed in the lower left quadrant surrounding 3-acetylpyrrole; 1,2-dimethyl-benzene; phenyl acetaldehyde; dodecanoic acid, ethyl ester; and 1-(1H-pyrrol-2-yl)-ethanone volatile compounds and round bowl chopped 10% lipid ground beef patties. This cluster indicates that these volatile compounds negatively impacted both flavor and texture, and were disliked by consumers. Chuck ground beef patties at 10% lipid ground to 6.4 mm grind size, round ground beef patties at 20% lipid and bowl chopped, sirloin ground beef patties at 10% lipid both bowl chopped and ground to a 6.4 mm grind size, and regular ground beef patties at 20% lipid ground to a 6.4 mm grind size were closely related to 2-methyl pyrazine, 2-undecenal, and 2-4-decadienal volatile compounds. This cluster of treatments contributed to negative flavor and positive texture, and represent treatments disliked by consumers. Many of the treatments on this biplot were nearing the center axis that indicated that they may not have had a large impact on variation in volatile compounds. Overall, compounds that contributed to consumer liking were largely Maillard products developed during the cooking process.

Relationships between Trained Descriptive Flavor Panel and Volatile Aromatic Compounds in Ground Beef

A partial least squares regression biplot for trained descriptive flavor panel and volatile aromatic compounds is shown in Figure 9. This figure helps show the relationships between the trained panel attributes and volatile compounds. The first factor (t1) segmented mainly for volatile compounds and trained panel attributes that contributed to flavor with attributes that positively impacted flavor on the right of the axis, and attributes that negatively impacted flavor on the left. In the top right quadrant, a cluster exists surrounding beef flavor identity, roasted, umami, refrigerator stale, and cooked milk flavor attributes, as well as 2-(hexyloxy)-ethanol, decanal, 2-heptanone, hexanoic acid, and 3-ethyl-2,5-dimethyl-pyrazine volatile compounds, and chuck bowl chopped 20% lipid and sirloin 6.4 mm 20% lipid ground beef treatments. These attributes all contribute positively to flavor and texture and are the most liked treatments. A cluster formed in the bottom right quadrant including butanoic acid, trimethyl-pyrazine, 3-methyl-butanal, 2-propanone, 2-butanone, 2-ethyl-6-methyl-pyrazine, acetic acid, methanethiol, octane, 2,5-dimethyl-pyrazine, and 2-ethyl-5-methyl-pyrazine volatile compounds, medicinal flavor, and round 6.4 mm 20% ground beef patties. This cluster represents attributes that positively impacted flavor, but negatively impacted texture.

The second factor (t2) segmented mainly for volatile compounds and trained panel attributes that impacted texture with attributes that positively impacted texture above the axis and attributes that negatively impacted texture below the axis. A good majority of the volatile compounds are present in the bottom right quadrant or in the top right quadrant indicating that most of the volatile compounds positively impacted perception of flavor. About half of the volatile compounds positively impacted texture, while the other half negatively impacted texture. In the bottom left quadrant, a small cluster surrounds bitter, liver like, and sour descriptive attributes, as well as 2-nonenal. This cluster negatively impacted both flavor and texture. This quadrant also possesses a large portion of the ground beef treatments, but they are found relatively close to where the axes cross indicating they may not have had a large impact on variation. Lastly, in the upper left quadrant, a cluster surrounds particle size, springiness, petroleum like, burnt, and smoky charcoal flavor attributes, 2-methyl-butanal and 2-ethyl-3,5-dimethyl-pyrazine volatile compounds, and regular 6.4 mm 20% fat, chuck 6.4 mm 20% fat, regular bowl chopped 20% fat, round bowl chopped 20% fat, and sirloin bowl chopped 10% fat treatments. This cluster represents attributes and treatments that negatively impacted flavor but positively impacted texture.

Cook Yield Discussion

The data was evaluated using cook yield as a covariate to determine whether or not it impacted the results or could be used to account for variation. Cook yield did not impact a majority of the results. Differences in the meat source by fat interaction for burnt ($P = 0.06$), brown ($P = 0.10$), and bloody/serumy ($P = 0.13$) that were previously significant ($P < 0.05$) was not significant ($P > 0.05$) when cook yield was used as a covariate. For overall sweet flavor, differences existed in the meat source by fat interaction (*P* = 0.08) and the grind by fat interaction (*P* = 0.05) where the main effect for meat source was not significant (*P* > 0.05) when previously reported without the covariate, it was significant (*P* < 0.05). Differences in fat level for metallic (*P* = 0.80) and smoky charcoal (*P* = 0.45) existed when using cook yield as a covariate. This indicates that while only minor, cook yield did accounted for some differences across attributes.

CHAPTER V

CONCLUSIONS

With ground beef accounting for such a large percentage of beef consumption, understanding how flavor and texture affect overall consumer liking is becoming more crucial. This study confirmed that fat level contributes to flavor development, but is one of the first to highlight the importance of ground beef texture to the eating experience. Differences in beef flavor attributes, texture attributes, and aromatic volatiles are present through the manipulation of meat source, fat percentage, and grind treatments.

Today's restaurant industries are increasingly taking artisan approaches to traditional food preparation. One of the ways this has been personified is through the manipulation of ground beef texture. In a central location test, consumers consistently showed a preference 6.4 mm ground patties over bowl chopped patties. Meat source, fat level, and grind treatment interactions were also significant in the development of flavor. These interactions were unique in their volatile aromatic and flavor development throughout the Maillard reaction, which contributed to many of the differences. This study is valuable because it is the first study to utilize the full beef flavor lexicon and texture attributes to better understand how meat source, fat level, and grind size affect flavor and consumer perception of ground beef flavor. This study provides a good foundation to support future ground beef flavor and texture research projects utilizing the full beef flavor lexicon to better understand and explain any interactions.

Based on the results of this study, generally speaking, 6.4 mm ground patties and 20% fat patties were most liked overall. Chuck meat source represents what was most liked in flavor and texture by consumers, and clusters closely with consumer liking attributes and positive beef flavor attributes. Consumers preferred the texture of 20% fat patties over 10% fat patties, and 20% patties also scored higher across many positive trained panel attributes compared to the 10% fat patties. Lastly, consumers preferred the 6.4 mm grind over the bowl chopped patties across all consumer attributes.

REFERENCES

Adhikari, Koushik, et al. 2011. Development of a lexicon for beef flavor in intact muscle. Journal of Sensory studies. 26.6:413-420.

Ames, J. M. 1992. The Maillard reaction. In Biochemistry of food proteins. pp. 99-153. Springer US.

AMSA 1983. Guidelines for sensory, physical and chemical measurements in ground beef. Chicago, IL: American Meat Science Association and National Live Stock and Meat Board.

Batzer, O. F., Santoro, A. T., Tan, M. C., Landmann, W. A., & Schweigert, B. S. 1960. Meat flavor chemistry, precursors of beef flavor. Journal of Agricultural and Food Chemistry. 8(6):498-501.

Berry, B. W. 1992. Low fat level effects on sensory, shear, cooking, and chemical properties of ground beef patties. Journal of food science. 57(3):537-537.

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(1):10-14.

Berry, B. W., & Hasty, R. W. 1982. Influence of demographic factors on consumer purchasing patterns and preferences for ground beef. Journal of Consumer Studies & Home Economics. 6(4):351-360.

Berry, B. W., & Leddy, K. F. 1984. Effects of fat level and cooking method on sensory and textural properties of ground beef patties. Journal of Food Science. 49(3):870-875.

Blackmon, T., Miller, R. K., Kerth, C., & Smith, S. B. 2015. Ground beef patties prepared from brisket, flank and plate have unique fatty acid and sensory characteristics. Meat science. 103:46-53.

Boutrolle, I., Arranz, D., Rogeaux, M., & Delarue, J. 2005. Comparing central location test and home use test results: Application of a new criterion. Food Quality and Preference. 16(8):704-713.

Boutrolle, I., Delarue, J., Arranz, D., Rogeaux, M., & Köster, E. P. 2007. Central location test vs. home use test: Contrasting results depending on product type. Food Quality and Preference. 18(3):490-499.

Brewer, M. S. 2012. Reducing the fat content in ground beef without sacrificing quality: a review. Meat Science. 91(4):385-395.

Brewer, M. S., & Novakofski, J. 1999. Cooking rate, pH and final endpoint temperature effects on color and cook loss of a lean ground beef model system. Meat science. 52(4):443-451.

Burdock, G. A. 2010. Fenaroli's handbook of flavor ingredients. CRC press.

Cerny, C., & Grosch, W. 1992. Evaluation of potent odorants in roasted beef by aroma extract dilution analysis. Zeitschrift für Lebensmitteluntersuchung und-Forschung A. 194(4):322-325.

Cleveland, B. D., McEwan, R., Unruh, J. A., Garner, C. M., & Stroda, S. 2014. Aging Time Affects Color Stability and Sensory Properties of Ground Beef Patties Adjusted to a Similar Fat Composition by Combining Subprimals from the Chuck Roll and Knuckle.

Corbin, C. H., O'Quinn, T. G., Garmyn, A. J., Legako, J. F., Hunt, M. R., Dinh, T. T. N., ... & Miller, M. F. 2015. Sensory evaluation of tender beef strip loin steaks of varying marbling levels and quality treatments. Meat Science. 100:24-31.

Cox, R. B., Kerth, C. R., Gentry, J. G., Prevatt, J. W., Braden, K. W., & Jones, W. R. 2006. Determining acceptance of domestic forage-or grain-finished beef by consumers from three southeastern US states. Journal of Food Science. 71(7):S542-S546.

Cross, H. R., Berry, B. W., & Wells, L. H. 1980. Effects of fat level and source on the chemical, sensory and cooking properties of ground beef patties. Journal of food Science. 45(4):791-794.

Cross, H. R., Stanfield, M. S., & Franks, W. J. 1978. Objective measurements of texture in ground beef patties. Journal of Food Science. 43(5):1510-1513.

Delwiche, J. 2004. The impact of perceptual interactions on perceived flavor. Food Quality and preference. 15(2):137-146.

Demaree, Scott R., et al. 2002. Conjugated linoleic acid differentially modifies fatty acid composition in subcellular fractions of muscle and adipose tissue but not adiposity of postweanling pigs. The Journal of nutrition. 132.11:3272-3279.

Elmore, J. S., Mottram, D. S., Enser, M., & Wood, J. D. 1999. Effect of the polyunsaturated fatty acid composition of beef muscle on the profile of aroma volatiles. Journal of Agricultural and Food Chemistry. 47(4):1619-1625.

Flament, I., & Bessière-Thomas, Y. 2002. Coffee flavor chemistry. John Wiley & Sons.

Font-i-Furnols, M., & Guerrero, L. 2014. Consumer preference, behavior and perception about meat and meat products: An overview. Meat Science. 98(3):361-371.

Gilbertson, Timothy A., Sami Damak, and Robert F. Margolskee. 2000. The molecular physiology of taste transduction. Current opinion in neurobiology. 10.4:519-527.

Griffin, R., & Stauffer, L. 1990. Product optimization in central-location testing and subsequent validation and calibration in home-use testing. Journal of Sensory Studies. 5(4):231-240.

Hodge, J. E. 1953. Dehydrated foods, chemistry of browning reactions in model systems. Journal of agricultural and food chemistry, 1(15):928-943.

Hodgen, J. M., Cuppett, S. L., & Calkins, C. R. 2007. Identification of Off-Flavor Compounds in Beef Round and Chuck Muscles. Nebraska Beef Cattle Reports. 84.

Hornstein, Irwin, and P. F. Crowe. 1960. Meat flavor chemistry, flavor studies on beef and pork. Journal of Agricultural and Food Chemistry. 8.6:494-498.

Huffman, K. L., Miller, M. F., Hoover, L. C., Wu, C. K., Brittin, H. C., & Ramsey, C. B. 1996. Effect of beef tenderness on consumer satisfaction with steaks consumed in the home and restaurant. Journal of animal science. 74(1):91-97.

Imafidon, Gilbert Idolo, and Arthur M. Spanier. 1994. Unraveling the secret of meat flavor. Trends in food science & technology. 5.10:315-321.

James, J. M., & Calkins, C. R. 2008. The influence of cooking rate and holding time on beef chuck and round flavor. Meat science. 78(4):429-437.

Jenschke, B. E., Hodgen, J. M., Meisinger, J. L., Hamling, A. E., Moss, D. A., Lundesjö Ahnström, M., ... & Calkins, C. R. 2007. Unsaturated fatty acids and sodium affect the liver-like off-flavor in cooked beef. Journal of animal science. 85(11):3072-3078.

Jenschke, B. E., Swedberg, B. J., & Calkins, C. R. 2008. Tenderness, Sensory, and Color Attributes of Two Muscles from the Beef Knuckle.

Jeremiah, L. E., Gibson, L. L., Aalhus, J. L., & Dugan, M. E. R. 2003. Assessment of palatability attributes of the major beef muscles. Meat science. 65(3):949-958.

Jousse, F., Jongen, T., Agterof, W., Russell, S., & Braat, P. 2002. Simplified kinetic scheme of flavor formation by the Maillard reaction. Journal of Food Science. 67(7):2534-2542.

Kerth, C. R., Harbison, A. L., Smith, S. B., & Miller, R. K. 2015. Consumer sensory evaluation, fatty acid composition, and shelf-life of ground beef with subcutaneous fat trimmings from different carcass locations. Meat science. 104:30-36.

Kerth, Chris R., and Rhonda K. Miller. 2015. Beef flavor: a review from chemistry to consumer. Journal of the Science of Food and Agriculture. 95.14: 2783-2798.

King, D. A., Shackelford, S. D., Wheeler, T. L., Pfeiffer, K. D., Mehaffey, J. M., Miller, M. F., ... & Koohmaraie, M. 2009. Consumer acceptance and steak cutting yields of beef top sirloin and knuckle subprimals. Meat science. 83(4):782-787.

Kosowska, M., A Majcher, M., & Fortuna, T. 2017. Volatile compounds in meat and meat products. Food Science and Technology (Campinas). (AHEAD):0-0.

Ladikos, D., & Lougovois, V. 1990. Lipid oxidation in muscle foods: A review. Food chemistry. 35(4):295-314.

Legako, J. F., Dinh, T. T. N., Miller, M. F., & Brooks, J. C. 2015. Effects of USDA beef quality grade and cooking on fatty acid composition of neutral and polar lipid fractions. Meat science. 100:246-255.

Legako, J. F., Dinh, T. T. N., Miller, M. F., Adhikari, K., & Brooks, J. C. 2016. Consumer palatability scores, sensory descriptive attributes, and volatile compounds of grilled beef steaks from three USDA Quality Grades. Meat science. 112:77-85.

Lindemann, Bernd, Yoko Ogiwara, and Yuzo Ninomiya. 2002. The discovery of umami. Chemical senses. 27.9:843-844.

MacLeod, G. 1994. The flavour of beef. Flavor of meat and meat products. Springer US, 4-37.

Mattes, R. D. 2009. Is there a fatty acid taste? Annual review of nutrition. *29*:305-327.

Meilgaard, Morten, Gail Vance Civille, and B. Thomas Carr. 2007. Sensory Evaluation Techniques. Boca Raton: Taylor & Francis. Print.

Meisinger, J. L., James, J. M., & Calkins, C. R. 2006. Flavor relationships among muscles from the beef chuck and round. Journal of animal science. 84(10):2826-2833.

Melton, Sharon L. 1999. Current status of meat flavor. Quality attributes of muscle foods. Springer US,115-133.

Miller, M. F., Andersen, M. K., Ramsey, C. B., & Reagan, J. O. 1993. Physical and sensory characteristics of low fat ground beef patties. Journal of food science. 58(3):461-463.

Miller, R. K., Luckemeyer, T., & Kerth, C. R. 2014. Beef flavor attributes and consumer perception II. Final report to the National Cattlemen's Beef Association, Centennial, CO.

Mottram, D. S. 1998. Flavour formation in meat and meat products: a review. Food chemistry. 62(4):415-424.

Mottram, D. S. 2007. The Maillard reaction: source of flavour in thermally processed foods. In Flavours and fragrances. Springer Berlin Heidelberg. 269-283.

National Center for Biotechnology Information. PubChem Compound Database; https://pubchem.ncbi.nlm.nih.gov (accessed May 11, 2017).

North American Meat Processors Association (Ed.). 2004. The meat buyers guide. John Wiley & Sons Incorporated.

Pan, Z., & Singh, R. P. 2001. Physical and thermal properties of ground beef during cooking. LWT-Food Science and Technology. 34(7):437-444.

Randall, C. J., & Larmond, E. 1977. Effect of method of comminution (flake-cutting and grinding) on the acceptability and quality of hamburger patties. Journal of Food Science. 42(3):728-730.

Resurreccion, A. V. A. 2004. Sensory aspects of consumer choices for meat and meat products. Meat Science. 66(1):11-20.

Savell, J. W., Branson, R. E., Cross, H. R., Stiffler, D. M., Wise, J. W., Griffin, D. B., & Smith, G. C. 1987. National consumer retail beef study: palatability evaluations of beef loin steaks that differed in marbling. Journal of Food Science. 52(3):517-519.

Sitz, B. M., Calkins, C. R., Feuz, D. M., Umberger, W. J., & Eskridge, K. M. 2005. Consumer sensory acceptance and value of domestic, Canadian, and Australian grass-fed beef steaks. Journal of Animal Science. 83(12):2863-2868.

Sosa, M., Martinez, C., Marquez, F., & Hough, G. 2008. Location and scale influence on sensory acceptability measurements among low-income consumers. Journal of Sensory Studies. 23(5):707-719.

Sveinsdottir, K., Martinsdottir, E., Thorsdottir, F., Schelvis, R., Kole, A., & Thorsdottir, I. 2010. Evaluation of farmed cod products by a trained sensory panel and consumers in different test settings. Journal of Sensory Studies. 25(2):280-293.

Troutt, E. S., Hunt, M. C., Johnson, D. E., Claus, J. R., Kastner, C. L., Kropf, D. H., & Stroda, S. 1992. Chemical, physical, and sensory characterization of ground beef containing 5 to 30 percent fat. Journal of Food Science. 57(1):25-29.

USDA. 1988. Processing procedures and cooking instructions for cooked, uncured meat patties. Fed. Reg. 53(248):52179.

USDA. 1993. Heat processing, cooking and cooling, handling and storage requirements for uncured meat patties; Rule. Fed. Reg. 58(146):41138.

USDA. 2001. 319.15. Raw Meat Products – Miscellaneous beef products. 9 CFR Ch. III (1-1-12 Edition)

Von Seggern, D. D., Calkins, C. R., Johnson, D. D., Brickler, J. E., & Gwartney, B. L. 2005. Muscle profiling: Characterizing the muscles of the beef chuck and round. Meat Science. 71(1):39-51.

Winter M., Gautschi F., Flament I., Stoll M. and Goldman I.M. (Firmenich & Cie)
1975. Flavoring Agents: pyrazine compounds. US Patent 391787.

APPENDIX A TABLES

Table 1. Definition and reference standards for beef descriptive flavor aromatics and basic taste sensory attributes and their intensities where 0 = none and 15 = extremely intense Adapted from Adhikari et al. (2011).

Attributes	Definition	Reference
Flavor		
Animal Hair	The aromatic perceived when raw wool is saturated with water.	Caproic acid (Hexanoic acid) = 12.0 (a)
Apricot	Fruity aromatics that can be described as specifically apricot.	Sun sweet dried apricot = 7.5 (f)
Asparagus	The slightly brown, slightly earthy green aromatics associated with cooked green asparagus.	Asparagus water (40 g asparagus and 300 mL water microwaved 3 min) = 7.5 (a); 6.5 (f)
Barnyard	Combination of pungent, slightly sour, hay-like aromatics associated with farm animals and the inside of a horn.	White pepper (0.45 g in 300 mL water heated to 180°F for 30 min) = 4.5 (a); 4.0 (f) Tinture of civet = 6.0 (a)
Beef Flavor ID	Amount of beef flavor identity in the sample.	Swanson's beef broth = 5.0 (f) 80% lean ground beef = 7.0 (f) Beef brisket (160 ^{o}F)= 11.0 (f)
Beet	A dark damp-musty-earthy note associated with caned red beets.	Food club sliced beets (1:2 juice to water) = 6.0 (a); 4.0 (f)
Bitter	The fundamental taste factor associated with a caffeine solution.	0.01% caffeine solution = 2.0 (f) 0.02% caffeine solution = 3.5 (f)
Bloody/Serumy	The aromatics associated with blood on cooked meat products. Closely related to metallic aromatic.	USDA Choice strip steak (60 ^{o}C internal) = 5.5 (f) Beef brisket = 6.0 (f)

Browned	Aromatic associated with the outside of grilled or broiled meat; seared but not blackened or burnt.	Steak cooked at high temperature (internal 137 °F, seared on outside)
Burnt	The sharp/acrid flavor note associated with over roasted pork muscle, something over baked or excessively browned in oil.	Arrowhead Mills Puffed Barley Cereal = 3.0 (a) (f)
Buttery	Sweet, dairy-like aromatic associated with natural butter.	Land O'Lakes Unsalted butter = 7.0 (f)
Cardboardy	Aromatic associated with slightly oxidized fats and oils, reminiscent of wet cardboard packaging.	Dry cardboard (1 in. square) = 5.0 (a) Wet cardboard (1 in. square and 1 cup water) = 7.0 (a)
Chemical	Aromatic associated with garden hose, hot Teflon pan, plastic packaging and petroleum based products such as charcoal lighter fluid.	Zip-Loc in medium snifter = 13.0 (a) Clorox® in water(1 drop in 200 mL of deionized water) = 6.5 (f)
Chocolate/Cocoa	Aromatics associated with cocoa beans and powdered cocoa and chocolate bars. Brown, sweet, dusty, often bitter aromatics.	Hershey chocolate kiss = 7.5 (a); 8.5 (f) Hershey cocoa powder in water = 3.0 (f)
Cooked Milk	The combination of sweet, brown flavor notes, and aromatics associated with heated milk.	Dillon's whole milk (1 cup microwaved for 2 minutes) = 4.5 (f) Mini Baybel Original Swiss Cheese Regular = 2.5 (f)
Cumin	The aromatics commonly associated with cumin and characterized as dry, pungent, woody and slightly floral.	McCormick or Shilling Ground Cumin = 10.0 (a); 7.0 (f)
Dairy	Aromatics associated with products made from cow's milk, containing butter fat such as cream, milk, sour cream or buttermilk	Dillon's 2% milk = 8.0 (f)
Fat-Like	The aromatics associated with cooked animal fat.	Hillshire farms Lit'l beef smokies = 7.0(f) Beef suet = 12.0 (f)
Fishy	Aromatic associated with trimethlamine and old fish	Canned StarKist Tuna = 12.0 (f); 10.0 (a)
Floral	Sweet light, slightly perfume impression associated with flowers.	Welch's White Grape juice Diluted (1:1) = 5.0 (f) Geraniol (1 drop on cotton ball) = 7.5 (a)

Green	Sharp, slightly pungent aromatics associated with green/plant/ vegetable matter such as parsley, spinach, pea pod, fresh cut grass, etc.	Hexanal (50 mL) in propylene glycol (10 mL) at 5000ppm = 6.5 (a) Fresh parsley water (25 g parsley Steeped in water for 15 min then drained) = 9.0 (f)
Green Haylike	Brown/green dusty aromatics associated with dry grasses, hay, dry parsley and tea leaves.	Dry parsley in medium snifter = 5.0 (a)
Heated Oil	The aromatics associated with oil heated to a high temperature.	Wesson Vegetable Oil (1/2 cup, 3 min microwaved) = 7.0 (a)(f) Lay's Potato Chips (4 chips in medium snifter) = 4.0 (a)
Leather (old)	Musty, old leather (like old book bindings).	2,3,4 – Trimethoxybenzaldehyde (neat) = 3.0 (a)
Liver-like	Aromatics associated with cooked organ meat/liver.	Beef liver (broiled) =7.5 (f) Brauschweiger liver sausage = 10.0 (f)
Medicinal	A clean sterile aromatic characteristic of antiseptic like products such as Band-Aids, alcohol and iodine	Band-Aid in medium snifter = 6.0 (a) Iodine drops on cotton ball in medium snifter
Metallic	The impression of slightly oxidized metal, such as iron, copper, and silver spoons.	0.10% Potassium Chloride solution = 1.5 (f) Select strip Steak (cooked to 60 ^{o}C internal) = 4.0 (f) Dole Canned Pineapple Juice = 6.0 (f)
Musty-Earthy/ Humus	Musty, sweet, decaying vegetation.	Mushrooms = 0 1000 ppm of 2,6-Dimethylcyclohexanol = 9.0 (a)
Nutty	Nutty characteristics are: sweet, oily, light brown, slightly musty, and/or buttery, earthy, woody, astringent, bitter, etc.	Diamond Shelled Walnuts (ground for one minute) = 6.5 (f)
Overall Sweet	The combination of sweet taste and sweet aromatics.	Post Shredded Wheat Spoon Size = 1.5 (f) Hillshire Farms Lit'l Beef Smokies (microwaved for 2.5 minutes with ¼ c water) = 3.0 (f) Lorna Doone Cookies = 5.0 (f)

Painty	Aromatic associated with oxidized oil; similar to the aromatic of linseed oil and oil-based paint.	Wesson oil 14 days at 100 ^{o}C = 8.0 (f); 10.0 (a)
Petroleum-like	A specific chemical aromatic associated with crude oil and it's refined products that have heavy oil characteristics.	Vaseline petroleum jelly = 3.0 (a)
Rancid	An aromatic commonly associated with oxidized fat and oils. These aromatics may include cardboard, painty, vanish, and fishy.	Wesson Vegetable Oil (1/2 cup, 3 min microwaved) = 7.0 (f) Wesson Vegetable Oil (1/2 cup, 5 min microwaved) = 9.0 (f)
Refrigerator Stale	Aromatics associated with products left in refrigerator for an extended period of time and absorbing a combination of odors (lack of freshness/flat).	Ground beef (1/2 lb. cooked to 165 ^{o}F with grease drained, stored overnight served room temp) = 4.5 (a); 5.5 (f)
Roasted	Aromatic associated with roasted meat.	Precooked Roast
Salty	The fundamental taste factor of which sodium chloride is typical.	0.15% sodium chloride solution = 1.5 0.25% sodium chloride solution = 3.5
Smoky Charcoal	An aromatic associated with meat juices and fat dripping on hot coals, which can be acrid, sour, burned, etc.	Wright's Natural Hickory seasoning (1/4 tsp. in 100 ml of water) = 9.0 (a)
Smoky Wood	Dry, dusty aromatic reminiscent of burning wood.	Wright's Natural Hickory seasoning (1/4 tsp. in 100 ml of water) = 7.5 (a)
Soapy	An aromatic commonly found in unscented hand soap.	Ivory Bar soap (0.5g soap in 100 mL water) = 6.5 (a)
Sour	The fundamental taste factor associated with citric acid.	0.015% citric acid solution = 1.5 (f) 0.050% citric acid solution = 3.5 (f)
Sour Aromatics	Aromatics associated with sour substances.	Dillon's buttermilk (covered) = 5.0 (a)
Sour Milk/Sour Dairy	Sour, fermented aromatics associated wit dairy products such as buttermilk and sour cream	Laughing Cow Light Swiss Cheese = 3.0 (a) Dillon's Buttermilk = 4.0 (a)

Spoiled-Putrid	The presence of inappropriate aromatics and flavors that is commonly associated with the products. It is a foul taste and or smell that indicates the product is starting to decay and putrefy.	Dimethyl disulfide (100mL) in propylene glycol (10mL) at 10000 ppm = 12.0 (a)
Sweet	The fundamental taste factor associated with sucrose.	2.0% sucrose solution = 2.0
Umami	Flat, salty, somewhat brothy. The taste of glutamate, salts of amino acids and other molecules called nucleotides.	0.035% Accent Flavor Enhancer solution = 7.5 (f)
Warmed Over	Perception of a product that has been previously cooked and reheated	Reheated ground beef (cook in 400 ^{o}F oven until internal temp is 165 ^{o}F) = 6.0 (f)
Texture		
Cohesiveness of Mass	The degree to which chewed sample (at 10 – 15 chews) holds together in a mass. Technique: chew sample with molars for up to 15 chews.	Licorice = 0.0 Carrots = 2.0 Mushrooms = 4.0 Frankfurter = 7.5 American Process Cheese = 9.0 Soft Brownie = 13.0 Pillsbury/Country Biscuit dough = 15.0
Hardness	The force to attain a given deformation, such as: force to compress with the molars; force to compress between tongue and palate; force to bite through with incisors.	Cream Cheese = 1.0 Egg White = 2.5 Yellow American Cheese = 4.5 Olives = 6.0 Hebrew National Frankfurter = 7.0 Planters Peanut = 9.5 Life Savers – 14.5
Initial Juiciness	The amount of perceived juice that is released from the product during the initial 2 – 3 chews.	Carrot = 8.5 Mushroom = 10.0 Cucumber = 12.0 Apple = 13.5 Watermelon = 15.0

Particle Size	The degree to how large or small the particle is.	Small pearly tapioca = 4.0 Boba tea tapioca = 8.0
Springiness	The degree to which sample returns to original shape or the rate with which sample returns to original shape. **Technique:** place sample between molars; compress partially without breaking the sample structure; release.	Cream Cheese = 0.0 Frankfurter = 5.0 Marshmallow = 9.5 Gelatin dessert = 15.0

Table 2. Least squares means for burnt flavor descriptive attribute interactions (Root Mean Square Error = 0.50)

Treatment	*P*-value	Burnt
Meat Source by Grind Interaction	0.03	
Regular, 6.4 mm		0.3^{ab}
Regular, bowl chop		0.3^{a}
Round, 6.4 mm		0.6^{b}
Round, bowl chop		0.2^{a}
Sirloin, 6.4 mm		0.3^{ab}
Sirloin, bowl chop		0.4^{ab}
Chuck, 6.4 mm		0.2^{a}
Chuck, bowl chop		0.4^{ab}
Meat Source by Fat Interaction	0.03	
Regular, 10% fat		0.2^{a}
Regular, 20% fat		0.4^{abc}
Round, 10% fat		0.5^{bc}
Round, 20% fat		0.3^{abc}
Sirloin, 10% fat		0.2^{a}
Sirloin, 20% fat		0.6^{c}
Chuck, 10% fat		0.3^{abc}
Chuck, 20% fat		0.3^{abc}

[abc]Mean values within a column and interaction followed by the same letter are not significantly different ($P > 0.05$).

Table 3. Least squares means for green flavor descriptive attribute interactions (Root Mean Square Error = 0.50)

Treatment	*P*-value	Green
Meat Source by Grind Interaction	0.02	
Regular, 6.4 mm		0.1[ab]
Regular, bowl chop		0.1[a]
Round, 6.4 mm		0.1[a]
Round, bowl chop		0.2[b]
Sirloin, 6.4 mm		0.0[a]
Sirloin, bowl chop		0.1[a]
Chuck, 6.4 mm		0.1[ab]
Chuck, bowl chop		0.0[a]

[ab]Mean values within a column and interaction followed by the same letter are not significantly different ($P > 0.05$).

Table 4. Least squares means for overall sweet flavor descriptive attribute interactions (Root Mean Square Error = 0.50)

Treatment	*P*-value	Overall Sweet
Meat Source by Fat Interaction	0.05	
Regular, 10% fat		1.4[bcd]
Regular, 20% fat		1.3[bc]
Round, 10% fat		1.1[a]
Round, 20% fat		1.4[bc]
Sirloin, 10% fat		1.2[ab]
Sirloin, 20% fat		1.5[cd]
Chuck, 10% fat		1.3[abc]
Chuck, 20% fat		1.6[d]
Grind by Fat Interaction	0.04	
6.4 mm, 10% fat		1.2[a]
6.4 mm, 20% fat		1.5[c]
Bowl chop, 10% fat		1.3[ab]
Bowl chop, 20% fat		1.4[bc]

[abcd]Mean values within a column and interaction followed by the same letter are not significantly different ($P > 0.05$).

Table 5. Least squares means for beef identity, brown, roasted, bloody/serumy, umami, salty, and particle size flavor and texture descriptive attribute interactions (Root Mean Square Error = 0.50)

Treatment		Beef Identity	Brown	Roasted	Bloody/ Serumy	Umami	Salty	Particle Size
Grind	(*P* > F)	0.27	0.25	0.29	0.81	0.0005	0.18	0.0004
6.4mm		10.0	10.2	9.1	2.0	4.2[b]	2.2	3.7[b]
Bowl chop		9.9	10.1	9.0	2.0	4.0[a]	2.2	3.5[a]
Meat Source by Fat Interaction	(*P* > F)	<0.0001	0.02	<0.0001	0.01	0.03	0.006	0.02
Regular, 10% fat		10.1[bc]	10.2[bc]	9.1[bc]	2.3[c]	3.9[a]	2.3[b]	3.6[ab]
Regular, 20% fat		9.6[a]	10.2[bc]	8.7[ab]	2.4[c]	3.8[a]	2.1[a]	4.0[c]
Round, 10% fat		9.9[ab]	10.2[bc]	9.2[cd]	1.7[a]	4.0[ab]	2.3[b]	3.4[a]
Round, 20% fat		10.0[bc]	10.1[bc]	9.1[cd]	1.7[a]	4.4[c]	2.2[b]	3.7[b]
Sirloin, 10% fat		9.5[a]	9.6[a]	8.5[a]	2.3[c]	3.7[a]	2.1[a]	3.6[ab]
Sirloin, 20% fat		10.3[c]	10.5[c]	9.5[d]	1.4[a]	4.3[c]	2.3[b]	3.5[ab]
Chuck, 10% fat		10.0[bc]	10.0[ab]	9.0[bc]	2.2[bc]	4.2[bc]	2.2[ab]	3.5[ab]
Chuck, 20% fat		10.2[bc]	10.1[bc]	9.1[cd]	1.8[ab]	4.5[c]	2.3[b]	3.5[ab]
Root Mean Square Error		0.57	0.66	0.57	0.71	0.48	0.20	0.32

[abcd]Mean values within a column and interaction followed by the same letter are not significantly different (*P* > 0.05).

Table 6. Least squares means for flavor and texture attributes not possessing interactions (Root Mean Square Error = 0.50)

	Grind Type			Meat Source					Fat Level			
Attribute	*P*-value	6.4 mm	Bowl Chop	*P*-value	Regular	Round	Sirloin	Chuck	*P*-value	10	20	RMSE
Flavor												
Bitter	0.91	2.3	2.2	0.01	2.1[a]	2.4[b]	2.3[b]	2.2[ab]	0.002	2.3[b]	2.2[a]	0.27
Buttery	0.71	0.9	0.9	0.28	1.0	0.9	0.8	1.0	<0.0001	0.6[a]	1.2[b]	0.58
Cardboardy	0.43	2.3	2.4	0.04	2.2[a]	2.3[ab]	2.6[b]	2.3[a]	0.0002	2.5[b]	2.2[a]	0.57
Cooked Milk	0.58	0.2	0.2	0.35	0.3	0.2	0.3	0.2	0.13	0.2	0.2	0.24
Fat-like	0.60	3.5	3.5	0.02	3.7[b]	3.3[a]	3.4[ab]	3.6[b]	<0.0001	3.1[a]	3.9[b]	0.52
Heated Oil	0.75	0.8	0.8	0.71	0.8	0.8	0.8	0.9	<0.0001	0.4[a]	1.2[b]	0.53
Liver-like	0.81	0.4	0.4	0.04	0.2[a]	0.6[b]	0.4[ab]	0.4[ab]	<0.0001	0.6[b]	0.2[a]	0.50
Medicinal	0.04	0.1	0.1	0.16	0.1	0.1	0.1	0.0	0.42	0.1	0.1	0.24
Metallic	0.56	2.4	2.4	0.67	2.5	2.4	2.3	2.4	<0.0001	2.5	2.2	0.43
Musty/ Earthy	0.15	0.6	0.8	0.19	0.5	0.8	0.9	0.7	0.08	0.8	0.6	0.65
Petroleum-Like	0.64	0.4	0.4	0.15	0.6	0.3	0.4	0.4	0.09	0.3	0.5	0.48
Refrigerator Stale	0.10	0.1	0.2	0.41	0.1	0.2	0.2	0.1	0.64	0.2	0.2	0.30
Smoky Charcoal	0.93	0.7	0.7	0.69	0.8	0.7	0.6	0.6	0.01	0.5[a]	0.8[b]	0.64
Sour	0.98	2.5	2.5	<0.0001	2.4[a]	2.8[b]	2.4[a]	2.5[a]	<0.0001	2.7[b]	2.3[a]	0.28
Sour Milk/ Sour Dairy	0.61	0.3	0.2	0.005	0.2[a]	0.5[b]	0.1[a]	0.3[a]	0.01	0.3[b]	0.2[a]	0.37
Sweet	0.41	1.8	1.8	0.39	1.8	1.8	1.8	1.9	0.005	1.8[a]	1.9[b]	0.26
Warmed Over	0.07	0.4	0.6	0.16	0.5	0.4	0.7	0.5	0.93	0.5	0.5	0.59
Texture												
Cohesiveness Of Mass	0.37	7.4	7.4	0.32	7.5	7.3	7.4	7.4	0.11	7.4	7.3	0.36
Hardness	<0.0001	5.3[a]	5.7[b]	0.007	5.7[b]	5.6[b]	5.5[ab]	5.3[a]	0.49	5.6	5.5	0.52
Juiciness	0.07	10.7	10.6	0.16	10.7	10.7	10.5	10.8	0.0001	10.5[a]	10.8[b]	0.56
Springiness	<0.0001	5.2[a]	5.5[b]	0.009	5.6[b]	5.3[a]	5.2[a]	5.3[a]	0.09	5.3	5.4	0.49

[ab]Mean values within a column and interaction followed by the same letter are not significantly different ($P > 0.05$).

Table 7. Demographic frequencies for beef consumers (n = 314) across four cities.

Question	Number of Respondents	Percentage of Respondents
Sex		
Male	132	42.2
Female	181	57.8
Age		
20 years or younger	4	1.3
21 – 25 years	38	12.1
26 – 35 years	97	30.9
36 – 45 years	62	19.7
46 – 55 years	65	20.7
56 – 65 years	46	14.7
66 years and older	2	0.6
Ethnicity		
African-American	19	6.1
Asian/Pacific Islanders	27	8.6
Caucasian (non-Hispanic)	244	77.7
Latino or Hispanic	14	4.5
Native American	3	1.0
Other	7	2.2
Household income		
Below $25,000	49	15.7
$25,001 - $49,999	79	25.3
$50,000 - $74,999	83	26.6
$75,000 - $99,999	52	16.7
$100,000 or more	49	15.7
Household size including yourself		
1	52	16.6
2	128	40.9
3	66	21.1
4	42	13.4
5	15	4.8
6 or more	10	3.2
Employment level		
Not employed	40	12.7
Part-time	55	17.5
Full-time	219	69.8

Proteins consumed at home or at a restaurant (away from home)

At Home	**Do not consume**	**Consume**	**Do not consume**	**Consume**
Chicken	7	306	2.2	97.8
Beef (steaks)	43	269	13.8	86.2
Ground Beef	13	259	4.8	95.2
Pork	37	235	13.6	86.4
Fish	47	225	17.3	82.7
Lamb	199	73	73.2	26.8
Egg	10	262	3.7	96.3
Soy Based Products	167	105	61.4	38.6

Away from Home /Restaurant	Do not consume	Consume	Do not consume	Consume
Chicken	16	296	5.1	94.9
Beef (steaks)	40	272	12.8	87.2
Ground Beef	24	248	8.8	91.2
Pork	59	213	21.7	78.3
Fish	40	232	14.7	85.3
Lamb	169	103	62.1	37.9
Eggs	32	240	11.8	88.2
Soy Based Products	171	101	62.9	37.1

Weekly consumption of protein		
Beef		
0	14	4.6
1 – 2	235	76.8
3 – 4	44	14.4
5 – 6	10	3.3
7 or more	3	1.0
Ground Beef		
0	6	1.9
1 – 2	216	69.5
3 – 4	75	24.1
5 – 6	12	3.9
7 or more	2	0.6
Pork		
0	38	12.8
1 – 2	230	77.4
3 – 4	28	9.4
5 – 6	1	0.4
7 or more	0	0.0
Lamb		
0	197	75.5
1 – 2	62	23.8
3 – 4	2	0.8
5 – 6	0	0.0
7 or more	0	0.0
Chicken		
0	4	1.3
1 – 2	134	43.2
3 – 4	130	41.9
5 – 6	38	12.3
7 or more	4	1.3
Fish		
0	50	16.9
1 – 2	213	72.0
3 – 4	26	8.8
5 – 6	6	2.0

7 or more	1	0.3
Soy Based Products		
0	155	57.0
1 – 2	99	36.4
3 – 4	15	5.5
5 – 6	1	0.4
7 or more	2	0.7

What cooking method do you prefer to use when cooking ground beef?

	Do not use	**Use**	**Do not use**	**Use**
Pan-frying or skillet on the Stove	53	259	17.0	83.0
Grilling outside	84	228	26.9	73.1
Oven baking	204	108	65.4	34.6
Electric appliance (George Forman Grill or other Electric grill)	254	58	81.4	18.6
Stir fry	218	94	69.9	30.1
Oven broiling	261	51	83.7	16.4
Microwave	289	23	92.6	7.4

Degree of doneness preference for ground beef

Rare	4	1.2
Medium Rare	65	18.8
Medium	99	28.7
Medium Well	104	30.1
Well	56	16.2
Very Well	17	4.9

When purchasing ground beef, what do you typically tend to buy at the retail store?

	Do not	**Purchase**	**Do not**	**Purchase**
Grass Fed	241	70	77.5	22.5
Dry Aged	305	6	98.1	1.9
Organic	258	53	83.0	17.0
Traditional beef at the retail store	78	233	25.1	74.9

What percentage of fat do you normally buy when purchasing ground beef?

	Do not	**Purchase**	**Do not**	**Purchase**
4%	280	29	90.6	9.4
7%	242	67	78.3	21.7
10%	216	93	69.9	30.1
15%	214	95	69.3	30.7
20%	253	56	81.9	18.1
27%	306	3	99.0	1.0

What type of ground beef do you typically buy at the retail store?

	Do not	**Purchase**	**Do not**	**Purchase**

Ground Chuck	217	94	69.8	30.2
Ground Round	286	25	92.0	8.0
Ground Sirloin	261	50	83.9	16.1
Ground Beef	94	217	30.2	69.8

What flavor or types of cuisines do you like?

	Do not eat	**Eat**	**Do not eat**	**Eat**
American	15	298	4.8	95.2
Chinese	53	260	16.9	83.1
French	182	131	58.2	41.9
Barbeque	23	290	7.4	92.7
Greek	157	156	50.2	49.8
Thai	131	182	41.9	58.2
Mexican/Spanish	34	279	10.9	89.1
Japanese	138	175	44.1	55.9
Lebanese	230	83	73.5	26.5
Indian	172	141	55.0	45.1
Italian	47	266	15.0	85.0

Table 8. Consumer liking attributes[a] for ground beef patties.

Effect		Cooked Appearance Liking	Overall Liking	Flavor Liking	Texture Liking
Meat Source	(P > F)	0.15	0.06	0.01	0.004
Regular		5.5	5.5	5.7[a]	5.4[b]
Round		5.7	5.6	5.8[a]	5.5[bc]
Sirloin		5.8	5.7	5.8[a]	5.6[cd]
Chuck		5.7	5.8	6.0[b]	5.8[d]
Grind	(P > F)	<0.0001	<0.0001	<0.0001	<0.0001
6.4 mm		5.9[c]	5.9[c]	6.0[c]	5.9[c]
Bowl		5.5[b]	5.4[b]	5.6[b]	5.2[b]
Fat Level, %	(P > F)	0.15	0.06	0.48	0.01
10		5.6	5.6	5.8	5.5[b]
20		5.7	5.7	5.9	5.7[c]
Grind by Fat	(P > F)	0.008	0.02	0.01	-
6.4 mm, 10% fat		5.9[e]	6.0[d]	6.1[c]	-
6.4 mm, 20% fat		5.8[d]	5.9[d]	6.0[c]	-
Bowl chop, 10% fat		5.3[b]	5.2[b]	5.5[b]	-
Bowl chop, 20% fat		5.6[c]	5.6[c]	5.8[b]	-
Meat Source by Fat Interaction	(P > F)	-	-	0.03	-
Regular, 10% fat		-	-	5.8[cde]	-
Regular, 20% fat		-	-	5.5[b]	-
Round, 10% fat		-	-	5.7[bcd]	-
Round, 20% fat		-	-	5.9[cde]	-
Sirloin, 10% fat		-	-	5.7[bc]	-
Sirloin, 20% fat		-	-	5.9[cde]	-
Chuck, 10% fat		-	-	6.0[de]	-
Chuck, 20% fat		-	-	6.1[e]	-
Root Mean Square Error		1.94	1.90	1.96	2.02

[a]Consumer liking measured where 0= extremely dislike and 9 = extremely like

[bcde]Mean values within a column and interaction followed by the same letter are not significantly different (P > 0.05).

Table 9. Least squares means for volatile compound grind by fat interactions.

Treatment	Acetic acid	2-ethyl-3,5-dimethyl-pyrazine
Grind by Fat Interaction (*P* >F)	0.01	0.04
6.4 mm, 10% fat	43616[a]	586[a]
6.4 mm, 20% fat	105029[b]	6525[b]
Bowl chop, 10% fat	76655[a]	3770[ab]
Bowl chop, 20% fat	41716[a]	1225[ab]

[ab]Mean values within a column and interaction followed by the same letter are not significantly different ($P > 0.05$).

Table 10. Least squares means for volatile compound meat by grind interactions.

Treatment	P-value	Hexanal
Meat Source by Grind Interaction	0.02	
Regular, 6.4 mm		861712^{b}
Regular, bowl chop		247041^{ab}
Round, 6.4 mm		833596^{b}
Round, bowl chop		139300^{a}
Sirloin, 6.4 mm		404668^{ab}
Sirloin, bowl chop		283700^{ab}
Chuck, 6.4 mm		174407^{ab}
Chuck, bowl chop		808124^{ab}

^{ab}Mean values within a column and interaction followed by the same letter are not significantly different ($P >$ 0.05).

Table 11. Least squares means for volatile compounds not possessing interactions.

	Meat Source					Grind Type			Fat Level		
Compound	*P*-value	Regular	Round	Sirloin	Chuck	*P*-value	6.4 mm	Bowl Chop	*P*-value	10	20	RMSE
Acids and Anhydrides												
Butanoic acid	0.35	0	3141	202	8478	0.29	4968	930	0.11	0	5949	22661.42
Decanoic acid, ethyl ester	0.26	15064	30238	272	32677	0.82	18102	21024	0.82	18107	21018	77556.41
Dodecanoic acid, ethyl ester	0.31	3731	11797	0	2152	0.06	59	8719	0.75	3635	5142	28023.54
Hexanoic acid	0.68	3743	8270	0	4226	0.42	5954	2130	0.43	5922	2162	28461.41
Alcohols												
1-Octen-3-ol	0.29	19683	38318	3884	12415	0.36	24570	12580	0.31	25148	12002	77531.54
2-(hexyloxy)-ethanol	0.005	23732^{a}	16772^{a}	9985^{a}	89595^{b}	0.24	24628	45413	0.97	35286	34756	104703.20
Aldehydes												
Benzaldehyde	0.49	596653	479484	486136	601663	0.25	584065	497902	0.006	644330^{b}	437638^{a}	442543.00
Phenyl Acetal-dehyde	0.89	8734	10289	7059	11479	0.23	6823	11958	0.12	12747	6033	25375.19
Nonenal	0.69	36860	17165	32130	24021	0.61	30715	24373	0.005	9944^{a}	45144^{b}	73885.14
Benzeneacet-aldehyde	0.12	44911	52106	15507	44311	0.02	52324^{b}	26094^{a}	0.53	42864	35554	68803.81
3-methyl-butanal	0.48	18394	10026	450	4051	0.16	14283	2178	0.19	2687	13773	50720.83
N Heptanal	0.97	84359	98606	92705	111571	0.30	118627	74994	0.50	82397	111223	252046.20
Octanal	0.84	154242	149934	143726	188406	0.27	180649	137506	0.32	178440	139714	231761.70
Tetradecanal	0.19	2847	0	3260	12309	0.49	6056	3132	0.14	1476	7711	25215.30
(E)-2-Nonenal	0.65	8244	14642	11972	21014	0.68	15452	12484	0.27	18025	9911	43420.43
Pentanal	0.95	11207	14764	10792	15985	0.13	18916	7458	0.19	8206	18168	44915.62
(E)-2-Decenal	0.63	125796	99030	123801	161082	0.92	125851	129003	0.58	118200	136654	200726.60
3-Dodecen-1-al	0.88	51945	50438	73125	66415	0.31	72354	48607	0.88	62232	58729	139274.20
2-Undecenal	0.87	49962	50681	24947	41230	0.08	20253	63157	0.30	29117	54293	145975.10
Nonanal	0.97	570933	586346	566668	609983	0.21	629794	537171	0.06	651811	515154	438362.90
(E, E)-2,4-decadienal	0.28	7162	22788	21864	26553	0.83	20376	18807	0.10	13416	25768	44588.76

Decanal	0.56	0	72	4038	6562	0.15	5447	0	0.16	0	5411	23060.12
2-methyl-butanal	0.33	0	10041	74	5011	0.09	7585	0	0.58	4984	2565	26390.85
Furans												
2-pentyl-furan	0.66	11772	18307	15639	8079	0.16	17747	9151	0.96	13326	13572	36818.06
Hydrocarbons												
1,3-dimethyl-benzene	0.11	0	0	1453	9095	0.21	623	4548	0.40	1262	3908	18645.42
1,2-dimethyl-benzene	0.37	7	918	0	0	0.34	10	443	0.29	462	0	2673.57
Heptane	0.41	0	0	11339	16277	0.66	4937	8685	0.09	0	13899	50458.05
Octane	0.47	10216	57781	3084	10195	0.24	36545	4092	0.34	7325	33313	163000.90
Ketones												
2-Heptanone	0.83	7173	8514	3272	4342	0.07	9916	1734	0.67	6781	4869	26849.84
3-hydroxy-2-butanone	0.39	3339	38332	31005	73672	0.16	57024	16150	0.53	27568	45606	172376.40
2-Propanone	0.99	19230	19882	18826	20912	0.14	27291	12134	0.55	16666	22759	61178.41
2-Butanone	0.93	6739	7869	4540	9968	0.14	11784	2774	0.81	6565	7993	36447.11
Pyrazine												
2,5-dimethyl-pyrazine	0.28	271807	253398	167707	159120	0.002	292949[b]	133068[a]	0.75	204926	221091	303334.10
3-ethyl-2,5-dimethyl-pyrazine	0.49	25662	22563	10033	12524	0.009	28786[b]	6605[a]	0.74	19065	16326	49952.67
trimethyl-pyrazine	0.66	72400	55591	40124	39637	0.01	76954[b]	26922[a]	0.84	49855	54021	125377.20
2-ethyl-5-methyl-pyrazine	0.11	20633	23655	9114	5174	0.03	21298[b]	7990[a]	0.80	15414	13874	37291.78
2-ethyl-6-methyl-pyrazine	0.61	15474	9778	7632	6155	0.02	15633[b]	3886[a]	0.48	7942	11578	30969.24
2-methyl-pyrazine	0.49	10336	127	5558	6216	0.19	8556	2563	0.05	10033	1086	27430.52

methyl-pyrazine	0.80	14096	8486	3365	10000	0.26	13291	4682	0.65	7305	10668	45061.19
Pyrroles												
3-Acetylpyrrole	0.60	0	2260	1100	308	0.56	545	1287	0.22	1697	136	7573.91
1-(1H-pyrrol-2-yl)-ethanone	0.15	23730	20277	4111	18016	0.75	15536	17531	0.002	26339[b]	6728[a]	37924.57
Thiols and Sulfides												
Carbon disulfide	0.16	7318	20035	4141	13917	0.94	11152	11554	0.49	13183	9523	31731.75
Methanethiol	0.28	534	1484	19	0	0.09	1024	0	0.37	233	786	3647.97
Other												
dl-Limonene	0.55	40	5248	5079	1209	0.87	3144	2644	0.89	2677	3111	18821.82

[ab]Mean values within a column and interaction followed by the same letter are not significantly different ($P > 0.05$).

Figure 1. Consumer liking (a) and dislike (b) descriptors for chuck meat source.

(a)

(b)

Figure 2. Consumer liking (a) and dislike (b) descriptors for regular meat source.

(a)

(b)

Figure 3. Consumer liking (a) and dislike (b) descriptors for round meat source.

(a) **(b)**

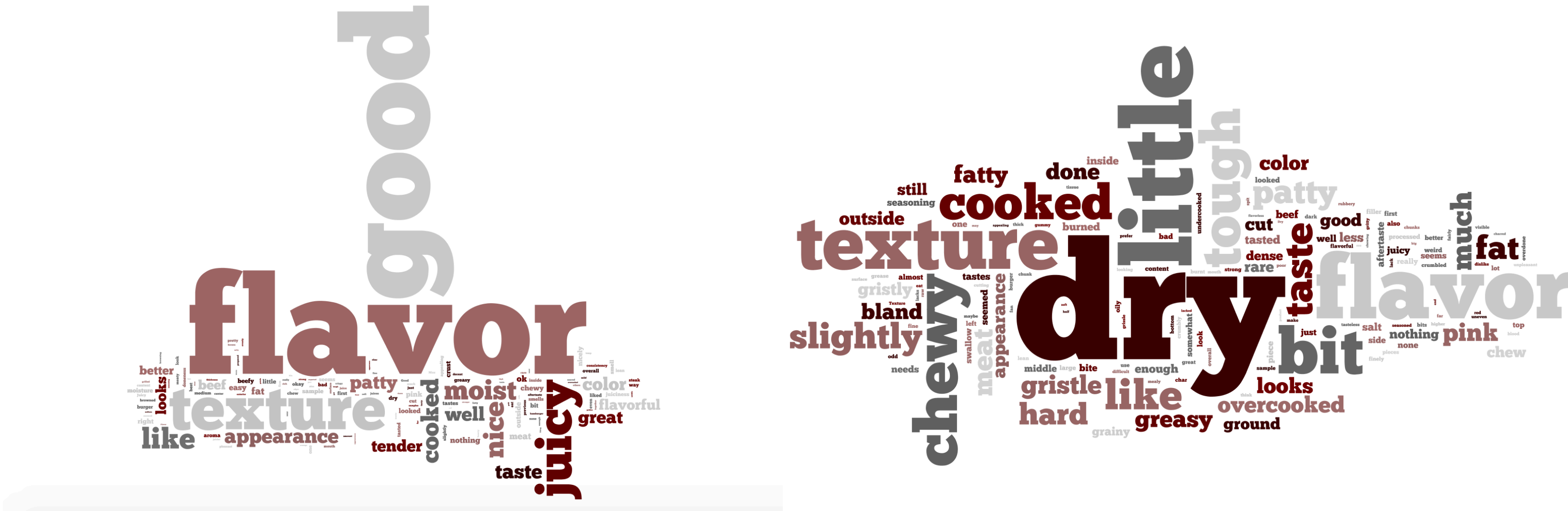


Figure 4. Consumer liking (a) and dislike (b) descriptors for sirloin meat source.

(a) **(b)**

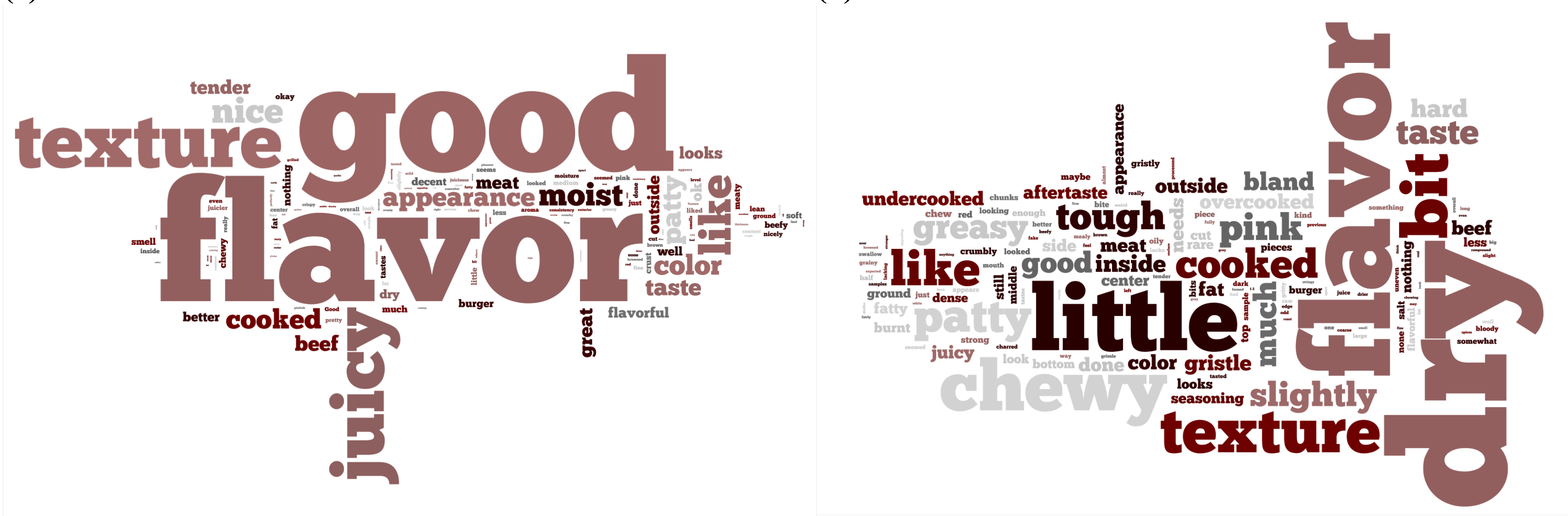


Figure 5. Consumer liking (a) and dislike (b) descriptors for 10% fat level and liking (c) and dislike (d) descriptors for 20% fat ground beef.

Figure 6. Consumer liking (a) and dislike (b) descriptors for 6.4 mm grind size and liking (c) and dislike (d) descriptors for bowl chopped.

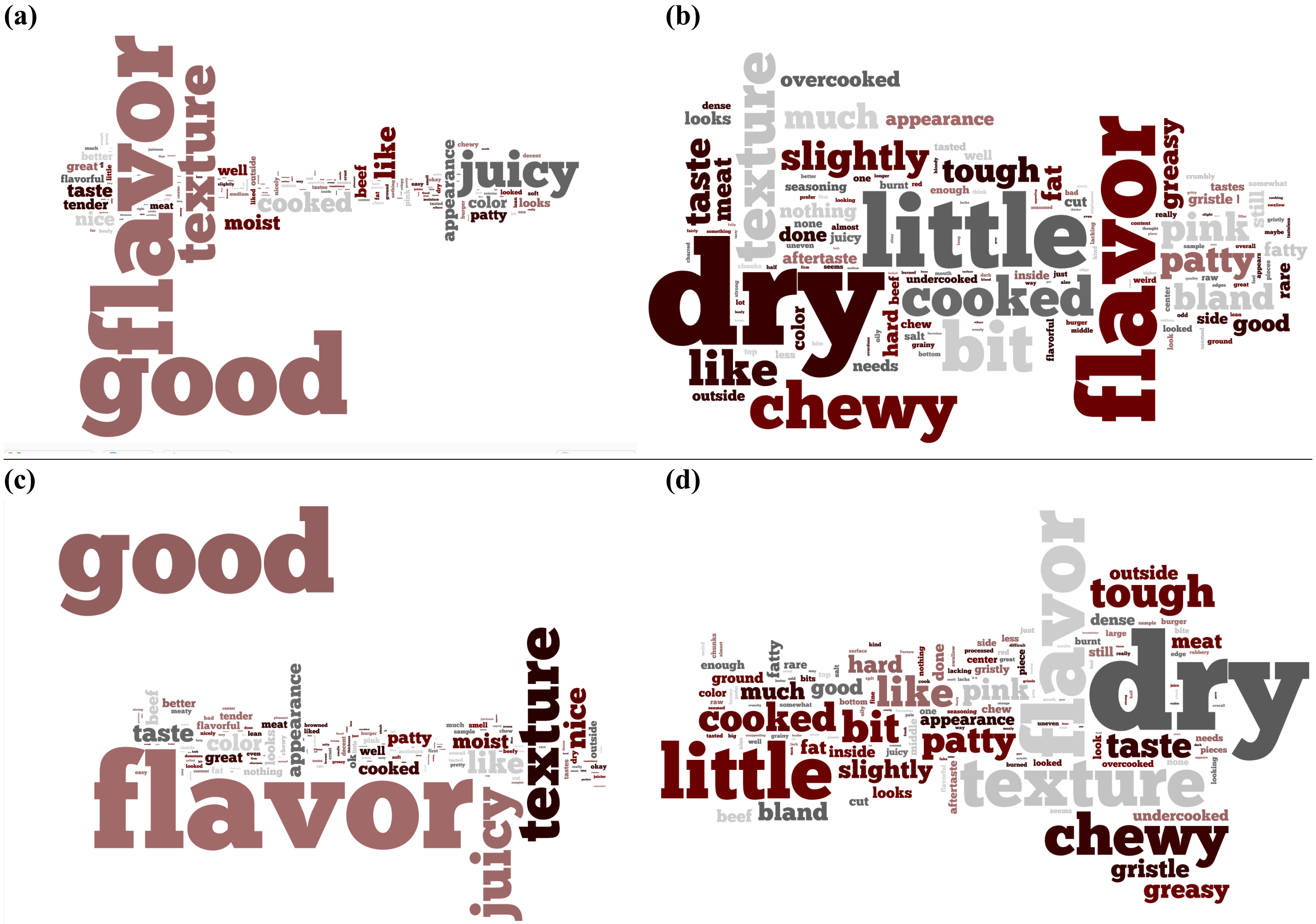


Figure 7. Partial least squares regression biplot for consumer liking sensory attributes (**O**), trained descriptive flavor (•), and ground beef treatments (◆).

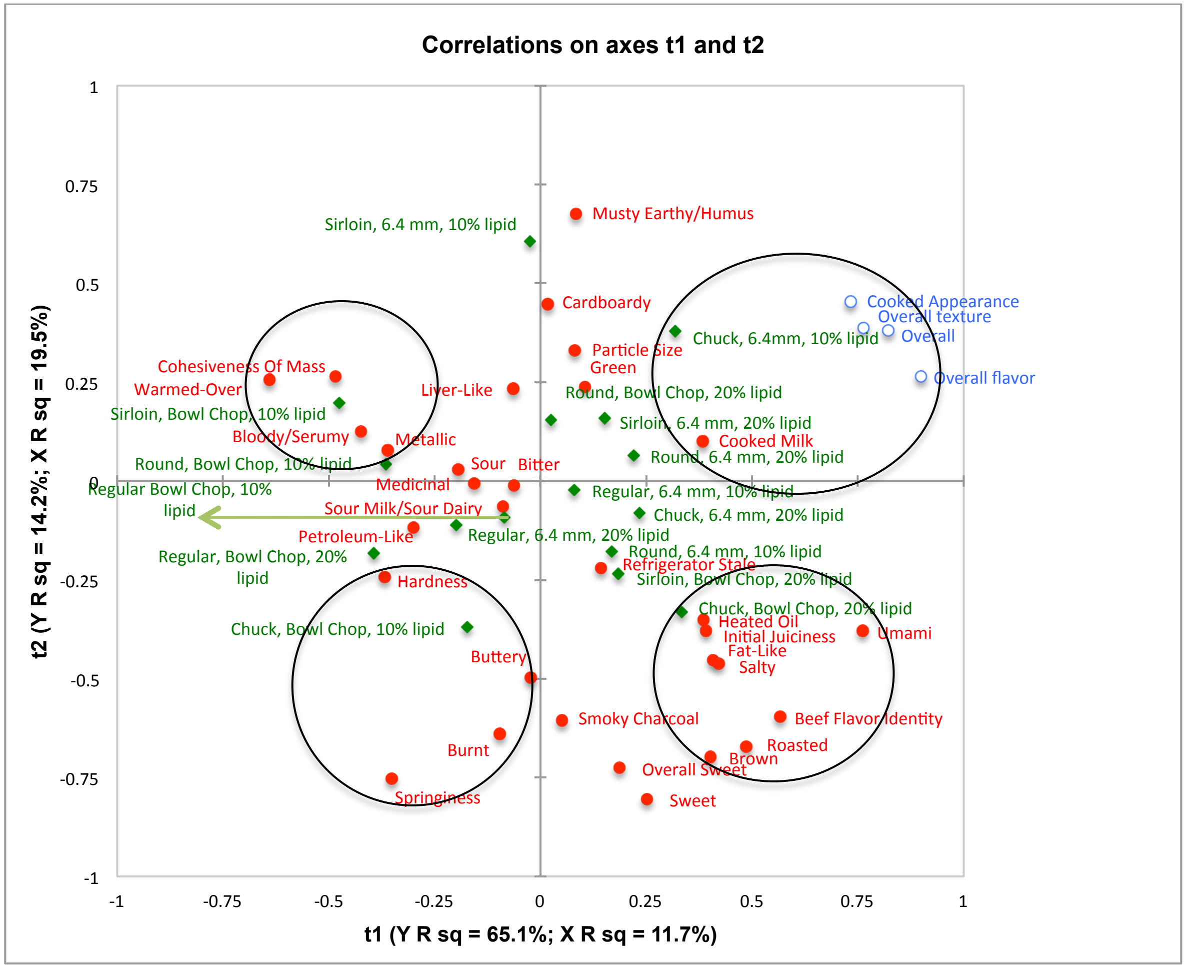


Figure 8. Partial least squares regression biplot for consumer liking sensory attributes (○), volatile aromatic compounds (•), and ground beef treatments (◆)

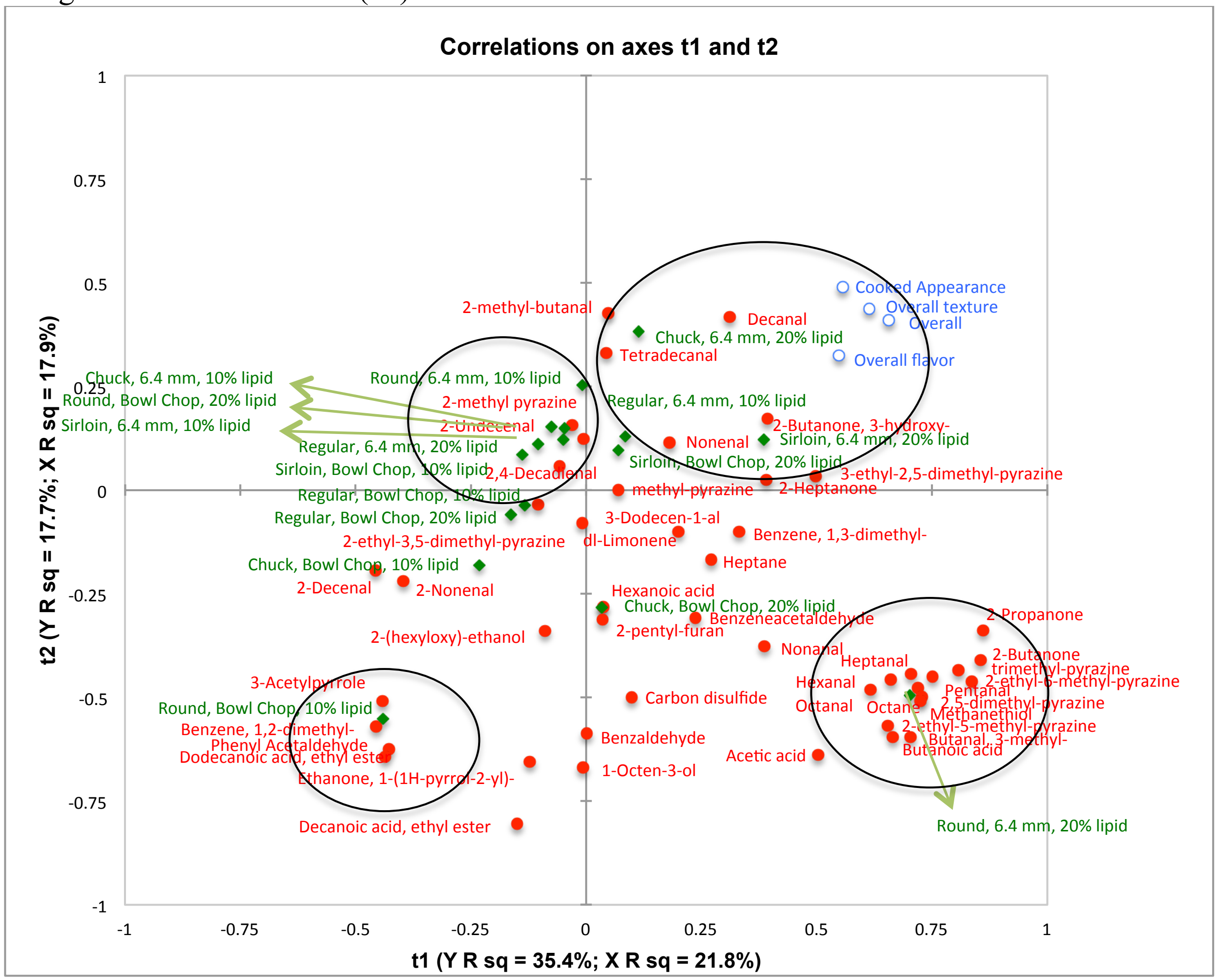
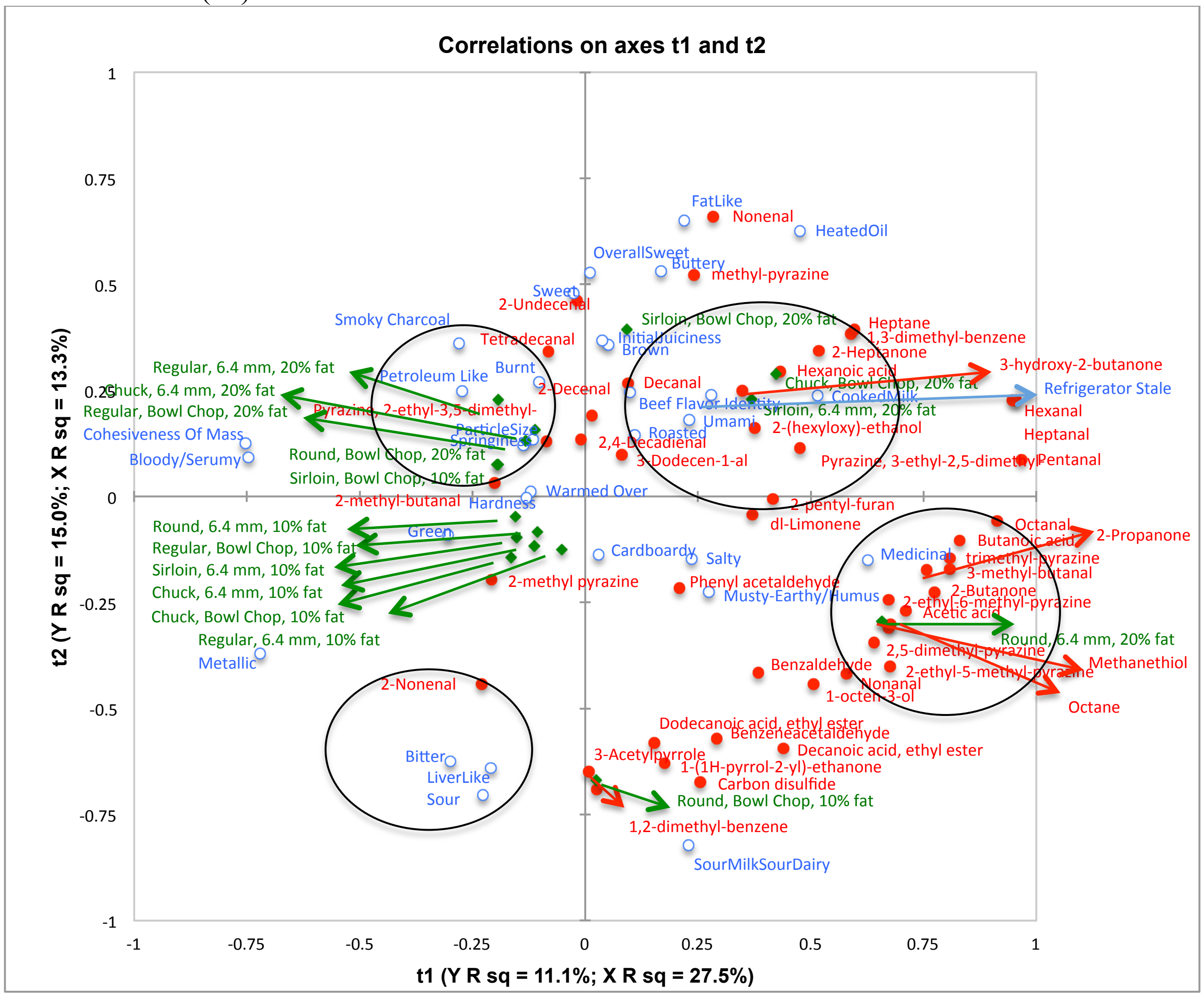


Figure 9. Partial least squares regression biplot for trained descriptive flavor (**O**), volatile aromatic compounds (•), and ground beef treatments (◆)



APPENDIX C

Trained Panel Cook Sheet Example

16-2 NCBA GB - BAB/RKM
Trained Panel Cook Sheets

1

Date	Order	Code	Meat	Grind	Fat	Rep	TrRep	RawWeight	Grill Temp	TempOn	TimeOn	TempOff	TimeOff	CookWeight
	W/U		**Regular**	**bowl**	**20**	**3**								
12/1/16	1	**248a**	Round	0.25	20	1	1							
		b												
		c												
		d												
12/1/16	2	**578a**	Sirloin	bowl	10	2	1							
		b												
		c												
		d												
12/1/16	3	**379a**	Round	bowl	20	2	1							
		b												
		c												
		d												
12/1/16	4	**122a**	Regular	0.25	10	2	1							
		b												
		c												
		d												

Recorded by: _____________
Date: _____________

Entered by: _____________
Date: _____________

Checked by: _________
Date: _________

Central Location Test Cook Sheet Example

16-2 NCBA GB - BAB/RKM
KSU Cook Sheets

Session	Group	Order	Code	Meat	Fat	Grind	Rep	RawWeight	TempOn	TimeOn	TempOff	TimeOff	CookWeight
1	1	1	**265**	Regular	20	1/4"	3						
1	2	1	**839**	Regular	20	Bowl	1						
1	3	1	**290**	Regular	20	Bowl	3						
1	4	1	**050**	Round	20	Bowl	2						
1	5	1	**039**	Chuck	10	Bowl	2						
1	6	1	**084**	Chuck	20	Bowl	3						
1	7	1	**025**	Regular	20	Bowl	2						
1	8	1	**079**	Round	20	1/4"	3						
1	9	1	**838**	Chuck	20	Bowl	1						
1	10	1	**238**	Round	20	Bowl	2						

Recorded by: ______________ Entered by: ______________ Checked by: ________
Date: ______________ Date: ______________ Date: _______1

Consumer Consent Form

Search documents an

TEXAS A&M UNIVERSITY HUMAN SUBJECTS PROTECTION PROGRAM

INFORMATION SHEET

Project Title: Flavor in Ground Beef Phase II

You are being invited to take part in a research study being conducted by Texas A&M University and asked to read this form so that you know about this research study. The information in this form is provided to help you decide whether or not to take part. If you decide you do not want to participate, there will be no penalty to you, and you will not lose any benefit you normally would have.

WHY IS THIS STUDY BEING DONE?
The purpose of this study is to tie consumer positive and negative flavor attributes with the trained panel, beef lexicon and chemicals that contribute to beef flavor.

WHY AM I BEING ASKED TO BE IN THIS STUDY?
You are being asked to be in this study because you have enrolled yourself in the individual research institution's consumer panel bank and because you eat beef. This study is being sponsored/funded by the National Cattlemen's Beef Association.

HOW MANY PEOPLE WILL BE ASKED TO BE IN THIS STUDY?
80 people (participants) will be enrolled in this study locally. Overall, a total of 160 people will be enrolled at 2 research study centers and 10 trained panelists at Texas A&M University.

WHAT ARE THE ALTERNATIVES TO BEING IN THIS STUDY?
The alternative is not to participate.

WHAT WILL YOU BE ASKED TO DO IN THIS STUDY?
Your participation in this study will last up to 60 minutes and includes 1 visit. The procedures you will be asked to perform are described below.

Session 1
This visit will last up to 60 minutes. During this visit you will be asked to sample a variety of beef steaks and roasts and complete a questionnaire relating to each sample. Upon completing the survey, you will be compensated up to $60.00 gift card.

Session 2
If selected, you will be asked to take part in an interview to last about 20 minutes regarding your purchasing decisions of beef. This interview will be audio recorded. Upon completing the survey, you will be compensated with an additional up to $20.00 gift card.

Session 3
You will be selected to take home 6 ground beef samples. You will be asked to cook the samples as you normally and complete a questionnaire relating to each sample. Upon completing and return of the survey, you will be compensated with an additional up to $20 gift card.

If you leave the study early, you may not receive compensation for your time.

ARE THERE ANY RISKS TO ME?
The only risks or discomforts would be from tasting the various samples of beef. Although the researchers have tried to avoid risks, you may feel that some questions/procedures that are asked of you will be stressful or upsetting. You do not have to answer anything you do not want to. Information about individuals who may be able to help you with problems or concerns will be given to you.

IRB NUMBER: IRB2016-0420
IRB APPROVAL DATE: 07/20/2016
IRB EXPIRATION DATE: 07/15/2021

ARE THERE ANY BENEFITS TO ME?
There may be no direct benefit to you by being in this study. What the researchers find out from this study may help provide others with a better beef product in the retail case and provide consumers with a better eating experience.

WILL THERE BE ANY COSTS TO ME?
Aside from your time, there are no costs for taking part in the study.

WILL I BE PAID TO BE IN THIS STUDY?
Compensation will be up to a $60 store gift card.

WILL INFORMATION FROM THIS STUDY BE KEPT PRIVATE?
The records of this study will be kept private. No identifiers linking you to this study will be included in any sort of report that might be published. Research records will be stored securely and only the National Cattlemen's Beef Association, Dr. Rhonda Miller and her lab will have access to the records.
Information about you will be stored in a limited access, coded entry lab on a computer's password protected hard drive.

Information about you will be kept confidential to the extent permitted or required by law. People who have access to your information include the Principal Investigator and research study personnel. Representatives of regulatory agencies such as the Office of Human Research Protections (OHRP) and entities such as the Texas A&M University Human Subjects Protection Program may access your records to make sure the study is being run correctly and that information is collected properly.

The agency that funds this study, the National Cattlemen's Beef Association, and the institution where study procedures are being performed, Texas A&M University, may also see your information. However, any information that is sent to them will be coded with a number so that they cannot tell who you are. If there are any reports about this study, your name will not be in them.

WHOM CAN I CONTACT FOR MORE INFORMATION?
You can call the Principal Investigator to tell him/her about a concern or complaint about this research study. The Principal Investigator Dr. Rhonda K. Miller, Ph.D. can be called at (979) 845-3935 or emailed at rmiller@tamu.edu. You may also contact Hannah Laird at (281) 910-3633or emailed at Hannah_Laird@tamu.edu. The IRB can also be contacted toll free at 1-855-795-8636.

For questions about your rights as a research participant; or if you have questions, complaints, or concerns about the research and cannot reach the Principal Investigator or want to talk to someone other than the Investigator, you may call the Texas A&M Human Subjects Protection Program office.

- Phone number: (979) 458-4067
- Email: irb@tamu.edu

MAY I CHANGE MY MIND ABOUT PARTICIPATING?
Your participation is voluntary. You have the choice whether or not to be in this research study. You may decide to not begin or to stop the study at any time. If you choose not to be in this study, there will be no effect on your evaluation. Refusal to participate will involve no penalty to you. You may discontinue participation at any time without penalty.

IRB NUMBER: IRB2016-0420
IRB APPROVAL DATE: 07/20/2016
IRB EXPIRATION DATE: 07/15/2021

STATEMENT OF CONSENT

I agree to be in this study and know that I am not giving up any legal rights by signing this form. The procedures, risks, and benefits have been explained to me, and my questions have been answered. I know that new information about this research study will be provided to me as it becomes available and that the researcher will tell me if I must be removed from the study. I can ask more questions if I want. If requested, a copy of this entire consent form will be given to me.

OPTIONAL RECORDINGS:

The researchers will make an audio recording during the study so that the one-on-one interview in Session 2 can be accurate only if you give your permission to do so. Indicate your decision below by initialing in the space provided.

________ I give my permission for audio recordings to be made of me during my participation in this research study.

________ I do not give my permission for audio recordings to be made of me during my participation in this research study.

________________________________ ________________________________

Participant's Signature Date

________________________________ ________________________________

Printed Name Date

INVESTIGATOR'S AFFIDAVIT:

Either I have or my agent has carefully explained to the participant the nature of the above project. I hereby certify that to the best of my knowledge the person who signed this consent form was informed of the nature, demands, benefits, and risks involved in his/her participation.

________________________________ ________________________________

Signature of Presenter Date

________________________________ ________________________________

IRB NUMBER: IRB2016-0420
IRB APPROVAL DATE: 07/20/2016
IRB EXPIRATION DATE: 07/15/2021

Central Location Ballot

Date ____________ Respondent Number ____________
Session ____________ City ________________________

Sample Number ____________

Order 1

Please take a bite of cracker followed by a sip of water prior to evaluating the the meat patty. Place a mark in the box that represents your answer for each of the following questions.

1. How much do you like or dislike the COOKED APPEARANCE of the patty?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — Neither Like or Dislike — Like Extremely

2. How much do you like or dislike this beef patty OVERALL?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — Neither Like or Dislike — Like Extremely

3. How much do you like or dislike of the OVERALL FLAVOR of this meat patty?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — Neither Like or Dislike — Like Extremely

4. How much do you like or dislike of the OVERALL TEXTURE of this meat patty?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — Neither Like or Dislike — Like Extremely

5. Please write any words that describe what you LIKE about this meat patty.

____

____

6. Please write any words that describe what you DISLIKE about this meat patty.

____

____

One on One Interview Questions

City
Interviewer
Respondent Number
Date

Reflection: In the experience that you just had: Can you describe the steak that you like the best and why?

What were the good flavors?

What were the bad flavors? Can you describe the steak that you liked the least and why?

What were the good flavors?

What were the bad flavors?

Beef: Think of the perfect raw ground beef in your mind.

Describe the raw appearance of that patty. Describe the appearance of the patty after it is cooked. What fat percentage is it? What type of ground beef is it? What are the most important characteristics in that patty for you?

Purchasing Decisions: Based on your ballot, I see that you eat beef ____ often. What factors affect how often you eat or purchase beef?

I see that you eat other proteins, like chicken, pork, fish, lamb or soy- based proteins, what factors affect your selection of other proteins?

When you approach the meat case to purchase beef, what are you thinking, what is important to you? Why do you eat beef?

Is there any time that you do not select beef and why? (Price, want variety, food preparation too difficult, menu ideas not diverse enough, nutrition/health concerns, food safety, animal welfare, nature/organic, how the animal is raised, etc.)

Can you describe a situation or a time when you were in a grocery store on a normal occasion purchasing food for you and/or your family? You decide to not purchase beef, but you do purchase other proteins like pork, chicken, fish or soy-/vegetable-based protein.

Why did you decide not to purchase beef? Why did you purchase the other protein?

Ground Beef Preparation:
Are you familiar with Quality Grades of beef?

If you were to purchase any beef for yourself, all financial factors aside, would you choose a Prime, Choice, Select or Standard Quality grade of beef?

What seasonings do you typically add to ground beef when you cook it?