MILLENNIAL'S PERCEPTION OF BEEF FLAVOR

A Thesis

by

HANNAH LYNNE LAIRD

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
Committee Members,	Christopher R. Kerth
	Joseph Awika
Head of Department,	H. Russell Cross

December 2015

Major Subject: Animal Science

ABSTRACT

The millennial generation now outnumbers other generations and it is important to understand their drivers of meat consumption. In this study, beef, pork and chicken flavor attributes were created by using beef Top Choice strip loin steaks, beef Select outside round flat roasts, boneless pork loins, pork inside ham roasts, chicken breasts, and chicken thighs cooked to 58.3°C, 62.7°C or 80°C utilizing a food-service grill or Crock-pot®. Trained descriptive sensory attribute panel, central location test (CLT), in-home test (HUT) and gas chromatography mass spectrometry olfactory (GC-MS-O) were utilized to determine flavor. Raw meat fatty acid composition, non-heme iron and myoglobin content, pH and fat and moisture were determined. Millennials (ages 18 to 34) or non-millennials (ages greater than 34) and were selected to be either light (eat beef 2 to 4 times per month) or heavy beef eaters (eat beef 3 or more times per week).

Cooking method, cut, and internal temperature impacted meat descriptive flavor and texture attributes. The Crock-pot®-cooked meat had less positive flavor attributes than the grill-cooked meat. Consumer group did not affect how consumers rated grill flavor, juiciness and tenderness. Light beef eaters rated overall, flavor, and species flavor lower than heavy beef eaters. Consumers liked beef regardless of generational segment or their consumption of beef. Millennials versus non-millennials did not differ in response to flavor of beef indicating that other factors drive consumption other than palatability factors.

Regression equations for beef, pork, chicken identity, brown/roasted, bloody/serumy, fat-like, metallic, liver-like, and umami accounted for 53, 64, 63, 42, 48, 46, 54, 56, and 46 percent of the variability, respectively using volatile aromatic compounds as independent variables. Overall flavor, tenderness, meat flavor, grill flavor, and juiciness liking accounted for 84 percent of the variation in overall consumer liking. Through interviews, consumers indicated that flavor was important to them when eating meat but price was the most important factor when purchasing beef.

The HUT reported millennials tended to not like the raw appearance at the same level as non-millennials. Millennial light beef eaters tended to rate some attributes lower, but this was seen across the four meat cuts. Consumers rated liking for the HUT higher than the CLT. In conclusion, millennial light and heavy beef eaters responded the same to flavor as non-millennial light and heavy beef eaters.

DEDICATION

This work is dedicated to my family, friends, and colleagues who have helped me develop into the person I am today.

ACKNOWLEDGEMENTS

Thank you to the National cattlemen's Beef Association for funding this project and for their continued dedication to the improvement of beef flavor and consumer knowledge.

Thank you to my committee Dr. Miller, Dr. Kerth, and Dr. Awika as well as all the other professors that helped and guided me throughout this project. Thank you Dr. Miller for choosing me to be apart of your team and giving me countless opportunities to enhance my career including this project. Thank you for always being available anytime I needed advice or someone to talk to. I am so grateful to have you as an advisor, a teacher, a mentor, and a friend. Without your support and guidance, I would not be where I am today. A special thank you goes to Dr. Kerth, for always having an open door to me anytime I needed help or just someone to vent to. Thanks for making my time at work more fun, enjoyable and memorable! It's been a blast traveling and having you as a mentor. Thank you to Dr. Awika for your willingness to be on my committee and for being a valuable resource to me throughout my Masters project. Dr. Adhikari, thank you for all of the fun memories from traveling all around the country and helping serve all of the samples. Thank you to both Dr. Miller and Dr. Kerth for giving me this research project and providing me with many opportunities to travel all across the country whether it was for research, conferences, or a meat science activity.

I want to thank all of the graduate students, student workers, and Rosenthal staff. A special thank you goes to Mark and Pudge for helping us with all of the meat and dealing with the broken equipment during the beginning of this project. Thank you goes out to Ale, Blythe, Sunny, Maria, Crystal, Kayley, Hillary, and Tyler for helping me with chemical tests, traveling and being a source of encouragement for me during the stressful times.

Tanner and Michael, thank you for traveling and dealing with me even when I drove you crazy. You both have become my best friends and I don't know what I am going to do without you next year. Michael, thank you for helping me tackle this massive project and sharing the work burden; I couldn't have done it all without your help.

Thank you to all of my family: my sister Abbie, brother Zach and my mother, Terri and Father, Ken. Thank you for molding me into the person I am today and encouraging me to pursue my dreams. Without your continuous love, support and motivation to succeed I wouldn't be where I am today. Finally, I am thankful for Matthew, my best friend and biggest fan, for his unconditional love and support.

TABLE OF CONTENTS

Page

Page

LIST OF FIGURES

Page

Page

Page

LIST OF TABLES

Page

Page

CHAPTER I

INTRODUCTION

Meat flavor is an important component of consumers demand. Although historically tenderness has been rated as the most important attribute, once tenderness reaches an acceptable level, flavor becomes the most important driving factor (Behrends, 2005; Goodson, 2002; Kerth & Miller, 2015). Glascock (2014) and Luckemeyer (2015) used the beef lexicon to correlate descriptive beef attributes with consumer perceptions. They both discovered that consumers, whether light or moderate to heavy beef consumers, liked beef cooked to medium rare on a high temperature grill. Beef consumers eat beef because they like the beefy flavor, versatility of beef in recipes and they consider beef to be an excellent protein source.

Shugall (2014) reported that millennials, individuals ages 18 to 34 years, did not consume beef at the same proportion as non-millennials. Non-millennials were people older than 34 years and include the consumer classifications of Generation X and baby boomers. The millennial generation has over 25% of the buying power currently and is expected to grow (Stegelin, 2002). They are the beef industry's next powerful consumer group, but to date, they tend to not cook, to eat more chicken than other protein sources, and to be very connected to digital media. Draves and Coates (2004) indicated that millennials have distinctly different behaviors, values and attitudes from previous generations as a response to the technological and economic implications of the internet. They discussed how millennials are the individuals who were born at the time when our society moved from the industrial age to the technological age. They have never lived without the internet or cell phones. They get information through digital media instead of print media. They segment their time differently than Generation X or baby boomers. As a beef industry, it is imperative to understand perceptions of millennials for beef and beef flavor.

It has been hypothesized that positive and negative beef flavor attributes may be different for millennials versus non-millennials and light- versus heavy-beef eaters within each age group. The objectives of this study were to select four consumer groups, Millennials and non-millennials that are either light (eat beef 2 to 4 times per month) or heavy (eat beef 3 or more times per week) beef eaters in four cities (Portland, OR; Olathe, KS; College Park, PA; Griffin, GA) and determine perceptions of overall liking based on being presented with beef, chicken and pork that has been cooked differently to create differences in flavor. The beef, chicken and pork were evaluated using an expert trained descriptive meat flavor panel, volatile chemicals compounds, and chemical attributes. These data were used to understand factors that drive flavor of beef and at no time will overall liking of beef, chicken and pork be compared or discussed. These results will allow us to tie consumer positive and negative flavor attributes within consumer segments with the trained panel beef lexicon and chemicals that contribute to beef flavor and to provide a road map for the beef industry to maximize customer satisfaction and to increase beef demand especially with millennials.

CHAPTER II

LITERATURE REVIEW

Generational Consumer Segments

Millennials are unlike any other generation because they are more numerous, more affluent, better educated and more ethnically diverse (Howe & Strauss, 2009). Millennials were born between 1977 and 1995 and represent about 25 % of the buying power in the U.S. economy (Stegelin, 2002). The United States Census Bureau (2015) defines millennials as babies born between 1982 and 2000 with numbers of 83.1 million people and representing more than one quarter of the America's population. As of June 2015, millennials exceeded the population of the baby boomers by 7.7 million people (U. S. Census Bureau, 2015). The census also estimates that the millennials are the most diverse generation in America history with 44.2 % being part of a minority group. Millennials are a technological dependent generation and have never known a world without the internet. This group of people is just starting to have kids and will be the primary consumers food over the next few decades. Millennials are consumers of the future.

The millennials have been described as special, sheltered, confident, team-oriented, achieving, pressured and conventional (Howe & Strauss, 2009). Since the millennials now outnumber the other generations, it is important to understand their drivers of meat consumption. The millennials, in particular, are the first generation born with technology and internet and have developed unique characteristics, such as openness to change and new perpectives. Since the millennials have had constant internet and social media outlets to connect with anybody, they are more likely to be open to change and are more self-expressive than older generations (Taylor & Keeter, 2010). Millenials use technology much more than the previous generations.

A study by Fromm et al. (2014) showed that more than two in five millennial parents support the local food movement. They look for foods fortified with more protein, fiber and antioxidants, foods with fewer artificial ingredients and buy organic food whenever they can. Millennials are regularly more aware of and want to know where their food comes from, and how it is produced. Many grocery stores have cued in on this market such as Whole Foods and Trader Joe’s. Millennials are willing to pay premium prices in time and money when it comes to a brand that has the same values they do (Fromm and Vidler, 2015). The National Restaurant Association surveyed 1,300 professional chefs to decide what the top trends for 2015 would be and the top trend was locally sourced meats and seafood (National Restaurant Foundation, 2015).

Mindswarms (2014) did a recent study trying to understand the role food origin plays in millennials’ attitudes about food and food quality and how this affects their food purchasing behaviors. They sampled millennials from 14 states to figure out how these opinions changed around the United States. They found that “local” is defined differently around millennials and it does impact their buying behavior. Overall, their local purchases make them feel like they are having a positive impact on their health, local economy and environment. The millennials approach to selecting and purchasing foods is very different from their parent's generation (Mindswarms, 2014).

Fromm et al. (2011) surveyed 1,051 millennials and 297 non-millennials who are the primary grocery shoppers in their households. Millennials shop differently than non-millennials and are pulling away from grocery store chains in favor of specialty or mass retailers such as Wal-Mart. Millennials enjoy being in the kitchen and cooking creative meals. Although time is a large priority for them, they want meals that are quick and easy that they can take on the road.

Shugall (2014) reported that millennials eat beef about twice a week, which is not the same as non-millennials. This study also showed that millennials are less likely to cook at home and more likely to eat out than other generations. This research reported that millennials are more likely to say price and value are more important than the other generations. Non-millennials are more likely to look for a specific cut of beef when purchasing; whereas, millennials are looking for a good price. The millennials purchase and cook more with ground beef than cuts of beef. Compared to the other generations, millennials are more likely to be food influencers and consider themselves "foodies." This study reported that millennials have five factors that are most important to them when deciding what to eat: great taste, good value, feeling comfortable and confidant preparing the dish, nutrition and ease of preparation.

Coates (2015) reported that millennials like to experiment in the kitchen and like cooking because it is a creative outlet for them to express themselves. They look for more resources and information to help them with their cooking expertise mostly on social media and the internet. When cooking beef, millennials settle with their reliable, go-to beef meals because it's risk free, easy and saves time. Steaks to the millennials are considered a splurge food when they want to indulge. Millennials recognize that there are several factors that affect the end result of a steak including cut, fat content, seasoning, temperature, and preparation. These variables add knowledge and experience that is necessary to cook a good steak. The millennials, who are less knowledgeable and have less experience, become less confident about their ability to master these (Coates, 2015). Coates (2015) also reported that millennials look for better prices, more packaging options, healthier beef and ways to be more successful when cooking.

Millennials and non-millennials are very different and need to be addressed differently in the consumer market. Many factors drive the purchasing decision for millennials and each industry needs to address them separately. In order to reach the Millennails, Fromm and Garton (2013) suggested to keep up with technology and engage the millennials. The defined limits of when the millennials were born vary from study to study but for the purposes of this study, millennials were born between 1980 and 1997.

Biological Response to Flavor

Flavor of food is complex, multi-dimensional and more than the taste perceived on the tongue. The perception of flavor is comprised of the aroma detected by the olfactory, the chemical feeling sensations, the taste perceived by the tongue and an interaction of these sensations. The visual and auditory cues of a food also contribute to the perceived flavor (Meilgaard et al., 2007). Flavor has been defined as the sum of perceptions resulting from stimulation of the sense ends that are grouped together at the entrance of the alimentary and respiratory tracts (Meilgaard et al., 2007). Flavor, as a whole describes the combination of taste, aroma, and other sensations within the mouth (Meilgaard et al., 2007).

Three main systems that play a role in flavor sensation are the gustatory, trigeminal, and olfactory systems. The combined sensory experience of olfaction and gustation is regarded as flavor. Gustatory signals start at the taste buds and are activated by water-soluble compounds and are defined as the basic tastes. Olfactory signals are produced from neurons in specialized patches of nasal epithelium and are triggered by volatile compounds (Chaudhari & Roper, 2010). Although the gustation and olfactory systems are different, their signals are mixed in the orbitofrontal and other areas of the cerebral cortex to generate flavors and mediate food recognition (Rolls & Baylis, 1994)

Gustation is responsible for detection of the basic tastes, solubilizing in water, oil or saliva, by receptors on the tongue and ultimately by the brain (Meilgaard et al., 2007). The five basic tastes: sweet, salty, sour, bitter, and umami are all important contributors of meat flavor and have been found in various chemical compounds in different meats. Sweetness in meat is associated with glucose, fructose, ribose, and several amino acids and organic acids (MacLeod, 1994). Sourness is from aspartic acid, glutamic acid, organic acids, and carboxylic acids (MacLeod, 1994). Inorganic salts have played a large role in saltiness (MacLeod, 1994). Bitter flavors may be derived from hypoxanthine, anserine, carnosine, and particular amino acids (MacLeod, 1994). As defined in the beef lexicon (Adhikari et al., 2011), umami is a flat, salty, somewhat brothy taste. It can be described as the taste of glutamate, salts of amino acids and other molecules called nucleotides (Adhikari, 2011). It is a savory, brothy flavor that plays a vital role in meat flavor. Flavor enhancers such as monosodium glutamate (MSG), 5'-inosine monophosphate (IMP), 5'-guanosine monophosphate (GMP) and certain peptides help create umami. MacLeod (1994) reported that glutamate is the most important contributor to the umami flavor but has a lower concentration in beef than in pork or chicken and can give a lower perceived umami intensity in beef (Kato & Nishimura, 1987). Umami has also been shown to increase in intensity in pork and chicken after aging, but there was no effect in beef (Nishimura et al., 1988).

Olfactory and gustatory systems compliment each other by enhancing the flavor. The olfactory senses are used for the detection of the aroma during tasting. Olfactory neurons that detect the volatile compounds are responsible for aromatic sensation perceived by the brain (Meilgaard et al., 2007). This system is able to discriminate among many different aromas and can identify a large number at a time (Breer, 2008). The aromas or volatiles are perceived by the olfactory system from food in the mouth via posterior nares. Whenever an aroma is present, the olfactory sensory neurons detect the aroma and an axon from the receptor cells sends the message directly to neurons in the olfactory bulb. This than projects to the pyriform cortex in the temporal lobe of the brain. The olfactory system is different from the other sensory systems because there is no delay in processing the information. Processing in the brain allows aromas to be identified and initiates responses to the olfactory creating a smell (Meilgaard et al., 2007). Humans have many natural differences in the olfactory system creating large variation in flavor perception among people. There are also thousands of odorous compounds that can be sensed by the olfactory system. Training panelists to detect many of these aromas may be difficult because of the vast number of aromas to identify and having a contact time too brief to detect the aroma (Meilgaard et al., 2007).

Trigeminal senses are the chemical sensations that are sensed in the mouth such as spice, heat, astringency, metallic, and cooling (Meilgaard et al., 2007). Other somatosensory cues such as texture and visual signals significantly influence the taste of foods (Small & Prescott, 2005). For example, fatty taste is a mix of somatosensory and gustatory perception (Chaudhari & Roper, 2010). In the past, fat was considered a texture but in recent years, specific membrane receptors for detecting fatty acids have been found on the tongue suggesting its a gustatory sensation (Laugerette et al., 2005; Sclafani et al., 2007; Wellendorph et al., 2009). Mattes (2009) suggested that the fatty taste may become recognized as another basic taste.

Descriptive Evaluation of Beef, Pork, and Chicken Flavor

Tenderness, juiciness, flavor, meal enjoyment, and consistent quality have the greatest influence on consumer beef purchasing decisions (Moeller & Courington, 1998). Consumers base their evaluations of cooked meat on three categories: tenderness, juiciness, and flavor (Spanier & Miller, 1993). Although tenderness has been rated the most important factor for years, once tenderness reaches an acceptable level, flavor becomes the most important driving factor (Behrends, 2005; Goodson, 2002; Kerth & Miller, 2015). The two most recent beef tenderness surveys showed that over 94% of beef from the rib and loin in foodservice and at the retail level were classified as tender or very tender based on Warner-Bratzler shear force values (Guelker et al., 2013; Voges et al., 2007). Reicks et al. (2011) also showed in a nation-wide survey of U.S. beef consumers, that flavor was rated as the most important purchasing motivator for beef steaks and roasts above tenderness and other factors.

The positive and negative beef flavor attributes from the beef lexicon (Adhikari, 2011) were discussed in Miller and Kerth (2012). Positive beef flavors were identified as beefy, brown/roasted, bloody/serumy, fat-like, sweet, salty, and umami; and the negative flavors as metallic, liver-like, sour, barnyard, musty-earty/humus and bitter. The lean portion of beef were associated with beefy, browned/roasted, bloody/serum, sweet, salt and umami; whereas, fat-like, liver-like, metallic and bitter were associated with the lipid portion. Flavors that have been associated with the myoglobin content, pH and lipid oxidation were liver-like and metallic (Miller and Kerth, 2012). Slightly higher levels of barnyard and musty-earthy/humus were found in roasts and may be components of positive flavors when combined with beefy, brown/roasted and umami attributes (Miller and Kerth, 2012).

Beef flavor is composed of many attributes creating an extremely complex flavor and dynamic sensory experience. Components of raw beef and the compounds created during cooking are responsible for the flavors in beef. Raw meat has been described as having a salty, metallic, bloody taste and a sweet aroma resembling serum (Wasserman, 1972). Crocker (1948) reported flavors present in raw meat lay in the juices and not in the muscle fiber, but once cooked, the fibers developed the meaty flavor. The main flavor constituents were water-soluble. This was expanded by Hornstein et al. (1960) who discovered that hamburgers prepared from water-extracted ground beef were essentially tasteless and odorless. When the water extracted from the hamburgers was concentrated and heated, a beef aroma was present.

The tenderness, juiciness and flavor of pork are responsible for a consumer's judgment of quality (Wood et al., 1995). Consumers rate flavor as the most important sensory attribute of pork (Bryhni et al., 2002). Pork flavor has a meaty flavor similar to beef but has a more inherent sweet taste and higher volatile fatty acid content. The pork flavor lexicon developed by Chu (2015) identified 24 flavors and five basic tastes present in intact pork muscle including: sweet, sour, salty, bitter, and umami basic tastes; pork identity, brown/roasted, fat-like, bloody/serumy, metallic, astringent, metallic, fat-like, vinegary, cardboard, soapy , heated oil, warmed-over, burnt, boar taint, refrigerator stale, and floral flavor aromatics. Shahidi (1994) identified carboxylic acids, such as butanoic acid as contributors to pork flavor. There is a gender impact on pork flavor with the off-flavor, boar taint. Male pigs that have not been castrated have increased levels of androstenone and skatole in their fat that causes an unpleasant odor and flavor (Babol et al., 1995).

Chicken is consumed all over the world and is among the cheapest protein sources. The cooked meat flavor of chicken is dependent on many factors including age, breed, sex, diet, postmortem aging, and method of cooking. Poultry meat is extremely susceptible to flavor changes during storage (Lyon, 1987). Similar to other meats, lipids play a fundamental role in flavor development of poultry. Maillard reaction, thermal degradation of lipids and Maillard-lipid interactions are considered to be the main components in flavor development. Maillard reaction and lipid oxidation produce many compounds responsible for chicken flavor: 2-methyl-3-furanthiol; 2-furfurylthiol; methionol; 2,4,5-trimethylthiazole; nonanol, 2- trans-nonenal; 2-formyl-5-methylthiophene; p-cresol, trans; trans-2,4-nonadienal; trans, trans-2,4-decadienal; 2-undecenal; β-ionone; ɣ-decalactone;, and ɣ-dodecalactone are the major sources of chicken flavor (Shi, 1994). Of all these compounds, the most important compound related to meaty flavor of chicken broth is 2-methyl-3-furanthiol (Shi, 1994). Lyons et al. (1987) developed a list of terms used to describe chicken flavor: chicken, meaty, brothy, liver/organy, browned, burned, cardboard/musty, warmed-over, rancid/painty, sweet, bitter, and metallic.

Meat is made up of many components: water, proteins, lipids, carbohydrates, minerals, and vitamins. Proteins, lipids and carbohydrates play leading roles in flavor development because they include numerous flavor precursors that are developed when heated. Mottram (1998) divided flavor precursors into two categories: water-soluble components and lipids. The water-soluble precursors are: amino acids, carbohydrates, nucleotides, peptides, and nitrogenous compounds. The two key water-soluble aromatic flavor components are cysteine and ribose. Once cysteine, a sulfuric compound, is heated in the presence of ribose, glucose, or xylose, a meat-like flavor is produced

(Morton, 1960). Cysteine plays an important role in the Maillard reaction and Strecker degradation. Ribose is a predominate sugar in muscle that is present in ribonucleotides such as adenosine triphosphate (ATP), ribonucleic acid (RNA), and deoxyribonucleic acid (DNA; Mottram, 1998). Two main reactions occur during cooking are largely responsible for flavor development in meat: the Maillard reaction and lipid degradation. These reactions are explained in detail in the subsequent sections.

Chemical Development of Flavor

Many compounds are released during the cooking processes of meat from either the Maillard reaction or lipid degradation or a combination of both. These reactions are believed to be most responsible for beef flavor development (Farmer, 1994). Each compound by itself contains a unique aroma, but in combination with all the compounds released, cooked meat develops its characteristic flavor (Farmer, 1994).

Maillard Reaction

The Maillard reaction, discovered by Louis-Camille Maillard in 1912, is one of the most important contributors to flavor in cooked meat and meat products. This reaction is responsible for the browning of steaks, toast, beer, and even self-tanning products. The Maillard reaction is a type of non-enzymatic browning that results from a chemical reaction between an amino acid and a reducing sugar, usually requiring heat.

The complex nature of the Maillard reaction provides numerous compounds that contribute to flavor, off-flavor, aroma and odor. Raw meat has a bland and metallic flavor, but during cooking the meat browns and develops the desirable meat flavor associated with cooked meats. The main flavors developed from the Maillard reaction are sweet and bitter (Hurrell, 1982). The Maillard reaction can contribute to a multitude of compounds and aromatics produced. Many of the flavors produced by this reaction can be described as roasted, browned, meaty, caramelized and various others (Kerth & Miller, 2015).

Maillard reactions occur between amino acids and reducing sugars where amine compounds condense with the carbonyl group of a reducing sugar in the presence of heat (Calkins & Hodgen, 2007). This reaction starts with a dehydration step when the amino compound condenses with a carbonyl group of a reducing sugar producing a glycosylamine. The glycosylamine is then rearranged and dehydrated to form furfural, furanone derivatives, hydroxyketones and dicarbonyl compounds. Intermediates from the reaction can react with other amines, amino acids, aldehydes, hydrogen sulfide, and ammonia. The compounds may continue to react with amine and other amino acids to produce more flavor-contributing compounds (Mottram, 1998).

Another part of the Maillard reaction that contributes more flavor development is the Strecker degradation of amino acids by carbonyl compounds formed in the Maillard reaction (Mottram, 1998). The amino acid is decarboxylated and deaminated to form an aldehyde, while the dicarbonyl is converted to an aminoketone or aminoalcohol (Kerth & Miller, 2015). The aldehydes are condensed to aldols that form furans, pyrazines, pyrroles, oxazoles, thiazoles and other heterocyclic odor compounds (Shahidi & Ho, 1998). Mottram (1998) reported that these compounds produced in this reaction are some of the most pungent compounds produced during cooking. If the amino acid is cysteine, the production of hydrogen sulfide, ammonia and acetaldehyde can result from the Strecker degradation (Thorpe & Baynes, 2003). The sulfur-containing compounds that are derived from cysteine and ribose produce important aromatic characteristics of cooked meats (Shahidi et al., 2004). Many researchers believe these compounds to be the most important in meat flavor (Shahidi & Ho, 1998).

Lipid Thermal Degradation

Lipid thermal degradation provides compounds which give fatty aromas to cooked meat and compounds which determine some of the aroma differences between meats from different species (Mottram, 1998). Lipid degradation products tend to contribute to flavor to a greater extent than Maillard reaction products (Mottram, 1998). This is the breakdown of lipids instead of water-soluble compounds as in the Maillard reaction. The lipid compounds tend to be more dominant in flavor development, unless high-heat cooking methods are used to cause large amounts of browning with more Maillard reaction products (Mottram, 1998) . Lipid degradation may add to the desirable flavor of cooked meat in many ways including undergoing a thermal oxidative change producing compounds that can contribute to meat aroma. They also may react with components from lean tissue to create different flavor compounds. They can act as a solvent for aroma compounds accumulated during production, processing and cooking of meat (Mottram & Edwards, 1983).

Thermal lipid degradation is an important factor in the development of meat flavor because this reaction produces several hundred volatile compounds (Mottram, 1998). Aliphatic hydrocarbons, aldehydes, ketones, alcohols and carboxylic acids and esters are a few on that list. Long-term storage encourages lipid degradation and can result in rancid off-flavors, but in cooked products, the reactions occur quickly to provide a different profile of volatiles that produce more desirable flavors (Mottram, 1998)

During cooking, the lipids are degraded giving off various aromatic compounds that conventionally have a much higher aroma threshold compared to Maillard reaction products (Mottram, 1998). Kerth and Miller (2015) reported that lipid thermal degradation is the breakdown of polar phospholipids and neutral triglyceride because of the change in energy stabilization during cooking. Polar lipids are generally favored for degradation over neutral lipids because of their higher degree of unsaturation and the lack of fatty acid on the third glycerol carbon (Kerth & Miller, 2015).

Lipid-Maillard Reactions

Volatiles produced from thermal lipid degradation may also interact with Maillard reaction products producing more volatile flavor compounds. These lipid oxidation products enter the Maillard reaction particularly in the Strecker degradation ending in other volatiles not formed by meat precursors (Melton, 1999). Generally, phospholipids in meat contribute the fatty acids that interact with Maillard reaction products (Melton, 1999). Mottram et al. (1983) showed that removal of triacylglycerols from lean beef caused no significant chemical or sensory aroma differences, but removal of both triacylglycerols and phospholipids resulted in a less meaty, more roasted aroma, lower concentrations of oxidation products and higher levels of heterocyclic compounds, predominantly alkyl pyrazines. Farmer and Mottram (1994) investigated the volatiles formed by lipid-Mailllard interactions in heated beef *Longissimus dorsi* (LD), heart muscle and in chicken breast muscles. Chicken had formation of alkylthiazoles with the long chain in the 5 position while in beef the long chain was found in the 2 position. The heart muscle formed more alkylthiazoles than the beef or chicken and had longer alkyl chains. Farmer and Mottram (1994) suggested that because the heart muscle contained elevated levels of phospholipids and higher levels of plasmologen aldehydes than the other muscles, these compounds were coming from fatty acids or from plasmologen aldehydes in the phospholipids.

Species-Specific Flavors

Meat flavor is created by compounds that originated from either lean or fatty tissues and can be divided into two categories; the characteristic meat flavor or, the specific flavor of beef, pork, poultry and other species (Myers et al., 2009). Although meat flavor comes from the lean and the fat, the general belief is that fat is the main contributor to species-specific flavors. Without the fat, lean muscle from different species produce a comparable meat flavor. Hornstein et al. (1960) found that aqueous extracts of beef and pork had similar aromas when heated, but while heating the fats, species-characteristic aromas developed. This study hypothesized that the compounds within the lean portion interacted with amino acids, carbohydrates, and polypeptides to produce a cooked meat flavor. Wasserman et al. (1965) confirmed Hornstein's hypothesis that water extracts of lean beef, pork and lamb developed a series of aromas during boiling that created roast meat-like aroma with no species characteristics. Mottram (1979) used triangle tests to differentiate pork and beef meat cakes cooked with and without fat. The panel was able to distinguish the meats easier with the addition of 10% subcutaneous fat, no matter what fat was added. This hypothesis becomes clearer as more than 650 fat volatiles were released in beef when it was heated (Shahidi, 1994). Mottram (1998) discussed that the higher proportion of unsaturated fatty acids in triglycerides of pork and chicken, compared with beef or lamb, gave more unsaturated aldehydes in these meats that could be important in determining species specific aromas. Hydrocarbons, alcohols, ketones, and aldehydes from lipid oxidation influence species-specific flavor (Mottram, 1998). Wasserman and Spinelli (1972) determined through a trained panel that adipose tissue extracts of beef aromas were described as meat-like aromas, but lamb and pork extracts were distinguishable with "piggy", "sour", and "goaty".

However, Myers et al. (2009) showed that the lean tissue in meat products may be the main contributor to species-specific flavors. In mixed species samples, the leading flavor was determined by the lean species. This study also showed that by increasing fat content in beef samples, the samples did not increase in beef flavor, and actually decreased in metallic/serumy flavor that was previously associated with beef samples. Although this was not the case for all species, Myers et al. (2009) showed that increasing fat content might not always relate to increased flavor.

Gas Chromatography and Mass Spectrometry

Gas chromatography (GC) and mass spectrometry (MS) systems are used in flavor research to identify flavor and aroma compounds. The GC/MS system has four steps in determining the compounds: collection of volatiles, separation of volatile compounds identification of each compound, and quantification of each compound (Chambers & Koppel, 2013). This technique is commonly accepted and routine in flavor studies of muscle foods (Shahidi, 1994). The volatiles are collected with a solid phase microextraction (SPME) in the headspace of a container. The SPME then is injected into the GC/MS and desorbed. The GC is able to separate the volatiles into individual compounds as the MS identifies the compounds. This system is able to identify thousands of compounds although some might not be aromatic. Mottram (1998) reported indications of only small fractions of volatiles occurring in food actually contribute to odor and aromas. In recent years, the addition of the gas chromatography with olfactory ports (GC-O) has modernized flavor research and provides a method to determine which compounds have aromas. The GC-O allows for identification of aroma-active components. The volatiles are separated by the GC column then transported to the olfactory port, where they are combined with humidified air to prevent human nasal passages from drying out and sniffed by humans (Shahidi, 1994). The human sniffers are usually trained panelists who are trained to identify volatiles from cooked meat samples. The GC-O helps identify volatiles that are odor-active and volatiles that are non-odor-active from human detection. As the odor-active volatiles flow through the column, the panelist is able to record the smell and its intensity creating an aromagram. The compounds are also being recorded through the MS creating a chromatogram. The aromagram and chromatogram are compared to determine which compounds are producing an odor. The volatile compounds identified can be used to correlate with trained or consumer sensory panels and ultimately which volatile aroma compounds correlate with overall consumer like and dislike.

Although individual compounds have different odor thresholds and humans detect them at different concentrations, the GC-O can have variation especially between different humans. Odors can occur at very low concentrations and have sensory significance due to low threshold values. Thus, the aromatic profile obtained by the GC-O might not reflect the human identified aroma profile of a compound. The aroma might also be to brief for the panelist to decipher and distinguish before the aroma passes. However, the GC-O is still great technology for identifying flavor compounds and aroma profiles and has revolutionized the flavor industry.

Factors Influencing Flavors

Muscle Comparison

Muscle cuts are very important when considering flavor. Various muscles in the body have different flavor profiles based on color, location, and function in the body (Xiong et al., 1999). Along with flavor differences between muscles, tenderness differences also exist. Studies have found clear flavor differences between different cuts. Shackelford et al. (1995) studied 10 major muscles from *Bos indicus* and *Bos taurus* cattle. This study showed that the *M. Longissimus lumborum* (LM) had greater beef intensity when compared to the *M. Bicepts femoris* (BF) and the BF was beefier than the *M. Gleteus medius* (GM). Calkins and Hodgen (2007) compiled a detailed chart from several different studies on the ranking of flavor and off-flavor intensity from different cuts. Ang and Lyon (1990) showed that overall flavor intensity was higher for chicken thighs than chicken breasts.

The effect of myoglobin concentrations has also been shown to alter flavors of different muscles. Yancey et al. (2006) studied the total iron, myoglobin, hemoglobin and lipid oxidation of the *Infraspinatus* (IN), GM, and *Psoas major* (PM). The GM had higher amounts of myoglobin in the muscle and a higher incidence for livery off-flavors than the other cuts. Meisenger et al. (2006) showed that there was a weak relationship between pH, heme-iron concentration and off-flavor intensity or off-flavor notes between muscles. This research contradicted the previous research and showed that the full effect of myoglobin content and pH on flavor attributes has not been fully explained (Meisinger et al., 2006). Glascock (2014) also did not show strong correlations between myoglobin or non-heme iron content and liver-like flavor.

An in-home use test was used to determine consumer perception of three different beef muscles (LM, GM, and *M. Adductor* (AD)) that differed in Quality grade (Neely et al., 1998). The consumers were able to prepare the steaks to the degree of doneness and preparation method of their liking. The consumers preferred steaks from the LM, followed by the steaks from the GM and finally from the AD. The AD is used for locomotion and has been shown to be higher in connective tissue levels (Neely et al., 1998). The AD was tougher and had fewer flavors from the cooking method. Muscles high in connective tissue have been recommended to be cooked using a moist heat method to breakdown the collagen more effectively (Neely et al. 1999).

Fatty Acids

Fatty acids have an important role in understanding firmness, shelf life and most importantly meat flavor (Wood et al., 2004). Muscle foods are composed of adipose tissues and cell membranes. Generally the adipose tissues contain over 98% triacylglycerides and the lipid component of cell membranes are phospholipids (Shahidi, 2002). Neutral lipids are the main lipids found in the body (Mottram, 1998). Lipids act as a source of energy for the cell and phospholipids contribute to membrane function. Wood et al. (2004) explained that in animal fats, the saturated fatty acids of palmitic acid

(16:0) and stearic acid (18:0) are present in higher levels and only small quantities of lauric aicd (12:0), myristic acid (14:0), or arachidonic acid (20:4) are present. The predominant unsaturated fatty acids are palmitoleic (16:1), oleic acid (18:1), linoleic, (18:2) and linolenic (18:3) with 18:2 being the most abundant fatty acid (Wood et al., 2004).

Westerling et al. (1979) evaluated the influence of fatty acids on the palatability of longissimus muscle steaks. Trained panel scores were negatively correlated with 16:0, 18:0, 18:2, and total saturated fatty acid content. Flavor scores from a trained panel were also positively correlated with 18:1 and total unsaturated fatty acids (Westerling & Hedrick, 1979). Baublits et al. (2009) showed a positive correlation between beefy/brothy and beef fat flavor aromatics with fatty acids 16:0, 16:1 and vaccenic acid (18:1 trans). A negative correlation was shown between beefy/brothy and beef fat flavor aromatics with pentadeconoic acid (15:0), alpha-linoleic acid (α-18:3), 20:4, eicosapentaenoic acid (20:5), docosapentaenoic acid (22:5) and docosahexaenoic acid (22:6). Negative aromatic flavor attributes, such as old/putrid aromatics were positively correlated with 12:0, 15:0, 15:1, and α-18:3, and negatively correlated with 18:1. Baublits et al. (2009) concluded that increased percentages of saturated and monounsaturated fatty acids enhanced the positive beef flavor attributes while the polyunsaturated fatty acids were observed with the negative flavor attributes.

The fatty acid composition was measured in pork, beef and lamb from retail supermarkets (Enser et al., 1996). The lamb had the highest total fatty acid composition of the *longissimus dorsi* (LD) while the pork had the lowest. The subcutaneous fat in pork had significant levels of long chain (C20-C22) n-3 PUFA and 18:2, a dietary fatty acid that can be deposited upon digestion into the tissues in both locations (Wood et al., 2008). Pork had the highest levels of 18:2.

Ruminants and non-ruminants differ in the deposition of fatty acids mainly because of differences in their digestive system (Jayasena et al., 2013) According to Calkins and Hodgen (2007) poultry and pork muscle have higher levels of polyunsaturated fatty acids in the triglycerides than lamb or beef. Thus poultry and pork have more unsaturated volatile aldehydes when compared to beef or lamb. Fatty acids 18:1 and 18:2 are the main triglycerides present in red meat and poultry. Phospholipids have a higher proportion of 18:2 and 20:4 (Shahidi, 2002). Depending on the type and proportion of unsaturated fatty acids in meats, lipid autoxidation and flavor deterioration can proceed at different rates with seafood deteriorating first, followed by chicken and than red meats (Shahidi, 2002).

Degree of Doneness

Raw meat has been described as weak, salty, and blood-like and the desirable characteristic beefy flavors develop as the degree of doneness increased (Crocker, 1948). The temperature of the heating element and the method of cooking affect the rate of cooking combined with final degree of doneness, all impact the rate and extent of chemical reactions (Crocker, 1948; Kerth, 2013). Higher degree of doneness can be achieved with longer cook times and higher temperatures to reach the formation of aromatic compounds resulting in roasted, nutty or fruity flavors. These flavors are developed from browning the surface of the steak from high surface temperatures or exposure to heat for long periods of time (Kerth, 2013). Luchak et al. (1998) studied sensory, chemical and cooking characteristics of retail beef cuts differing in intramuscular and external fat. The lower internal temperature endpoint were juicier and more tender, and had the lowest Warner-Bratzler Shear values.

Bowers et al. (1987) heated beef longissimus muscle steaks to seven internal temperatures between 55° and 85°C. The various endpoint temperatures influenced panel ratings for flavors and juiciness. The intensity of the mouth-filling blend note increased as the internal temperature increased, and the bloody/serumy, metallic and sourness flavor attributes decreased as temperature increased. Miller (2001) showed similar results as degree of doneness increased, serumy/bloody, metallic, sour, and bitter notes decreased while liver-like and cooked beef/brothy aromatics increased. By varying cooking methods and internal temperatures Calkins et al. (2007) created different flavors ranging from bland to strong meaty notes, some with high grill-like flavor, and others were noticeably roasted. Higher temperatures result in more Maillard reaction products (Imafidon & Spanier, 1994). Therefore, flavor intensity may be influenced by degree of doneness may also be influenced by the Maillard reaction.

Belk et al. (1993) indicated that at lower temperatures, metallic and astringent mouth feels, bitter and sour basic tastes bloody/serumy, painty, and soured aromatics were detected in beef roasts cooked to different internal temperatures. As the temperature increased, cooked beefy/brothy, cowy/grainy, cardboardy and liver-like flavors aromatics also increased. Another study done by Moeller et al. (2010), measured the cook end point temperatures of pork loins and found no significant effects on flavor as determined by a trained panel. Myers et al. (2009) found similar results when comparing degree of doneness with ground beef and ground pork patties cooked to 66°or 71°C.

Mottram (1985) showed how degree of doneness affected cooked pork volatiles by cooking chops to a light (10 min per side), medium (15 min per side), and well done (30 min per side). The well-done pork chops contained 66 heterocyclic compounds, mainly pyrazines with others such as thiazoles, thiophenes, furans, pyroles, and oxazole. Whereas, the lower degrees on doneness chops did not produce as many heterocyclic compounds and had more oxidative compounds. The well-done pork produced more Maillard reaction products such as alkyprazines and thiazoles. Acetylthiazole was found in less severe cooking procedures such as boiling or lightly grilled chops.

Quality Grade

A Quality grade is a prediction for consumer palatability (tenderness, juiciness, and flavor) by indirectly assessing the extent to which flavor and aroma producing compounds and precursors are likely to be present in the beef (Smith et al., 1983). The factors that are taken into account include: carcass maturity; firmness, texture, and color of lean; and the amount and distribution of marbling. Beef Quality grades are based on two main factors: the degree of maturity and degree of marbling. The degree of maturity is determined from the animal's age by evaluating bone maturity, color, and texture of the lean. There are significant differences in palatability when youthful beef is compared to mature beef (A vs. E maturity; Smith et al., 1982). Beef from older animals is more intense in flavor than younger animals and their meat is tougher due to the increase in insoluble collagen linkages (Miller, 1994).

The degree of marbling is the amount and distribution of intramuscular fat within the LD muscle at the 12th and 13th rib interface. Higher levels of marbling are eligible for higher Quality grades. Marbling in beef has been related to tenderness and palatability. A carcass with a higher Quality grade would be expected to produce meat with more desirable palatability than the meat from a lower Quality grade carcass (Miller, 1994). Marbling is believed to effect beef flavor in two ways, the oxidation products produced from fatty acids upon heating and fat may act as a storage depot for other volatile compounds released during cooking (Hornstein, 1971). McBee and Wiles (1967) and Smith et al. (1983) showed that as marbling score increased from practically devoid to moderately abundant, flavor desirability increased. Smith et al. (1983) also concluded that marbling score ultimately evaluated concentrations of flavor and aroma in beef. This means that carcasses with higher marbling scores should produce more beefy tasting meat. Smith et al. (1983) also found that a higher marbling score considerably decreased the presence of undesirable flavors. As the marbling score increased from practically devoid to moderately abundant, the undesirable ratings decreased from more than 55 percent to zero.

Miller et al. (1997) studied slaughter plant location, USDA Quality grade, external fat thickness, and aging time effects on sensory characteristics of beef loin strip and found that Choice steaks had a higher flavor intensity ratings than Select steaks. Miller (2001) reported that as the amount of marbling or intramuscular fat increased, the amount of fat flavor increased. Marbling is a key component of beef flavor and higher levels of marbling within beef cuts are expected to be more tender, juicy and flavorful.

Cooking Method

Cooking has one of the most significant affects on the flavor and tenderness of muscle foods. Both temperature and moisture content will be affected by cooking method, which in turn will control many chemical reactions that occur during cooking, such as lipid degradation and Maillard reactions (Aberle et al. 2001).The type of cooking method will dramatically change the flavor development of cooked meats (Aberle et al. 2001). More specifically the difference between moist-heat and dry-heat cookery causes a major change in flavor development. Cooking meat in water in a closed or partially closed system such as braising, boiling, simmering or stewing are all examples of moist-heat cookery. The clamshell grill produces similar characteristics from moist-heat cooking because it traps the moisture and causes the beef to steam cook. Kerth and Miller (2015) reported moist-heat cookery with lower temperatures prevents the beef from reaching sufficient surface temperature for the development of Maillard reaction products and inhibits dehydration of the surface to initiate the first step of the Maillard reaction. Moist-heat cookery, as in cooking stews or boiling meat, around 100°C will have a significantly different odor and flavor from meat that is produced when cooking meat by dry heat such as roasting at 163°C (Rhee, 1989). Dry heat cookery, such as grill and oven methods, uses higher temperatures to cause dehydration of the surface and initiate the Maillard reaction and browning (Kerth & Miller, 2015).

Wasserman (1972) observed that the aromas stewed or braised meat heated at 100°C was different from the same meat roasted with dry heat at 190°C. It was also noted was that the internal temperature varied from about 60°C to 80°C thus, the flavor is derived from the surface. Roasting, grilling, frying or pressure-cooking of chicken meat can produce a large number of heterocyclic compounds including pyrazines, alkylpyrazines, pyridines, pyrroles and thiazoles. This could be due to the higher temperature and lower moisture conditions used in these cooking methods. These compounds are absent in boiled meat (Melton, 1999; Shi, 1994). Dry method cooking is able to change flavors by increasing compounds formed during the Maillard reaction, lipid degradation and Maillard-lipid interactions.

Cooking method effects on top loin steaks were studied by Lorenzen et at. (1999). Outdoor grilling was the most prevalent type of cooking and Choice top loin steaks had the highest flavor intensity liking. Neely et al. (1999) focused on the cooking methods of top round steaks and found that moist-heat cookery methods had higher liking ratings. Consumer liking of the top rounds steak was dependent on cooking method and city-specific attitudes.

Tenderness

In the past, tenderness was the most important factor influencing consumer satisfaction for beef palatability (Dikeman 1987; Miller et al., 1995; Savell et al., 1987; Savell et al., 1999) Recently, studies have shown that once tenderness reaches an acceptable level, it no longer was as important (Behrends et al., 2005; Goodson et al., 2002). However, tenderness is still an important factor influencing consumer satisfaction for palatability. Consumers want a tender, flavorful, juicy steak. Tenderness is a concern to the meat industry because of the variation in tenderness (Smith et al., 1992). Several variables including: animal age, gender, rate of glycolysis, amount and solubility of collagen, amount of intramuscular fat, sarcomere length, ionic strength, and degradation of myofibrillar proteins all affect meat tenderness (Koohmaraie, 1992).

The beef industry uses the USDA quality grading system to predict tenderness using marbling and carcass maturity. Although marbling has a large influence, marbling only accounts for a low amount of variability in beef tenderness (Blumer, 1963). There are four marbling theories to help explain marbling's effect on tenderness: bulk density theory, lubrication theory, insulation theory, and the strain theory (Smith & Carpenter, 1974). The bulk density theory explains that fat is less dense than the lean tissue causing softer pockets. Adipose tissue deposited among the muscle fibers decreases the lean per volume and lowers the bulk density. The lubrication theory suggests that intramuscular fats, in and around the muscle fibers, lubricate the fibers and fibrils to make a more tender and juicier product upon cooking. The melted fat during mastication coats and lubricates the fibers making it easier to bite through and the meat appears more tender. The insulation theory suggests that more marbling creates insulation for the muscle fibers allowing for higher temperature methods of cookery. This theory provides insurance against cooking meat too rapidly, overcooking, or using the wrong cooking method without decreasing the palatability. The adipose tissue does not conduct heat as fast as lean tissue allowing for highly marbled meat to be cooked at higher temperatures without overcooking the muscle fibers with less heat denaturation of the proteins. The final marbling theory is the strain theory. As marbling accumulates inside the walls of the connective tissue, the connective tissue's effect on tenderness is weakened. The fat has been hypothesized to spread apart the strands of connective tissue between the muscle fibers and between the muscle bundles increasing tenderness. Carpenter (1962) concluded that marbling that has been deposited between the connective tissue aids in the breakdown of collagen because the fat deposits spread the connective tissue fibrils apart to provide a looser structure that aids in heat penetration and ultimately the solubilization of these connective tissue strands. Although the exact mechanism for how fat deposition increases tenderness is not known, these theories provide a good understanding of what could be happening. Intramuscular fat as it relates to tenderness have conflicting reports. DeVol et al. (1988) found that increasing intramuscular fat significantly correlated with tenderness as seen by a trained panel. Fernandez et al. (1999) reported that increasing intramuscular fat from approximately 1.25 to 3.25% created a trend increasing tenderness, but the trend was not seen when consumers evaluated pork loin. Novakofski (1987) stated that lower levels of intramuscular fat are unfavorable to palatability but higher levels over a threshold do not increase beneficial effects. Moeller et al. (2010) reported that pork intramuscular fat contributed only a small influence of perception of tenderness by trained panelists and consumers.

Postmortem aging is necessary for reaching peak tenderness in most species of meat (Aberle et al., 2001). Upon the completion of rigor mortis, meat is the least tender due to the shortening of sarcomeres (Aberle et al., 2001). As rigor moves into the resolution phase, tenderness begins to improve. Tenderness tends to increase as postmortem storage time increases (Wilson, 1960) . Tenderization is also caused by degradation to both myofibrillar and cytoskeletal proteins in muscle (Huff-Lonergan et al., 1996). Post-mortem tenderization is caused by enzymatic degradation of key proteins (Mohammad Koohmaraie, 1996). The calpain system has an essential role in postmortem muscle protein degradation. Calpain is a calcium–activated, cysteine-protease that is most active in the neutral pH range (Strasburg, 2008). Regulation of calpain is done by calpastatin, a calpain-specific protein inhibitor, along with calcium and phospholipids (Goll et al., 2003). The three capains that are present in muscle and help with muscle fiber degradation are *m*-calpain, μ-calpain, and calpain 3 (Bartoli & Richard, 2005). μ -calpain is mostly responsible for postmortem tenderization (Koohmaraie, 1996). Calpain 3 (also called p94 or CAPN3) is a skeletal muscle-specific calpain isoform that binds to certain regions of titin (Sorimachi et al., 1995). Unlike m-calpain and μ-calpain, calpain 3 is not inhibited by calpastatin suggesting that it does not aid in meat tenderness because animals with high calpastatin do not produce tender meat (Kemp et al., 2010).

Both *m*-calpain and μ-calpain are concentrated in the Z-discs and can cause complete loss of the Z-discs (Strasburg, 2008). As Ca^{2+} concentration increases postmortem, mostly *m*-calpains and μ-calpains are activated and start degradation of muscle proteins such as troponin-T, titin, nebulin, C-protein, desmin, filamin, vinculin, and synemin (Huff-Lonergan et al., 1996). Once the Z-disks and other structural proteins are disrupted, actin and myosin are released together with other proteins from the sarcomere and become substrates for other proteolytic enzymes (Strasburg, 2008). Koohmaraie et al. (1992) determined that desmin degradation could show variation in rates between species. Autolysis of *m*- and μ-calpain will happen in the presence of sufficient calcium with the ultimate loss of activity (Koohmaraie, 1992).

The calpain enzyme system presents a breed difference in overall beef tenderness. *Bos indicus* cattle are known to be tougher than *Bos taurus* cattle because of reduced postmortem proteolysis of myofibrilar proteins in *Bos indicus* cattle (Whipple et al. 1990) . It has been shown that as the percentage of *Bos indicus* increases, the level of tenderness decreases (Crouse et al., 1989). *Bos indicus* cattle have higher calpastatin activity postrigor than in *Bos taurus* cattle (Shackelford et al., 1991; Whipple, 1990). Whipple et al. (1990) suggested that the higher calpastatin might slow desmin degradation in the *Bos indicus* cattle.

The total amount and solubility of connective tissue has a key impact on tenderness. Collagen, the most abundant connective tissue protein, is found throughout the body and it is a large factor in meat tenderness variation. It contributes significantly to the toughness of muscle and is an important functional ingredient in many foods such as gelatin (Strasburg, 2008). Collagen molecules are held together through intermolecular crosslinks to help provide structure and strength to the collagen molecule. The crosslinks over time stabilize and are replaced by mature, thermally-stable, less soluble crosslinks. Cross et al. (1973) reported that percent soluble collagen was significantly related to the connective tissue contribution to toughness. There are two types of collagen crosslinks that determine collagen solubility: heat-labile and heat-stable. Heat-labile collagen melts or gelatinizes in the presence of heat increasing tenderness; whereas, heat-stable collagen does not melt, decreasing tenderness (Hill, 1966). As an animal matures and ages, the crosslinks slowly stabilize into the insoluble, heat-resistant type causing a reduction in tenderness. This concept is the basis for the maturity-beef tenderness relationship (Miller et al., 1983). This relationship was seen in Herring et al. (1967) who reported that as each maturity group increased, the collagen solubility significantly decreased in both the LD and *Semimembranosus* muscles. The collagen solubility was higher in the LD than the *Semimembranosus.* This relationship is why cattle are harvested at a young age in the United States (Herring et al., 1967). Age-related connective tissue toughness is not a major factor for the chicken industry since the market age of broilers is less than 7 to 8 weeks of age (Fletcher, 2002). The type of nutrition cattle are being fed has also shown to affect collagen solubility. Aberle et al. (1981) showed that feeding high-energy diets to youthful cattle increased collagen solubility. There have also been variations in soluble collagen between bulls and steers. Burson et al. (1986) stated that LD of steers contained more heat-soluble collagen than from bulls. Gerrard et al. (1987) proposed the reason behind this concept is that bull collagen decreases in degradation rate more rapidly than steer collagen, causing more enzymatic crosslinking and forming of heat-stable crosslinks. This shows the effects of testosterone on collagen maturation and solubility. In chicken, collagen solubility has had little influence and does not correlate with tenderness (Nakamura et al., 1975).

Muscles vary in connective tissue throughout the animal. Muscles can differ in the amount and percentage of soluble collagen. Seggern et al. (2005) found that the *Cutaneous omo-brachialis* had the highest collagen of all of the muscles studied because of the muscles location and function. Warner-Bratzler shear force was determined on 40 muscles to determine tenderness categories (Belew et al., 2003). It was found that the *M. infraspinatus* and the *M. psoas major* were in the very tender category. The *M. longissimus thoracis*, *M. longissimus lumborum*, and the *M. gluteus medius* were placed in the tender category, The *M. glueteobiceps* and the *M. semimembranosus,* both members of the round, were both identified as tough muscles. Connective tissue within muscle is extremely variable and depends on the developmental stage, muscle position/function, animal breed, nutrition, exercise and injury (Purslow, 2005). In pork, collagen content is weakly correlated with tenderness (Wheeler et al., 2000).

Cooking can cause tenderization or toughening of meat. Generally, heat makes collagen more tender by converting it to gelatin, but heat coagulates and toughens the protein. Davey and Gilbert (1974) showed cooking toughening in two stages. The first stage, which occurred at 40 to 50°C, denatured the contractile proteins, actin and myosin and caused an initial loss of fluid. The second stage, at 64 to 68°C, caused the denaturation of collagen resulting in the shrinkage of the fibrils and more fluid loss (Davey & Gilbert, 1974).

Conclusion

Flavor is a very complex and multidimensional concept especially in reference to meat. Based on previous research, it is obvious that meat is a complex food. Recent research studied the importance of beef flavor and consumer perception of heavy beef eaters (Glascock, 2014) and light beef eaters (Luckemeyer, 2015). Glascock (2014) and Luckemeyer (2015) found that different aromatic volatiles were characteristic of various beef lexicon attributes, as well as different flavors identified in the beef lexicon could be manipulated by muscle, Quality grade, pH level, cooking method and final internal temperature endpoint. With a new generation of consumers, it is important to understand what is driving acceptability.

CHAPTER III

MATERIALS AND METHODS

Sample Selection and Preparation

USDA upper two-thirds Choice beef loin, strip loin, boneless (IMPS 180) subprimals were collected from 30 beef carcasses (2 per carcass) and Select round, outside round (flat;IMPS 171B) were obtained from 60 beef carcasses (2 per carcass) on two selection days at Kane Beef in Corpus Christi, TX. The carcasses were selected based on grading by a USDA grader and grading by Texas A&M Meat Science personnel trained in grading to confirm Quality grade. Chicken boneless butterfly breasts and boneless chicken thighs (not enhanced); and pork loins, boneless (IMPS 413) and leg, inside (not enhanced; IMPS 402F) were purchased from Ruffino Meats in Bryan, TX. These cuts were selected to differ in flavor based on previous research (Glascock, 2014; Luckemeyer, 2015; Miller et al., 2012). The Top Choice strip loins and boneless pork loins were aged for 14 d, frozen whole and then cut into steaks. Top strip loins were cut into 2.54 cm thick top loin steaks beginning at the anterior end with 0.25 cm external fat. Pork loins were cut into pork loin chops (2.54 cm thick) starting at the 10^{th} rib. Steaks and chops within a loin were randomly assigned to either trained, consumer sensory evaluation, or chemical evaluation across treatments (cooked to 58.3°C for beef, 62.7°C for pork or 80°C on a commercial electric flat grill). The Select bottom rounds, flat roasts and inside ham roasts were also aged 14 d and then cut into roasts (approximately 0.9 kg). Roasts within a carcass were randomly assigned to either trained or consumer sensory evaluation, or chemical evaluation across treatments (cooked to 58.3°C or 80°C in a Crock-pot®). The chicken breasts were split into individual breasts and randomly assigned to each treatment (cooked to 62.7°C or 80°C on a commercial electric flat grill). The chicken breasts and thighs were aged 14 d then frozen. The chicken breasts and thighs within a box were randomly assigned to cooking methods (Crock-pot® cooking for chicken thighs to 62.7°C or 80°C; and 62.7°C or 80°C on a commercial electric flat grill for chicken breasts). The steaks, chops, roasts, breasts and thighs were vacuum-packaged (B2470, Cryovac Sealed Air Corporation, Duncan, SC) with an oxygen transmission rate of 3-6 cc at 4°C (m^2, 24 h atm 4°C, 0% RH) and a water vapor transmission rate of 0.5-0.6 g at 38°C (100% RH, 0.6 m^2, 24 h) and were frozen and stored at -40°C until evaluated. The steaks, roasts, breasts, and thighs were randomly assigned to each treatment within animal. For each analysis, individual steaks were selected and thawed in refrigerated (4ºC) storage for 12 to 24 h. The intent was to create a set of steaks, chops, breast, thighs and/or roasts that differed in key flavor attributes.

Top loin steaks, chicken breasts and pork chops were cooked on a commercial electric grill (StarMax 536GF 36 inch Countertop Electric Griddle, Star Manufacturing International, Inc., St. Louis, MO) set at 204.4°C. Beef bottom round roasts, chicken thigh meat and inside ham roasts were cooked in a Crock-pot® (6.5-Quart Cook and Carry, Jarden Corporation, Boca Raton, FL) using the high setting with 1.4 L of pre-heated water. These cook methods have been shown to induce differences in Maillard reaction products and heat-induced lipid oxidation. Internal temperatures were monitored by iron-constantan thermocouples (Omega Engineering, Stamford, CT) inserted into the cut geometric center of each steak, chop, breast, thigh or roast. Sensory analysis was conducted as defined by AMSA (2015) and Meilgaard et al. (2007). Sensory evaluation was approved by the Institutional Review Board for Use of Humans In Research at Texas A&M University (IRB2014-0487D).

Expert, Trained Descriptive Beef Flavor Analysis

The steaks, chops, breast, thighs and roasts were evaluated by an expert trained meat descriptive attribute panel that helped develop and validate the beef lexicon, developed the pork lexicon and has used the chicken lexicon extensively. This panel was retrained using the beef, and adapted versions of the pork and chicken lexicons for 14 d (Adhikari, 2011; Chu, 2015; Lyon, 1987). Beef, pork and chicken flavor attributes were measured using a 16-point scale within each lexicon (0 = none and 15 = extremely intense) defined in Tables 1, 2, and 3. After training was complete, panelists were presented 12 samples per day, divided into two sessions ten minutes apart. Prior to the start of each trained panel evaluation day, panelists were calibrated using one orientation or "warm up" sample that was evaluated and discussed orally. After evaluation of the orientation sample, panelists were served the first sample of the session and asked to individually rate the sample for each beef, pork, or chicken flavor lexicon attribute. Double distilled water, unsalted saltine crackers and fat-free ricotta cheese were available for cleansing the palate between samples. During evaluation, panelists were seated in individual breadbox-style booths separated from the preparation area and samples were evaluated under red lights. In order to prevent taste fatigue, each evaluation day was divided into two sessions, with a ten-minute break between sessions and samples were served four minutes apart.

After cooking, samples were cut into 1.27 cm X 1.27 cm X cut thickness cubes. Three cubes per sample were served in clear, plastic 59 mL soufflé cups (translucent plastic 2 oz. portion cups, Georgia-Pacific, Asheboro, North Carolina) tested to assure that they did not impart flavors on the samples. Samples were identified with random three-digit codes and served in random order. Samples were cut and served immediately to assure samples were approximately 37˚ C upon time of serving.

Consumer Location Evaluation

Consumers (n = 120 per city) were randomly selected in four cities (Griffin, GA; Olathe, KS; State College, PA; and Portland, OR) so that geographical areas represented the Southeast, the Midwest, the east coast, and the west coast. In each city, six consumer sessions with approximately 20 consumers per session were conducted. Within each city, consumers were selected to be either millennials (ages 18 to 34; n = 60) or non-millennials (n = 60; ages greater than 34) and within age categories to be either light (n = 30 per age group (millennial light beef eaters (ML) and millennial heavy beef eaters (MH)); eat beef 2 to 4 times per month) or heavy beef eaters (n = 30 per age group (non-millennial light beef eaters (NL) and non-millennial heavy beef eaters (NH)); eat beef 3 or more times per week). Overall, flavor, meat flavor, grilled flavor, juiciness and tenderness liking was included on the ballot using 9-point hedonic scales. After completion of each consumer session, four consumers were asked to participate in one-on-one interviews to determine attitudes toward beef and beef flavor. These four consumers represented one from each of the aforementioned consumer groups. Demographic questions, hedonic questions and one-on-one interview questions are presented in appendices C, D, and E, respectively.

Consumer panelists were recruited by the individual research intuition and all panelists were required to pass a consumer screener guaranteeing them to be over 18 y of age, have no food allergies, and they were in one of the consumer groups mentioned previously. On the day of evaluation, recruited consumer panelists were asked to sign an informed consent document. An instructional document, demographic ballot and eight individual sample ballots were provided to the consumer upon entering the testing room. Consumer demographics for age, sex, income, household income, type of employment, dietary restrictions, protein sources consumed, meat consumption levels of beef, and meat shopping habits were determined (Appendix C). The ballot included overall liking, overall flavor liking, meat flavor liking, grilled flavor liking, and juiciness liking, and tenderness liking rankings using a nine-point hedonic. Consumers also were asked two open-ended questions: "Please write any words that describe the positive or good flavors in this meat;" and "Please write any words that describe the negative or bad flavors in this meat." An example of this ballot is provided in Appendix D. Panelists were provided eight pre-identified random samples in a pre-determined random order four minutes apart. Samples were served in clear plastic weigh boat containers labeled with a random three-digit number corresponding to their ballot. Samples were cut and prepared as defined for expert, trained beef flavor descriptive analysis. Four consumers evaluated from each sample.

In-home Consumer Use Evaluation

The in-home consumers were selected from the initial 120 consumers that participated in the central location test. Twenty consumers from each of the four consumer categories previously identified (MH, ML, NH, NL) were selected for a total of 80 participants per city. For all four cities, 80 consumers were included from each age and usage group for the study for a total of 320 consumers. Consumers were provided one USDA Choice beef top loin steak, one Select beef bottom round flat roast, one chicken breast and one boneless pork loin chop. Each meat product was vacuum-packaged, labeled and frozen as defined in the central location test. The intent was to create a set of steaks, chops, breasts and/or roasts that differed in the key flavor attributes that they could prepare at home. Consumers were asked to answer a questionnaire as they prepared each product that included cooking method, ingredients added, degree of doneness, cuisine classification, and preparation time. Consumers also were provided a ballot and asked to rate the cooked product for appearance, overall like, flavor and texture liking using 9-point hedonic scales as in the original project (Appendix D) (AMSA, 2015; Meilgaard et al. 2007). Consumers were provided color scales for determination of degree of doneness using the American Meat Science Association Beef Steak Color Guide (AMSA, 1995) and the Pork Chop Cooked Color Guide (Hawthorne et al.), descriptions of cooking methods (Appendix G, H, I), and a self-addressed stamped envelope to return their ballot and questionnaire. After receipt of the questionnaire and ballot, consumers were provided a $20 gift card for their participation.

Cooked Meat Volatile Flavor Evaluation

Volatiles were captured from the same steaks, roasts, breasts, and thighs evaluated by the consumer panelists in State College, PA. After samples were prepared for consumers, approximately 75 g of 1.25 cm beef, pork and chicken cubes were placed in foil with a tag separated from the meat samples. Samples were placed in liquid nitrogen and frozen to -196°C and stored at -80°C until volatile analysis. Volatiles were evaluated using the Aroma Trax gas chromatograph (GC) /mass spectrophotometer (MS) system with dual sniff ports for characterization of aromatics. This separates individual volatile compounds, identifies their chemical structure and characterizes the aroma/flavor associated with the compound at parts per trillion. Samples were placed in heated glass jars (473 mL) with a Teflon® lid under the metal screw-top to avoid off-aromas and then set in a water bath at 60°C and thawed, then the headspace was sampled 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 2 h for each sample after the sample reached 60°C. 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 (Agilent Technologies 7920 series GC, Santa Clara, CA) into the first column (30m X 0.53mm ID/ BPX5 (5% Phenyl Polysilphenylene-siloxane) X 0.5 µm, SGE Analytical Sciences, Austin, TX), which separates compounds based on boiling point. Through the first column, 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), which separates compounds based on polarity. The gas chromatography column then spilt into three different columns at a three-way valve with one going to the mass spectrometer (Agilent Technologies 5975 Series MSD, Santa Clara, CA) and two going to the two humidified sniff ports that were heated to a temperature of 115° C with glass nose pieces. The sniff ports and software for determining flavor and aroma were a part of the AromaTrax program (MicroAnalytics-Aromatrax, Round Rock, TX). Panelists were trained to accurately use the Aromatrax software, after they had also been trained according to the beef, pork and chicken lexicon aromas.

Warner-Bratzler Shear Force

Steaks, roasts, breasts and thighs for Warner-Bratzler shear force (WBSF) were cooked in the same manner and at the same time as trained descriptive beef flavor analysis steaks. Cooking yield percentages were determined from weights recorded before and after cooking, and total cooking time was recorded for individual meat type. Steaks, chops, roasts and chicken were trimmed of visible connective tissue to expose muscle fiber orientation. Six 1.3 cm diameter round cores were removed from each muscle. Roasts were cut in 2.54 cm section and then cores were removed. Chicken thighs were not a uniform thickness; therefore care was taken to get cores. Cores were removed parallel to the muscle fibers and sheared once, perpendicular to the muscle fibers, on a United Testing machine (United SSTM-500, Huntington Beach, CA) at a cross-head speed of 200 mm/min using a 500 kg load cell, and a 1.02 cm thick V-shape blade with a 60° angle and a half-round peak. The peak force (kg) needed to shear each core was recorded (kg), converted to Newtons (N), and the mean peak shear force of the cores was used for statistical analysis. WBS values were converted using the following equation: The WBS force (N) = WBS force (kg) × 9.806.

Raw Chemical Analyses

Raw meat pH, fatty acid composition, myoglobin content, non-heme iron content, and fat and moistures were determined from each raw muscle within carcass of the beef and pork loin. For the chicken breast, chicken thigh and inside ham roasts cuts, 30 samples were randomly selected. Muscle samples were cubed, frozen in liquid nitrogen, and pulverized with a Waring blender (Waring Products Division, New Hartford, CT). Pulverized samples were stored at -20°C and used for all chemical analyses. The pH was determined in duplicate (pH meter calibrated daily with 4.0, 7.0, and 10.0 pH buffer solutions; IQ Scientific Instrument, Model IQ150, IQ Scientific Instrument, Inc., Carlsbad, CA, U.S.A.) by blending 25 g of meat with 100 mL of water.

Fat and moisture analyses were determined in triplicate on the powered meat samples according to the AOAC (1990) procedures using the ether extraction and air-drying oven methods. Thimbles were constructed from Whatman #1 filter paper folded into a sleeve. Approximately 2-3 g of powdered meat was placed into the thimble, sealed with a stable and weighed. The samples were dried at 100°C for 16-18 h, placed in a desiccator for 1 h and the dried thimble weight was recorded. The thimbles were placed in a Soxhlet apparatus with petroleum ether and extracted for 18 h. Samples were then allowed to dry for 30 min before being placed in the oven for 12 h. Then, the samples were placed in a desiccator for 1 h and weighed. Finally, the moisture and fat were calculated from the following formulation: Percent moisture = [(initial thimble/sample weight)-(dried thimble/sample weight)] / sample weight *100; percent fat level = [(dried thimble/sample weight)-(extracted thimble/sample weight)] / sample weight *100.

Fatty acid methyl esters (FAME) were prepared from the lipid extracts as described by Morrison and Smith (1964). Approximately, 3-5 g of powdered meat was combined with 1 mL of 0.5 KOH in MeOH and heated at 70 °C for 10 min. After cooling, 1 mL of boron trifluoride (BF3; 14%, wt/vol) was added to each sample, which was flushed with N_2 , loosely capped, and heated at 70 °C for 30 min. The samples were removed from the bath, allowed to cool to room temperature, and 2 mL of HPLC grade hexane and 2 mL of saturated NaCl were added to the samples and vortexed. After phase separation, the upper phase was transferred to a tube containing 800 mg of Na_2SO_4 to remove moisture from the sample. An additional 2 mL of hexane was added to the tube with the saturated NaCl and vortexed again. The upper layer was transferred into the tube containing the Na_2SO_4. The hexane extract was transferred to glass scintillation vials. The sample was evaporated to dryness at 60 °C under N_2 gas, subsequently reconstituted with HPLC grade hexane, and analyzed using a Varian gas chromatograph (model CP-3800 fixed with a CP-8200 auto- sampler, Varian Inc., Walnut Creek, CA; Chung et al., 2006). Separation of FAME was accomplished on a fused silica capillary column CP-Sil88 (100 m x 0.25 mm (i.d.); Chrompack Inc., Middleburg, The Netherlands), with helium as the carrier gas (flow rate = 1.2 mL/min). After 32 min at 180 °C, oven temperature increased at 20 °C/min to 225 °C and held for 13.75 min. Total run time was 48 min. Injector and detector temperatures were at 270 °C and 300 °C, respectively. Standards from Nu-Check Prep, Inc. (Elysian, MN) were used for identification of individual FAME. Individual FAME were quantified as a percentage of total FAME analyzed. All fatty acids normally occurring in beef lean and fat trim, including isomers of conjugated linoleic acid, were identified by this procedure.

Myoglobin concentration was conducted according to Ricksand and Henrickson (1967) with modification to be read using a 96-well plate reader. Duplicate 25g samples were blended with 100 mL of DDH_2O for 3 min and centrifuged at 2000 x *g* at 6°C for 15 min. The supernatant was filtered through Whatman No. 3 filter paper and brought to volume in a 200 mL volumetric flask. From this 200 mL portion, duplicate 5 mL portions were taken and adjusted to pH of 7.1 using 0.5 M phosphate buffer. Then 1.25

mL of saturated lead acetate was added to the tube and centrifuged at 2000 x *g* for 15 min, 2.5 mL of the supernatant was combined with a mixture of mono- and di-basic phosphate to bring the phosphate concentration to 3M and the pH to 6.6 and was again centrifuged at 2000 x *g* for 15 min. One milliliter of the supernatant was combined with 0.7 mL of potassium ferricyanide and 0.7 mL of potassium cyanide to convert all forms of myoglobin to cyanmetmyoglobin. The samples were again centrifuged at 2000 x *g* for 15 min to ensure that all myoglobin had been transformed. Two hundred microliters were pipetted in triplicate on a 96 well plate and measured absorbance at 520 nm.

For non-heme iron, samples were prepared following the procedures described by Rhee and Ziprin (1987) and measured absorbance at 533 nm using a Epoch UV/visual Spectrophotometer (BioTek,Winooski, VT). To determine total non-heme iron, final absorbance of each sample was calculated by subtracting the absorbance of the incubated liquid phase with no color reagent added from the absorbance of the incubated liquid phase with color reagent added. Next, final concentration was calculated by subtracting the intercept of the standard curve from the final absorbance and dividing by the slope of the standard curve. Finally, non-heme iron was calculated as follows: μg non-heme Fe/g meat = concentration (μg/mL) x (15 + 0.2 + moisture in 5 g meat)/5 g x 1 mL.

Statistical Analyses

The trained panel descriptive flavor attributes and the volatile compounds were analyzed using means, correlations, and stepwise linear regressions procedures in SAS (version 9.3, SAS Institute, Cary, NC) to understand what chemical attributes drive specific beef flavor attributes. A predetermined alpha of ($P < 0.05$) was used in all analyses. For stepwise regression analysis, dependent variables were defined as overall consumer liking and trained descriptive attributes of beef identity, brown/roasted, bloody/serumy, metallic, liver-like and umami. Independent variables were volatile compounds defined using the Aroma Trax and were allowed to enter the equation ($P \leq 0.05$). Final equations were presented and the intercept ß values and partial r^2 for each independent variable and final equation for r^2 are presented. For analysis of variance of chemical data, treatment was defined as a main effect. For trained panel data, data were averaged across panelists and sensory day and order served were defined as random variables. For consumer data, city, treatment and their interaction were included as main effects and order served was defined as a random variable. For volatile category data, treatment was included as the main effect. Least squares means were calculated using Fisher's least significance differences in SAS to determine differences between means when significance was defined in ANOVA 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 Meat Flavor Analysis

The beef, pork, and chicken attributes, definition, and reference standards used in this study are outlined in Tables 1, 2, and 3 (Adhikari, 2011; Chu, 2015; Lyon, 1987). The juiciness and tenderness attributes are also included in Tables 1, 2 and 3 (AMSA, 2015). Descriptive sensory attributes were evaluated using 0 - 15 scales where 0 = none and 15 = extremely intense. Least square means for cut, cooking method and final cooked internal temperature endpoint affected meat flavor descriptive attributes ($P <$ 0.001; Table 4). Beef identity, pork identity, chicken identity, brown/roasted, bloody serumy, fat-like, metallic, liver-like, umami, sweet, sour, salty, bitter, overall sweet, astringent, burnt, cardboard, nutty, sour milk, spoiled putrid, juiciness, muscle fiber tenderness, connective tissue amount, overall tenderness, and Warner-Braxler shear force differed ($P < 0.001$) across treatments. Animal hair, apricot, asparagus, barnyard, green hay-like, boar taint, beet, buttery, chemical, chocolate, cooked milk, cumin, dairy, fishy, floral, green, heated oil, leather, wet feathers, musty/earthy, sour aromatic, soapy, warmed over, medicinal, painty, petroleum, refrigerator stale, smoky charcoal and smoky wood were not found in the meat samples and data were not presented. Treatments differed in meat flavor attributes. As expected, beef cuts had higher beef identity; pork cuts had higher pork identity and chicken cuts had higher chicken identity

($P < 0.05$). For beef cuts, cooking to higher internal cook temperature endpoints increased ($P < 0.05$) beef flavor identity, but internal cook temperature endpoint did not affect ($P > 0.05$) pork and chicken cuts. Glascock (2014) concluded that as degree of doneness increased, beef identity increased. Pork identity was higher ($P < 0.05$) in pork cooked to the lower degree of doneness. Moeller et al. (2010) showed that as degrees of doneness increased in pork loins, flavor did not change. Chicken identity was the same ($P > 0.05$) for chicken breasts and thighs. These results disagree with Ang and Lyon (1990), who showed that chicken thighs had higher overall flavor intensity than chicken breasts. Beef identity was higher ($P < 0.05$) for the Choice top loin steaks than the Select bottom round roasts. Similarly, the pork chops had more ($P < 0.05$) pork identity than the pork inside round roasts. These results were similar to Shackelford et al. (1995), who reported that *M. Longissimus lumborum* (top loin) steaks were beefier than *M. Biceps femoris* (bottom round) steaks.

Choice top loin steaks had the highest ($P < 0.05$) level of brown/roasted flavor and umami, sweet, and salty basic tastes. For the Crock-pot® treatments, brown/roasted was not reported. The chicken breasts and Choice top loins had higher ($P < 0.05$) levels of brown/roasted for the higher degree of doneness treatments. The chicken thighs and Choice top loin steaks had higher ($P < 0.05$) levels of fat-like flavor than meat from other treatments. This would be expected as the chicken thigh and Choice top loin steaks had the highest ($P < 0.05$) chemical lipid percentage at 4.1 and 7.2, respectively. Bloody/serumy was highest ($P < 0.05$) in Select beef bottom round roasts cooked to 58°C. Metallic and liver-like flavors, and sour basic tastes were highest ($P < 0.05$) in

Select beef bottom round roasts cooked in Crock-pot®s. Metallic flavors and sour basic tastes differed in beef treatments and were higher ($P < 0.05$) for the cuts cooked to lower degrees of doneness. Sour also was higher ($P < 0.05$) in the pork inside round roasts cooked to the lower degree of doneness. These results agree with Belk et al. (1993) who reported that beef roasts cooked to low degree of doneness had higher metallic and astringent mouth feels and bitter, sour, bloody/serumy, painty and sour aromatics than in roasts cooked to higher degrees of doneness. Glascock (2014) and Luckemeyer (2015) also concluded that as brown/roasted flavor was lower and bloody/serumy flavor was higher when steaks or roasts were cooked to lower internal temperature endpoints.

Chicken breasts and thighs had slightly higher ($P < 0.05$) bitter basic tastes, astringent mouthfeel, and burnt flavors than meat in the other treatments. The chicken breasts had longer ($P < 0.05$) cooking times than any other cut, which could explain the increase in burnt and bitter flavors.

Select beef bottom rounds cooked in a Crock-pot® and chicken breasts grilled to 58°C had the highest ($P < 0.05$) levels of cardboardy flavor attributes. Pork inside rounds had slightly higher ($P < 0.05$) levels of nutty flavor attributes than meat in the other treatments. Nutty is only identified in the pork lexicon that could explain this difference (Chu, 2015). Meinert et al. (2007) determined roasted nut flavor aromatics to be an attribute in pork and roasted nut flavor aromatics were higher in grilled pork when compared to pan-fried pork chops cooked to the same internal endpoint temperature. Chicken thighs cooked in a Crock-pot® had slightly higher ($P < 0.05$) levels of spoiled/putrid flavor attributes than meat in other treatments. All meat was aged for 14 d including the chicken thighs, which could contribute to this off flavor development. Gill et al (1990) reported that persistent putrid odors were evident at 3 wk in a vacuum-packaged chicken carcass.

Juiciness was highest ($P < 0.05$) in chicken breasts, chicken thighs, pork inside round roasts and Choice top loin steaks cooked to 58°C compared to similar treatments cooked to 80°C. Lorenzen et al. (1999) found that as degrees of doneness increased for steaks grilled outdoors and broiled steaks, juiciness decreased. Juiciness was lowest for Select bottom round roasts cooked in a Crock-pot® to 80°C. Muscle fiber and overall tenderness was highest ($P < 0.05$) for chicken thighs. Chicken breasts were more tender ($P < 0.05$) than the pork and beef cuts and within pork and beef cuts, pork inside ham roasts were more tender ($P < 0.05$) than grilled pork loin chops and Choice top loin steaks and Crock-pot® cooked beef bottom round roasts. Select beef bottom round roasts had the highest ($P < 0.05$) level of connective tissue. Warner-Bratzler shear force values showed similar ($P < 0.05$) trends as reported for muscle fiber and overall tenderness ratings. Chicken thighs had the lowest ($P < 0.05$) Warner-Bratzler shear force values, followed by chicken breasts and than pork and beef cuts. These results were expected as perceived tenderness has been reported to be impacted by marbling, muscle fiber tenderness, and connective tissue amount and solubility (Carpertner et al., 1974; Cross et al., 1973; Koohmaraie, 1996).

These results indicate that flavor, juiciness and tenderness differences were found in the 12 treatments used in this study. Therefore, these treatments provided acceptable treatments to understand how millennial and non-millennial light and heavy beef eaters respond to meat flavor, juiciness and tenderness. Additionally, note that treatments varied in their relationships between meat flavor attributes and juiciness and tenderness. Some treatments were juicy and tender, but had different flavor attributes than other treatments. The beef attributes results were expected and comparable to recent beef flavor studies with descriptive panel results by Glascock (2014), and Luckemeyer (2015), Miller and Kerth (2012).

Consumer Demographics

Consumer demographics (n = 450) are reported in Table 5. Slightly more females participated in the study compared to males and consumers were somewhat evenly distributed for age groups, household income, and household size. The majority (60.0%) of consumers were employed full time. Consumers were heavy consumers of chicken, beef, pork, fish and eggs and tended to eat these protein sources at home and away from home. For beef, chicken, and pork, consumers preferred using outside grilling for cooking followed by pan-frying and oven baking. The majority of consumers ate American, barbeque, Mexican/Spanish, Chinese, and Italian cuisines. Most consumers purchased traditional beef at the retail store, and about 20% purchased either grass-fed or dry-aged when purchasing at the retail store. About 18% of consumers in this study purchased organic beef. In Table 6, the type of beef purchased was examined for each consumer group with the millennial light beef eater consumers having the most organic consumption followed by the millennial heavy beef eaters. For the millennial light beef eater, these results agree with Fromm et al. (2014) who reported millennials support the local food movement and buy more organic food. Portland, OR is also a highly organic market and has a high prevalence of organic eaters (USDA, 2014). Although this does not agree with the results from the Millennial, heavy beef eaters group, this consumer group had the highest values for grass-fed purchases.

According to the USDA, organic food sales for meat, fish and poultry have increased from 256 million dollars in 2005 to 1.724 billion dollars in sales in 2014. This only accounts for about 3.3% of the market. This value is only slightly lower than the FreshLook Marketing data for total U.S. total beef dollar sales for the second quarter of 2015 that accounted for 5.9% of dollar sales for the total beef sales in the United States (FreshLook, 2015). Lockie et al. (2004) reported that age, gender, education level and household size played an important role in the purchasing decision of organic products. The grass-fed purchasers were highest for the millennial heavy beef eater group. Dry aged beef purchases were also higher for the millennial groups than the non-millennial groups.

Consumer Perception of Meat Flavor

The same samples used for the expert, trained descriptive meat flavor analysis were used for consumer evaluations in Griffin GA, Olathe KS, Portland OR and State College PA. Consumers were segmented into four consumer groups (millennial light beef eaters, millennial heavy beef eaters, non-millennial light beef eaters and non-millennial heavy beef eaters). These consumer groups were used as treatments to understand if consumer groups affected consumer-liking ratings (Table 7). Millennial and non-millennial light beef eaters rated the beef, pork and chicken samples lower ($P < 0.05$) for overall liking and tended ($P < 0.05$) to rate samples lower for overall flavor liking and beef/pork/chicken flavor liking. The millennials are the "foodie" generation and have been shown to be more critical of food (Shugall, 2014)

Interestingly, consumer group did not affect how consumers rated grill flavor, juiciness and tenderness liking. These results indicate that the four consumer groups rated grill flavor, juiciness and tenderness similar ($P < 0.05$) across the meat treatments, that light beef eaters tended ($P < 0.05$) to rate overall, flavor and species flavor lower than heavy beef eaters for both generational segments.

To further understand relationships between consumer attributes to overall liking, stepwise regression was conducted to predict overall liking using the other consumer attributes in Table 8. Overall flavor liking was the first variable to enter into the regression equation and accounted for 78% of the variability in overall liking. Tenderness liking was the second variable to enter the equation and accounted for 4% additional variation in overall liking. Meat flavor, grill flavor and juiciness were the 3rd, 4th and 5th variables to enter the stepwise regression equation; however, they did not account for significant improvements in variation accounted for in overall consumer liking ($r^2 = .84$). These results indicated that overall flavor was the biggest driver of consumer liking and that tenderness, while not accounting for a great amount of variation, was still contributing to variation in overall consumer liking. Other attributes of flavor did not contribute appreciably to overall consumer liking. Lorenzen et al. (2005) concluded that tenderness was not the only driving factor in consumer acceptance, but that flavor played an important role as well. Other research has shown once tenderness reaches an acceptable level, flavor becomes the most important driving factor as in this study (Behrends, 2005; Goodson, 2002; Kerth and Miller, 2015).

Trained Descriptive Flavor Panel and Consumer Perception of Beef Relationships

Simple correlations were calculated between consumer and trained panel descriptive attributes (Table 9). Beef and pork identity were not ($P > 0.05$) highly correlated to consumer liking attributes; however, chicken identity was positively and moderately correlated to tenderness liking ($P < 0.05$). As chicken identity increased, consumer ratings for tenderness ($P < 0.05$) increased. Brown/roasted and umami flavor attributes was positively, moderately to highly correlated to overall liking, overall flavor liking, beef/pork/chicken flavor liking and grill flavor liking ($P < 0.05$). Brown/roasted was highly correlated to grill flavor liking ($P < 0.05$). Fat –like positively and slightly correlated with juiciness and tenderness liking ($P < 0.05$). As liver-like flavor increased, overall, juiciness and tenderness liking decreased ($P < 0.05$). Salty basic taste and overall sweet flavor was moderately ($P < 0.05$) related to overall liking, overall flavor liking, beef/pork/chicken flavor liking and grill flavor liking. As spoiled putrid and liver-like flavors increased, overall like, overall flavor like, meat flavor liking and grilled flavor liking decreased ($P < 0.05$). Consumers from the aforementioned consumer attributes liked meat samples with higher ($P < 0.05$) brown/roasted and overall sweet flavors and salt and umami basic tastes. Muscle fiber tenderness and connective tissue attributes were moderately related to consumer tenderness liking and negatively related to Warner-Bratzler shear force ($P < 0.05$). Therefore, meat samples that were more tender with less connective tissue had higher ($P < 0.05$) juiciness and tenderness liking ratings. These results show that trained meat descriptive sensory attributes and consumer liking ratings were related.

To further understand relationships between trained and consumer sensory attributes, a partial least squares regression was conducted (Figure 1). As expected, flavor liking attributes were most closely related to brown/roasted. Brown/roasted was the trained sensory attribute most closely related to overall liking and flavor liking attributes. Salty, umami, and overall sweet attribute also clustered next to consumer overall and flavor liking attributes. Chicken identity, muscle fiber and overall tenderness attributes were closely associated to chicken breasts and chicken thighs. This is to be expected since both the chicken breast and thigh exhibited the highest amount of tenderness from the trained panel scores and lowest Warner-Bratzler shear force values. Fat-like, burnt and juiciness attributes were closely clustered with consumer juiciness liking. Warner-Bratzler shear force was negatively related to juiciness and tenderness attributes as would be expected as higher ($P < 0.05$) Warner-Bratzler shear force values have been related to tougher and drier meat. Rancid, cardboardy, liver-like, warmed over, nutty, sour aromatics, bloody/serumy and metallic aromatics were negatively related to overall liking indicating that as levels of these attributes increased, overall liking decreased. Astringent, sour milk, and spoiled putrid flavor, and sour basic tastes were negatively related (*P* < 0.05) to overall liking. Pork identity, overall sweet, and beef identity flavor attributes and sweet, salty and umami basic tastes were closely associated and clustered most closely with meat flavor liking. These results were similar as previously discussed and show that consumer liking and trained descriptive attributes are related across beef, pork and chicken products cooked to differ in flavor, tenderness and juiciness.

Raw Chemical Analyses

Raw chemical attributes were measured across treatments to determine if raw chemical attributes in the meat were predictive or indicators of consumer liking. Raw chemical attribute least squares means across meat cuts are reported in Tables 10 and 11. Inside ham roasts and chicken thighs were highest (*P* < 0.05) in pH and the top loin steaks were the lowest (*P* < 0.05) in pH. The ultimate pH for red meats is about 5.5 and ultimate pH has been reported to be slightly higher 5.7-6.2 in poultry meat (Dransfield, 1994).

Choice top loin steaks were lowest (*P* < 0.05) in pH and non-heme iron. Chicken thighs were highest and chicken breasts and inside ham roasts were lowest in myoglobin (*P* < 0.05). This disagreed with the average myoglobin levels for meats presented in Miller (1994), in which poultry white and dark meat had an average myoglobin content of 0.30 mg/g and 2.50 mg/g, respectively. Although the white meat chicken values are similar to values determined from this study, the dark meat values were not. The method for myoglobin analysis used was predominantly for red meats. Chicken thigh myoglobin values may have been elevated due to the procedure. Samples were cloudier indicating other chemicals possible lipid, may have interfered with the readings for thighs. Choice top loin steaks were highest ($P < 0.05$) in lipid and lowest ($P < 0.05$) in moisture percentages and chicken thighs were intermediate in lipid and moisture content compared to the other meat treatments. The Choice top loins would be expected to be higher ($P < 0.05$) in lipid than the Select bottom rounds as USDA Quality grades are related to chemical lipid content.

Fatty acid composition was affected by meat treatment (Table 11). Choice top loin steaks were highest in 14:0, 16:0, 18:0 and lowest in 18:1 trans, 18:2, 18:3 and 20:4 fatty acids ($P < 0.05$). Pork loin chops and pork inside ham roasts were lowest in 16:0 and 16:1 and highest in 18:1 and 18:1 trans fatty acids ($P < 0.05$). Chicken breasts and thighs were lowest in 14:0, and chicken thighs were highest in 16:1, 18:0, and 18:2 fatty acids ($P < 0.05$). Previous literature has linked raw chemical data and fatty acid content to meat flavor (Calkins and Hodgen, 2007; Enser et al., 1996; Meisinger et al., 2006; Westerling et al., 1979; Wood et al., 2004; Yancey et al., 2006;).

Relationships between raw chemical attributes and meat descriptive sensory attributes are reported in Table 12. Beef identity was high to moderately and positively correlated with lipid percentage, 14:0, and 18:0, and was high to moderately and negatively correlated with pH, non-heme iron content, moisture, 18:1 trans, 18:2 and 20:4 fatty acid levels ($P < 0.05$). Baublits et al. (2009) concluded that positive beef flavor attributes were enhanced by higher amounts of saturated and monounsaturated fatty acids, while polyunsaturated fatty acids had a negative effect on beef flavor, agreeing with these results. Pork identity was highly correlated with 18:1 trans and negatively correlated with 16:1 fatty acid lipid percentage and myoglobin content ($P <$ 0.05). Chicken identity was highly related ($P < 0.05$) to 14:0, 16:1, 18:0 and 18:2 fatty acid content. Umami was negatively correlated ($P < 0.05$) to moisture, pH, 18:2, 18:3, and 20:4 fatty acid levels and highly and moderately correlated ($P < 0.05$) to lipid percentage and 14:0 fatty acid. Fat-like was moderately correlated with myoglobin content, lipid percentage, and 16:1 fatty acid ($P < 0.05$). Spoiled putrid was highly related to myoglobin content and 16:1 fatty acid level, moderately related to moisture content and weakly related to pH, non-heme iron levels, 18:1 trans, 18:2, and 18:3 fatty acids ($P < 0.05$). The chicken thighs had the highest myoglobin content and spoiled putrid levels. Sour milk was moderately correlated with non-heme iron content and myoglobin content. Baublits et al. (2009) found that 12:0, 15:0, 15:1, and α-18:3 fatty acids positively correlated with old/putrid flavors. Liver-like flavor was slightly correlated ($P < 0.05$) with myoglobin concentration. Muscle fiber tenderness was correlated ($P < 0.05$) with 14:0, 16:1, 18:0 and 18:2 fatty acid levels.

Stepwise regression was conducted where overall consumer liking was defined as a dependent variable and the raw chemical data were defined as independent variables in Table 13. Myoglobin content was the first variable to enter the equation and accounted for 21% of the variation in overall consumer liking. Moisture percentage, 14:0 fatty acid, and pH entered the regression in the next three steps, respectively. The final equation accounted for 38% of the variation in consumer liking. These results showed moderate relationships between raw chemical data and consumer liking, raw chemical data was related to consumer and trained descriptive attribute sensory evaluation using partial least squares regression to further understand relationships (Figure 2). Raw chemical attributes were not closely clustered with consumer sensory attributes, but 18:1 and 18:1 trans fatty acids were closely associated with trained sensory juiciness, fat-like and pork identity flavors. Beef identity was closely related to 18:0 and 14:0 fatty acids. Beef flavor has been related to fatty acid content (Mottram and Edwards, 1983). Overall, this research agreed with Baublits et al. (2009). Fat percentage and 16:0 fatty acid were clustered with sweet and were slightly clustered with meat flavor and overall flavor liking. Fat percentage is used in USDA Quality grades to predict palatability (USDA, 1996). Non-heme iron, pH, moisture percentage and myoglobin content were clustered with spoiled putrid and 18:2 and 18:3 fatty acids were closely associated with chicken identity and muscle fiber tenderness. Yancy et al. (2006) suggested that muscles with higher concentrations of myoglobin and heme iron usually exhibited liver-like and metallic flavors. Agreeing with Meisinger et al. (2006), this research did not find strong correlations or clustering of these attributes. These relationships indicated that raw chemical composition was related to trained panel descriptive attributes and may explain some of the variation in flavor attributes in beef, pork and chicken.

Cooked Meat Volatile Flavor Evaluation

Volatile aromatic chemical compounds (n = 289) were identified in the cooked beef samples (Table 14). The total ion count mean under the curve for each compound was reported. Luckemeyer (2015) found 248 volatiles, which is similar to the number of compounds identified in this study. Luckemeyer (2015) had 20 treatments amongst six different cuts of beef (Choice tenderloin steaks, high pH top loin steaks, Choice and Select bottom round roasts, Choice top loin steaks, and Select top sirloin steaks), three cooking methods (George Foreman, Grill, and Crock-pot®) and two degrees of doneness (58°C and 80°C). Only four of the 20 treatments used moist heat cookery, whereas, six of the 12 treatments identified in this study were moist heat cookery used to decrease the amount of Maillard reaction products produced. Miller and Kerth (2015) reported that Maillard reaction products were not produced from moist heat cookery since the first step in the Maillard reaction is dehydration. This limited the amount of Maillard reaction products identified throughout this study. The current study also added pork and chicken meat as treatments that would expectantly change the volatile compounds present.

To understand if volatile aromatic chemicals were associated with consumer liking, and trained descriptive flavor attribute data, stepwise regression equations were calculated (Tables 15 to 24). Overall liking, beef flavor identity, pork flavor identity, chicken flavor identity, brown/roasted, bloody/serumy, fat-like, metallic, liver-like, and umami, respectively, were defined as dependent variables and volatile aromatic chemical compounds were defined as potential independent variables. For overall consumer liking, ethanol, 3-ethyl-2,5-dimethyl-pyrazine, 2-methyl-butanal and thiobis-methane where the first four variables to enter the equation and accounted for 31% of the variation. Additional variables were included in the equation where each variable accounted for small amounts of variation, but the variables were significant ($P < 0.15$). The final equation accounted for 58% of the variation in overall consumer liking and included 31 volatile aromatic chemical compounds. Several pyrazines compounds were observed in this equation. Pyrazines are Maillard reaction products that are associated with roasted flavors (Mottram, 1998). These compounds are found in meat cooked to higher degrees of doneness and in well-done grilled meat, the compounds are reported to be the major class of volatiles (Mottram, 1985). For beef, pork and chicken identity, different volatile aromatic compounds were used to predict the dependent variable; however, chemical compounds associated with lipid degradation and Maillard reaction products were used in equations.

Of the 289 volatile aromatic compounds reported in the study, 117 of these compounds were used in the regression equations. In Table 16, 3-hydroxy-2-butanone was closely related to beef identity and accounted for 29% of the variation. 1-Pentanol and 1-(1H-pyrrol-2-yl)-ethanone were the second and third variables to enter the equation and contributed 9% additional variation. Eighteen compounds were identified and accounted for 53% of variation for beef flavor identity.

For chicken identity (Table 18), nonacosane was closely related to chicken identity. Contradictory to Jayasena et al. (2013) who concluded that 2-methyl-3-

furfanthiol was the most important compound imparting flavor in cooked chicken meat flavor. 2-methyl-3-furfanthiol was not identified in this study. A number of volatile aromatic compounds were associated with pork identity (Table 17). The first compound to enter the equation was 2-octenal in pork identity. A total of 26 compounds entered the equation accounting for 64% of the variability.

In Table 19, in the stepwise linear regression for brown/roasted flavor aromatics, 1-(1H-pyrrol-2-yl) ethanone entered the equation first and accounted for 9% of the variation. This compound also entered in the beef identity equation third and umami equation second. Glascock (2014) also reported 1-(1H-pyrrol-2-yl) ethanone to enter the stepwise regression for brown/roasted flavor aromatics first. Thiobis-methane, reported in this equation, was also seen in the overall like fat-like and umami aromatic equations and was the first to enter into the metallic flavor equation. Several notable compounds entered the bloody/serumy (Table 20) prediction equation including butanoic acid, 2,3-butanedione, e-2-octenal and hexadecanal accounting for 17%, 5%, 5% and 3% of the variation, respectively.

Twenty-two compounds accounted for 46% of the variation in fat-like (Table 21). Ethanol entered the equation first, followed by trans-2-dodecenal accounting for 18% of the variation. Several sulfur containing compounds were identified in this regression equation including dimethyl sulfide, thiobis-methane, and 2-methyl-thiophene. Dimethyl disulfide is a sulfur-containing compound that is a result of amino acid degradation through the Maillard reaction. This compound primarily contributes to meaty aromas, but can produce a green, vegetable-like, or sulfurous aroma, and can impart aromas at low concentrations due to a low threshold value (Shahidi, 1994).

Notable compounds to enter the stepwise regression equation and contribute to metallic flavor (Table 22) were thiobis-methane, thiourea, dimethyl sulfide and 2-methyl-furan accounting for 9, 8, and 3% of the variation, respectively. These compounds are interesting because the first three are sulfur-containing compounds. In a stepwise regression for liver-like (Table 23) flavor attributes, thiourea entered the equation first and accounted for 16% of the variation. Dimethyl sulfide and acetic acid entered next and accounted for 12% of the variation. Werkhoff et al. (1996) reported flavor volatiles associated with livery flavor included thiols, sulfides, thiazoles, and sulfur-substituted furans. Some studies have indicated that sulfur-containing compounds might interact with carbonyl compounds to produce the livery flavor attribute (Yancy et al. 2006).

Table 24 identified volatile compounds related to umami basic tastes. 3-hydroxy-2-butanone was the first compound to enter the equation and accounted for 13% of the variation in umami basic tastes. Overall, 21 compounds entered the equation accounting for 56% of the variation. Shahidi (1994) identified 5' nucleotides such as 5'inosinate and 5'- guanylate as being characteristic of umami flavor. Shahidi (1994) also explained that previous research showed compounds contributing to umami flavor decreased as internal temperature increased. Low amounts of glutamate, a flavor component of umami, were seen when meat was cooked in water. These cooking treatments could account for some of the variation seen in this study. Glascock (2014) and Luckemeyer (2015) reported many more compounds in the prediction equation for umami, unlike this study with only 21 compounds reported. This difference is most likely due to the treatment differences discussed earlier. These results indicate that volatile aromatic compounds are related to trained descriptive sensory flavor attributes and could be used to measure flavor in meat products. These aromatic chemical attributes can be used to predict beef flavor attributes. Although it is not practical to measure each of these attributes for every piece of beef cooked or served, examination of treatments or conditions that affect or increase aromatic compounds related to beef identity, browned/roasted, bloody/serumy, and fat-like flavor aromatics, and umami basic taste would increase consumer acceptance.

In order to see and further understand these relationships between flavor aromatics, trained panel attributes, and consumer attributes a partial least squares regression biplot was used (Figure 3). The nutty flavor was closely clustered with 1-octen-3-one and heptane. Cardboardy and fat-like flavor aromatics were closely associated with lipid oxidation products. Volatile aromatic compounds were closely related to sour and bloody/serumy flavor aromatics.

3-ethyl-2,5-dimethyl-pyrazine (C72) and 1-(1H-pyrrol-2-yl-ethanone (C63) were clustered with brown roasted and overall liking, grilled flavor liking, overall flavor liking and meat flavor liking consumer attributes. 3-ethyl-2,5-dimethyl-pyrazine (C72) was the second compound to enter the overall liking predication equation and also entered the beef identity flavor equation. 1-(1H-pyrrol-2-yl-ethanone (C63) entered the brown/roasted, beef identity and umami flavor and basic taste prediction equations.

These are all identified as positive beef flavor attributes (Miller and Kerth, 2012) and would be expected to cluster with the consumer liking attributes.

In Figure 4, consumer groups by the 12 treatments categories used to segment data for Figure 3 are presented. These data show that non-millennial light (NL), non-millennial heavy (NH), millennial light (ML), and millennial heavy (MH) consumers responded to the 12 treatments that differed in flavor, juiciness and tenderness similarly as all treatments within consumer groups were segmented on top of each other. These data indicated that for the treatments used in this study, consumer groups responded similarly. These results imply that millennial light beef eaters respond to palatability in beef, pork and chicken similar to a millennial light, non-millennial light, and non-millennial heavy beef eaters. Therefore, when meat samples were prepared for consumers in each consumer group, they rated palatability attributes similarly. These results indicated that other factors, other than palatability issues, drive millennial light beef eaters to not purchase beef. These factors may include social issues, time limitations or food preparation knowledge. Millennials like beef but do not purchase it as much as the other generations. Shugall (2014) suggested that why millennials do not purchase as much beef may be related to their lack of confidence in preparing the dish, price, value, or nutrition. These influences were examined in the one-on-one interviews.

Consumer One-On-One Interviews

Consumers indicated that flavor was very important to them when eating meat. The consumers were not able to segment tenderness, juiciness and flavor as separate attributes. Consumers from Portland and Millennials tended to be more concerned with how the beef was raised (natural, organic, grass-fed) than consumers from other cities. Consumers from Kansas were more knowledgeable of Quality grades in comparison to Portland, Griffin and State College consumers. Price was important to all consumer groups

In Figure 5, word maps were used to examine the responses from the one-on-one interviews. A larger font size indicates a more frequent response. Price was a large factor for all consumer groups. Millennials enjoyed the taste of beef, but they wanted to get a good value for their purchases. Millennials have started to shop at mass marketing or warehouse type stores in order to achieve this value (Fromm et al., 2001). Shugall (2014) reported that the millennials were looking for a good price and value was more important to them than other generations. Organic, grass-fed, and origins showed up more in the millennial word maps. Fromm et al. (2014) reported that 2 in 5 millennial parents want to know where their food comes from and buy organic whenever they can. Although this represents a small group of millennial parents, they represent a trend in the millennial generation. Mindswarms (2014) reported on the attitudes about food and food origins. Even though "local" had many definitions amongst the millennials, buying local made millennials feel as if they were having a positive impact on their health, local economy and environment. Similar attitudes have not been reported for older generations. Appearance, variety, healthy, sales, mood and recipes all showed up as important on word maps for each consumer treatments.

In-home Consumer Demographics

To understand if results would be similar when consumers prepared meat in their home, an in-home placement study (HUT) was conducted with consumers used in the central location study. Demographics for consumers across four cities who participated in the in-home placement study are presented in Table 25. Slightly more females participated in the study compared to males and consumers were somewhat evenly distributed for age groups, household income, and household size. The majority of consumers were employed full time. Consumers were heavy consumers of chicken, beef, pork, fish and eggs and tended to eat these protein sources at home and away from home. For beef, chicken, and pork, consumers preferred using outside grilling for cooking followed by pan-frying and oven baking. Consumers (77.8%) purchased beef at the retail store, and about 20% purchased either grass-fed or traditional beef when purchasing at the retail store. About 17% of consumers in this study purchased organic beef. The majority of consumers ate American, barbeque, Mexican/Spanish, Chinese, and Italian cuisines. The demographic percentages of the in-home portion only slightly differed from the demographics of the central location study.

In-home Consumer Preparation of Meats

Consumer preparation methods are presented in Table 26. The majority of consumers thawed the meat the day before or the day of preparation by placing the meat in the refrigerator, while some consumers (about 7%) thawed the meat out at room temperature or under cold water. Today, consumers do not plan meals in advance. They decide that day or at the end of the day based on their time and ingredients on hand (Resurreccion, 2004). Most consumers in this study, planned on what protein they would eat for dinner the next night because they thawed the meat in the refrigerator. Although there is always a possibility for participants to be biased (Resurreccion, 2007). Subjects might feel guilty and be more likely to give the thaw method they believe is the right answer (Boutrolle et al., 2007).

The majority of consumers did not do anything to the top loin steak, bottom round roast or pork chop before cooking, whereas 51% of consumers did not do anything to the chicken breast before cooking. For chicken breasts, 12% of consumers cut the chicken into small pieces and 17% cut it into strips before cooking. Ten percent of consumers cut the beef bottom round roast into strips and cut the pork chop into small pieces before cooking. The majority of consumers added salt, pepper and spices to the four meat cuts before cooking, whereas between 10 and 20% of consumers marinated, added sauces or added other items to the meat before cooking. For top loin steaks, the consumers tended to either cook the steaks on the outdoor grill or pan fry/sauté. About 10% of top loin steaks were broiled or cooked on an indoor grill. About 20% of consumers oven-roasted uncovered, simmer and stewed, or used other cooking methods for bottom round roasts. Interestingly, 11% of consumers cooked bottom round roasts on the outdoor grill and 8% pan fried/sautéed meat from these roasts. About 10% of consumers braised beef bottom round roasts. For pork loin chops, about 25% of consumers pan fried/sautéed their pork chops with outdoor grilling and oven roasting uncovered was the second most common cooking method. Almost 30% of consumers pan fried/sautéed the chicken breast with about 20% cooking chicken breasts using the outdoor grill or oven roasting uncovered. Some consumers stir-fried the meat from the chicken breast (10%). The preparation methods only slightly differed amongst consumer treatment shown in Figures 6 to 12. The HUT design allows consumers to choose how they prepare and eat the products (Boutrolle et al., 2007). This is not always possible in the CLT. Matuszewska et al. (1997) compared scores of margarine samples from three different tasting methods: consumer spreading on bread, prepared spread bread slice or margarine with no bread. The study showed that individual preparation led to better discrimination (Matuszewska et al., 1997).

Consumers indicated that the majority of beef top loin steaks were cooked to a medium degree of doneness with about 25% of top loin steaks cooked to either medium rare or well-done degree of doneness (Table 26). The majority of beef bottom round roasts, pork loin chops and chicken breasts were cooked to well done degree of doneness with about 25% of beef bottom round roasts and pork loin chops cooked to medium degree of doneness. The majority of the meat in this study was served as the main course on the plate but some consumers combined the meat with other ingredients. Most consumers did not add additional ingredients to top loin steaks and pork loin chops at the table, but about 25% of consumers added salt and pepper to these two cuts. For bottom round roasts between 20 and 30% of consumers either ate the roast plain, added nothing as the roast was cooked in sauce, or added salt and pepper. For chicken breasts, about 25% of consumers either ate it plain or added salt and pepper. Between 15 and 20% of consumers added nothing as it was cooked in sauce, added other dry ingredients or added sauces to chicken breast at the table before they consumed the product. King et al. (2004) showed discrimination decreased with eating under natural eating conditions. Pizza was better discriminated when tested alone than when tested in combination with salad and beverages (King et al., 2004). This could have had an effect on the results of the HUT test but the majority of the consumers ate the meat as a main course and the main ingredients added before and after cooking were salt and pepper.

To understand if consumer group and meat influenced preparation methods frequency percentages were reported in Figures 6 to 12. Across all four consumer groups, the preparation methods only slightly differed. Consumer group did not differ across thawing methods. Consumers thawed meat and added seasoning at the table similarly regardless of consumer group. Millennial heavy beef eaters had the highest values for pan fry/sautéing the meat. The millennial light beef eaters and the non-millennial consumer groups had the highest percentages of outdoor grill and broil cooking methods. All consumer groups cooked to well-done internal temperatures.

Partial least squares regression was conducted to further examine the relationships between consumer demographics, consumer liking and consumer group (Figures 13, 14 and 15). Consumer sensory attributes clustered with gender and household size. These results indicate that females and larger households tended to rate the samples in this study higher for liking. Additionally, the frequency of beef purchases and thaw method were closely related to consumer liking ratings indicating that consumers who purchased beef more frequently and who thawed the meat either in the refrigerator the same day or that used other thawing methods other than placing the meat in the refrigerator the day before tended to rate the meat higher for consumer sensory attributes. Employment was negatively associated with consumer liking ratings. These results indicated that as employment went from not employed, part-time to full-time employment, consumer liking ratings decreased. As this was an in-home placement study, individuals with less than full time employment may have liked meat in the study due to taking more time to prepare or due to positive associations with free meat. As degree of doneness increased and consumers added more spices prior to cooking, consumers did not rate the meat as high for consumer liking. In Figure 14, responses for consumer group by cooking method are presented. These results are presented to understand if cooking method by consumer group affected consumer liking ratings as they were the observation levels for the partial least squares regression presented in Figure 15. These results indicated that consumer group by cooking method did not appreciably impact consumer liking ratings. Millennial and non-millennial heavy beef eaters that cooked the meat using deep frying cooking methods tended to rate consumer liking attributes higher and millennial heavy beef eaters who either stir fried or simmer/stewed meat, and millennial light beef eaters who braised the meat tended to rate consumer liking attributes lower. As there were limited number of consumers represented in these groups, the impact of these cooking methods were minimal. Non-millennial heavy beef eaters who pan broiled meat were the consumers most closely related to consumer liking ratings indicating that these consumers who cooked their meat by pan broiling tended to like the meat to a greater extent. These results indicate that consumer groups, while differing in frequency of how they prepared the meat, did not rate liking appreciably different.

Another partial least squares regression analysis was conducted where data were averaged across cooking methods within consumer groups and demographic information (Figure 16). In this analysis, non-millennial heavy beef eaters were more closely associated with consumer liking attributes and non-millennial light beef eaters, while positively associated with consumer liking for appearance and flavor attributes, these consumers were more influenced by tenderness liking than non-millennial heavy beef eaters. Millennial consumers, both heavy and light, were negatively associated with consumer liking attributes indicating that they had different liking scores for consumer attributes. Employment, income and age were closely associated with consumer liking attributes, and frequency of purchasing pork was more closely associated with consumer liking than frequency of purchase of other protein sources. Frequency of purchase for beef and lamb were clustered, but not strongly affected by consumer liking ratings. Frequency of purchase of chicken was closely associated with household size or as household size increased, purchase of chicken increased. Consumer liking attributes were negatively associated with purchase frequency of chicken and fish. Millennial light beef eaters were somewhat associated with millennial light beef eaters.

In-home Consumer Perception of Meat Flavor

Consumers were asked to rate the raw appearance, cooked appearance, overall liking, overall flavor liking, juiciness liking and tenderness liking of meat after preparing and eating it at home. Consumers were segmented into consumer groups. This type of natural eating situation (HUT) is different from controlled eating situations (CLT) and can cause differences in the consumer attributes depending on preparation differences (Boutrolle et al., 2007). Least squares means for meat by consumer groups for the consumer sensory attributes is presented in Table 27. Differences in consumer attributes across meat type and consumer group was significant ($P < 0.05$). For chicken breasts, millennials rated raw appearance, juiciness and tenderness liking lower ($P < 0.05$) than non-millennials. Light beef eaters rated cooked appearance liking lower ($P < 0.05$) than heavy beef eaters across age groups. For chicken breasts, consumer group did not affect ($P > 0.05$) overall or overall flavor liking. For pork loin chops, non-millennial heavy beef eaters rated the raw and cooked appearance liking and overall liking of pork chops higher than consumers in the other age groups ($P < 0.05$). Non-millennials, regardless of level of beef consumption, rated pork loin chops higher ($P < 0.05$) for juiciness and tenderness liking than non-millennials. Non-millennials liked the raw appearance of beef bottom round roasts more ($P < 0.05$) than millennials. Cooked appearance and overall flavor liking was not affected ($P < 0.05$) by consumer group for bottom round roasts. Millennial heavy beef eaters did not like beef bottom round roasts as much ($P < 0.05$) as non-millennial light beef eaters. Light beef eaters liked the juiciness and tenderness of beef bottom round roasts more (*P* < 0.05) than heavy beef eaters. For top loin steaks, consumer group rated steaks similar (*P* > 0.05) for raw appearance, overall, overall flavor, juiciness and tenderness liking. Non-millennial heavy beef eaters liked the cooked appearance of top loin steaks more (*P* < 0.05) than consumers from the other consumer groups. While these results indicated that there were some differences in how consumer groups liked the meat provided, most of the differences were related to raw appearance differences where millennials tended (*P* < 0.05) to not like the raw appearance at the same level as non-millennials. It was hypothesized the millennial light beef eaters would have different preferences than non-millennial heavy beef eaters. This was not clearly reported. Millennial light beef eaters tended to rate some attributes lower, but this was seen across the four meat cuts.

To further understand factors affecting consumer groups, partial least squares regression biplots were generated for consumer liking, trained descriptive attributes and consumer groups (Figure 17). Consumer liking attributes were closely related. Juiciness and tenderness were closely associated and were similarly clustered with overall flavor and appearance before cooking liking. Cooked appearance liking was not as closely related to overall liking as other consumer liking attributes. Chicken identity, bitter, beef identity and muscle fiber tenderness attributes were the trained descriptive attributes most closely associated with overall liking. Non-millennial heavy beef eaters were clustered with bloody/serumy, sweet, sour, sour aromatic and spoiled putrid attributes and these consumers were the consumer group most closely associated with overall liking indicating that they rated meat samples highest for consumer liking attributes.

Non-millennial light beef eaters were closely associated with overall tenderness, burnt and astringent attributes and negatively associated with cardboardy and liver-like attributes. Non-millennial light beef eaters where somewhat related to consumer liking ratings, but not to the same degree as non-millennial heavy beef eaters. Millennial consumers were negatively related to consumer liking ratings indicating that they rated liking of meat lower than non-millennials. Millennial heavy beef eaters were most closely associated with warmed over flavor. Millennial light beef eaters were opposite of non-millennial heavy beef eaters indicating that different flavors drove their liking ratings. Millennial light beef eaters were clustered with overall sweet, nutty, salty, fat-like, brown roasted, umami and connective tissue amount attributes.

Consumers from four locations participated in the study to account for regional differences in consumer preferences. Consumer's preferences for raw appearance, juiciness and tenderness liking were affected by city (Table 28). Consumers in Portland, OR, representing the west coast, rated appearance lower ($P < 0.05$) than consumers in Griffin, GA, and State College, PA. For juiciness, consumers in Griffin, GA, rated meat products higher ($P < 0.05$) than consumers in the other three locations. Portland, OR, consumers rated meat lower ($P < 0.05$) in tenderness liking than consumers in Griffin, GA. Neeley et al. (1998) also reported the lowest tenderness values were from consumers on the west coast in a HUT beef consumer study. Additionally, city affected ($P < 0.05$) meat preparation methods except for cooking method (Figures 18-24), Consumers in Griffin, GA, thawed meat less in the refrigerator the day prior to cooking, tended ($P < 0.05$) to use slightly different preparation methods prior to cooking, and cooked meat to slightly higher degrees of doneness than consumers in other locations. Griffin, GA consumers also added different ingredients to meat prior to cooking than consumers in Olathe, KS and State College, PA. Consumers in Olathe, KS and State College, PA added fewer (P < 0.05) ingredients to meat at the table than consumers in Griffin, GA and Portland, OR. Regional differences would be expected.

To understand what consumer sensory attributes where most closely related to overall consumer liking, stepwise regression equations were calculated where consumer overall liking was defined as the dependent variable and the remainder of consumer sensory attributes were defined as independent variables (Table 29). Overall flavor liking accounted for 66% of the variability in overall liking. Tenderness liking accounted for 9% of the variation in overall liking and the addition of other sensory liking attributes did not appreciably increase the predictability of the equation. These results indicated that flavor liking was the biggest driver of overall consumer liking and that tenderness liking, while still important, was not as big of a driver of overall liking for meat prepared at home. These results agreed with the results from the central location study reported earlier.

Simple correlations between the CLT scores and the HUT scores by cut are shown in Table 30. The chicken breast CLT and HUT showed correlations between HUT tenderness liking and CLT juiciness and tenderness liking (P < 0.05). The Choice strip loin was slightly correlated (P < 0.05) with HUT overall liking and CLT overall liking and overall flavor liking. The pork loin was significantly correlated with all HUT liking (P < 0.05). This shows that the consumers responded similarly to each cut in the CLT and the HUT. Although slightly higher liking scores were seen in the HUT test, this may be due to the consumer being able to prepare and cook the meat how they wanted. Multivariate analysis was not successful because either all of the variation was accounted for or less than two percent of variation accounted for when examining relationship between consumer liking scores for CLT and HUT. Many studies have reported a difference in level of liking scores with CLT scores being lower than HUT (Boutrolle et al., 2005; Kozlowska et al., 2003). The results from this study agrees with those tests. The consumers rated meat in the HUT test higher than the same cut from the CLT. This may be due to consumers being allowed to prepare the meat and they were in their own environment. Some studies did not show this relationship (Daillant-Spinnler and Issanchou, 1995; Hellemann et al., 1993). The longer contact time with the sample in HUT could explain the increase in liking. Zajonc (1968) showed increased product liking scores due to familiarization with the product. Another hypothesis could be that in CLT, the conditions are standardized and the sensation of a formal experiment could have placed the consumers in an analytical mindset to be more critical of the samples (Boutrolle et al., 2007). Pound et al. (2000) found that the formal condition of a CLT might lead the subjects to be more critical and demanding towards the tested products.

In-home, Expert, Trained Descriptive Meat Flavor Analysis

Meat presented to consumers was also used for trained descriptive attribute sensory evaluation (Table 31). Consumers cook meat to different degrees of doneness, but for trained sensory evaluation, chicken breasts and top loin steaks were cooked to two different internal cooked temperature endpoints. Trained descriptive flavor, juiciness and tenderness attributes differed ($P < 0.05$) across meat treatments. Top loin steaks had the highest ($P < 0.05$) level of beef identity, fat-like, and overall sweet flavor aromatics. Pork loin chops had the highest ($P < 0.05$) level of pork identity and chicken breasts had the highest ($P < 0.05$) level of chicken identity and burnt flavor aromatics, and astringent mouthfeel. Top loin steaks cooked to 80°C were highest ($P < 0.05$) in brown/roasted. Select bottom round roasts cooked in a Crock-pot® to 58.3°C were highest ($P < 0.05$) in bloody/serumy, metallic, cardboardy, rancid, and spoiled putrid flavor attributes. Umami, sweet and salty basic tastes were highest in top loin steaks, sour basic taste was highest in Select bottom round roasts and bitter basic taste was highest in chicken breasts ($P < 0.05$). Pork loin chops were highest in nutty flavor aromatics ($P < 0.05$). Pork loin chops and top loin steaks cooked to 58.3°C were juiciest and Select bottom round roasts, chicken breasts and top loin steaks cooked to 80°C were the driest ($P < 0.05$). Chicken breasts cooked to 62.7°C were the most tender with the lowest connective tissue amount and the lowest Warner-Bratzler shear force values ($P < 0.05$). Chicken breast cooked to 80°C were slightly tougher with slightly more connective tissue than chicken breasts cooked to 62.7°C, but were more tender, had less connective tissue and had lower Warner-Bratzler shear force values than the pork and beef treatments ($P < 0.05$). These differences in flavor, juiciness, and tenderness attributes were as expected across meat sources. These treatments were used to create differences in flavor, juiciness and tenderness. To understand if consumer in-home sensory attributes and trained descriptive sensory attributes were related, simple correlation coefficients were calculated (Table 32). Correlation coefficients were low except brown/roasted was slightly correlated ($P < 0.05$) to overall consumer and consumer juiciness liking. Overall flavor liking was moderately related ($P < 0.05$) to muscle fiber tenderness.

To more closely understand these relationships, a partial least square regression biplot is presented in Figure 25. Consumer sensory attributes were closely related to overall liking with cooked appearance liking being more closely related to overall liking than other consumer attributes. Chicken breasts were closely associated with the trained meat tenderness attributes, chicken identity, astringent, burn and bitter flavor attributes. Pork loin chops were clustered with nutty and pork identity. Juiciness and sour aromatics were closely associated. Top loin steaks were closely associated with fat-like, overall sweet, juiciness, beef identity, umami and sweet attributes. Bottom round roasts were clustered closely with liver-like, cardboardy, sour and spoiled putrid attributes. Sour aromatics, metallic, bloody/serumy and warmed over flavor aromatics were negative attributes and clustered with each other. Consumers least liked beef bottom round roasts. These results showed that meat treatments differed in flavor attributes similarly as previously reported for consumer tests using similar treatments in a CLT where samples were prepared for consumers. The HUT expert, trained descriptive meat flavor analysis only slightly differed from the CLT trained flavor analysis results.

In-home Raw Chemical Analysis

Raw chemical data was determined to understand if these attributes explained differences in consumer perceptions or trained sensory attributes in the meat sources. Raw chemical attributes differed by meat source (Tables 33 and 34). Chicken breasts and pork loin chops had the highest pH and top loin steaks had the lowest pH ($P < 0.05$). Non-heme iron was highest in chicken breasts and lowest in top loin steaks and myoglobin content was lowest in chicken breasts and highest in beef bottom round roasts and top loin steaks ($P < 0.05$). Beef top loin steaks were highest in lipid and lowest in moisture percentage and chicken breasts were lowest in lipid and highest in moisture percentage ($P < 0.05$). For fatty acid composition, chicken breasts were lowest in 14:0, 16:1, 18:0, 18:1 and highest in 18:2 and 20:4 ($P < 0.05$). Beef top loin steaks were highest in 14:0, 16:0, 18:0, 18:1, and 18:2 and lowest in 16:1, 18:1 trans, and 20:4 ($P < 0.05$). Pork loin chops were intermediate in fatty acid composition. Bottom round roasts, while similar to top loin steaks, was slightly lower in 14:0, 16:0, and 18:0, and slightly higher in 18:1trans, 18:2 and 20:4 ($P < 0.05$). These results are similar to previously reported for the CLT results for compositional differences across meat sources.

To examine the relationships between sensory descriptive attributes and raw chemical composition, simple correlation coefficients were calculated (Table 35). pH was moderately related ($P < 0.05$) to beef identity, chicken identity, fat-like and overall sweet. Non-heme iron and myoglobin content were moderately correlated to beef identity and chicken identity flavor aromatics, and myoglobin content was negatively and moderately related to connective tissue amount, overall tenderness, and Warner-Bratzler shear force ($P < 0.05$). Moisture and lipid percentages, while inverse in their relationships to sensory attributes, were highly related to beef identity flavor and umami basic tastes, and moderately related to brown roasted, fat-like, salty, and overall sweet flavor aromatics ($P < 0.05$). Moisture was moderately and negatively correlated with overall tenderness ($P < 0.05$).

Fatty acids were related to descriptive sensory attributes. Myristic fatty acid (14:0) was moderately and positively related to beef identity, bloody/serumy, and astringent attributes, and negatively and moderately related to connective tissue amount and overall tenderness ($P < 0.05$). Correlations were not strong ($P > 0.05$) between 16:0, 16:1 and 18:1 and descriptive flavor attributes and Warner-Bratzler shear force. Beef identity, fat-like, umami, overall sweet, connective tissue amount, and overall tenderness attributes were moderately related ($P < 0.05$) to 18:0 fatty acid. Pork and beef identity flavor aromatics were moderately related ($P < 0.05$) to 18:1trans fatty acid level. Beef identity, chicken identity, bloody/serumy, umami, overall sweet, connective tissue amount, and overall tenderness attributes were moderately correlated ($P < 0.05$) to 18:2 fatty acid level and chicken identity, connective tissue amount, and overall tenderness attributes were moderately related to 18:3 fatty acid content. Arachidonic fatty acid (20:4) was negatively and moderately related to beef identity, fat-like, umami, and overall sweet attributes, and positively and moderately related to connective tissue amount and overall tenderness attributes ($P < 0.05$). While these relationships were stronger than these relationships previously reported in the CLT, it is most likely due to greater variation in raw chemical data across meat sources.

The raw chemical attributes were examined to see if they related to consumer sensory attributes. Simple correlation coefficients between raw chemical components and consumer sensory attributes are reported in Table 36. Correlations between consumer sensory liking attributes and raw chemical measures were low indicting weak relationships between these data. Stepwise regression was conducted to understand if raw chemical attributes were predictive of overall consumer liking (Table 37). While significant ($P < 0.15$), 14:0 and 18:1 fatty acids entered the equation, but accounted for a minimal amount of variation in overall consumer liking. Partial least squares regression was used to understand relationships between consumer sensory attributes, trained descriptive attributes, Warner-Bratzler shear force, and raw chemical composition across meat source (Figure 26) and a second biplot was presented for the same attributes across consumer groups (Figure 27). While consumer and trained descriptive attributes relationships are as previously discussed for Figure 3 and 4, relationships with of these attributes with raw chemical composition can be seen. Palmitic acid (16:0) and lipid percentage clustered with top loin steaks, and overall sweet, sweet, umami and fat-like descriptive attributes. The top loin steak was also the closest treatment to salty, raw appearance liking, overall flavor liking, and brown/roasted flavor aromatics.

Warner-Bratzler shear force was closely related to 14:0 and 18:0 fatty acids. Beef identity was also closely related to 14:0, 18:0 and 18:1 fatty acids. This is very similar to the results reported in the CLT. As expected, myoglobin was closely associated with metallic and bloody/serumy flavor attributes. The bottom round roasts were closely related to liver-like, sour, cardboardy and spoiled putrid attributes. Nutty and pork identity flavor aromatics were closely related to the pork loin chop. Moisture percentage, pH, 20:4, 16:1, 18:2, 18:3 fatty acids and non-heme iron were clustered with astringent, bitter, chicken identity and chicken breasts and 18:1 trans was not associated with any clusters. These results indicated that raw chemical data were associated with trained descriptive attribute flavor descriptors. When data were averaged across consumer groups some of the aforementioned relationships shifted. This was expected as in Figure 26, relationships were driven by differences in the meat source, whereas relationship presented in Figure 27 were driven by differences by consumer group.

Non-millennial heavy beef eaters were associated with 20:4, 18:3 and 16:1 fatty acids and as previously discussed were more closely related to consumer liking attributes. This indicates that non-millennial heavy beef eating consumers liked beef with higher levels of 20:4, 18:3, and 16:1 fatty acids and meat that was higher in spoiled putrid, sour aromatics, sour, sweet, bitter, beef identity, bloody/serumy, and astringent flavor attributes. Whereas, millennial heavy beef eaters liked meat that was higher in non-heme iron, moisture percentage, and metallic and warmed over flavor attributes. Millennial light beef eating consumers were associated with lipid percentage, brown/roasted and connective tissue trained sensory attributes. Pork identity, fat-like, salty and nutty descriptive attributes, pH, and 18:0 were somewhat associated with millennial light beef eaters. Non-millennial light beef eaters, while somewhat positively associated with consumer liking attributes, umami, overall tenderness and muscle fiber tenderness attributes, these consumers were not closely segmented with traits evaluated. Overall, the HUT chemical analysis did not differ from the CLT chemical analysis.

These results indicated that consumer groups tended to differ in drivers of liking. Non-millennial heavy beef eaters, non-millennial light beef eaters, millennial heavy beef eaters and millennial light beef eaters used slightly different cooking methods when cooking beef, pork and chicken. Visual appearance, both before cooking and after cooking, was more important to non-millennial heavy beef eaters. Additionally, non-millennial light beef eaters liked meat that was more tender, whereas non-millennial heavy beef eaters liked beef that was more bloody/serumy or had been cooked to lower degrees of doneness and had higher levels of beef identity flavor. Millennials had different drivers of liking for meat. Millennial heavy beef eaters accepted meat that was higher in percentage moisture, it could be slightly tougher, and they accepted metallic flavors and higher non-heme iron levels. Millennial light beef eaters liked more fat-like flavor, higher lipid percentage, salty basic taste and brown/roasted flavor attributes. Consumer groups responded to meat sources similarly meaning that whether eating beef, pork or chicken, the same drivers as defined above were important to them.

CHAPTER V

CONCLUSIONS

As the beef industry evolves, the importance of sensory attributes of their products has become apparent. Flavor continues to be one of the most important sensory attributes and a driver for beef consumption. Millennials versus non-millennials respond similarly in response to flavor of meat indicating that other factors drive consumption more than palatability factors. Other factors could include lifestyle, health or financial reasons. One factor that was seen to have a large concern for all generations but more specifically the millennials was price. Since the consumers were able to prepare the meat themselves, they could have responded with higher liking scores for the HUT compared to the CLT.

Ultimately this research could be used to improve overall flavor of beef, pork and chicken to maximize the positive flavors and minimize the negative flavors. The consumers responded similarly for all the meat cuts but more negative flavors were associated with Crock-pot® cookery methods. The grill cooking methods produced more positive flavors that the consumers liked more. Identifying the aromatic volatiles that drive consumer liking is an important step that needs more research in the study of flavor chemistry. By identifying these compounds, we will have the ability to better predict and improve beef, pork and chicken to maximize positive flavors.

Millennials thrive on social media and learn from unreliable sources. The beef industry should be transparent with this generation and allow them to talk to each other and experts about beef and beef production. This generation will be, if not already a huge driving force in the economy and the beef industry should capitalize on this market and cater towards them to increase consumption.

REFERENCES

Aberle, E., Reeves, E., Judge, M., Hunsley, R., & Perry, T. (1981). Palatability and muscle characteristics of cattle with controlled weight gain: Time on a high energy diet. *Journal of Animal Science, 52*(4), 757-763.

Aberle, E. D., John C. Forrest, David E. Gerrard, Edward W. Mills. (2001). *Principles of Meat Science* (Fourth ed.). Dubuque, Iowa: Kendall Hunt.

Adhikari, K., Chambers IV, E., Miller, R., Vazquez-Araujo, L., Bhumiratana, N., Philip, C.. (2011). Development of a lexicon for beef flavor in intact muscle. *Journal of Sensory Studies*, *26*(6), 413-420.

AMSA. (2015). Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurements of meat. Savoy, Illinois: American Meat Science Association.

AMSA. (1995). Beef Steak Color Guide. Savoy, Illinois: American Meat Science Association..

Ang, C., & Lyon, B. (1990). Evaluations of warmed ‐ over flavor during chill storage of cooked broiler breast, thigh and skin by chemical, instrumental and sensory methods. *Journal of Food Science, 55*(3), 644-648.

Babol, J., Squires, E., & Gullett, E. (1995). Investigation of factors responsible for the development of boar taint. *Food Research International*, *28*(6), 573-581.

Bartoli, M., & Richard, I. (2005). Calpains in muscle wasting. *The International Journal of Biochemistry & Cell Biology, 37*(10), 2115-2133.

Baublits, R., Pohlman, F., Brown, A., Johnson, Z., Rule, D., Onks, D., Murrieta, C., Richards, C., Sandelin, B., & Loveday, H. (2009). Correlations and prediction equations for fatty acids and sensory characteristics of beef longissimus rib steaks from forage‐fed cattle and retail USDA Choice and Select rib steaks. *Journal of Muscle Foods, 20*(1), 1-17.

Behrends, J. M., Goodson, K. J., Koohmaraie, M., Shackelford, S. D.,Wheeler, T. L., Morgan., W. W.,Reagan, J. O., Gwartney, B.L., Wise, J. W., & Savell, J. W. (2005). Beef customer satisfaction: USDA quality grade and marination effects on consumer evaluations of top round steaks. *Journal of Animal Science, 83*(3), 662-670.

Belew, J., Brooks, J., Mckenna, D., & Savell, J. (2003). Warner–Bratzler shear evaluations of 40 bovine muscles. *Meat Science, 64*(4), 507-512.

Belk, K., Miller, R., Evans, L., Liu, S., & Acuff, G. (1993). Flavor attributes and microbial levels of fresh beef roasts cooked with varying foodservice methodology1. *Journal of Muscle Foods, 4*(4), 321-337.

Blumer, T. (1963). Relationship of marbling to the palatability of beef. *Journal of Animal Science, 22*(3), 771-778.

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.

Bowers, J. A., Craig, J. A., Kropf, D., & Tucker, T. J. (1987). Flavor, color, and other characteristics of beef longissimus muscle heated to seven internal temperatures between 55 and 85 c. *Journal of Food Science, 52*(3), 533-536.

Breer, H. (2008). The sense of smell: Reception of flavors *Annals of the New York Academy of Sciences, 1126*(1), 1-6.

Bryhni, E., Byrne, D., Rødbotten, M., Claudi-Magnussen, C., Agerhem, H., Johansson, M., Lea, P., & Martens, M. (2002). Consumer perceptions of pork in denmark, norway and sweden. *Food Quality and Preference, 13*(5), 257-266.

Bureau, U. S. C. (2015). Millennials outnumber baby boomers and are far more diverse *Census Bureau Reports*.

Burson, D., Hunt, M., Unruh, J., & Dikeman, M. (1986). Proportion of types i and iii collagen in longissimus collagen from bulls and steers. *Journal of Animal Science, 63*(2), 453-456.

Calkins, C., & Hodgen, J. (2007). A fresh look at meat flavor. *Meat Science, 77*(1), 63-80.

Carpenter, Z. L. (1962). *Histological and physical characteristics of pork muscle and their relationship to pork quality*. Ph. D. Dissertation University of Wisconsin--Madison.

Chambers, E., & Koppel, K. (2013). Associations of volatile compounds with sensory aroma and flavor: The complex nature of flavor. *Molecules, 18*(5), 4887-4905.

Chaudhari, N., & Roper, S. D. (2010). The cell biology of taste. *Journal of Cell Biology, 190*(3), 285-296.

Chu, S. K. (2015). *Development of an intact muscle pork flavor lexicon.* Master of Science Texas A&M University

Coates, D. (2015). *Food: Millennials' first love.* Paper presented at the National Cattlemens Beef Assocaition Annual Convention, San Antonio.

Crocker, E. (1948). Flavor of meat. *Journal of Food Science, 13*(3), 179-183.

Cross, H., Carpenter, Z., & Smith, G. (1973). Effects of intramuscular collagen and elastin on bovine muscle tenderness. *Journal of Food Science, 38*(6), 998-1003.

Crouse, J. D., Cundiff, L. V., Koch, R. M., Koohmaraie, M., & Seideman, S. C. (1989). Comparisons of and inheritance for carcass beef characteristics and meat palatability. *Journal of Animal Science, 67*(10), 2661-2668.

Daillant-Spinnler, B., & Issanchou, S. (1995). Influence of label and location of testing on acceptability of cream cheese varying in fat content. *Appetite, 24*(2), 101-105.

Davey, C. L., & Gilbert, K. V. (1974). Temperature ‐ dependent cooking toughness in beef. *Journal of the Science of Food and Agriculture, 25*(8), 931-938.

Devol, D., Mckeith, F., Bechtel, P. J., Novakofski, J., Shanks, R., & Carr, T. (1988). Variation in composition and palatability traits and relationships between muscle characteristics and palatability in a random sample of pork carcasses. *Journal of Animal Science, 66*(2), 385-395.

Dikeman, M. (1987). *Fat reduction in animals and the effects on palatability and consumer acceptance of meat products.* Paper presented at the Proceedings-Annual Reciprocal Meat Conference of the American Meat Science Association (USA).

Dransfield, E. (1994). Tenderness of meat, poultry and fish. *Quality attributes and their measurement in meat, poultry and fish products* (pp. 289-315). New York City, New York: Springer.

Draves, W. A., & Coates, J. (2004). *Nine shift: Work, life and education in the 21st century*. River Falls, WI LERN Books.

Enser, M., Hallett, K., Hewitt, B., Fursey, G., & Wood, J. (1996). Fatty acid content and composition of english beef, lamb and pork at retail. *Meat Science, 42*(4), 443-456.

Farmer, L., & Mottram, D. (1994). Lipid-maillard interactions in the formation of volatile aroma compounds. *Developments in food science*.

Farmer, L. J. (1994). The role of nutrients in meat flavour formation. *Proceedings of the Nutrition Society*, *53*(02), 327-333.

Fernandez, X., Monin, G., Talmant, A., Mourot, J., & Lebret, B. (1999). Influence of intramuscular fat content on the quality of pig meat—1. Composition of the lipid fraction and sensory characteristics of m. Longissimus lumborum. *Meat Science, 53*(1), 59-65.

Fletcher, D. (2002). Poultry meat quality. *World's Poultry Science Journal, 58*(02), 131-145.

FreshLook Marketing (2015). Natural/organic share of total beef (dollar) *NCBA Retail Marketing.*

Fromm, J., & Vidler, M. (2015). Millennials with kids: Marketing to this powerful and surprisingly different generation of parents

Fromm, J. & Garton, C. (2013). *Marketing to millennials: Reach the largest and most influential generation of consumers ever*. New York Barkley, Inc.

Gerrard, D., Jones, S., Aberle, E., Lemenager, R., Diekman, M., & Judge, M. (1987). Collagen stability, testosterone secretion and meat tenderness in growing bulls and steers. *Journal of Animal Science, 65*(5), 1236-1242.

Glascok, R. (2014). *Beef flavor attributes and consumer perception.* Master of Science Texas A&M University College Station, TX.

Goll, D. E., Thompson, V. F., Li, H., Wei, W., & Cong, J. (2003). The calpain system. *Physiological reviews, 83*(3), 731-801.

Goodson, K., Morgan, Ww, Reagan, Jo, Gwartney, Bl, Courington, Sm, Wise, Jw, Savell, Jw. (2002). Beef customer satisfaction: Factors affecting consumer evaluations of clod steaks. *Journal of Animal Science, 80*(2), 401-408.

Guelker, M., Haneklaus, A., Brooks, J., Carr, C., Delmore, R., Griffin, D., Hale, D., Harris, K., Mafi, G., & Johnson, D. (2013). National beef tenderness survey–2010: Warner-Bratzler shear force values and sensory panel ratings for beef steaks from united states retail and food service establishments. *Journal of Animal Science, 91*(2), 1005-1014.

Hawthorne, S. A., Lien, R., Hunt, M. C., & Kropf, D. H. Pork Chop Cooked Color Guide. K-State Research and Extension, the National Pork Producers Council, and the National Pork Board, Des Moines, IA.

Hellemann, U. A., Mela, D. J., Aaron, J. I., & Evans, R. E. (1993). Role of fat in meal acceptance. *Food Quality and Preference, 4*(1), 90.

Herring, H. Cassens, R., & Briskey, E. (1967). Factors affecting collagen solubility in bovine muscles. *Journal of Food Science, 32*(5), 534-538.

Hill, F. (1966). The solubility of intramuscular collagen in meat animals of various ages. *Journal of Food Science, 31*(2), 161-166.

Hornstein, I. (1971). Chemistry of meat flavor. In Price, J. F. & Schweigert B. S. (Ed.), *The Science of Meat and Meat Products*. San Francisco: W.H. Freeman and Company.

Hornstein, I., & Crowe, P. (1960). Meat flavor chemistry, flavor studies on beef and pork. *Journal of Agricultural and Food Chemistry, 8*(6), 494-498.

Howe, N., & Strauss, W. (2009). *Millennials rising: The next great generation*. New York: Vintage.

Huff-Lonergan, E., Mitsuhashi, T., Beekman, D. D., Parrish, F., Olson, D. G., & Robson, R. M. (1996). Proteolysis of specific muscle structural proteins by mu-calpain at low pH and temperature is similar to degradation in postmortem bovine muscle. *Journal of Animal Science, 74*(5), 993-1008.

Hurrell, R. (1982). Maillard reaction in flavour. *Food Flavours,* 399-437.

Imafidon, G. I., & Spanier, A. M. (1994). Unraveling the secret of meat flavor. *Trends in Food Science & Technology*, *5*(10), 315-321.

Jayasena, D. D., Ahn, D. U., Nam, K., & Jo, C. (2013). Factors affecting cooked chicken meat flavour: A review. *World's Poultry Science Journal*, *69*(03), 515-526.

Kato, H., & Nishimura, T. (1987). Taste components and conditioning of beef, pork, and chicken. *Umami: A basic taste*, 289-306.

Kemp, C. M., Sensky, P. L., Bardsley, R. G., Buttery, P. J., & Parr, T. (2010). Tenderness–an enzymatic view. *Meat Science, 84*(2), 248-256.

Kerth, C. R. (2013). Determination of aromatic production from surface browning to improve flavor in steaks using differences in steak thickness and cook surface temperature. *Final Report to the National Cattlemen's Beef Association, Centennial, CO*.

Kerth, C. R., & Miller, R. K. (2015). Beef flavor: A review from chemistry to consumer. *Journal of Science of Food and Agriculture*. 95(14), 2783-2798.

King, S. C., Weber, A. J., Meiselman, H. L., & Lv, N. (2004). The effect of meal situation, social interaction, physical environment and choice on food acceptability. *Food Quality and Preference*, *15*(7), 645-653.

Koohmaraie, M. (1992). The role of Ca^{2+}dependent proteases (calpains) in post mortem proteolysis and meat tenderness. *Biochimie*, *74*(3), 239-245.

Koohmaraie, M. (1996). Biochemical factors regulating the toughening and tenderization processes of meat. *Meat Science, 43*, 193-201.

Kozlowska, K., Jeruszka, M., Matuszewska, I., Roszkowski, W., Barylko-Pikielna, N., & Brzozowska, A. (2003). Hedonic tests in different locations as predictors of apple juice consumption at home in elderly and young subjects. *Food Quality and Preference, 14*(8), 653-661.

Laugerette, F., Passilly-Degrace, P., Patris, B., Niot, I., Febbraio, M., Montmayeur. , J. P., & Besnard, P. (2005). Cd36 involvement in orosensory detection of dietary lipids, spontaneous fat preference, and digestive secretions. *Journal of Clinical Investigation, 115*(11), 3177.

Lockie, S., Lyons, K., Lawrence, G., & Grice, J. (2004). Choosing organics: A path analysis of factors underlying the selection of organic food among Australian consumers. *Appetite, 43*(2), 135-146.

Lorenzen, C., Neely, T., Miller, R., Tatum, J., Wise, J., Taylor, J. , Buyck, M., Reagan, J., & Savell, J. (1999). Beef customer satisfaction: Cooking method and degree of doneness effects on the top loin steak. *Journal of Animal Science, 77*, 637-644.

Luchak, G., Miller, R., Belk, K., Hale, D., Michaelsen, S., Johnson, D., West, R., Leak, F., Cross, H., & Savell, J. (1998). Determination of sensory, chemical and cooking characteristics of retail beef cuts differing in intramuscular and external fat. *Meat Science, 50*(1), 55-72.

Luckemeyer, T. (2015). *Beef flavor attributes and consumer perception of light beef eaters.* Master of Science, Texas A&M University, College Station, TX.

Lyon, B. (1987). Development of chicken flavor descriptive attribute terms aided by multivariate statistical procedures1. *Journal of Sensory Studies, 2*(1), 55-67.

Macleod, G. (1994). The flavour of beef. *Flavor of Meat and Meat Products* (pp. 4-37). New York City, New York: Springer.

Mattes, R. D. (2009). Is there a fatty acid taste? *Annual Review of Nutrition, 29*, 305.

Matuszewska, I., Baryłko-Pikielna, N., Szczecinska, A., & Radzanowska, J. (1997). Comparison of three procedures for consumer assessment of fat spreads: Short report. *Polish journal of food and nutrition sciences, 6*(3), 139-142.

Mcbee, J. L., & Wiles, J. A. (1967). Influence of marbling and carcass grade on the physical and chemical characteristics of beef. *Journal of Animal Science, 26*(4), 701-704.

Meilgaard, M., G. V. Civille, and B. T. Carr. (2007). *Sensory Evaluation Techniques* (4th ed.). Boca Raton: Taylor & Francis.

Meinert, L., Tikk, K., Tikk, M., Brockhoff, P. B., Bejerholm, C., & Aaslyng, M. D. (2008). Flavour formation in pork semimembranosus: Combination of pan-temperature and raw meat quality. *Meat Science, 80*(2), 249-258.

Meisinger, J. L., James, J., & Calkins, C. (2006). Flavor relationships among muscles from the beef chuck and round. *Journal of Animal Science, 84*(10), 2826-2833.

Melton, S. L. (1999). Current status of meat flavor. *Quality Attributes of Muscle Foods* (pp. 115-133). New York City, New York: Springer.

Miller, M., Hoover, L., Cook, K., Guerra, A., Huffman, K., Tinney, K. , Ramsey, C., Brittin, H., & Huffman, L. (1995). Consumer acceptability of beef steak tenderness in the home and restaurant. *Journal of Food Science, 60*(5), 963-965.

Miller, M., Kerth, C., Wise, J., Lansdell, J., Stowell, J., & Ramsey, C. (1997). Slaughter plant location, USDA quality grade, external fat thickness, and aging time effects on sensory characteristics of beef loin strip steak. *Journal of Animal Science, 75*(3), 662-667.

Miller, R. (2001). Beef flavor: A white paper. *A paper prepared for the National Cattlemen's Beef Association, Centennial, CO*.

Miller, R., & Kerth, C. (2012). Identification of compounds responsible for positive beef flavor. *Final Report to the National Cattlemen's Beef Association, Centennial, CO*.

Miller, R., Tatum, J., Cross, H., Bowling, R., & Clayton, R. (1983). Effects of carcass maturity on collagen solubility and palatability of beef from grain ‐ finished steers. *Journal of Food Science, 48*(2), 484-486.

Miller, R. K. (1994). Quality characteristics *Muscle foods* (pp. 296-332). New York City, New York: Springer.

Mindswarms. (2014). The power of local food. NCBA Retail Research.

Moeller, R., & Courington, S. (1998). Branded beef study. *National Cattlemen's Beef Association, Englewood, CO*.

Moeller, S., Miller, R., Aldredge, T., Logan, K., Edwards, K., Zerby, H., Boggess, M., Box-Steffensmeier, J., & Stahl, C. (2010). Trained sensory perception of pork eating quality as affected by fresh and cooked pork quality attributes and end-point cooked temperature. *Meat Science, 85*(1), 96-103.

Morrison, W. R., & Smith, L. M. (1964). Preparation of fatty acid methyl esters and dimethylacetals from lipids with boron fluoride–methanol. *Journal of lipid research, 5*(4), 600-608.

Morton, I. D., P. Akroyd, and C. G. May. (1960). U. S. Patent 2,918,376.

Mottram, D., & Edwards, R. (1983). The role of triglycerides and phospholipids in the aroma of cooked beef. *Journal of the Science of Food and Agriculture, 34*(5), 517-522.

Mottram, D. S. (1979). The flavor of cooked meats. *Agricultural Research Council Meat Research Institute (Bristol) Biennial Report*(1977-79), 87-88.

Mottram, D. S. (1985). The effect of cooking conditions on the formation of volatile heterocyclic compounds in pork. *Journal of the Science of Food and Agriculture, 36*(5), 377-382.

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

Myers, A., Scramlin, S., Dilger, A., Souza, C., Mckeith, F., & Killefer, J. (2009). Contribution of lean, fat, muscle color and degree of doneness to pork and beef species flavor. *Meat Science, 82*(1), 59-63.

Nakamura, R., Sekoguchi, S., & Sato, Y. (1975). The contribution of intramuscular collagen to the tenderness of meat from chickens with different ages. *Poultry Science, 54*(5), 1604-1612.

National Restaurant Foundation. (2015). What's hot 2015 culinary forecast. *NCBA retail Marketing, Englewood, CO.*

Neely, T., Lorenzen, C., Miller, R., Tatum, J., Wise, J., Taylor, J., Buyck, M., Reagan, J., & Savell, J. (1998). Beef customer satisfaction: Role of cut, USDA quality grade, and city on in-home consumer ratings. *Journal of Animal Science, 76*(4), 1027-1033.

Neely, T., Lorenzen, C., Miller, R., Tatum, J., Wise, J., & Taylor, J.., Buyck, M., Reagan, J., & Savell, J. (1999). Beef customer satisfaction: Cooking method and degree of doneness effects on the top round steak. *Journal of Animal Science, 77*(3), 653-660.

Nishimura, T., Rhue, M. R., Okitani, A., & Kato, H. (1988). Components contributing to the improvement of meat taste during storage. *Agricultural and Biological Chemistry, 52*(9), 2323-2330.

Novakofski, J. (1987). *Repartitioned pork. Sensory quality and consumer acceptance.* Paper presented at the Proc. University of Illinois Pork Ind. Conf.

Pound, C., Duizer, L., & Mcdowell, K. (2000). Improved consumer product development. Part one: Is a laboratory necessary to assess consumer opinion? *British Food Journal, 102*(11), 810-820.

Purslow, P. P. (2005). Intramuscular connective tissue and its role in meat quality. *Meat Science, 70*(3), 435-447.

Reicks, A., Brooks, J., Garmyn, A., Thompson, L., Lyford, C., & Miller, M. (2011). Demographics and beef preferences affect consumer motivation for purchasing fresh beef steaks and roasts. *Meat Science, 87*(4), 403-411.

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

Resurreccion, A. V. (2007). 13 consumer sensory testing for food product development. *Developing New Food Products for a Changing Marketplace*, 365.

Rhee, K. S. (1989). Chemistry of meat flavor. *Flavor chemistry of lipid foods*, 166-189.

Rhee, K. S., & Ziprin, Y. A. (1987). Modification of the schricker nonheme iron method to minimize pigment effects for red meats. *Journal of Food Science, 52*(5), 1174-1176.

Rickansrud, D. A., & Henrickson, R. L. (1967). Total pigments and myoglobin concentration in four bovine muscles. *Journal of Food Science, 32*(1), 57-61.

Rolls, E. T., & Baylis, L. L. (1994). Gustatory, olfactory, and visual convergence within the primate orbitofrontal cortex. *The Journal of Neuroscience, 14*(9), 5437-5452.

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

Savell, J., Lorenzen, C., Neely, T., Miller, R., Tatum, J., Wise, J., Taylor, J., Buyck, M., & Reagan, J. (1999). Beef customer satisfaction: Cooking method and degree of doneness effects on the top sirloin steak. *Journal of Animal Science, 77*(3), 645-652.

Sclafani, A., Ackroff, K., & Abumrad, N. A. (2007). Cd36 gene deletion reduces fat preference and intake but not post-oral fat conditioning in mice. *American*

Journal of Physiology-Regulatory, Integrative and Comparative Physiology, 293(5), R1823-R1832.

Shackelford, S., Koohmaraie, M., Miller, M., Crouse, J., & Reagan, J. (1991). An evaluation of tenderness of the longissimus muscle of angus by hereford versus brahman crossbred heifers. *Journal of Animal Science, 69*(1), 171-177.

Shackelford, S., Wheeler, T., & Koohmaraie, M. (1995). Relationship between shear force and trained sensory panel tenderness ratings of 10 major muscles from *bos indicus* and *bos taurus* cattle. *Journal of Animal Science 73*, 3333-3340.

Shahidi, F. (1994). *Flavor of Meat and Meat Products*. New York, Philadelphia: Springer Science & Business Media.

Shahidi, F. (2002). Lipid-derived flavors in meat products. *Meat processing: improving quality*, 105-121.

Shahidi, F., & Ho, C.-T. (1998). Process-induced chemical changes in foods *Process-induced chemical changes in food* (pp. 1-3). New York City, New York: Springer.

Shahidi, F., Samaranayaka, A. G. P., & Pegg, R. B. (2004). Maillard reaction and browning. In C. D. W. K. Jensen, and M. Dikenman (Ed.), *Heat effects on meat* (Vol. 2). Oxford: Elsevier Limited

Shi, H. a. H. C. T. (1994). The flavour of poultry meat In F. Shahidi (Ed.), *Flavor of meat and meat products* (pp. 52-69). New York City, New York Springer.

Small, D. M., & Prescott, J. (2005). Odor/taste integration and the perception of flavor. *Experimental Brain Research, 166*(3-4), 345-357. doi: 10.1007/s00221-005-2376-9

Smith, G., & Carpenter, Z. (1974). *Eating quality of animal products and their fat content.* Paper presented at the Proc. Symposium on changing the fat content and composition of animal products. National Research Council, Washington DC, USA: National Academy of Sciences.

Smith, G., Savell, J., Cross, H., & Carpenter, Z. (1983). The relationship of USDA quality grade to beef flavor. *Food Technology, 37*(5), 233-238.

Smith, G. C., Savell, J. W., Clayton, R. P., Field, T. G., Griffin, D. B., Hale, D., S. , M. F. Miller, T. H. Montgomery, J. B. Morgan, J. D. Tatum, & J. W. Wise. (1992). The final report of the national beef quality audit--1991. *Colorado State University and Texas A&M University.*

Sorimachi, H., Kinbara, K., Kimura, S., Takahashi, M., Ishiura, S., Sasagawa, N., Sorimachi, N., Shimada, H., Tagawa, K., & Maruyama, K. (1995). Muscle-specific calpain, p94, responsible for limb girdle muscular dystrophy type 2a, associates with connecting through is 2, a p94-specific sequence. *Journal of Biological Chemistry, 270*(52), 31158-31162.

Spanier, A., & Miller, J. (1993). *Role of proteins and peptides in meat flavor.* Paper presented at the ACS symposium series (USA).

Stegelin, F. (2002). Food and the millennial generation. *Journal of Food Distribution Research, 33*(1), 182-184.

Strasburg, G., Youling L. Xiong, and Wen Chiang. (2008). Physiology and chemistry of edible muslce tissue In K. L. P. Srinivasan Damodaran, and Owen R. Fennema (Ed.), *Fennema's Food Chemistry* Boca Raton, FL Taylor & Francis Group.

Taylor, P., & Keeter, S. (2010). Millennials: A portrait of generation next: Confident, connected, open to change: Pew Research Center.

Thorpe, S., & Baynes, J. (2003). Maillard reaction products in tissue proteins: New products and new perspectives. *Amino Acids, 25*(3-4), 275-281.

USDA. (1996). *United States standards for grades of slaughter cattle*. Washington, DC.

Voges, K., Mason, C., Brooks, J., Delmore, R., Griffin, D., & Hale, D., Henning, W., Johnson, D., Lorenzen, C., & Maddock, R. (2007). National beef tenderness survey–2006: Assessment of Warner–Bratzler shear and sensory panel ratings for beef from us retail and foodservice establishments. *Meat Science, 77*(3), 357-364.

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

Wasserman, A. E. (1972). Thermally produced flavor components in the aroma of meat and poultry. *Journal of Agricultural and Food Chemistry, 20*(4), 737-741.

Wasserman, A. E., & Gray, N. (1965). Meat flavor. I. Fractionation of water ‐ soluble flavor precursors of beef. *Journal of Food Science, 30*(5), 801-807.

Wellendorph, P., Johansen, L. D., & Bräuner-Osborne, H. (2009). Molecular pharmacology of promiscuous seven transmembrane receptors sensing organic nutrients. *Molecular Pharmacology, 76*(3), 453-465.

Werkhoff, P., Brüning, J., Güntert, M., Kaulen, J., Krammer, G., & Sommer, H. (1996). Potent mercapto/methylthio-substituted aldehydes and ketones in cooked beef liver. *Advances in Food Sciences, 18*(1-2), 19-27.

Westerling, D. B., & Hedrick, H. (1979). Fatty acid composition of bovine lipids as influenced by diet, sex and anatomical location and relationship to sensory characteristics. *Journal of Animal Science, 48*(6), 1343-1348.

Wheeler, T., Shackelford, S., & Koohmaraie, M. (2000). Variation in proteolysis, sarcomere length, collagen content, and tenderness among major pork muscles. *Journal of Animal Science, 78*(4), 958-965.

Whipple, G., Koohmaraie, M, Dikeman, M. E., Crouse, J. D., Hunt, M. C., & Klemm, R. D. (1990). Evaluation of attributes that affect longissimus muscle tenderness in bos taurus and bos indicus cattle. *Journal of Animal Science, 68*(9), 2716-2728.

Wilson, G. D. (1960). *Factors influencing quality of fresh meats*. San Francisco: W.H. Freeman and Co.

Wood, J., Enser, M., Fisher, A., Nute, G., Sheard, P., Richardson, R., Hughes, S., & Whittington, F. (2008). Fat deposition, fatty acid composition and meat quality: A review. *Meat Science, 78*(4), 343-358.

Wood, J., Nute, G., Fursey, G., & Cuthbertson, A. (1995). The effect of cooking conditions on the eating quality of pork. *Meat Science, 40*(2), 127-135.

Wood, J., Richardson, R., Nute, G., Fisher, A., Campo, M., Kasapidou, E., Sheard, P., & Enser, M. (2004). Effects of fatty acids on meat quality: A review. *Meat Science, 66*(1), 21-32.

Xiong, Y. L., Ho, C.-T., & Shahidi, F. (1999). Quality characteristics of muscle foods *Quality Attributes of Muscle Foods* (pp. 1-10). New York City, New York: Springer.

Yancey, E., Grobbel, J., Dikeman, M., Smith, J., Hachmeister, K., Chambers, E., Gadgil, P., Milliken, G., & Dressler, E. (2006). Effects of total iron, myoglobin, hemoglobin, and lipid oxidation of uncooked muscles on livery flavor development and volatiles of cooked beef steaks. *Meat Science, 73*(4), 680-686.

Zajonc, R. B. (1968). Attitudinal effects of mere exposure. *Journal of Personality and Social Psychology, 9*(2p2), 1.

APPENDIX I

FIGURES AND TABLES

Table 1. Definition and reference standards for beef descriptive flavor aromatics and basic taste sensory attributes and their intensities where 1 = none; 16 = extremely intense from Adhikari et al. (2011).

Attributes	Definition	Reference
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 = 6.5 (F); 7.5 (A)
Animal hair	The aromatics perceived when raw wool is saturate with water.	Caproic acid = 12.0
Barnyard	Combination of pungent, slightly sour, hay-like aromatics	White pepper in water = 4.0 (F); 4.5 (A)
	Associated with farm animals and the inside of a horn	Tinure of civet = 6.0 (A)
Beef identity	Amount of beef flavor identity in the sample.	Swanson's beef broth = 5.0 80% lean ground beef = 7.0 Beef brisket = 11.0
Beet	A dark damp-musty-earthy note associated	Food Club sliced beets juice with 1 part juice with canned red beets to 2 parts water = 4.0 (F)
Bitter	The fundamental taste factor associated with a caffeine solution.	0.01% caffeine solution = 2.0 0.02% caffeine solution = 3.5
Bloody/serumy	The aromatics associated with blood on cooked meat products. Closely related to metallic aromatic.	USDA Choice strip steak = 5.5 Beef brisket = 6.0
Brown/roasted	A round, full aromatic generally associated with beef suet that has been broiled.	Beef suet = 8.0 80% lean ground beef = 10.0

Buttery	Sweet, dairy-like aromatic associated with natural butter	Land O'Lakes unsalted butter = 7.0 (F)
Burnt	The sharp/acrid flavor note associate with over-roasted beef muscle, something over-baked or excessively browned in oil.	Alf's red wheat Puffs = 5.0
Chemical	The aromatics associated with garden hose, hot Teflon pan, plastic packaging and petroleum based product such as charcoal liter fluid.	Zip-Loc sandwich bag =13.0 Clorox in water = 6.5
Chocolate/ Cocoa	The aromatics associated with cocoa beans and powdered cocoa and chocolate bars. Brown, sweet, dusty, often bitter aromatics.	Hershey's cocoa powder in water = 3.0 Hershey's chocolate kiss = 8.5 (F)
Cooked milk	A combination of sweet, brown flavor notes and aromatics associated with heated milk.	Mini Babybel original Swiss cheese = 2.5 Dillon's whole milk = 4.5
Cumin	The aromatics commonly associated wit cumin and characterized as dry, pungent, woody an slightly floral	McCormick or Shilling ground cumin = 7.0 (F); 10.0 (A)
Dairy	The aromatics associated with products made from cow's milk, such as cream, milk, sour cream or butter milk.	Dillon's reduced fat milk (2%) = 8.0
Fat-like	The aromatics associated with cooked animal fat.	Hillshire farms Lit'l beef smokies = 7.0 Beef suet = 12.0
Floral	Sweet light, slightly perfume impression associated with flowers	Welch's white grape juice, diluted 1:1 with water = 5.0 (F); Geraniol = 7.5 (A)
Green	Sharp, slightly pungent aromatics associated with green/plant/ vegetable matters such as parsley, spinach, pea pod, fresh cut grass, etc.	Hexanal in propylene glycol (5,000 ppm) = 6.5 (aroma) Fresh parsley water = 9.0
Green-hay like	Brown/green dusty aromatics associated with dry grasses, hay, dry parsley and tea leaves	Dry parsley in medium snifter = 5.0 (A) Dry parsley in ~30-mL cup = 6.
Heated Oil	The aromatics associated with oil heated to a high temperature	Wesson Oil, microwaved 3 min = 7.0 (F&A) Lay's Potato Chips = 4.0 (A)
Leather	Musty, old leather (like old book bindings)	2,3,4-Trimethoxybenzaldehyde= 3.0(A)

Liver-like	The aromatics associated with cooked organ meat/liver	Beef liver = 7.5 Oscar Mayer Braunschweiger liver sausage = 10.0
Medicinal	A clean sterile aromatic characteristic of antiseptic like products such as Band-Aids, alcohol and iodine	Band-Aid = 6.0 (A)
Metallic	The impression of slightly oxidized metal, such as iron, copper and silver spoons.	0.10% potassium chloride solution = 1.5 USDA choice strip steak = 4.0 Dole canned pineapple juice = 6.0
Musty/earthy/ Humus	Musty, sweet, decaying vegetation	Sliced button mushrooms = 3.0 (F); 3.0 (A) 1000 ppm of 2,6-Dimethcycyclohexanol in propylene glycol = 9.0 (A)
Overall sweet	A combination of sweet taste and sweet aromatics. The aromatics associated with the impression of sweet	Post-shredded wheat spoon size = 1.5 Hillshire farms Lit'l beef smokies = 3.0 SAFC ethyl maltol 99% = 4.5 (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	The aromatics commonly associated with oxidized fat and oils. These aromatics may include cardboard, painty, varnish and fishy	Microwaved Wesson vegetable oil (3 min at high) = 7.0 Microwaved Wesson vegetable oil (5 min at high) = 9.0
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 cooked over medium-high heat to 165˚F, grease drained, store overnight in covered glass container at room temperature = 4.5 (F); 5.5 (A)
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	An aromatic associated with meat juices and fat drippings on	Wright's Natural Hickory

Charcoal	hot coats which can be acrid, sour, burned, etc.	seasonings in water = 9.0 (A)
Smoky wood	Dry, dusty aromatic reminiscent of burning wood	Wright's Natural Hickory seasoning in water = 7.5 (A)
Soapy	An aromatic commonly found in unscented hand soap	Ivory bar soap in 100 ml water = 6.5 (A)
Sour aromatics	The aromatics associated with sour substances.	Dillon's buttermilk = 5.0
Sour milk/ Sour dairy	Sour, fermented aromatics associated with dairy products such as buttermilk and sour cream.	Laughing cow light Swiss cheese = 7.0 Dillon's buttermilk = 9.0
Sour	The fundamental taste factor associated with citric acid.	0.015% citric acid solution = 1.5 0.050% citric acid solution = 3.5
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 in propylene glycol 10,000 ppm) = 12.0 (aroma)
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
Warmed-over	Perception of a product that has been previously cooked and reheated.	80% lean ground beef (reheated) = 6.0
Juiciness	The amount of perceived juice that is released from the product during mastication.	Carrot = 8.5; Mushroom = 10.0; Cucumber = 12.0; Apple = 13.5; Watermelon = 15.0 Choice top loin steak cooked to 58°C = 11.0 Choice top loin steak cooked to 80°C = 9.0
Muscle fiber tenderness	The ease in which the muscle fiber fragments during mastication	Select eye of round steak cooked to 70°C = 9.0 Select tenderloin steak cooked to 70°C = 14.0

Connective tissue amount	The structural component of the muscle surrounding the during mastication	Cross cut beef shank cooked to muscle fiber that will not break down 70°C = 7.0 Select tenderloin cooked to 70°C = 14.0
Overall tenderness	Average of muscle fiber tenderness and connective tissue amount when connective tissue amount is 6 or less.	If connective tissue amount is 12 to 15, than overall tenderness = the value of muscle fiber tenderness; If connective tissue amount is than overall tenderness is the average of connective tissue amount and muscle fiber tenderness.

Table 2. Definitions and references for pork flavor attributes, where 0 = none and 15 = extremely intense adapted from Chu (2015).

Attribute	Definition	Reference
Bitter	The fundamental taste factor associated with a caffeine solution	0.05% caffeine in 1000 mL water = 2.0 0.08% caffeine in 1000mL water = 5.0
Salty	The fundamental taste factor of which sodium chloride is typical	0.2% Salt in 1000mL water = 2.5 0.35% Salt in 1000mL water = 5.0
Sour	The fundamental taste factor associated with citric acid solution	0.05% Citric Acid in 1000mL water = 2.0 0.08% Citric Acid in 1000mL water = 5.0
Sweet	The fundamental taste factor associated with a sucrose solution	0.05% Sugar in 1000mL water = 2.0 0.08% Sugar in 1000mL water = 5.0
Umami	Flat, salty, somewhat brothy. The taste of glutamate, salts of amino acids and other molecules called nucleotides.	0.035% Accent flavoring in 1000mL water = 7.5 (F)
Boar Taint	Aromatic associated with boar taint; hormone-like; sweat, animal urine.	0.1g 3-methylindole, sniffed = 13.0 (A) Androstenone wafted directly from bottle = 15.0 (A)
Bloody/Serumy	An aromatic associated with blood on cooked meat products; closely related to metallic aromatic	Boneless Pork Chop, 135°F = 2.0
Brown/Roasted	A round, full aromatic generally associated with broiled pork suet	Pork Fat, cooked and browned = 3.0 (F), 4.0 (A)
Burnt	The sharp/acrid flavor note associated with over roasted pork, muscle something over baked or excessively browned in oil	Arrowhead Barley Cereal, 7-10 puffs = 3.0

Cardboardy	Aromatic associated with slightly oxidized fats and oils, reminiscent of wet cardboard packaging	Dry cardboard, 1 in square = 5.0 (F), 3.0 (A) Wet cardboard, 1 in square steeped in 1 cup water for 30 min = 7.0(F), 6.0(A)
Chemical	Aromatic associated with garden hose, hot Teflon pan, plastic packaging and petroleum-based products such as charcoal lighter fluid	1 drop Clorox in 200 mL water = 6.5 Ziploc Bag in snifter = 2.0 (A)
Fat-Like	Aromatics associated with cooked animal fat	Pork Fat, cooked and browned = 10.0 (F); 7.0 (A)
Floral	Sweet, light, slightly perfume impression associated with flowers	0.12 oz. Clorox Wipe Liquid in 4 oz. water= 8.0 (A) Geraniol, 2 drops on cotton ball in snifter = 7.5 (A) 1:1 White Grape Juice to Water = 5.0
Heated Oil	The aromatics associated with oil heated to a high temperature	Wesson Oil, microwaved 3 min = 7.0 Lay's Potato Chips = 4.0 (A)
Liver-Like	Aromatics associated with cooked organ meat/liver	Pork Liver, 71°C = 15.0 (F); 12.0(A)
Metallic	The impression of slightly oxidized metal, such as iron, copper,and silver spoons	Dole Pineapple Juice = 6.0 (A&F) 0.10% KCl in 1L water = 1.5 (A&F)
Nutty	Nutty characteristics are: sweet, oily, light brown, slightly musty and/or buttery, earthy, woody, astringent, bitter, etc.	Diamond Shelled Walnut, ground for 1 min= 6.5 (F)
Pork Identity	Amount of pork flavor identity in the sample	Boneless Pork Chop, 175° = 7.0(F), 5.0(A) 80/20 Ground Pork, 71°C = 6.0(F);5.0 (A)
Refrigerator Stale	Aromatics associated with products left in the refrigerator for period time and absorbing a combination of odors (lack of freshness/flat)	80/20 Ground Pork, 71°C, left chilled overnight, served room temperature = 6.0 (F), 8.0 (A)
Soapy	An aromatic commonly found in unscented hand soap	0.12 oz. Clorox Wipe Liquid in 4 oz. water = 3.0 (A)

		0.5g Ivory Bar Soap in 100mL water = 6.5(A)
Spoiled/Putrid	The presence of inappropriate aromatics and flavors that is commonly associated with spoiled products. It is a foul taste and/or smell that indicates product is starting to decay and putrefy	Boneless Pork Chop room temperature raw for 24 h, refrigerate for 6 days, 175°F, smelled only = 3.0 (A) 80/20 Ground Pork, same as above, 71°C = 5.0 (A)
Vinegary	Aroma notes associated with vinegar	1.1g Vinegar in 200g water = 6.0 (F); 4.0 (A)
Warmed-Over	Perception of a product that has been previously cooked and reheated	80/20 Ground Pork, cooked to 71°C, left chilled overnight and microwaved for 1 min = 5.0 (F&A)
Astringent	The chemical feeling factor on the tongue or other skin surfaces of the oral cavity described as a puckering/dry and associated with tannins or alum	Lipton Tea, 1 bag in 1 cup boiling water and steeped for 3 min = 6.0 (F) Lipton Tea, 3 bags in 1 cup boiling water and steeped for 3 min = 12.0 (F)

Table 3. Definitions and references for chicken flavor attributes, where 0 = none and 15 = extremely intense adapted by Lyons (1987).

Attribute	Definition	Reference
Basic Tastes		
Bitter	The fundamental taste factor associated with a caffeine solution	0.05% caffeine in 1000 mL water = 2.0 0.08% caffeine in 1000mL water = 5.0
Salty	The fundamental taste factor of which sodium chloride is typical	0.2% Salt in 1000mL water = 2.5 0.35% Salt in 1000mL water = 5.0
Sour	The fundamental taste factor associated with citric acid solution	0.05% Citric Acid in 1000mL water = 2.0 0.08% Citric Acid in 1000mL water = 5.0
Sweet	The fundamental taste factor associated with a sucrose solution	0.05% Sugar in 1000mL water = 2.0 0.08% Sugar in 1000mL water = 5.0
Umami	Flat, salty, somewhat brothy. The taste of glutamate, salts of amino acids and other molecules called nucleotides.	0.035% Accent flavoring in 1000mL water = 7.5
Flavor Aromatics		
Bloody/Serumy	An aromatic associated with blood on cooked meat products; closely related to metallic aromatic	Boneless Pork Chop, 135°F = 2.0
Brown/Roasted	A round, full aromatic generally associated with broiled pork suet	Pork Fat, cooked and browned = 3.0 (F), 4.0 (A)
Burnt	The sharp/acrid flavor note associated with over roasted muscle, something over baked or excessively browned in oil	Arrowhead Barley Cereal = 3.0 pork
Cardboardy	Aromatic associated with slightly oxidized fats and oils, reminiscent of wet cardboard packaging	Dry cardboard,2.54 cm square = 5.0 (F), 3.0 (A) Wet cardboard,2.54 cm square steeped in 1 cup water for 30 min = 7.0(F), 6.0(A)
Chemical	Aromatic associated with garden hose, hot Teflon pan, plastic	1 drop Clorox in 200 mL water = 6.5 (F)

	Packaging and petroleum-based products such as charcoal lighter fluid	Ziploc Bag in snifter = 2.0 (A)
Chicken identity	Amount of chicken flavor identity in the sample	Chicken breast grilled to 71°C = 4.0 Ground chicken cooked in skillet set at 350°F to 71°C internal temperature = 5.0 Swanson's chicken broth = 7.0 (F) Dark chicken baked thigh to 175°C internal temperature = 6.0 (F) White chicken breast baked to 175°C Internal temperature = 4.0 (F)
Fat-like	Aromatics associated with cooked chicken fat	Chicken fat from the thigh, covered with water, cooked in pan with lid, boiled for 20 minutes, remove lid and cooked until the water evaporates = 8.0 (F) Grilled chicken skin in skillet set at 350°F until brown = 5.0 (F)
Fishy	Aromatics associated with fish	Canned StarKist tuna = 12 (F); 10 (A)
Liver-Like	Aromatics associated with cooked organ meat/liver	Chicken liver 71°C = 9.0 (F)
Metallic	The impression of slightly oxidized metal, such as iron, copper, and silver spoons	Dole Pineapple Juice = 6.0 (A&F) 0.10% KCl in 1L water = 1.5 (A&F)
Painty	Aromatics associated with paint	Wesson oil placed in covered glass container in 100°C oven for 14 days = 8 (F); 10 (A)
Soapy	An aromatic commonly found in unscented hand soap	0.12 oz. Clorox Wipe Liquid in 4 oz. water = 3.0 (A) 0.5g Ivory Bar Soap in 100mL water = 6.5 (A)
Warmed-Over	Perception of a product that has been previously cooked and reheated	80/20 Ground Chicken, cooked to 71°C, left chilled reheated overnight and microwaved for 1 min = 5.0
Mouthfeels		

Astringent	The chemical feeling factor on the tongue or other skin surfaces as a puckering/dry and associated with tannins or alum	Lipton Tea, 1 bag in 1 cup boiling water and steeped of the oral cavity described for 3 min = 6.0 (F) Lipton Tea, 3 bags in 1 cup boiling water and steeped for 3 min = 12.0 (F)

Table 4. Flavor, basic tastes and tenderness attributes[h] least squares means by meat and cooking treatments.

Treatment	Beef identity	Pork identity	Chicken identity	Brown/ roasted	Bloody/ serumy	Fat-like	Metallic	Liver-like
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
<u>Chicken breasts</u>								
Grill, 62.7°C	0.0[a]	0.1[a]	4.9[b]	1.0[b]	0.1[a]	0.5[ab]	1.7[ab]	0.0[a]
Grill, 80°C	0.0[a]	0.3[a]	4.8[b]	1.2[cd]	0.1[a]	0.5[ab]	1.7[a]	0.0[a]
<u>Chicken thighs</u>								
Crock-pot®, 62.7°C	0.1[a]	0.2[a]	5.1[b]	0.0[a]	0.3[ab]	1.6[f]	1.7[a]	0.1[a]
Crock-pot®, 80°C	0.1[a]	0.1[a]	5.1[b]	0.2[a]	0.2[a]	1.4[c]	1.8[ab]	0.0[a]
<u>Pork inside round roasts</u>								
Crock-pot®, 62.7°C	0.1[a]	4.1[c]	0.3[a]	0.0[a]	0.6[bc]	0.7[b]	1.9[b]	0.0[a]
Crock-pot®, 80°C	0.4[a]	3.8[b]	0.8[a]	0.1[a]	0.2[a]	0.5[ab]	1.8[ab]	0.1[a]
<u>Pork loin chop</u>								
Grill, 62.7°C	0.0[a]	4.7[d]	0.5[a]	1.2[d]	0.2[a]	0.9[c]	1.8[ab]	0.0[a]
Grill, 80°C	0.1[a]	4.7[d]	0.3[a]	1.4[d]	0.1[a]	0.6[b]	1.8[ab]	0.0[a]
<u>Select bottom round roasts</u>								
Crock-pot®, 58.3°C	3.6[b]	0.8[a]	0.0[a]	0.0[a]	1.7[d]	0.4[a]	2.3[d]	0.4[b]
Crock-pot®, 80°C	4.5[c]	0.4[a]	0.0[a]	0.1[a]	0.6[bc]	0.4[a]	2.1[c]	0.5[b]
<u>Choice top loin steaks</u>								
Grill, 58.3°C	6.2[d]	0.1[a]	0.0[a]	1.9[e]	1.0[c]	1.6[e]	2.0[c]	0.0[a]
Grill, 80°C	6.9[e]	0.0[a]	0.1[a]	2.5[f]	0.6[b]	1.5[d]	1.9[ab]	0.0[a]
RMSE	0.67	0.71	0.63	0.40	0.61	0.32	0.27	0.23

Table 4 (con't). Flavor, basic tastes and tenderness attributes[h] least squares means by meat and cooking treatments.

Treatment	Basic Tastes								
	Umami	Sweet	Sour	Salty	Bitter	Overall Sweet	Astringent	Burnt	Card-boardy
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Chicken breasts									
Grill, 62.7°C	0.0[a]	0.5[ab]	2.0[def]	1.5[cde]	2.2[b]	0.2[a]	2.1[bcd]	0.5[c]	0.3[bcd]
Grill, 80°C	0.1[ab]	0.5[ab]	1.8[bcd]	1.4[abcd]	2.2[b]	0.3[ab]	2.2[d]	0.6[c]	0.0[a]
Chicken thighs									
Crock-pot®, 62.7°C	0.1[bc]	0.6[c]	2.2[cf]	1.3[abc]	2.2[b]	0.3[ab]	2.2[d]	0.0[a]	0.1[abc]
Crock-pot®, 80°C	0.1[abc]	0.7[c]	2.1[ef]	1.3[ab]	2.2[b]	0.3[ab]	2.2[d]	0.1[a]	0.1[ab]
Pork inside round roasts									
Crock-pot®, 62.7°C	0.2[c]	0.5[a]	2.0[cde]	1.3[ab]	1.8[a]	0.2[a]	1.8[a]	0.0[a]	0.2[abc]
Crock-pot®, 80°C	0.2[bc]	0.4[a]	1.7[ab]	1.2[a]	1.7[a]	0.4[bc]	2.0[abcd]	0.0[a]	0.3[bcd]
Pork loin chop									
Grill, 62.7°C	0.3[d]	0.6[bc]	1.7[ab]	1.6[e]	1.7[a]	0.5[d]	1.8[a]	0.0[a]	0.2[abc]
Grill, 80°C	0.2[cd]	0.5[ab]	1.6[a]	1.5[cde]	1.9[a]	0.5[cd]	2.0[abcd]	0.3[b]	0.1[abc]
Select bottom round roasts									
Crock-pot®, 58.3°C	0.1[abc]	0.5[ab]	2.2[f]	1.5[cde]	1.9[a]	0.2[a]	2.1[cd]	0.0[a]	0.4[d]
Crock-pot®, 80°C	0.2[bc]	0.6[abc]	1.9[cde]	1.4[bcd]	1.8[a]	0.3[ab]	1.9[abc]	0.0[a]	0.3[cd]
Choice top loin steaks									
Grill, 58.3°C	1.1[e]	0.8[d]	1.8[bc]	1.7[f]	1.8[a]	0.9[e]	1.8[a]	0.1[a]	0.1[a]
Grill, 80°C	1.2[e]	1.0[e]	1.8[bc]	1.7[f]	1.9[a]	1.0[e]	1.9[ab]	0.2[ab]	0.0[a]
RMSE	0.20	0.19	0.30	0.23	0.32	0.19	0.43	0.27	0.18

Table 4 (con't). Flavor, basic tastes and tenderness attributes[h] least squares means by meat and cooking treatments.

Treatment	Nutty	Sour Milk	Spoiled Putrid	Juiciness	Muscle Fiber Tenderness	Connective Tissue Amount	Overall Tenderness	Warner-Braxler Shear Force, kg
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
<u>Chicken breasts</u>								
Grill, 145F	0.0[a]	0.0[abc]	0.0[a]	10.6[c]	13.4[e]	14.0[fg]	13.7[e]	1.6[b]
Grill, 80°C	0.0[a]	0.1[cd]	0.0[abc]	9.9[bc]	13.2[e]	13.9[efg]	13.4[de]	1.8[bc]
<u>Chicken thighs</u>								
Crock-pot®, 62.7°C	0.0[a]	0.2[e]	0.4[d]	10.2[bc]	14.2[d]	14.6[g]	14.0[e]	0.9[a]
Crock-pot®, 176° F	0.0[ab]	0.1[de]	0.4[d]	9.9[bc]	14.2[d]	14.5[fg]	14.0[e]	0.9[a]
<u>Pork inside round roasts</u>								
Crock-pot®, 62.7°C	0.2[c]	0.0[abc]	0.0[a]	10.2[c]	12.2[cd]	12.7[de]	13.0[cde]	2.0[cd]
Crock-pot®, 80°C	0.2[c]	0.0[abc]	0.0[abc]	9.3[ab]	12.4[d]	13.1[def]	11.9[abcd]	2.1[cde]
<u>Pork loin chop</u>								
Grill, 62.7°C	0.1[b]	0.0[ab]	0.0[a]	9.7[b]	11.8[bc]	13.4[defg]	11.9[abcd]	2.4[ef]
Grill, 80°C	0.1[b]	0.0[a]	0.0[ab]	9.3[ab]	11.8[bc]	12.5[cde]	12.9[bcde]	2.4[ef]
<u>Select bottom round roasts</u>								
Crock-pot®, 58.3°C	0.0[a]	0.0[bc]	0.1[bc]	9.9[bc]	11.2[a]	10.1[a]	11.7[ab]	2.5[ef]
Crock-pot®, 80°C	0.0[a]	0.0[abc]	0.1[c]	8.4[a]	11.3[ab]	10.9[ab]	11.1[a]	2.8[f]
<u>Choice top loin steak</u>								
Grill, 58.3°C	0.0[a]	0.0[abc]	0.0[a]	10.7[c]	11.9[cd]	12.4[cd]	11.1[a]	2.2[de]
Grill, 80°C	0.0[a]	0.0[abc]	0.0[ab]	9.6[b]	11.4[ab]	11.7[bc]	11.7[abc]	2.6[f]
RMSE	0.11	0.12	0.12	1.44	0.76	2.19	2.29	0.65

[abcdefge]Mean values within a column and effect followed by the same letter are not significantly different ($P > 0.05$).
[h]Aroma measured where 0 = none and 15 = extremely intense.

Table 5. Demographic frequencies for beef consumers (n = 453) across four cities.

Question	Number of Respondents	Percentage of Respondents
Sex		
Male	191	42.2
Female	262	57.8
Age		
20 years or younger	29	6.4
21 - 25 years	52	11.5
26 - 35 years	142	31.3
36 - 45 years	84	18.5
46 - 55 years	88	19.4
56 - 65 years	57	12.6
66 years and older	2	0.4
Generation identification		
Millennial, Light Beef Eaters	131	28.9
Millennial, Heavy Beef Eaters	93	20.5
Non-millennial, Light Beef Eaters	137	30.2
Non-Millennial, Heavy Beef Eaters	93	20.5
Household income		
Below $25,000	98	21.6
$25,001 - $49,999	111	24.5
$50,000 - $74,999	89	19.6
$75,000 - $99,999	78	17.2
$100,000 or more	76	16.8
Household size including yourself		
1	66	14.4
2	157	34.6
3	104	22.9
4	75	16.5
5	33	7.3
6 or more	18	4.0
Employment level		
Not employed	101	22.3
Part-time	79	17.5
Full-time	271	60.0

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

At Home	**Do not Consume**	**Consume**	**Do not Consume**	**Consume**
Chicken	3	451	0.7	99.3
Beef	9	445	2.0	98.0
Pork	35	419	7.7	92.3
Fish	84	370	18.5	81.5
Lamb	354	100	78.0	22.0
Eggs	17	437	3.8	96.3
Soy Based Products	293	161	64.5	35.5
Away from Home/ Restaurant	**Do not Consume**	**Consume**	**Do not Consume**	**Consume**
Chicken	15	439	3.3	96.7
Beef	7	447	1.5	98.5
Pork	45	409	9.9	90.1
Fish	59	395	13.0	87.0
Lamb	274	180	60.4	39.6
Eggs	40	414	8.8	91.2
Soy Based Products	298	156	65.6	33.4

Weekly consumption of protein

Beef		
0	4	0.9
1-2	264	58.5
3-4	142	31.5
5-6	30	6.7
7 or more	11	2.4
Pork		
0	23	5.2
1-2	363	82.1
3-4	41	9.3
5-6	12	2.7
7 or more	3	0.7
Lamb		
0	306	77.9
1-2	80	20.4
3-4	3	0.8
5-6	4	1.0
7 or more	0	0.0
Chicken		
0	1	0.2
1-2	160	35.6

3-4	214	47.7
5-6	59	13.1
7 or more	15	3.3
Fish		
0	74	17.2
1-2	306	71.0
3-4	42	9.7
5-6	8	1.9
7 or more	1	0.2
Soy Based Products		
0	224	58.2
1-2	131	34.0
3-4	21	5.5
5-6	7	1.8
7 or more	2	0.5

What cooking method do you prefer to use when cooking a beef steak?

	Do not use	**Use**	**Do not use**	**Use**
Pan-frying or using a skillet on the stove	211	239	46.9	53.1
Stir Fry	303	148	67.2	32.8
Grilling Outside	78	373	17.3	82.7
Oven Broiling	329	122	72.9	27.1
Oven Baking	315	136	69.8	30.2
Microwave	435	16	96.4	3.5
Electric Appliance (George Foreman Grill or other electric grill)	368	83	81.6	18.4

What cooking method do you prefer to use when cooking chicken?

	Do not use	**Use**	**Do not use**	**Use**
Pan-frying or using a skillet on the stove	160	290	35.6	64.4
Stir Fry	214	236	47.6	52.4
Grilling Outside	130	320	28.9	71.1
Oven Broiling	362	88	80.4	19.6
Oven Baking	113	337	25.1	74.9
Microwave	423	27	94.0	6.0
Electric Appliance (George Foreman Grill or other electric grill)	372	78	82.7	17.3

What cooking method do you prefer to use when cooking pork?

	Do not use	**Use**	**Do not use**	**Use**

Pan-frying or using a skillet on the stove	185	264	41.2	58.8
Stir Fry	347	102	77.3	22.7
Grilling Outside	190	259	42.3	57.7
Oven Broiling	383	66	85.3	14.7
Oven Baking	181	268	40.3	59.7
Microwave	430	19	95.8	4.2
Electric Appliance (George Foreman Grill or other electric grill)	375	74	83.5	16.5
Degree of doneness preference				
Rare		22		4.9
Medium Rare		131		29.2
Medium		138		30.7
Medium Well		107		23.8
Well		40		8.9
Very Well		11		2.5
When purchasing beef, what do you typically tend to buy at the retail store?				
Grass Fed		87		19.3
Dry Aged		11		2.4
Organic		79		17.6
Traditional beef at the retail store		345		76.7
What flavor or types of cuisines do you like?				
	Do not Eat	**Eat**	**Do not eat**	**Eat**
American	23	428	5.1	94.9
Barbeque	31	420	6.9	93.1
Mexican/Spanish	45	406	10.0	90.0
Indian	267	184	59.2	40.8
Chinese	58	393	12.9	87.1
Greek	221	230	49.0	51.0
Japanese	194	257	43.0	57.0
Italian	55	396	12.2	87.8
French	268	163	63.9	36.1
Thai	205	246	45.5	54.5
Lebanese	354	97	78.5	21.5

Table 6. Demographic frequencies for consumer treatments when asked "When purchasing beef, what do you typically tend to buy at the retail store?"

Consumer treatment	Number of Respondents	Percentage of Respondents
Millennial, Light beef eaters		
Grass Fed	23	14.8
Dry Aged	5	3.2
Organic	35	22.4
Traditional beef at the retail store	93	59.6
Millennial, Heavy beef eaters		
Grass Fed	26	23.2
Dry Aged	4	3.6
Organic	17	15.2
Traditional beef at the retail store	65	58.0
Non-millennial, Light beef eaters		
Grass Fed	22	14.6
Dry Aged	1	0.7
Organic	15	9.9
Traditional beef at the retail store	113	74.8
Non-millennial, heavy beef eaters		
Grass Fed	16	15.5
Dry Aged	1	1.0
Organic	12	11.7
Traditional beef at the retail store	74	71.8

Table 7. Least squares means for consumer sensory attributes across consumer groups.

Treatment	Overall liking	Overall flavor liking	Beef/Pork/ Chicken flavor liking	Grill flavor liking	Juiciness liking	Tenderness liking
P-value	0.01	0.07	0.08	0.36	0.34	0.44
Millennial, light beef eater	5.9[a]	5.8	6.0	5.4	6.3	6.2
Millennial, heavy beef eater	6.2[bc]	6.0	6.1	5.6	6.2	6.3
Non-millennial, light beef eater	5.9[ab]	5.9	5.9	5.5	6.2	6.3
Non-millennial, heavy beef eater	6.3[c]	6.1	6.3	5.6	6.5	6.5
RMSE	2.21	2.23	2.22	2.34	2.28	2.27

[abc]Mean values within a column followed by the same or no letter are not significantly different ($P > 0.05$).

Table 8. Stepwise linear regression for prediction of consumer overall liking as the dependent variable and consumer sensory attributes as independent variables.

Step	Variables[a]	Estimate[b]	Partial r^2	Equation r^2
	Intercept	-0.13		
1	Overall flavor liking	0.49	0.78	0.78
2	Tenderness liking	0.20	0.04	0.83
3	Meat flavor liking	0.20	0.01	0.83
4	Grill flavor liking	0.08	0.00	0.84
5	Juiciness liking	0.05	0.00	0.84

[a]Variables measured using 9-point hedonic and intensity scales were 1 = extremely dislike or none; 9 = extremely like or extremely intense.
[b]Estimates are the □-values for the final regression equation when the defined variable was included.

Table 9. Simple correlation coefficients[a] between consumer sensory attributes and trained descriptive sensory panel flavor attributes.

Effect	Overall liking	Overall flavor liking	Beef/Pork Chicken flavor liking	Grill flavor liking	Juiciness liking	Tenderness liking
Beef identity	0.10	0.22	0.25	0.22	-0.10	-0.25
Pork identity	0.14	0.12	0.14	0.09	-0.04	-0.07
Chicken identity	-0.10	-0.21	-0.28	-0.17	0.24	0.42
Brown/roasted	0.60	0.64	0.60	0.71	0.31	0.28
Bloody/serumy	-0.10	-0.09	-0.05	-0.12	-0.03	-0.21
Fat-like	0.00	-0.02	-0.09	0.04	0.24	0.20
Metallic	-0.07	-0.02	-0.01	-0.09	-0.13	-0.27
Liver-like	-0.35	-0.28	-0.26	-0.29	-0.35	-0.39
Umami	0.36	0.41	0.41	0.43	0.18	0.05
Sweet	0.16	0.21	0.17	0.21	0.12	0.11
Sour	-0.23	-0.28	-0.29	-0.27	0.03	-0.03
Salty	0.36	0.40	0.37	0.42	0.18	0.09
Bitter	0.03	-0.02	-0.05	0.00	0.16	0.21
Overall sweet	0.34	0.40	0.39	0.41	0.14	0.05
Astringent	-0.14	-0.19	-0.20	-0.19	0.03	0.09
Burnt	0.28	0.25	0.23	0.29	0.15	0.25
Cardboardy	-0.08	-0.07	-0.02	-0.10	-0.04	-0.08
Nutty	-0.05	-0.09	-0.06	-0.16	-0.08	-0.04
Sour milk	-0.21	-0.25	-0.25	-0.25	0.02	0.03
Spoiled putrid	-0.42	-0.47	-0.50	-0.46	-0.05	-0.01
Juiciness	0.15	0.10	0.09	0.07	0.27	0.23
Muscle fiber tenderness	-0.01	-0.12	-0.17	-0.11	0.26	0.42
Connective tissue amount	0.13	0.04	-0.03	0.05	0.32	0.48
Overall tenderness	0.01	-0.06	-0.78	-0.05	0.20	0.29
Warner-Bratzler shear force	0.13	0.23	0.28	0.19	-0.26	-0.38

[a] Simple correlation coefficients > 0.13 are significant ($P < 0.05$)

Figure 1. Partial least squares regression biplot (r^2 = 86.3) of consumer liking sensory attributes (9-point hedonic scales; •) and trained meat descriptive attributes (0 = none and 15 = extremely intense; ◆).

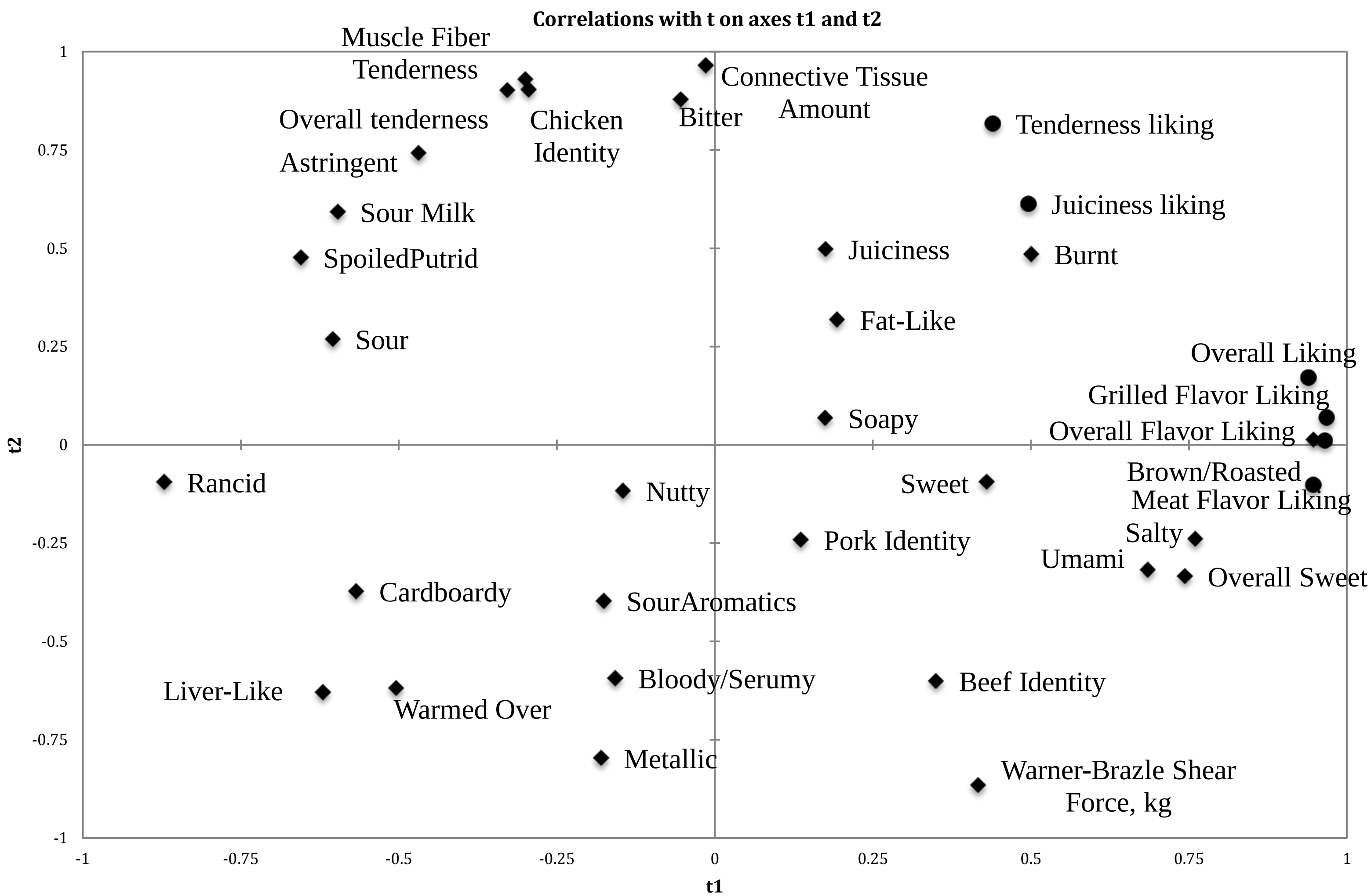


Table 10. Least squares means for raw chemical components for six meat treatments.

Effect	pH	Non-Heme iron, mg/g	Myoglobin mg/g	Moisture %	Lipid %
P-value	<0.001	<0.001	<0.001	<0.001	<0.001
Chicken breasts	5.9[b]	3.6[b]	0.6[a]	74.6[b]	1.8[a]
Chicken thighs	6.4[c]	4.6[c]	6.3[d]	75.9[c]	4.1[b]
Pork loin chops	5.9[b]	3.0[b]	1.2[b]	75.4[c]	2.2[a]
Inside ham roasts	6.5[c]	4.4[c]	0.9[ab]	74.7[b]	2.0[a]
Select bottom round roasts	5.9[b]	3.4[b]	1.6[c]	74.4[b]	2.0[a]
Choice top loin steak	5.3[a]	2.3[a]	1.6[c]	69.8[a]	7.2[c]
RMSE	0.36	1.28	0.79	1.13	0.96

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

Table 11. Least squares means for fatty acid components for six meat treatments for fatty acid percentage.

Effect	14:0	16:0	16:1	18:0	18:1	18:1 trans	18:2	18:3	20:4
p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chicken breasts	0.5[a]	25.0[cd]	4.5[c]	7.7[b]	36.2[a]	2.0[c]	14.9[d]	0.4[d]	2.6[d]
Chicken thighs	0.5[a]	25.6[d]	6.0[d]	6.5[a]	39.1[bc]	6.0[b]	15.5[d]	0.3[cd]	1.3[b]
Pork loin chops	1.2[b]	23.5[b]	3.1[a]	10.9[d]	40.0[c]	3.5[d]	12.4[c]	0.2[ab]	1.5[b]
Inside ham roasts	1.1[b]	22.6[a]	2.8[a]	9.1[c]	38.0[b]	3.2[d]	12.7[d]	0.2[bc]	2.0[c]
Select bottom round roasts	2.6[c]	24.4[c]	3.4[b]	10.8[d]	36.4[a]	1.7[bc]	6.5[b]	0.1[ab]	1.6[b]
Choice top loin steak	3.2[d]	27.7[e]	3.2[ab]	12.6[e]	38.6[bc]	1.3[a]	3.0[a]	0.0[a]	0.4[a]
RMSE	0.52	1.54	0.69	1.38	2.70	0.58	2.23	0.24	0.64

[a,b,c,d] Mean values within a column and effect followed by the same letter are not significantly different ($P > 0.05$).

Table 12. Simple correlation coefficients[a] between chemical measures and trained descriptive sensory panel flavor attributes.

Descriptive Flavor Attributes	pH	Non-Heme iron, mg/g	Myo-globin mg/g	Moisture %	Lipid %	14:0	16:0	16:1	18:0	18:1	18:1 trans	18:2	18:3	20:4
Beef identity	-0.58	-0.36	-0.11	-0.75	0.64	0.82	0.16	-0.26	0.61	-0.04	-0.51	-0.85	-0.32	-0.51
Pork identity	0.25	0.02	-0.36	0.28	-0.38	-0.17	-0.06	-0.47	0.14	0.21	0.75	0.28	-0.07	0.12
Chicken identity	0.23	0.28	0.48	0.36	-0.10	-0.62	-0.06	0.75	-0.69	-0.10	-0.24	0.54	0.38	0.29
Brown/roasted	-0.59	-0.41	-0.27	-0.54	0.47	0.32	0.10	-0.18	0.37	0.15	-0.12	-0.41	-0.13	-0.31
Bloody/serumy	-0.22	-0.10	-0.11	-0.18	0.06	0.44	0.03	-0.20	0.28	-0.18	-0.20	-0.40	-0.23	-0.12
Fat-like	-0.13	-0.04	0.57	-0.22	0.62	0.07	0.04	0.34	-0.02	0.25	-0.27	-0.13	-0.04	-0.44
Metallic	-0.20	-0.12	-0.11	-0.20	0.10	0.49	0.02	-0.16	0.31	-0.11	-0.22	-0.44	-0.23	-0.16
Liver-like	0.08	0.03	0.02	0.22	-0.16	0.17	-0.03	0.00	0.05	-0.17	-0.14	-0.16	-0.13	0.08
Overall sweet	-0.44	-0.27	-0.07	-0.58	0.62	0.47	0.20	-0.20	0.46	0.18	-0.18	-0.51	-0.18	-0.49
Umami	-0.52	-0.36	-0.11	-0.73	0.74	0.62	0.16	-0.26	0.51	0.11	-0.28	-0.62	-0.51	-0.51
Sweet	-0.24	-0.19	0.09	-0.30	0.43	0.28	0.12	0.01	0.26	0.09	-0.27	-0.34	-0.05	-0.32
Sour	0.05	0.06	0.19	0.10	-0.06	-0.03	0.01	0.25	-0.17	-0.26	-0.17	0.05	0.04	0.16
Salty	-0.41	-0.25	-0.12	-0.35	0.34	0.31	0.07	-0.10	0.28	0.13	-0.13	-0.38	-0.15	-0.25
Bitter	0.08	0.06	0.19	0.18	-0.05	-0.25	0.02	0.34	-0.38	-0.19	-0.12	0.26	0.18	0.18
Astringent	0.00	0.17	0.18	0.11	-0.12	-0.06	0.00	0.21	-0.23	-0.15	-0.13	0.08	-0.01	0.10
Burnt	-0.10	-0.05	-0.21	0.09	-0.17	-0.17	-0.03	0.11	-0.16	-0.14	-0.02	0.12	0.18	0.22
Cardboardy	0.06	0.02	-0.04	0.17	-0.18	-0.02	-0.04	-0.00	-0.04	-0.13	0.07	0.02	-0.05	0.20
Nutty	0.32	0.26	-0.15	0.11	-0.21	-0.13	-0.03	-0.22	-0.08	-0.02	0.32	0.31	-0.05	0.14
Spoiled Putrid	0.32	0.28	0.75	0.37	0.09	-0.28	-0.03	0.61	-0.46	0.09	-0.24	0.26	0.17	-0.07
Sour Milk	0.12	0.43	0.43	0.14	-0.02	-0.21	0.02	0.29	-0.27	0.01	-0.14	0.16	-0.02	0.01
Juiciness	-0.11	-0.05	-0.03	-0.11	-0.13	0.04	0.02	0.01	0.02	-0.02	0.09	-0.07	0.04	-0.05
Muscle fiber Tenderness	0.18	0.19	0.40	0.23	0.11	-0.50	-0.09	0.57	-0.56	-0.02	-0.15	0.45	0.32	0.20
Overall	0.14	0.14	0.18	0.12	-0.03	-0.23	-0.05	0.31	-0.31	0.07	-0.00	0.20	0.14	0.04

tenderness														
Connective tissue amount	0.16	0.05	0.12	0.28	0.00	0.33	-0.02	0.24	-0.28	0.11	0.11	0.30	0.14	0.08

[a] Simple correlation coefficients > 0.15 is significant ($P < 0.05$)

Table 13. Stepwise linear regression for prediction of consumer overall like as the dependent variable and chemical data as independent variables.

Step	Variables	Estimate[a]	Partial r^2	Equation r^2
	Intercept	25.34		
1	Myoglobin	-0.20	0.21	0.21
2	Moisture, %	-0.21	0.08	0.29
3	14:0	-0.35	0.06	0.35
4	pH	-0.47	0.04	0.38

[a]Estimates are the □-values for the final regression equation when the defined variable was included

Figure 2. Partial least squares regression biplot (r^2 = 74.4) for consumer sensory attributes (•) and trained descriptive flavor (◆) and raw meat chemical measures (▲).

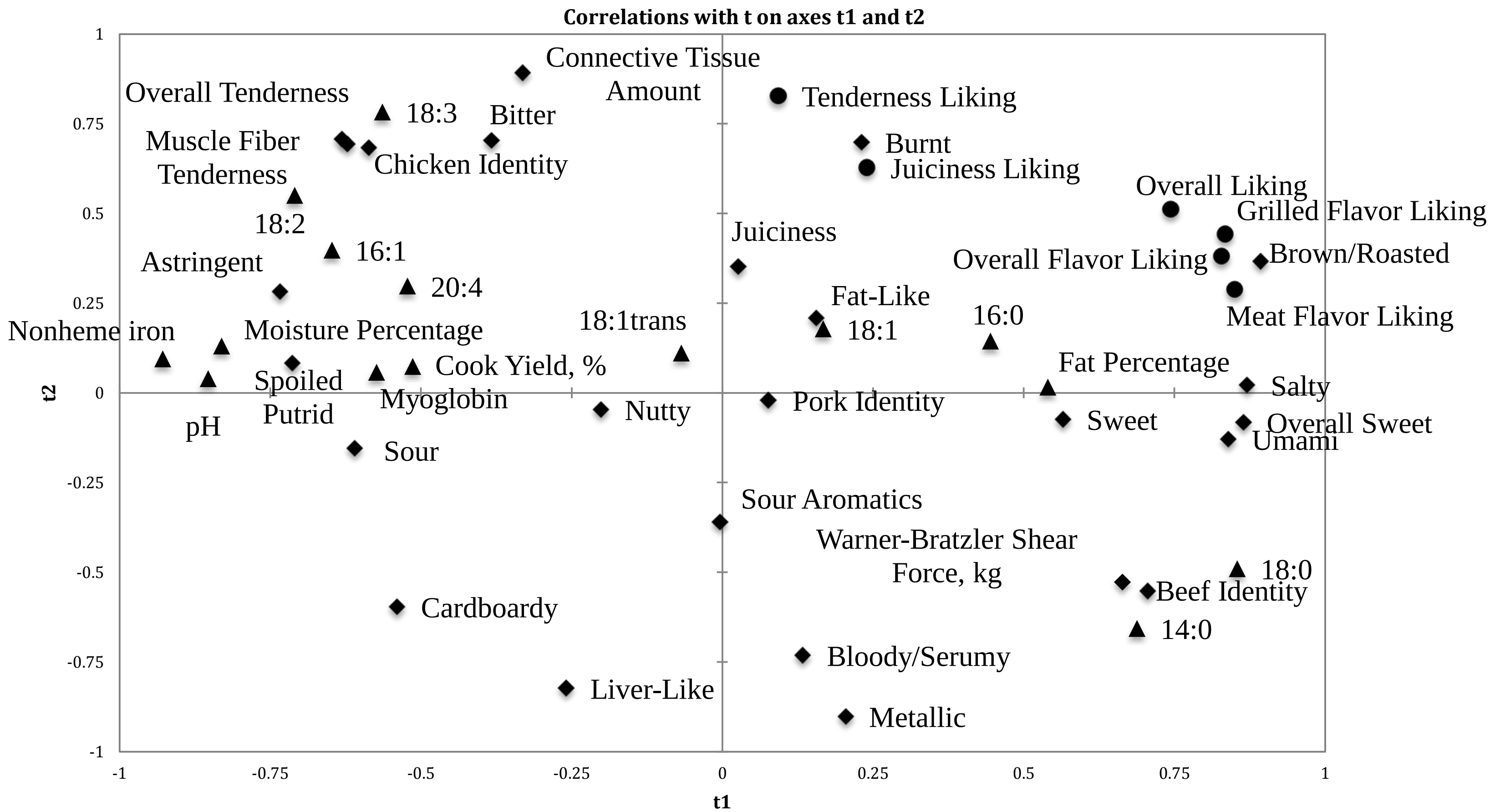


Table 14. Overall means and standard deviation values for volatile, aromatic chemicals (n = 289) identified by the AromaTrax System.

Code	Volatile, Aromatic Chemical	Mean Total Ion Count	Standard Deviation
		85013	175108.9
C1	2-Butanone, 3-Hydroxy-	1325.0	3154.7
C2	Dimethyldisulfide	57.3	215.8
C3	Methane, Thiobis-	44.8	130.2
C4	Methanethiol	76.9	167.8
C6	Pentanal	1917.2	2316.5
C7	Sulfur Dioxide	395.3	1445.2
C8	1-Heptanol	453.2	1167.1
C9	1-Octen-3-Ol	2793.9	6779.6
C10	1-Pentanol	1423.4	1832.2
C11	2-Decenal	316.7	864.6
C12	2-Heptanone	325.5	738.7
C13	2-Octenal	80.3	309.5
C14	2,3-Dimethylbenzaldehyde	2.9	23.3
C15	2,3-Octanedione	1064.1	3057.4
C16	2,4-Decadienal	60.9	215.1
C17	Benzaldehyde	6681.4	11061.5
C18	Bis[4-(Phenylsulphonyl)Phenyl]Carbonate	4.7	20.1
C19	Carbon Disulfide	337.1	538.0
C20	Cyclooctanol	72.8	290.2
C21	Decanal	655.3	1397.3
C22	Furan, 2-Pentyl-	1480.4	4168.9
C23	Hentriacontane	17.2	77.9
C24	Heptanal	32.3	189.5
C25	Hexadecane, 7,9-Dimethyl-	3.2	37.0
C26	Hexanal	17945.7	33292.2
C27	N Heptanal	3662.9	6769.2
C28	Nonanal	11441.0	19416.1
C29	Nonenal	162.1	507.0
C30	Octanal	5219.0	9417.6
C31	Propanoic Acid, 2-(Aminooxy)-	6.7	31.9
C32	Tridecane	60.4	250.3
C33	1-Octanol	874.3	1821.5
C34	1h-Imidazole, 4-(2-Propenyl)-	12.1	40.7
C35	2 Octenal	402.3	1277.3
C36	2-Heptenal	304.3	1120.8

C37	Acetic Acid	600.9	1216.2
C38	Acetone	54.8	290.8
C40	Butanediamide, 2-Methylene-	2.6	22.9
C41	Butanoic Acid	30.0	157.9
C42	Dimethyl Sulfide	14.0	87.6
C43	Dodecanal	94.0	555.3
C44	Hexanoic Acid	176.3	479.3
C45	Octacosane	12.2	44.1
C46	Oxalic Acid, Dodecyl Isohexyl Ester	1.6	13.9
C47	Phenyl Acetaldehyde	54.2	223.2
C48	Styrene	101.9	322.6
C50	Thiourea	76.2	325.7
C51	1-Hexanol	296.3	661.9
C52	2-Nonanone	56.6	232.2
C54	2-Nonenal	92.0	301.5
C55	2(5h)-Furanone	3.4	37.4
C57	3-Dodecen-1-Al	82.5	311.4
C58	Acetaldehyde	36.6	109.2
C60	Benzene, Methyl-	4704.1	13389.2
C61	Butanal, 3-Methyl-	203.3	497.0
C62	Ethanol, 2-(Hexyloxy)-	559.4	1436.4
C63	Ethanone, 1-(1h-Pyrrol-2-Yl)-	32.1	161.1
C64	Nonacosane	14.3	43.5
C65	Oxirane, Heptadecyl-	19.4	216.6
C66	Pentadecane	24.9	149.7
C67	Pyrazine, 2-Ethyl-6-Methyl-	53.0	280.8
C69	Pyrazine, 2,5-Dimethyl-	479.7	1308.9
C70	Pyrazine, 2,5-Dimethyl-3-(3-Methylbutyl)-	13.9	62.3
C72	Pyrazine, 3-Ethyl-2,5-Dimethyl-	285.5	811.2
C73	Pyrazine, Methyl-	140.2	450.0
C74	Pyrazine, Trimethyl-	403.3	1207.7
C75	Tetradecanal	163.5	493.1
C77	2-Undecanone, 6,10-Dimethyl-	8.6	42.7
C78	N-Caproic Acid Vinyl Ester	472.8	2381.2
C79	Pyridine	57.1	399.0
C80	2,3-Butanedione	418.1	2174.3
C82	1h-Pyrrole, 1-Ethyl-	14.3	80.4
C83	2-Acetylthiazole	9.0	65.5
C84	2-Butanone	519.5	1276.4
C86	2-Dodecanone	8.9	65.1
C87	2-Propanone	165.5	424.0
C90	2-Tridecanone	5.1	40.0
C91	Benzene, 1,3-Bis(1,1-Dimethylethyl)-	298.5	967.2
C92	Benzene, Ethyl-	18.6	129.4

C94	Benzeneacetaldehyde	73.8	362.6
C96	Butanal	8.5	67.5
C97	Butanal, 2-Methyl-	213.4	660.9
C98	Cycloheptane	6.9	59.4
C99	Dodecane	304.6	839.9
C100	Furan, 2-Methyl-	2.2	19.8
C101	Octane	622.7	2229.8
C102	Pentanoic Acid	5.6	50.9
C103	Pyrazine, 2-Methyl-5-(1-Propenyl)-	3.4	25.1
C105	Toluene	2359.2	7169.7
C106	Undecanal	152.1	571.3
C109	Undecenal	172.3	672.1
C110	1-Octene	193.0	900.9
C111	1,3-Octadiene	77.3	531.5
C112	2-Dodecenal	20.7	135.9
C114	2-Pentanone	71.2	441.3
C116	2-Undecanone	12.5	88.3
C117	2-Undecenal	47.0	227.7
C118	2,5-Hexanedione	16.6	178.4
C119	3-Heptanol	25.7	156.9
C120	3-Pentanol, 3-(1,1-Dimethylethyl)-2,2,4,4-Tetramethyl-	123.5	845.2
C121	Benzene, Propyl-	11.1	54.7
C122	D-Galacturonic Acid	2.2	15.6
C123	Decane	31.3	236.1
C124	Heptacosane	3.4	26.9
C128	Heptane, 3-Methyl-	39.1	214.3
C129	Nonadecane	25.0	124.7
C131	Phenol, 2,6-Bis(1,1-Dimethylethyl)-4-Methyl-	15.6	68.3
C132	Thiophene, 2-Methyl-	1.9	20.4
C133	1-Nonanol	19.4	133.3
C134	1-Octen-3-One	9.5	93.4
C135	1-Pentanol, 3-Methyl-	5.1	36.6
C138	2-Heptanone, 6-Methyl-	13.2	97.2
C139	2-Hexenal	19.4	98.0
C140	2,4-Nonadienal	17.4	87.8
C141	5-Pentyl-2(5h)-Furanone	13.8	68.5
C144	Benzaldehyde, 3-Ethyl-	16.8	93.8
C145	Decanoic Acid	8.0	42.2
C146	Heptane	39.1	186.5
C147	Octadecane	16.9	98.2
C150	Octane, 2-Chloro-	13.8	52.9
C151	Oxirane, Phenyl-	24.5	224.4
C152	Pentane	7.6	75.9

C154	Tridecanal	94.6	297.9
C155	1,3-Hexadiene, 3-Ethyl-2-Methyl-	58.6	281.2
C158	1h-Azepine, Hexahydro-	12.9	140.9
C159	2-Pentadecanone, 6,10,14-Trimethyl-	1.8	19.2
C160	Benzoic Acid, 4-Hydroxy-	2.3	17.8
C161	Ethanone, 1-Phenyl-	4.3	31.5
C162	Octanoic Acid	1.4	14.4
C163	Pyrazine, 2-Ethyl-3,5-Dimethyl-	19.7	116.6
C164	2-Cyclohexen-1-Ol	16.6	130.5
C166	Pyrazine, 2-Ethyl-5-Methyl-	51.1	440.5
C167	1-Heptadecanamine	0.7	8.1
C170	1-Nonen-3-Ol	34.3	394.5
C171	2-Decanone	58.4	253.0
C172	2-Methyl 5h-6,7-Dihydrocyclopentapyrazine	12.4	79.1
C173	3-Hydroxytetrahydropyran	2.8	15.9
C174	4-Decene, 2,2-Dimethyl-	41.2	436.7
C175	5-Methyl--6,7-Dihydro-(5h)-Cyclopentapyrazine	0.4	4.8
C176	Benzene, 1,4-Bis(1,1-Dimethylethyl)-	32.0	227.2
C177	Benzoic Acid	23.2	173.7
C181	Benzyl Nitrile	6.7	42.8
C182	Heptanol	21.7	152.9
C183	Pentadecylamine	2.8	17.1
C184	Propanal, 2-Methyl-	63.7	275.0
C185	Thiophene, 2,3-Dimethyl-	0.7	6.0
C186	Thiophene, 3-Methyl-	34.1	173.6
C188	2-Propenoic Acid, 2-Methyl-, Methyl Ester	40.9	147.8
C189	1-Hydroxyundecan-10-One	5.2	40.4
C190	1,2-Di-Tert-Butylbenzene	5.1	31.8
C192	2-Propanone, 1-(Acetyloxy)-	8.5	82.8
C194	2(3h)-Furanone, Dihydro-	167.2	1248.6
C196	Decane, 2,2,3-Trimethyl-	14.1	124.8
C197	S-2-[4-Succinimidobutylamino] Ethyl Thiosulfuric Acid	5.3	28.8
C198	1-Hexanol, 2-Ethyl-	6.7	58.4
C201	1-Pentanol, 4-Methyl-	2.2	23.7
C202	2-Butylfuran	5.0	33.5
C203	2-Decen-1-Ol	37.2	348.7
C204	2-Octanone	20.3	95.1
C205	Benzofuran, 2,3-Dihydro-	2.2	23.1
C207	Hexadecanal	93.7	625.4
C208	Phenol, 4-Methyl-	12.9	60.6
C210	Trans,Trans-2,4-Dodecadienal	6.4	47.8
C212	1-Decanol	5.1	46.5

C214	2-Octene	164.6	957.2
C215	3-Methylpyridazine	1.6	12.2
C217	Benzene, 1,2-Dimethyl-	2.5	25.7
C218	Benzeneacetonitrile	3.9	29.3
C219	Ethanol	276.2	782.7
C220	Ethanone, 1-(4,5-Dihydro-2-Thiazolyl)-	9.3	54.9
C222	Ethyl Acetate	130.8	728.0
C223	Formic Acid, Octyl Ester	125.5	659.2
C224	Heptane, 4-Methyl-	14.3	176.9
C226	Pentane, 2,2,3,4-Tetramethyl-	11.8	109.8
C227	Cyclohexanecarboxamide, N-Furfuryl-	1.1	11.8
C228	Heptenal	81.7	325.6
C229	Pentadecane, 2-Methyl-	3.2	35.5
C232	2-Docecen-1-Al	18.4	137.5
C233	Acetic Acid, Ethyl Ester	182.2	685.5
C247	1-Undecanol	15.8	128.9
C250	2-Pentyl-4,5-Dimethyloxazole	23.0	170.0
C251	Undecane, 4,6-Dimethyl-	12.6	118.1
C256	3-Octanone	2.4	26.8
C258	E-2-Octenal	2.6	28.3
C260	2-Propen-1-Ol, 2-Methyl-	18.8	95.4
C261	Furan, 2,3-Dihydro-4-Methyl-	1.5	13.7
C267	3-(Hydroxyphenylmethyl)- 2-Methyl-3-Buten-1-Ol	4.7	35.0
C269	3,4-Dihydropyran	7.4	73.3
C270	Acetic Acid Ethenyl Ester	13.8	120.5
C276	Acetophenone	5.6	52.7
C277	Eicosane	8.7	78.5
C285	Nonacosane, 3-Methyl-	0.6	6.6
C286	Piperidine, 3-Methyl-	1.6	15.0
C289	Propane, 1-(1,1-Dimethylethoxy)-2-Methyl-	58.3	537.0
C291	Trans-2-Dodecenal	18.5	258.4
C292	Ethanethiol	1.8	22.9
C296	1-Butanol	9.3	70.5
C299	Dodecane, 2-Methyl-	10.4	99.4
C302	Butane, 2-Methyl-	2.6	33.2
C303	Cyclohexene, 3-(1-Methylethyl)-	3.6	25.2
C306	Tetradecane	40.9	249.1
C308	1h-Pyrrole	3.3	35.4
C309	1h-Pyrrole, 1-Methyl-	5.0	53.1
C310	Ethane, (Methylthio)-	0.4	4.2
C313	2-Acetyl-2-Thiazoline	1.9	21.2
C315	2,4-Undecadienal	1.7	17.0
C316	Octadecanal	6.6	57.0

C324	1-Tetradecanol	19.5	176.1
C325	1h-Indole	3.3	25.9
C326	2-Furanmethanol	6.3	56.5
C327	2(3h)-Furanone, 5-Heptyldihydro-	3.6	33.3
C332	4-Octanone	7.7	80.9
C333	Hexadecane	8.5	59.7
C334	Propanal, 3-(Methylthio)-	4.5	39.7
C335	Pyrrolidine, 1-Nitroso-	0.5	5.5
C337	S-2-[2-Succinimidoethylamino] Ethyl Thiosulfuric Acid	7.0	40.4
C338	16-Octadecenal	5.6	59.9
C342	Formic Acid, Heptyl Ester	4.3	46.0
C344	1,3-Butadiene, 2-Methyl-	5.1	40.5
C345	Propane, 1-(Ethylthio)-	1.2	9.6
C347	1-[2-(2-Methylbutyl)Phenyl]Ethanone	11.6	122.9
C348	2-Octen-1-Ol	30.0	308.2
C350	2-Octylfuran	6.9	43.0
C352	2-Heptene	10.7	92.4
C353	Decane, 2,5,6-Trimethyl-	11.8	83.1
C358	Hexadecane, 2,6,11,15-Tetramethyl-	3.8	40.7
C363	Hexane, 2,2,5-Trimethyl-	20.7	179.9
C364	Octane, 2,2-Dimethyl-	19.6	177.1
C368	Trans-2-Undecen-1-Ol	23.0	220.2
C372	Undecane, 2,6-Dimethyl-	42.0	285.3
C373	1,3-Pentadiene	5.9	32.4
C374	2-Nonen-1-Ol	24.0	168.3
C376	3-Cyclohepten-1-One	38.0	339.1
C382	Undecane	22.4	149.0
C389	3-Pentenoic Acid, 4-Methyl-	11.5	91.5
C390	Butanoic Acid, Ethyl Ester	14.3	139.7
C393	Propanoic Acid, 2,2-Dimethyl-	108.8	884.6
C399	2(3h)-Furanone, Dihydro-5-Pentyl-	5.2	39.4
C405	3,6-Dimethyl-2-Pentylpyrazine	5.2	30.2
C407	Aloxiprin	21.7	163.4
C422	Phenol	5.6	33.5
C423	Propane, 2-(Ethenyloxy)-	2.1	15.8
C424	2-Pyrrolidinone, 1-Methyl-	4.4	45.9
C434	2h-Pyran, Tetrahydro-2-(Methylthio)-	1.5	14.6
C445	Oxalic Acid, Isobutyl Nonyl Ester	3.2	31.5
C456	1-Butanol, 3-Methyl-	26.1	347.6
C498	1h-Imidazole-4-Methanol	5.4	52.2
C532	2-Undecene, 9-Methyl-	2.0	24.2
C600	Cyclodecane	3.0	33.0
C601	Piperazine, 2-Methyl-	0.7	7.0

C602	S-2-[4-Glutarimidobutylamino] Ethyl Thiosulfuric Acid	2.3	24.2
C603	Benzenemethanol	1.4	10.9
C604	Cyclopentane, 1-Ethyl-2-Methyl-	1.6	19.3
C605	Fumaric Acid, 3-Heptyl Tridecyl Ester	2.8	30.3
C606	Heptane, 3,5-Dimethyl-	1.0	10.6
C607	Hexyl Octyl Ether	1.2	13.2
C608	Octane, 2,3-Dimethyl-	2.3	24.7
C609	Pentane, 2,3,3-Trimethyl-	3.1	31.0
C610	Pentanoic Acid, 3-Methyl-2-Oxo-, Methyl Ester	121.1	1061.8
C611	2-Dodecen-1-Ol	5.3	58.9
C612	Dimethyl Tetrasulphide	4.1	59.7
C613	Acetic Acid, Decyl Ester	5.6	51.1
C614	3-N-Butylcyclopentanone	3.6	41.7
C615	Heptanoic Acid	14.5	87.1
C616	2-Hexen-1-Ol,	3.5	30.1
C617	Pentadecanal-	60.5	833.4
C618	2-Furancarboxaldehyde, 5-Methyl-	0.7	7.8
C619	Pyrazine, 2,3-Dimethyl-	22.2	172.0
C620	Cyclohexanecarboxamide, N -(4-Morpholylcarbonyl)-	1.4	11.6
C621	Decane-1,2-D2	2.8	31.4
C622	Pyridine, 4-Methyl-	1.3	17.6
C623	1-Dodecanol	7.0	58.8
C624	2-Buten-1-Ol, 3-Methyl-	1.0	10.5
C625	2(3h)-Furanone, 5-Hexyldihydro-	2.1	24.2
C626	3-Octanol	1.8	21.1
C627	3-Octanone, 2-Methyl-	75.7	820.9
C628	Cyclopentanone, 3-Butyl-	5.9	66.1
C629	Butanoic Acid, 3,4-Dihydroxy-2-Methylene-	0.8	7.4
C630	Cyclohexanol	25.7	232.4
C631	Hexahydropyridine, 1-Methyl-4 -[4,5-Dihydroxyphenyl]-	1.4	12.5
C632	Heptane, 2,4-Dimethyl-	1.6	17.1
C633	Heptane, 1,1'-Oxybis-	26.8	234.5
C634	Cyclopentanone, 2-Ethyl-	1.0	11.5
C635	Trans-2-Tridecenal	4.7	60.0
C636	Di-Tert-Butyl Malonate	93.6	1381.7
C637	Hexane, 3-Methyl-	9.8	136.9
C638	Methane, Dichloro-	4.7	48.8
C639	Pyridine, 2-Methyl-	0.8	9.4
C640	1,3-Butanediol	2.2	26.9

Table 15. Stepwise linear regression for prediction of consumer overall liking as the dependent variable and aromatic volatile compounds as independent variables.

Step	Variables		Estimate[a] x 10^{-4}	Partial r^2	Equation r^2
	Intercept		6.28		
1	C219	Ethanol	-5.15	0.16	0.16
2	C72	Pyrazine, 3-ethyl-2,5-dimethyl-	5.53	0.08	0.23
3	C97	Butanal, 2-methyl-	3.89	0.04	0.28
4	C3	Methane, thiobis-	-21.00	0.03	0.31
5	C117	2-Undecenal	-5.78	0.02	0.33
6	C247	1-Undecanol	-16.10	0.02	0.35
7	C42	Dimethyl sulfide	-20.00	0.02	0.37
8	C291	Trans-2-Dodecenal	10.20	0.02	0.39
9	C163	Pyrazine, 2-Ethyl-3,5-Dimethyl-	9.28	0.01	0.40
10	C67	Pyrazine, 2-Ethyl-6-Methyl-	-6.20	0.01	0.42
11	C14	2,3-Dimethylbenzaldehyde	-95.20	0.01	0.43
12	C150	Octane, 2-Chloro-	-25.30	0.01	0.44
13	C40	Butanediamide, 2-Methylene-	-44.70	0.01	0.45
14	C19	Carbon Disulfide		0.01	0.46
15	C188	2-Propenoic Acid, 2-Methyl-, Methyl Ester	-15.00	0.01	0.47
16	C123	Decane	6.33	0.01	0.49
17	C84	2-Butanone	3.04	0.01	0.49
18	C2	Dimethyldisulfide	-11.70	0.01	0.50
19	C640	1,3-Butanediol	-29.90	0.01	0.51
20	C129	Nonadecane	-10.50	0.01	0.51
21	C60	Benzene, Methyl-	-0.12	0.01	0.52
22	C10	1-Pentanol	0.83	0.01	0.53
23	C105	Toluene	-0.17	0.01	0.54
24	C186	Thiophene, 3-Methyl-	-8.92	0.01	0.54
25	C50	Thiourea	-3.40	0.01	0.55
26	C19	Carbon Disulfide		0.00	0.55
27	C207	Hexadecanal	1.61	0.01	0.55
28	C260	2-Propen-1-Ol, 2-Methyl-	8.64	0.01	0.56
29	C393	Propanoic Acid, 2,2-Dimethyl-	1.01	0.01	0.57
30	C175	5-Methyl--6,7-Dihydro -(5h)-Cyclopentapyrazine	215.50	0.01	0.57
31	C37	Acetic Acid	-0.65	0.01	0.58
32	C96	Butanal	10.80	0.00	0.58

[a]Estimates are the □-values for the final regression equation when the defined variable was included.

Table 16. Stepwise linear regression for prediction of beef flavor identity as the dependent variable and aromatic volatile compounds as independent variables.

Step	Variables		Estimate[a] x 10^{-4}	Partial r^2	Equation[b] r^2
Intercept			1.76		
1	C1	2-Butanone, 3-hydroxy-	3.90	0.29	0.29
2	C10	1-Pentanol	-4.01	0.06	0.35
3	C63	Ethanone, 1-(1H-pyrrol-2-yl)-	35.70	0.03	0.39
4	C146	Heptane	33.50	0.02	0.41
5	C285	Nonacosane, 3-methyl-	-528.40	0.02	0.43
6	C601	Piperazine, 2-methyl-	857.60	0.01	0.44
7	C72	Pyrazine, 3-ethyl-2,5-dimethyl-	-5.46	0.01	0.45
8	C532	2-Undecene, 9-methyl-	-194.50	0.01	0.46
9	C219	Ethanol	-4.92	0.01	0.47
10	C37	Acetic acid	2.95	0.01	0.48
11	C188	2-Propenoic acid, 2-methyl-, methyl ester	32.30	0.01	0.49
12	C215	3-Methylpyridazine	-299.80	0.01	0.50
13	C260	2-Propen-1-ol, 2-methyl-	21.40	0.01	0.51
14	C23	Hentriacontane	32.00	0.01	0.51
15	C96	Butanal	34.90	0.01	0.52
16	C617	Pentadecanal-	2.88	0.01	0.52
17	C84	2-Butanone	-1.82	0.01	0.53
18	C19	Carbon disulfide	-4.64	0.01	0.53

[a]Estimates are the b-values for the final regression equation when the defined variable was included and variables are not listed in the order that they entered the equation.

Table 17. Stepwise linear regression for prediction of pork flavor identity as the dependent variable and aromatic volatile compounds as independent variables.

Step	Variables		Estimate[a] x 10^{-4}	Partial r^2	Equation r^2
Intercept			1.40		
1	C35	2 Octenal	4.55	0.15	0.15
2	C87	2-Propanone	-6.70	0.01	0.21
3	C219	Ethanol	-4.28	0.01	0.28
4	C10	1-Pentanol	4.01	0.01	0.36
5	C139	2-Hexenal	-62.10	0.03	0.39
6	C146	Heptane	-22.90	0.03	0.42
7	C6	Pentanal	2.49	0.03	0.45
8	C97	Butanal, 2-Methyl-	-3.33	0.03	0.48
9	C122	D-Galacturonic Acid	233.10	0.02	0.49
10	C45	Octacosane	-54.90	0.02	0.51
11	C159	2-Pentadecanone, 6,10,14-Trimethyl-	150.40	0.01	0.52
12	C233	Acetic Acid, Ethyl Ester	-4.22	0.01	0.53
13	C184	Propanal, 2-Methyl-	-13.10	0.01	0.54
14	C77	2-Undecanone, 6,10-Dimethyl-	80.80	0.02	0.56
15	C84	2-Butanone	-2.08	0.01	0.57
16	C60	Benzene, Methyl-	-0.19	0.01	0.59
17	C98	Cycloheptane	34.00	0.01	0.59
18	C31	Propanoic Acid, 2-(Aminooxy)-	52.90	0.01	0.60
19	C131	Phenol, 2,6-Bis (1,1-Dimethylethyl)-4-Methyl-	-56.80	0.01	0.60
20	C40	Butanediamide, 2-Methylene-	93.40	0.01	0.61
21	C50	Thiourea	-5.07	0.01	0.61
22	C47	Phenyl Acetaldehyde	-10.20	0.00	0.62
23	C18	Bis[4-(Phenylsulphonyl)Phenyl] Carbonate	-104.00	0.01	0.62
24	C353	Decane, 2,5,6-Trimethyl-	25.60	0.01	0.63
25	C37	Acetic Acid	-1.31	0.00	0.63
26	C105	Toluene	-0.20	0.00	0.64

[a]Estimates are the b-values for the final regression equation when the defined variable was included and variables are not listed in the order that they entered the equation.

Table 18. Stepwise linear regression for prediction of chicken flavor identity as the dependent variable and aromatic volatile compounds as independent variables.

Step	Variables		Estimate[a] x 10^{-4}	Partial r^2	Equation r^2
Intercept			1.49		
1	C219	Ethanol	14.60	0.25	0.25
2	C82	1H-Pyrrole, 1-ethyl-	76.60	0.01	0.33
3	C1	2-Butanone, 3-hydroxy-	-2.18	0.04	0.37
4	C61	Butanal, 3-methyl-	4.82	0.04	0.41
5	C33	1-Octanol	-2.11	0.04	0.45
6	C233	Acetic acid, ethyl ester	6.63	0.02	0.47
7	C6	Pentanal	-2.38	0.02	0.49
8	C60	Benzene, methyl-	0.24	0.01	0.50
9	C218	Benzeneacetonitrile	96.80	0.01	0.52
10	C84	2-Butanone	2.73	0.01	0.53
11	C250	2-pentyl-4,5-dimethyloxazole	17.00	0.01	0.54
12	C105	Toluene	0.41	0.01	0.56
13	C196	Decane, 2,2,3-trimethyl-	-20.20	0.01	0.57
14	C139	2-Hexenal	28.80	0.01	0.58
15	C308	1H-Pyrrole	53.90	0.01	0.59
16	C334	Propanal, 3-(methylthio)-	53.50	0.01	0.60
17	C227	Cyclohexanecarboxamide, N-furfuryl-	355.60	0.01	0.60
18	C292	Ethanethiol	91.10	0.01	0.61
19	C498	1H-Imidazole-4-methanol	43.90	0.01	0.62
20	C47	Phenyl Acetaldehyde	-8.43	0.00	0.62
21	C116	2-Undecanone	-30.50	0.01	0.63
22	C186	Thiophene, 3-methyl-	11.10	0.00	0.63

[a]Estimates are the b-values for the final regression equation when the defined variable was included and variables are not listed in the order that they entered the equation.

Table 19. Stepwise linear regression for prediction of brown/roasted as the dependent variable and aromatic volatile compounds as independent variables.

Step	Variables		Estimate[a] x 10^{-4}	Partial r^2	Equation r^2
Intercept			0.90		
1	C63	Ethanone, 1-(1H-pyrrol-2-yl)-	13.80	0.09	0.09
2	C260	2-Propen-1-ol, 2-methyl-	23.40	0.07	0.20
3	C97	Butanal, 2-methyl-	2.57	0.06	0.21
4	C219	Ethanol	-2.72	0.04	0.26
5	C3	Methane, thiobis-	-17.00	0.02	0.28
6	C114	2-Pentanone	3.03	0.02	0.29
7	C50	Thiourea	-3.16	0.01	0.30
8	C34	1H-Imidazole, 4-(2-propenyl)-	-23.40	0.02	0.32
9	C315	2,4-Undecadienal	115.90	0.01	0.33
10	C6	Pentanal	-0.51	0.01	0.35
11	C52	2-Nonanone	5.41	0.01	0.36
12	C43	Dodecanal	-1.82	0.01	0.37
13	C186	Thiophene, 3-methyl-		0.01	0.38
14	C250	2-pentyl-4,5-dimethyloxazole	-5.19	0.01	0.39
15	C42	Dimethyl sulfide	-13.90	0.01	0.40
16	C1	2-Butanone, 3-hydroxy-	0.47	0.01	0.41
17	C163	Pyrazine, 2-ethyl-3,5-dimethyl-	7.82	0.01	0.42
18	C186	Thiophene, 3-methyl-		0.01	0.41
19	C54	2-Nonenal	-2.59	0.01	0.42
20	C14	2,3-Dimethylbenzaldehyde	-41.70	0.01	0.42

[a]Estimates are the b-values for the final regression equation when the defined variable was included and variables are not listed in the order that they entered the equation..

Table 20. Stepwise linear regression for prediction of bloody/serumy as the dependent variable and aromatic volatile compounds as independent variables.

Step	Variables		Estimate[a] x 10^{-4}	Partial r^2	Equation r^2
Intercept			0.43		
1	C41	Butanoic acid	11.90	0.17	0.17
2	C80	2,3-Butanedione		0.05	0.21
3	C258	E-2-octenal	39.70	0.05	0.27
4	C207	Hexadecanal	1.35	0.03	0.30
5	C10	1-Pentanol		0.02	0.32
6	C42	Dimethyl sulfide		0.02	0.34
7	C100	Furan, 2-methyl-		0.02	0.36
8	C313	2-Acetyl-2-thiazoline		0.01	0.37
9	C75	Tetradecanal	-3.36	0.03	0.38
10	C602	S-2-[4-Glutarimidobutylamino] ethyl thiosulfuric acid	17.40	0.01	0.39
11	C189	1-Hydroxyundecan-10-one		0.01	0.29
12	C37	Acetic acid		0.01	0.40
13	C389	3-Pentenoic acid, 4-methyl-	-9.59	0.01	0.41
14	C1	2-Butanone, 3-hydroxy-	0.53	0.01	0.42
15	C333	Hexadecane	20.70	0.01	0.42
16	C84	2-Butanone	-1.43	0.01	0.43
17	C102	Pentanoic acid	32.30	0.01	0.44
18	C42	Dimethyl sulfide		0.00	0.44
19	C80	2,3-Butanedione		0.01	0.43
20	C313	2-Acetyl-2-thiazoline		0.01	0.43
21	C2	Dimethyldisulfide	6.70	0.01	0.44
22	C100	Furan, 2-methyl-		0.01	0.43
23	C50	Thiourea	2.30	0.01	0.44
24	C6	Pentanal	-0.45	0.01	0.45
25	C10	1-Pentanol		0.00	0.45
26	C37	Acetic acid		0.00	0.44
27	C134	1-Octen-3-one	9.05	0.01	0.45
28	C189	1-Hydroxyundecan-10-one		0.00	0.45
29	C633	Heptane, 1,1'-oxybis-	2.69	0.01	0.45
30	C196	Decane, 2,2,3-trimethyl-	-5.32	0.01	0.46
31	C368	trans-2-Undecen-1-ol	2.21	0.01	0.47
32	C260	2-Propen-1-ol, 2-methyl-	-4.75	0.01	0.47
33	C609	Pentane, 2,3,3-trimethyl-	-14.50	0.01	0.48

[a]Estimates are the b-values for the final regression equation when the defined variable was included and variables are not listed in the order that they entered the equation.

Table 21. Stepwise linear regression for prediction of descriptive sensory fat-like flavor as the dependent variable and aromatic volatile compounds as independent variables.

Step	Variables		Estimate[a] x 10^{-4}	Partial r^2	Equation r^2
Intercept			0.87		
1	C219	Ethanol	2.91	0.14	0.14
2	C291	Trans-2-Dodecenal	-3.98	0.05	0.18
3	C269	3,4-Dihydropyran	14.90	0.03	0.21
4	C3	Methane,	-13.10	0.03	0.23
5	C38	Acetone	4.16	0.04	0.28
6	C637	Hexane, 3-Methyl-	-6.38	0.02	0.29
7	C1	2-Butanone, 3-Hydroxy-	0.41	0.02	0.31
8	C389	3-Pentenoic Acid, 4-Methyl-	-10.40	0.02	0.33
9	C42	Dimethyl Sulfide	-9.76	0.01	0.34
10	C335	Pyrrolidine, 1-Nitroso-	-113.90	0.01	0.35
11	C186	Thiophene, 3-Methyl-	-2.97	0.01	0.36
12	C611	2-Dodecen-1-Ol	-12.60	0.01	0.37
13	C6	Pentanal	-0.53	0.01	0.38
14	C18	Bis[4-(Phenylsulphonyl)Phenyl] Carbonate	34.60	0.01	0.39
15	C456	1-Butanol, 3-Methyl-	2.05	0.01	0.40
16	C233	Acetic Acid, Ethyl Ester	1.44	0.01	0.42
17	C603	Benzenemethanol	52.30	0.01	0.43
18	C60	Benzene, Methyl-	0.04	0.01	0.43
19	C46	Oxalic Acid, Dodecyl Isohexyl Ester	-68.20	0.01	0.45
20	C163	Pyrazine, 2-Ethyl-3,5-Dimethyl-	6.44	0.01	0.45
21	C40	Butanediamide, 2-Methylene-	21.40	0.01	0.45
22	C232	2-Docecen-1-Al	-3.53	0.01	0.46

[a]Estimates are the b-values for the final regression equation when the defined variable was included and variables are not listed in the order that they entered the equation.

Table 22. Stepwise linear regression for prediction of descriptive sensory metallic flavor attribute as the dependent variable and aromatic volatile compounds as independent variables.

Step	Variables		Estimate[a] x 10^{-4}	Partial r^2	Equation r^2
Intercept			1.86		
1	C3	Methane, thiobis-	7.13	0.09	0.09
2	C50	Thiourea	-3.81	0.08	0.17
3	C42	Dimethyl sulfide	6.85	0.03	0.21
4	C100	Furan, 2-methyl-	-32.40	0.03	0.25
5	C46	Oxalic acid, dodecyl isohexyl ester	-58.40	0.02	0.28
6	C600	Cyclodecane	-23.50	0.02	0.30
7	C19	Carbon disulfide	-1.60	0.02	0.32
8	C20	Cyclooctanol	1.81	0.02	0.33
9	C333	Hexadecane	11.20	0.01	0.35
10	C422	Phenol	-13.00	0.01	0.37
11	C310	Ethane, (methylthio)-		0.01	0.38
12	C159	2-Pentadecanone, 6,10,14-trimethyl-	-17.20	0.01	0.39
13	C334	Propanal, 3-(methylthio)-	-13.20	0.01	0.40
14	C175	5-Methyl--6,7-Dihydro -(5h)-Cyclopentapyrazine	-91.80	0.01	0.40
15	C135	1-Pentanol, 3-Methyl-	13.00	0.01	0.41
16	C364	Octane, 2,2-Dimethyl-	5.22	0.01	0.42
17	C232	2-Docecen-1-Al	-7.22	0.02	0.45
18	C64	Nonacosane	16.80	0.01	0.45
19	C215	3-Methylpyridazine		0.01	0.46
20	C310	Ethane, (methylthio)-		0.01	0.46
21	C261	Furan, 2,3-dihydro-4-methyl-	-51.00	0.01	0.47
22	C609	Pentane, 2,3,3-trimethyl-	14.30	0.01	0.48
23	C353	Decane, 2,5,6-trimethyl-	-16.40	0.01	0.49
24	C184	Propanal, 2-methyl-	1.69	0.01	0.50
25	C215	3-Methylpyridazine		0.01	0.49
26	C608	Octane, 2,3-dimethyl-	26.10	0.01	0.50
27	C37	Acetic acid	0.23	0.01	0.51
28	C218	Benzeneacetonitrile	-9.93	0.01	0.52
29	C623	1-Dodecanol	5.83	0.01	0.53
30	C372	Undecane, 2,6-dimethyl-	2.03	0.01	0.53
31	C177	Benzoic acid	1.56	0.01	0.54

32	C256	3-Octanone	11.80	0.01	0.54
33	C2	Dimethyldisulfide	1.47	0.01	0.55
34	C79	Pyridine	-0.67	0.01	0.55
35	C13	2-Octenal	1.00	0.01	0.56

[a]Estimates are the b-values for the final regression equation when the defined variable was included and variables are not listed in the order that they entered the equation.

Table 23. Stepwise linear regression for prediction of descriptive sensory liver-like flavor attribute as the dependent variable and aromatic volatile compounds as independent variables.

Step		Variables	Estimate[a] x 10^{-4}	Partial r^2	Equation r^2
Intercept		0.03			
1	C50	Thiourea	5.06	0.16	0.16
2	C42	Dimethyl sulfide	19.30	0.07	0.23
3	C37	Acetic acid	0.69	0.05	0.28
4	C87	2-Propanone	1.20	0.03	0.31
5	C61	Butanal, 3-methyl-	-0.79	0.03	0.34
6	C609	Pentane, 2,3,3-trimethyl-	-18.70	0.02	0.36
7	C260	2-Propen-1-ol, 2-methyl-	-4.58	0.02	0.38
8	C498	1H-Imidazole-4-methanol	-8.82	0.02	0.40
9	C289	Propane, 1-(1,1-dimethylethoxy) -2-methyl-	1.48	0.02	0.41
10	C114	2-Pentanone	-1.04	0.02	0.43
11	C227	Cyclohexanecarboxamide, N-furfuryl-	-68.10	0.02	0.45
12	C219	Ethanol	-0.46	0.02	0.47
13	C363	Hexane, 2,2,5-trimethyl-	1.60	0.01	0.48
14	C640	1,3-Butanediol	11.60	0.01	0.49
15	C625	2(3H)-Furanone, 5-hexyldihydro-	14.30	0.01	0.50
16	C285	Nonacosane, 3-methyl-	-173.00	0.01	0.51
17	C147	Octadecane	7.19	0.01	0.52
18	C102	Pentanoic acid	-14.50	0.01	0.53
19	C203	2-Decen-1-ol	-1.20	0.01	0.55
20	C158	1H-Azepine, hexahydro-	-2.88	0.01	0.56
21	C445	Oxalic acid, isobutyl nonyl ester	-7.30	0.01	0.56

[a]Estimates are the b-values for the final regression equation when the defined variable was included and variables are not listed in the order that they entered the equation.

Table 24. Stepwise linear regression for prediction of descriptive sensory umami flavor attribute as the dependent variable and aromatic volatile compounds as independent variables.

Step	Variables		Estimate[a] x 10^{-4}	Partial r^2	Equation r^2
Intercept			0.32		
1	C1	2-Butanone, 3-hydroxy-	0.62	0.13	0.13
2	C63	Ethanone, 1-(1H-pyrrol-2-yl)-	11.00	0.06	0.20
3	C258	E-2-octenal	21.30	0.04	0.23
4	C17	Benzaldehyde	-0.08	0.02	0.25
5	C38	Acetone	3.75	0.03	0.28
6	C389	3-Pentenoic acid, 4-methyl-	-6.66	0.02	0.30
7	C3	Methane, thiobis-	-3.85	0.02	0.32
8	C55	2(5H)-Furanone	-24.60	0.02	0.34
9	C335	Pyrrolidine, 1-nitroso-	-120.80	0.02	0.36
10	C260	2-Propen-1-ol, 2-methyl-	5.98	0.03	0.37
11	C50	Thiourea	-1.59	0.01	0.37
12	C270	Acetic acid ethenyl ester	-5.80	0.01	0.38
13	C80	2,3-Butanedione	-0.27	0.01	0.40
14	C105	Toluene	-0.06	0.01	0.41
15	C219	Ethanol	-0.58	0.01	0.43
16	C186	Thiophene, 3-methyl-	-2.11	0.01	0.44
17	C327	2(3H)-Furanone, 5-heptyldihydro-	10.90	0.01	0.44
18	C96	Butanal	5.50	0.01	0.45
19	C619	Pyrazine, 2,3-dimethyl-	2.32	0.01	0.46

[a]Estimates are the b-values for the final regression equation when the defined variable was included and variables are not listed in the order that they entered the equation.

Figure 3. Partial least squares regression biplot (r^2 = 85) for consumer sensory attributes (•) and trained descriptive flavor (■) and volatile aromatic compounds (◆).

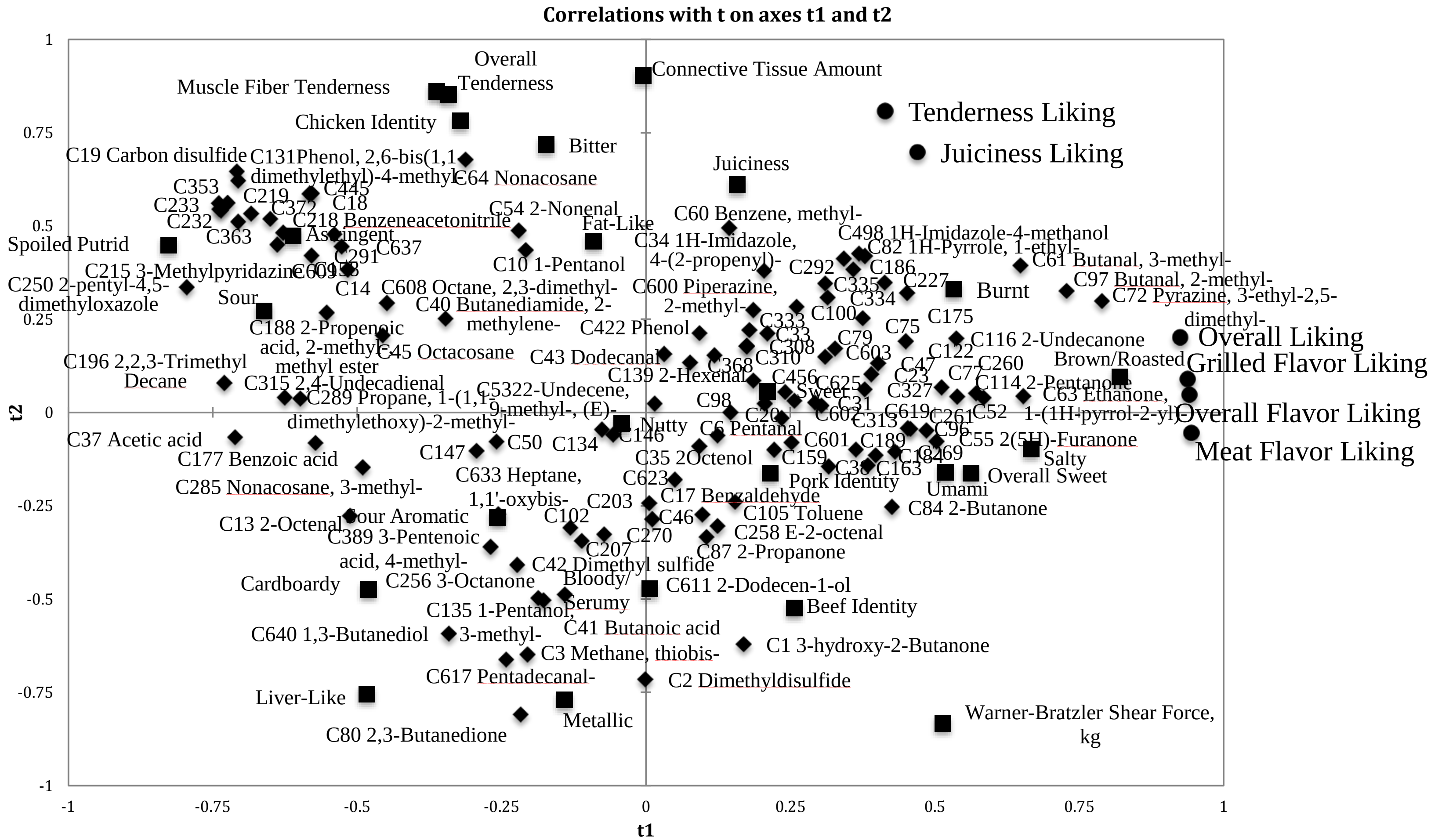


Figure 4. Partial least squares regression biplot ($r^2 = 85$) for consumer groups by meat treatments. Millennial light beef eaters (ML), millennial heavy beef eaters (MH), non-millennial light beef eaters (NL), and non-millennial heavy beef eaters (NH).

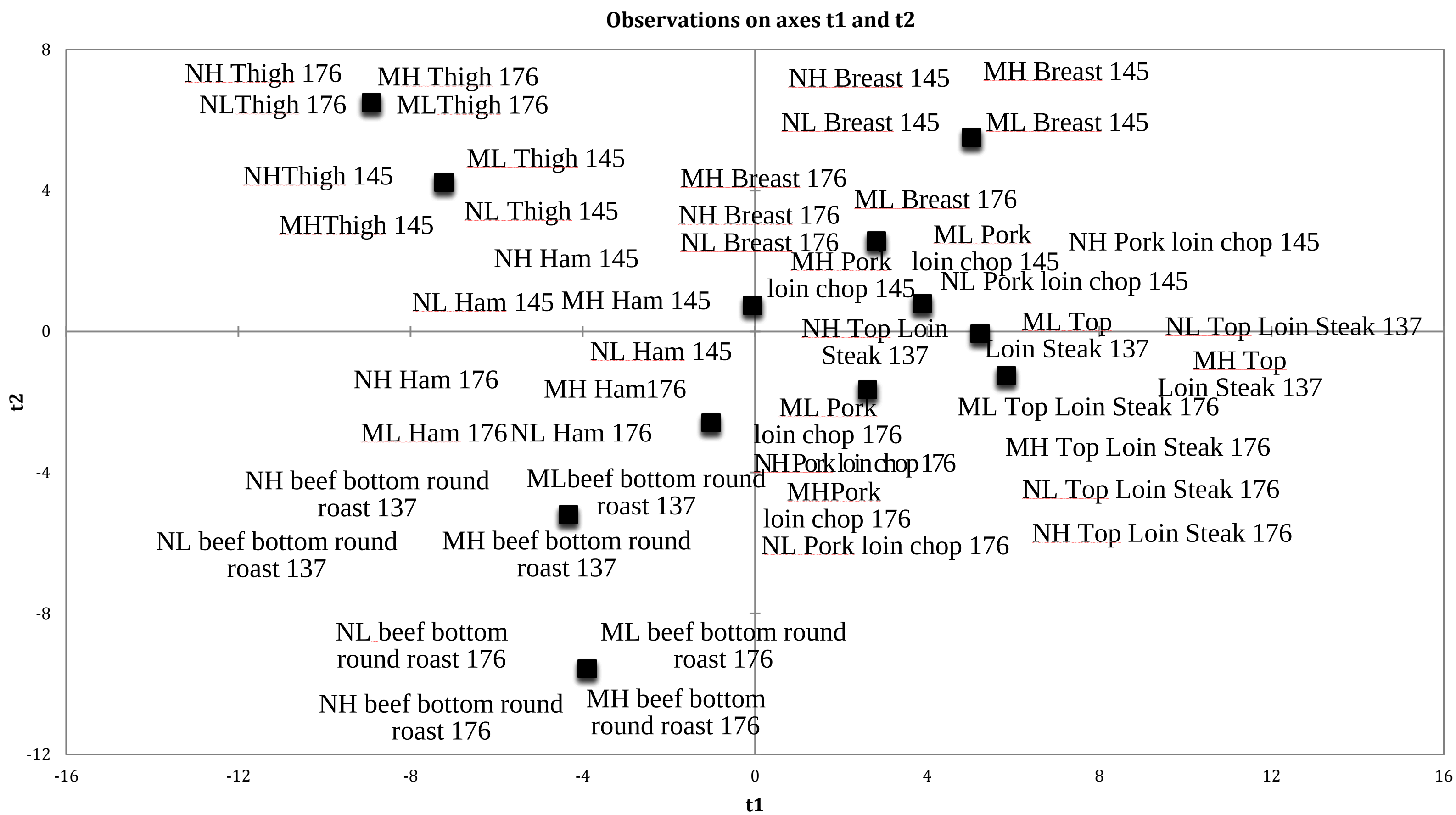


Figure 5. One-on-one interview beef, pork, and chicken purchasing decisions for Non-millennial light beef eaters (top left), non-millennial heavy beef eaters (top right) millennial light beef eaters (bottom left), millennial heavy beef eaters (bottom right).

Table 25. Demographic frequencies for in-home consumers (n = 267) across four cities who participated in the in-home placement study.

Question	Number of Respondents	Percentage of Respondents
Sex		
Male	114	42.7
Female	153	57.3
Age		
20 years or younger	11	4.1
21 - 25 years	28	10.5
26 - 35 years	85	31.8
36 - 45 years	51	19.1
46 - 55 years	51	19.1
56 - 65 years	39	14.6
66 years and older	2	0.8
Generation identification		
Millennial, Light Beef Eaters	72	27.0
Millennial, Heavy Beef Eaters	52	19.5
Non-Millennial, Light Beef Eaters	83	31.1
Non-millennial, Heavy Beef Eaters	60	22.5
Household income		
Below $25,000	59	22.1
$25,001 - $49,999	66	24.7
$50,000 - $74,999	46	17.2
$75,000 - $99,999	49	18.4
$100,000 or more	46	17.2
Household size including yourself		
1	38	14.2
2	97	36.3
3	57	21.4
4	46	17.2
5	18	6.7
6 or more	11	4.1
Employment level		
Not employed	57	21.4
Part-time	41	15.4
Full-time	168	62.9
Proteins consumed at home or at a restaurant (away from home)		

At Home	**Do not Consume**	**Consume**	**Do not Consume**	**Consume**
Chicken	3	264	1.1	98.9
Beef	7	260	2.6	97.4
Pork	18	249	6.7	93.3
Fish	49	218	18.4	81.7
Lamb		208	59	77.9
22.1				
Eggs	13	254	4.9	95.1
Soy Based Products	171	96	64.1	36.0
Away from Home/ Restaurant	**Do not Consume**	**Consume**	**Do not Consume**	**Consume**
Chicken	10	257	3.8	96.3
Beef	7	260	2.6	97.4
Pork	25	242	9.4	90.6
Fish	35	232	13.1	86.9
Lamb		156	111	58.4
41.6				
Eggs	25	242	9.4	90.6
Soy Based Products	173	94	64.8	35.3
Weekly consumption of protein				
Beef				
0		5		1.9
1-2		153		57.3
3-4		87		32.6
5-6		17		6.4
7 or more		5		1.9
Pork				
0		19		7.1
1-2		215		80.5
3-4		26		9.7
5-6		6		2.3
7 or more		1		0.4
Lamb				
0		218		81.7
1-2		45		16.9
3-4		3		1.1
5-6		1		0.4
7 or more		0		0.0
Chicken				
0		3		1.1
1-2		101		37.8
3-4		124		46.4
5-6		33		12.4
7 or more		6		2.3

Fish

0	57	21.4
1-2	180	67.4
3-4	25	9.4
5-6	5	1.9
7 or more	0	0.0

Soy Based Products

0	172	64.4
1-2	80	30.0
3-4	11	4.1
5-6	3	1.1
7 or more	1	0.4

What cooking method do you prefer to use when cooking a beef steak?

	Do not use	**Use**	**Do not use**	**Use**
Pan-frying or using a skillet on the stove	126	141	47.2	52.8
Stir Fry	181	86	81.7	18.4
Grilling Outside	48	219	18.0	82.0
Oven Broiling	196	71	73.4	26.6
Oven Baking	193	74	72.3	27.7
Microwave	258	9	96.6	3.4
Electric Appliance (George Foreman Grill or other electric grill)	218	49	82.0	18.4

What cooking method do you prefer to use when cooking chicken?

	Do not use	**Use**	**Do not use**	**Use**
Pan-frying or using a skillet on the stove	94	173	35.3	64.8
Stir Fry	125	142	46.8	53.2
Grilling Outside	86	181	32.2	67.8
Oven Broiling	219	48	82.0	18.0
Oven Baking	73	194	27.3	72.7
Microwave	254	13	95.1	5.0
Electric Appliance (George Foreman Grill or other electric grill)	223	44	83.5	17.0

What cooking method do you prefer to use when cooking pork?

	Do not use	**Use**	**Do not use**	**Use**
Pan-frying or using a skillet on the stove	113	154	42.3	57.7
Stir Fry	208	59	77.9	22.1
Grilling Outside	115	152	43.1	56.9
Oven Broiling	229	38	85.8	14.2
Oven Baking	111	156	41.6	58.4

Microwave	254	13	95.1	4.9
Electric Appliance (George Foreman Grill or other electric grill)	225	42	84.3	15.7
Degree of doneness preference				
Rare	12		4.5	
Medium Rare	74		27.7	
Medium	81		30.3	
Medium Well	61		22.9	
Well	29		10.9	
Very Well	7		2.6	
When purchasing beef, what do you typically tend to buy at the retail store?				
Grass Fed	48		18.5	
Dry Aged	6		2.3	
Organic	45		16.9	
Traditional beef at the retail store	207		77.8	
What flavor or types of cuisines do you like?				
	Do not Eat	**Eat**	**Do not eat**	**Eat**
American	21	245	7.9	92.1
Barbeque	25	242	9.4	90.6
Mexican/Spanish	32	235	12.0	88.0
Indian	157	110	58.8	41.2
Chinese	38	229	14.2	85.8
Greek	129	138	48.3	51.7
Japanese	108	159	40.4	59.6
Italian	40	227	15.0	85.0
French	170	97	63.7	36.3
Thai	119	148	44.6	55.4
Lebanese	204	63	76.4	23.6

Table 26. Percentage of in-home consumer responses to preparation information for Choice top loin steak, Select bottom round roast, chicken breast and pork loin chop.

	Top Loin Steak	Bottom Round Roast	Pork Chop	Chicken Breast
How did you thaw the meat?				
Placed in refrigerator day before	66.5	70.3	68.6	64.9
Placed in refrigerator same day	13.2	12.0	10.2	13.2
In microwave	5.3	5.3	7.6	9.1
At room temperature	7.1	7.1	7.6	7.5
Under cold water	7.9	6.0	8.0	7.2
Under hot water	4.5	3.0	3.4	4.9
Cooked frozen	1.5	3.0	1.1	1.1
Which of these, if any, did you do to the meat before cooking?				
Cut it into small pieces	4.9	7.9	10.1	12.1
Cut it into large chucks	4.9	8.3	4.9	9.8
Cut into slices/strips	5.3	10.5	5.6	17.4
Pound it to flatten it	2.6	2.6	3.8	7.9
Use a fork or other utensils to piece the surface	9.4	8.3	9.0	6.8
Grind it	0.4	0.0	0.0	0.4
None of these	74.1	67.3	68.9	51.7
What was added to the beef, pork or chicken, if anything, as it was prepared or cooked?				
Salt	53.4	66.8	56.1	65.3
Pepper	49.0	63.4	53.1	59.8
Spices/herbs, such as garlic, oregano	52.2	57.7	53.4	50.6
Tenderizer such as Adolph's	2.4	6.8	3.8	5.8
Marinade	18.9	13.6	9.9	10.4
Flour or crumbs to top and/or bottom	9.5	1.9	8.0	1.2
Sauces, such as soy, BBQ, etc.	17.8	17.4	17.9	11.2
Other	15.0	22.6	9.5	12.0

How did you cook the meat?				
Outdoor grill	29.9	11.3	19.7	19.2
Broil	13.1	3.8	8.5	4.1
Indoor grill	10.8	3.0	8.5	5.6
Oven roast uncovered	7.8	21.4	14.5	18.1
Pan broil	7.1	2.3	4.5	1.1
Pan fry/sauté	25.0	8.6	26.9	28.6
Stir fry	3.0	3.4	7.8	10.5
Braise	2.2	9.7	4.1	1.5
Simmer and stew	1.5	17.7	2.2	3.4
Deep fry	0.0	0.0	0.0	1.5
Other	4.9	23.3	5.9	6.4
What was the degree of doneness for the meat when you ate it?				
Very rare	0.4	0.0	0.8	.8
Rare	4.9	1.1	0.4	.4
Medium rare	23.5	7.5	6.0	3.4
Medium	35.8	26.7	28.7	15.7
Well done	28.0	46.6	53.0	65.5
Very well	7.5	18.1	11.2	14.2
Was this meat the main course of the plate, was it combined with other ingredients as the main course or was it a side dish?				
Main course on plate	83.2	69.1	77.4	67.0
Combined with other ingredients	13.4	28.3	19.3	27.8
Side dish	2.6	2.6	3.0	3.7
Which of these did you add to the meal at the table before you ate?				
Nothing: ate it plain	43.3	31.1	39.2	28.8
Nothing: it was cooked in sauce	6.3	21.7	11.6	19.5
Salt	28.7	28.8	27.2	28.1
Pepper	23.9	25.5	22.0	24.1
Other dry ingredients	13.8	13.5	13.4	16.1
Ketchup	2.6	3.7	2.2	2.6
Other sauces (soy or BBQ sauce, A-1, etc.)	19.0	16.9	15.3	15.0

Other	7.5	12.4	10.4	11.2

Figure 6. Percentage of in-home consumer responses to “How did you thaw the meat?” for consumer treatment. Millennial light beef eaters (ML), millennial heavy beef eaters (MH), non-millennial light beef eaters (NL), and non-millennial heavy beef eaters (NH).

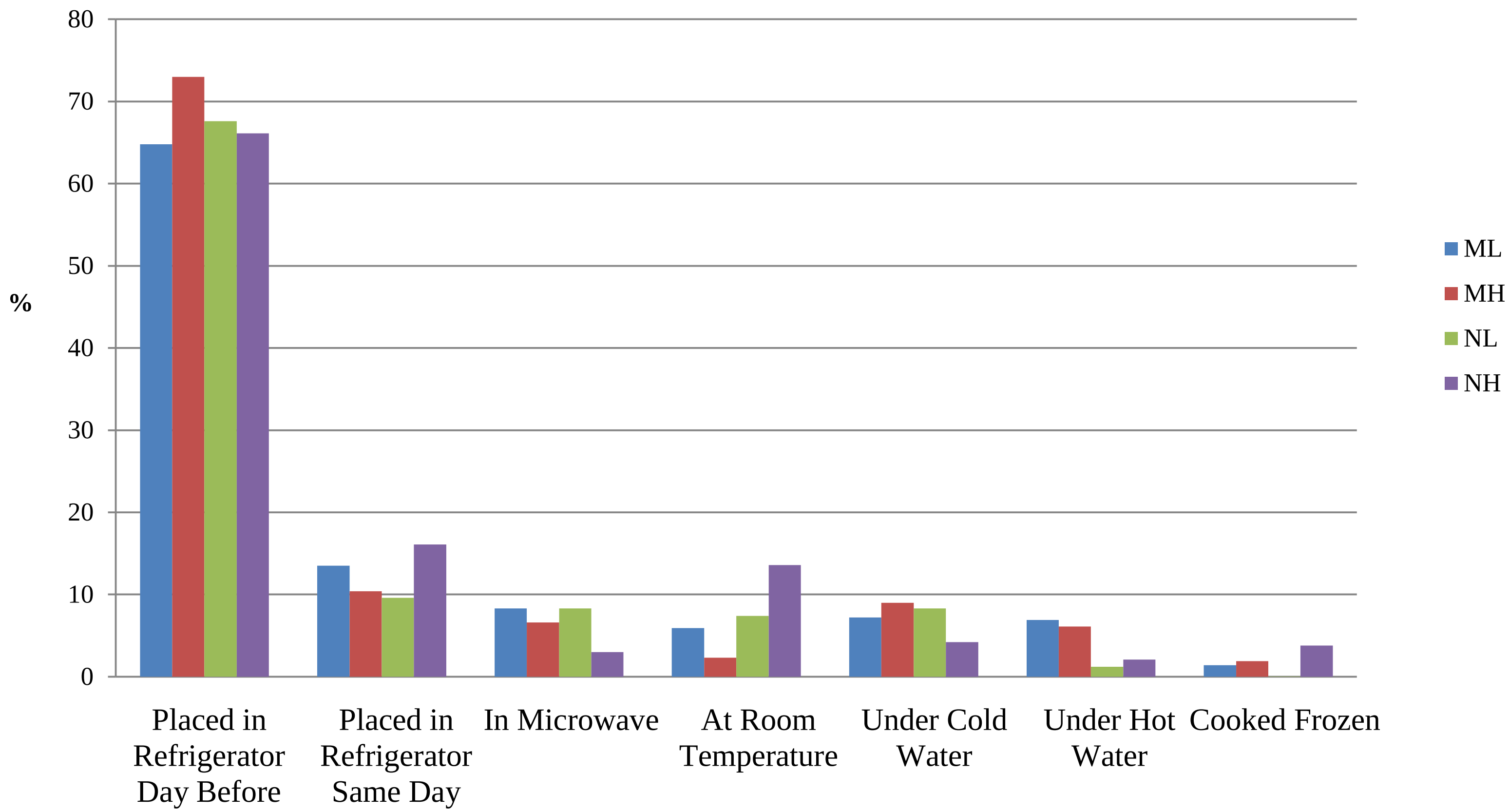


Figure 7. Percentage of in-home consumer responses to “Which of these, if any, did you do to the meat before cooking?” for consumer treatment. Millennial light beef eaters (ML), millennial heavy beef eaters (MH), non-millennial light beef eaters (NL), and non-millennial heavy beef eaters (NH).

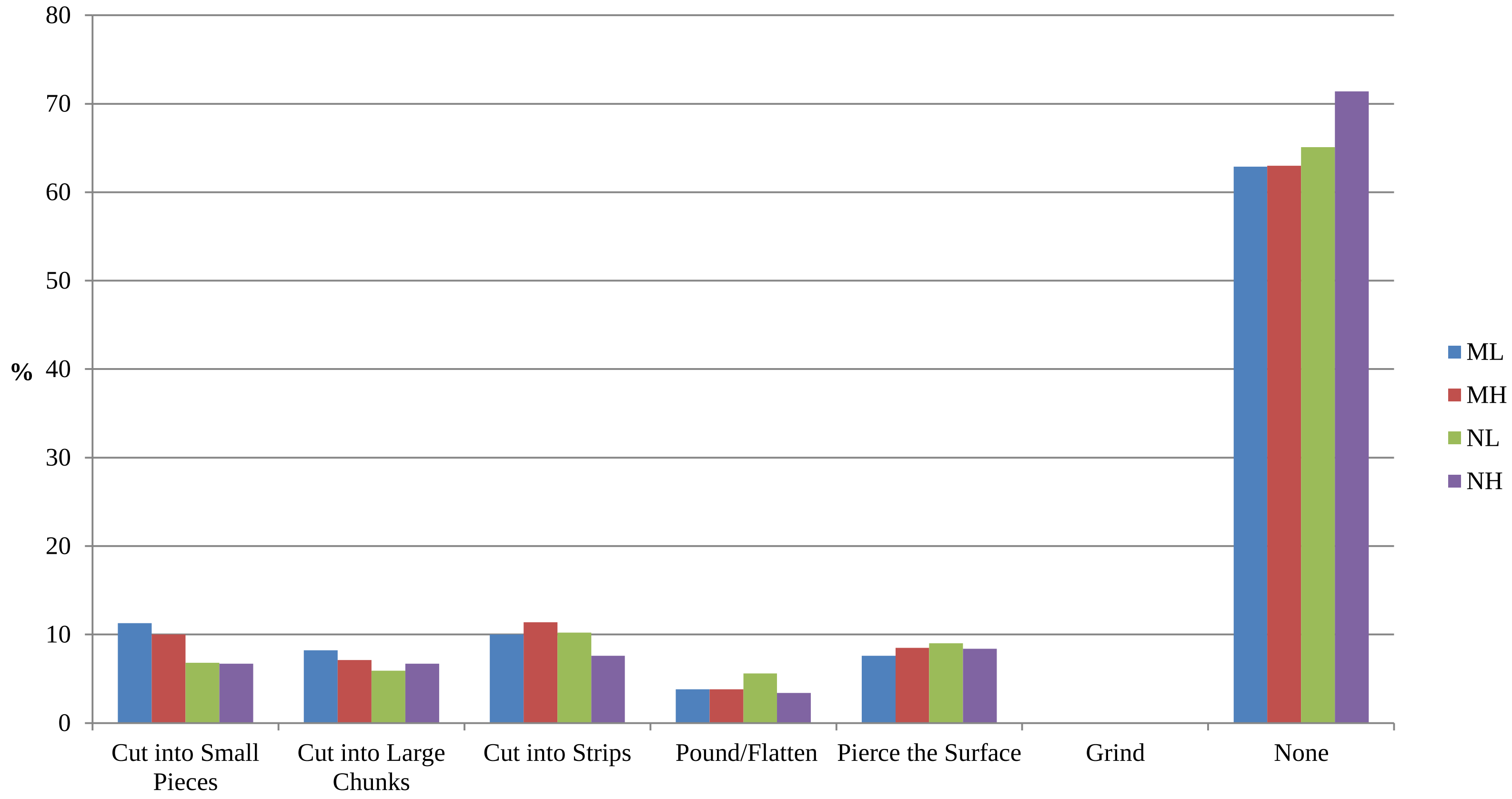


Figure 8. Percentage of in-home consumer responses to “What was added to the beef, pork or chicken, if anything, as it was prepared or cooked?” for consumer treatment. Millennial light beef eaters (ML), millennial heavy beef eaters (MH), non-millennial light beef eaters (NL), and non-millennial heavy beef eaters (NH).

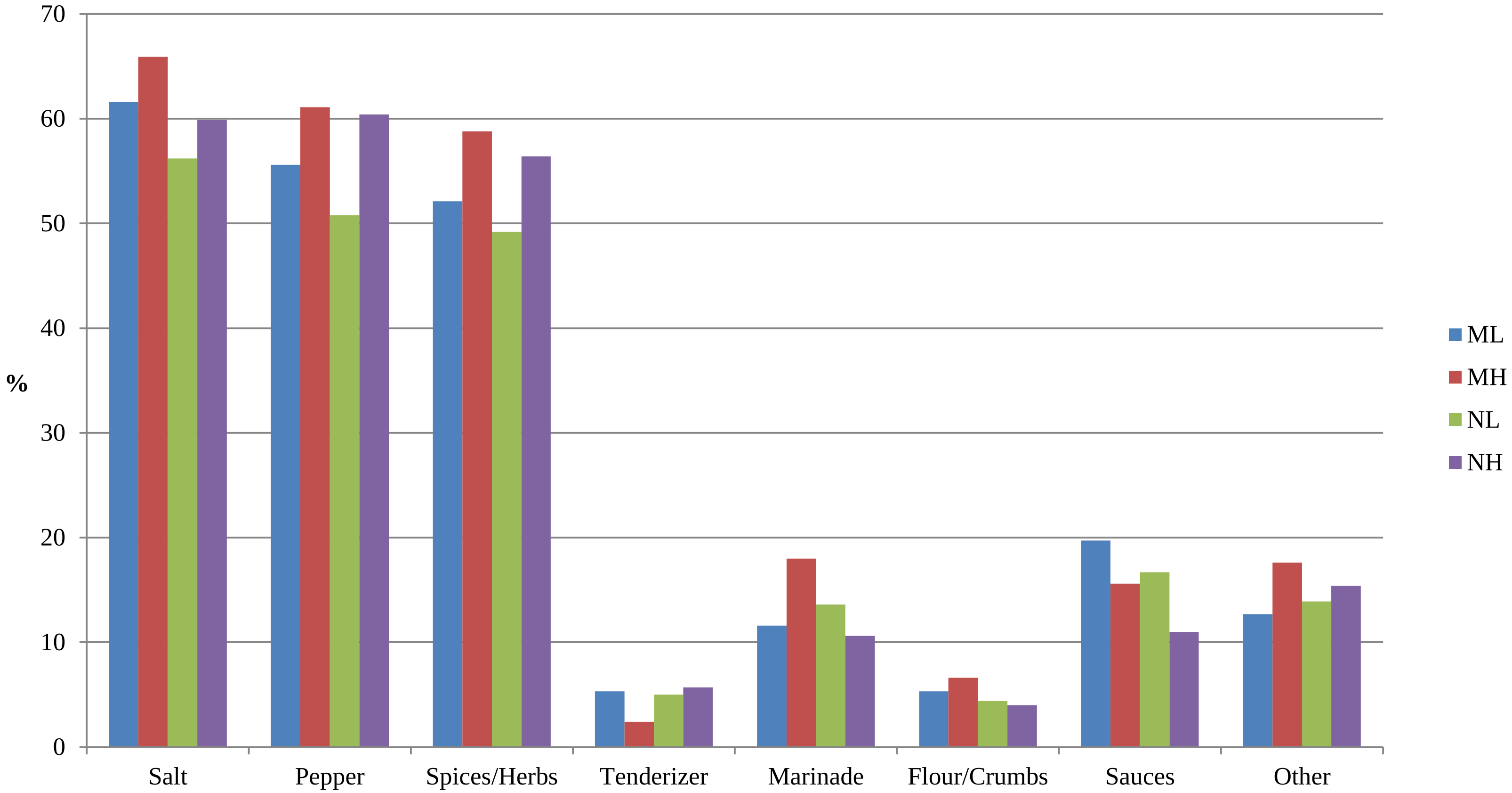


Figure 9. Percentage of in-home consumer responses to "How did you cook the meat?" for consumer treatment. Millennial light beef eaters (ML), millennial heavy beef eaters (MH), non-millennial light beef eaters (NL), and non-millennial heavy beef eaters (NH).

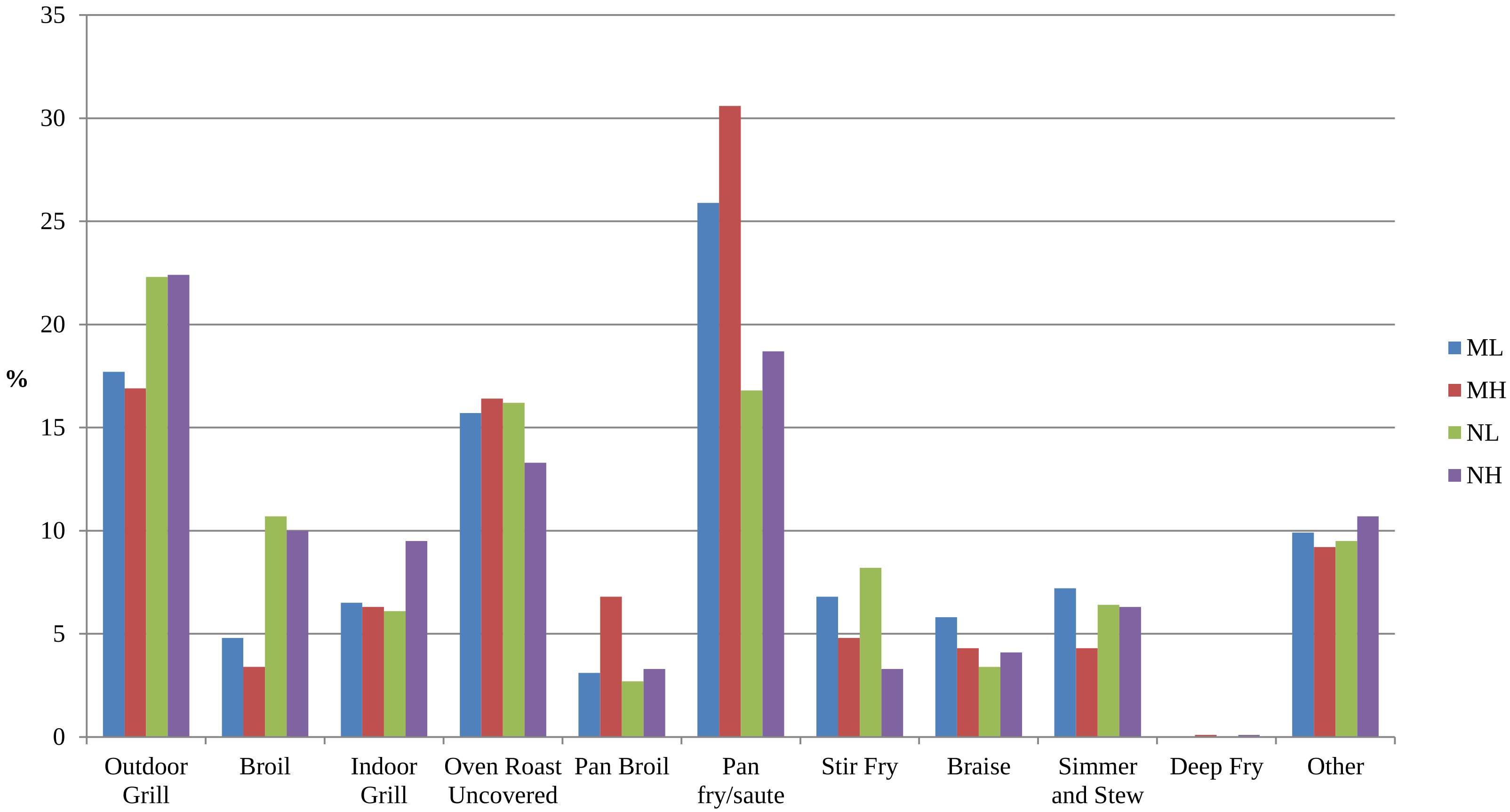


Figure 10. Percentage of in-home consumer responses to "What was the degree of doneness for the meat when you ate it?" for consumer treatment. Millennial light beef eaters (ML), millennial heavy beef eaters (MH), non-millennial light beef eaters (NL), and non-millennial heavy beef eaters (NH).

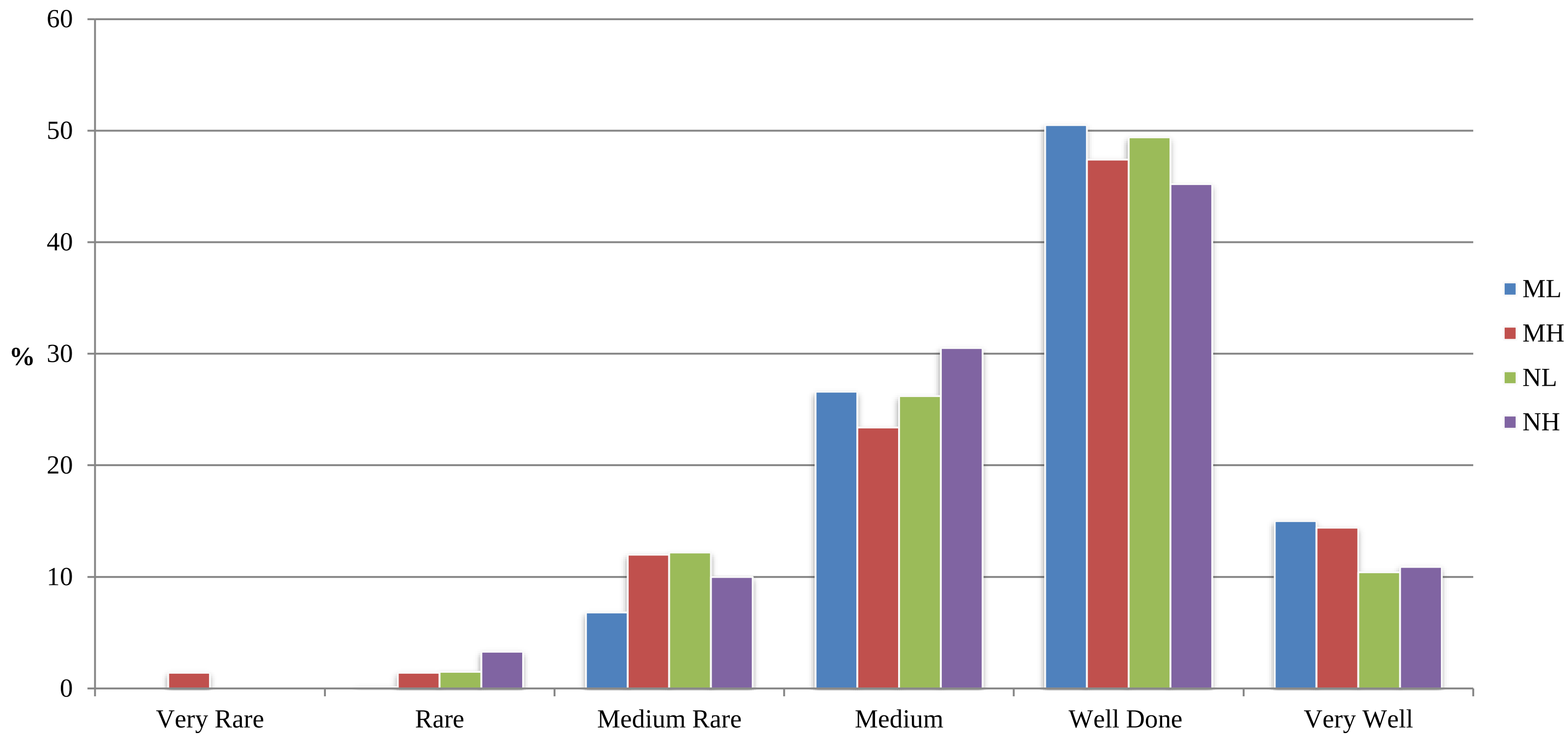


Figure 11. Percentage of in-home consumer responses to “Was this meat the main course of the plate, was it combined with other ingredients as the main course or was it a side dish?” for consumer treatment. Millennial light beef eaters (ML), millennial heavy beef eaters (MH), non-millennial light beef eaters (NL), and non-millennial heavy beef eaters (NH).

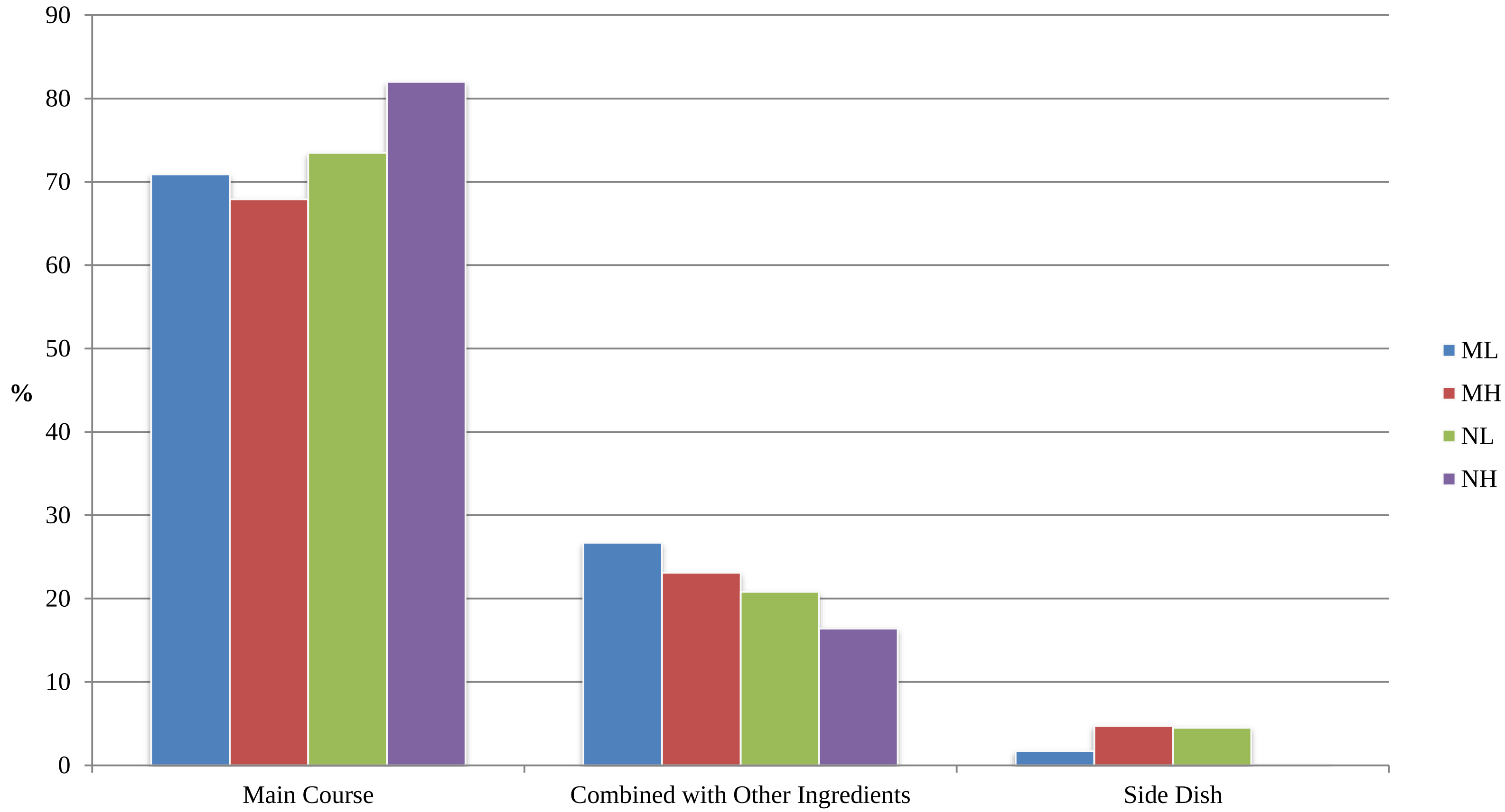


Figure 12. Percentage of in-home consumer responses to “Which of these did you add to the meal at the table before you ate?” for consumer treatment. Millennial light beef eaters (ML), millennial heavy beef eaters (MH), non-millennial light beef eaters (NL), and non-millennial heavy beef eaters (NH).

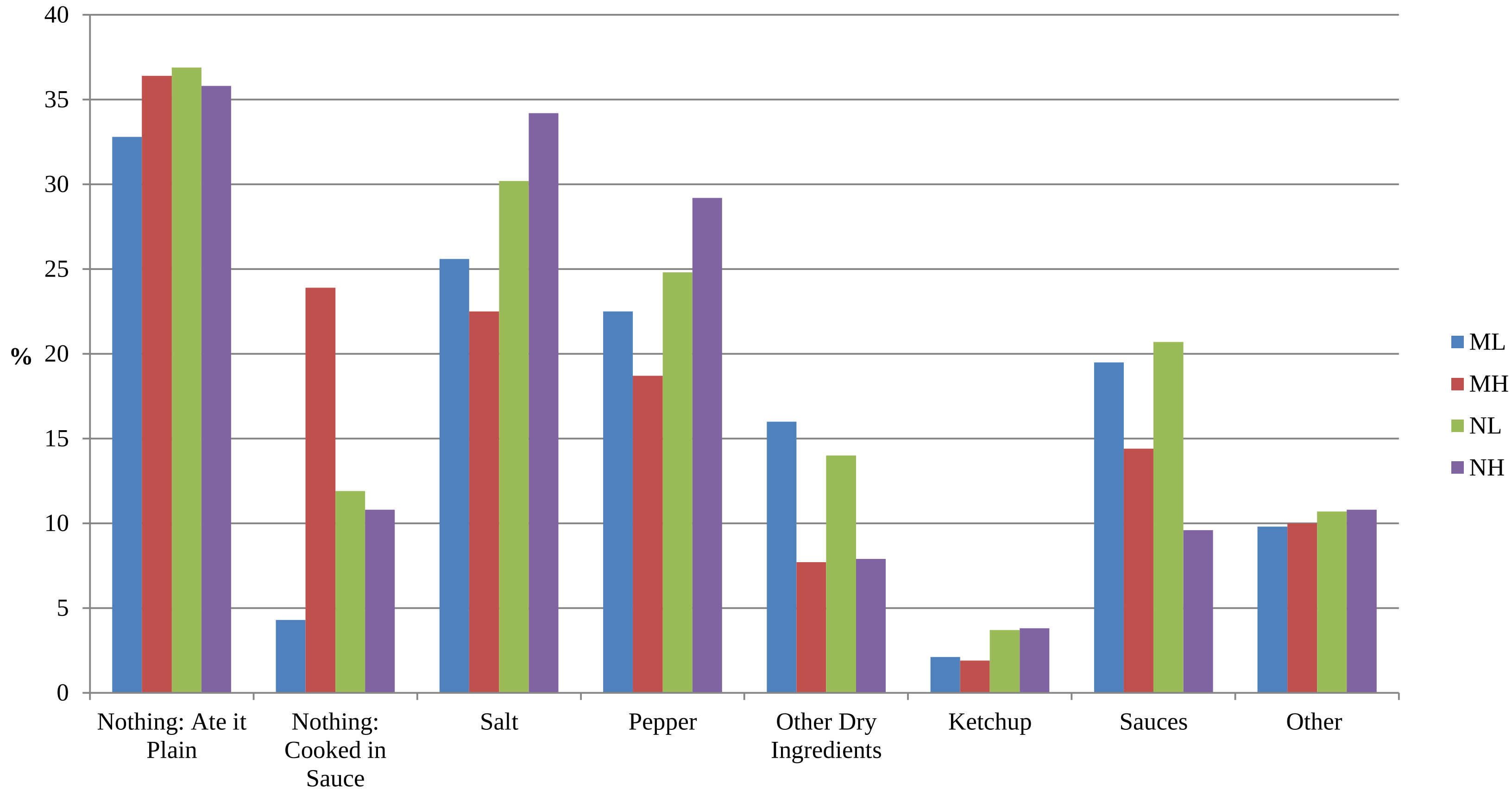


Figure 13. Partial least squares regression biplot ($r^2 = 0.35$) for in-home consumer liking attributes (•) and demographic information (◆).

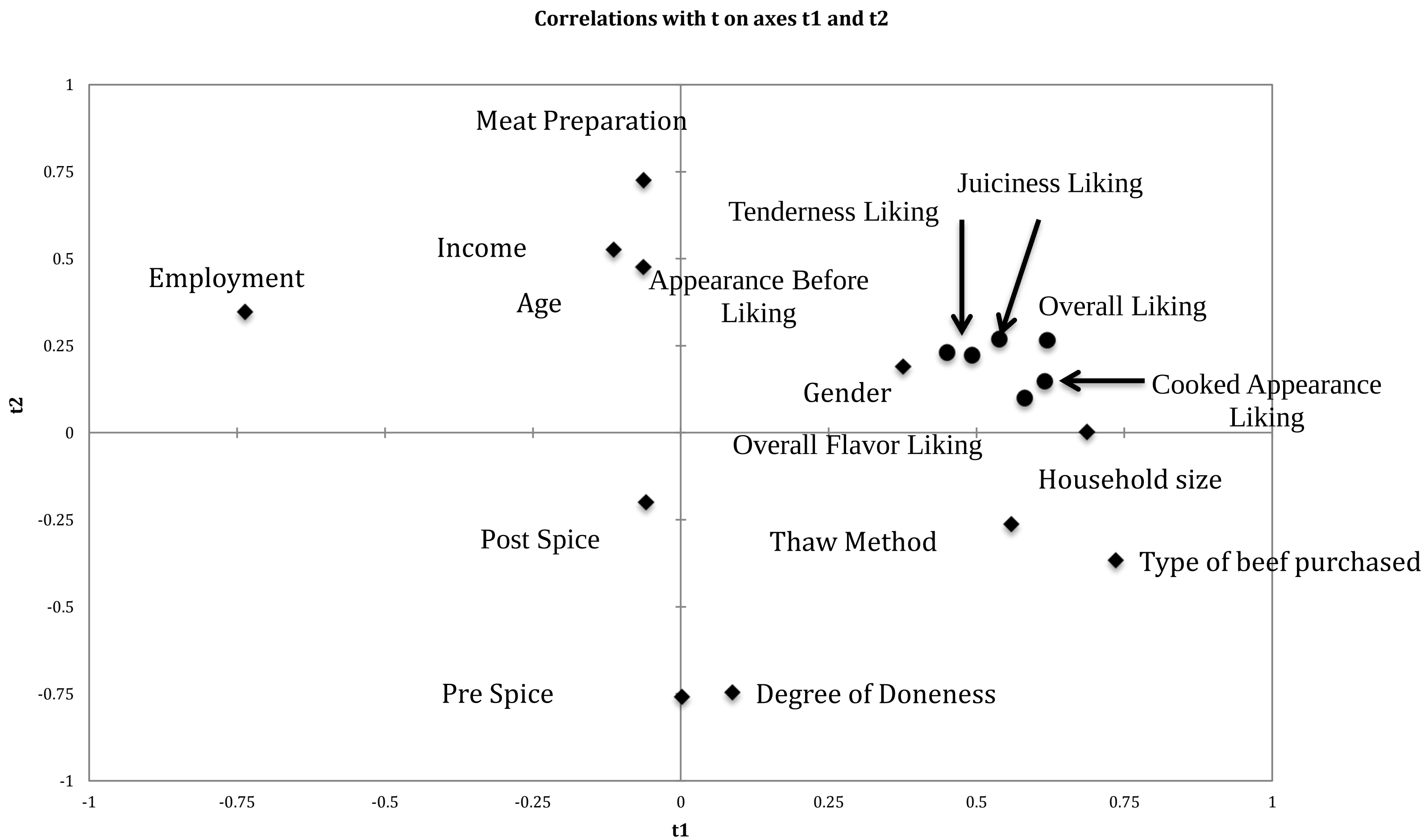


Figure 14. Partial least squares regression biplot (r^2 = 0.35) for in-home consumer groups across cooking methods. Millennial light beef eaters (ML), millennial heavy beef eaters (MH), non-millennial light beef eaters (NL), and non-millennial heavy beef eaters (NH).

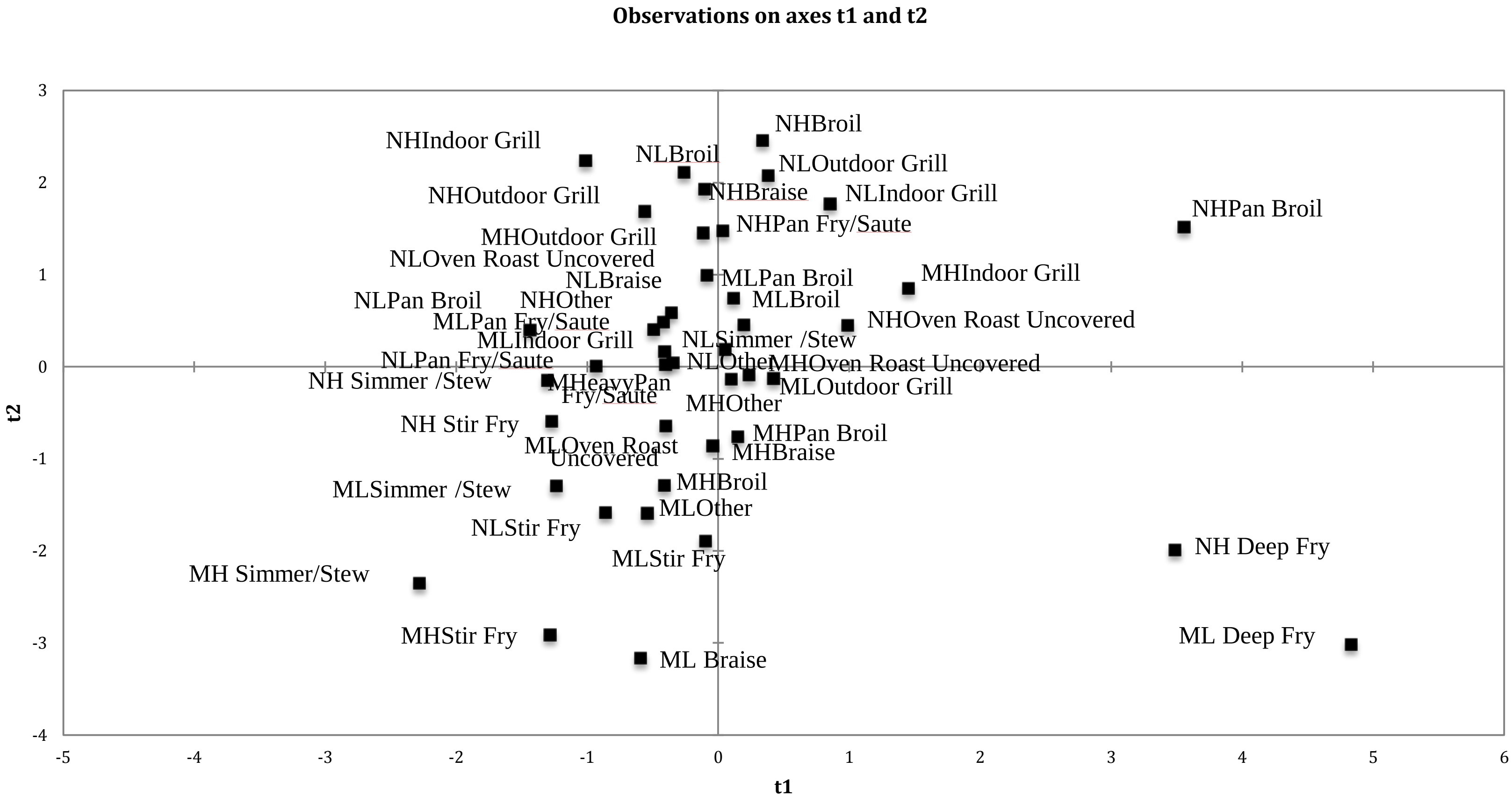


Figure 15. Partial least squares regression biplot ($r^2 = 0.35$) for in-home with consumer liking attributes (•), demographic information (◆), and consumer groups by cooking methods (■). Millennial light beef eaters (ML), millennial heavy beef eaters (MH), non-millennial light beef eaters (NL), and non-millennial heavy beef eaters (NH).

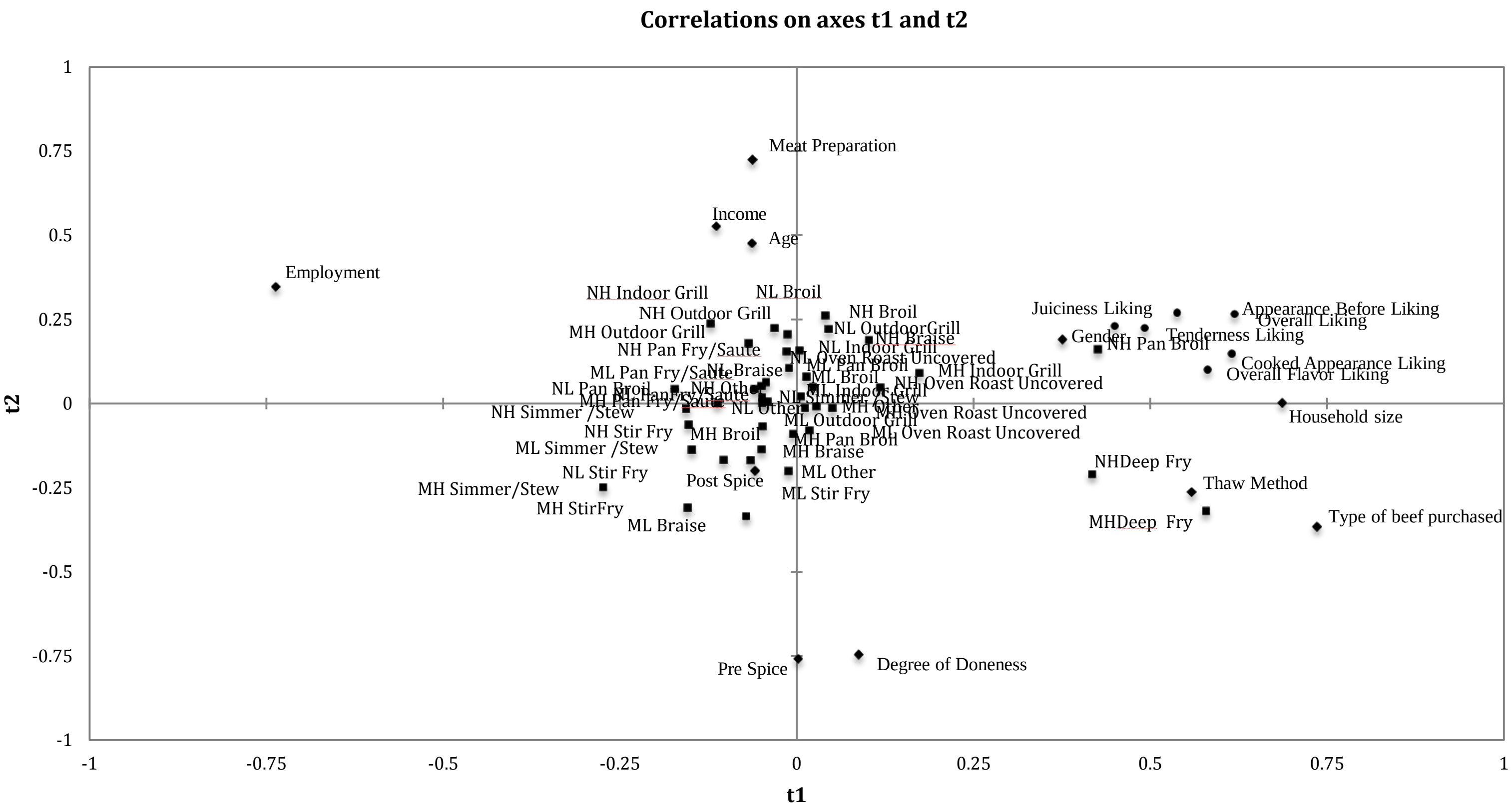


Figure 16. Partial least squares regression biplot ($r^2 = 0.90$) for in-home consumer liking attributes (•), demographic information (◆) across consumer groups (■).

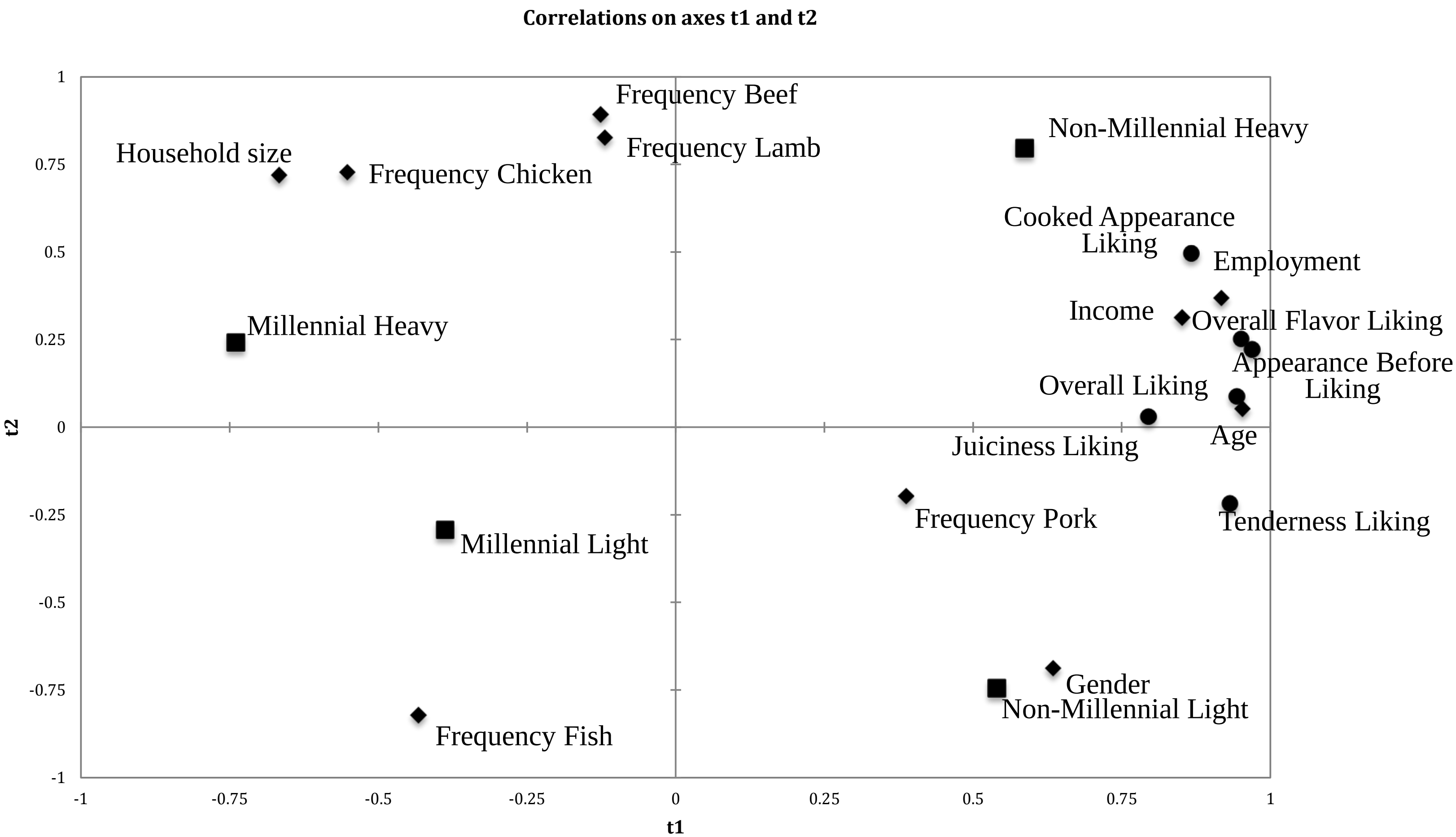


Table 27. Least squares means for in-home consumer attributes where 1 = dislike extremely and 9 = like extremely for beef, pork and chicken cuts from the in-home placement study.

Treatment	Raw Appearance liking	Cooked Appearance liking	Overall liking	Overall flavor liking	Juiciness liking	Tenderness liking
P-value	0.005	0.02	0.001	0.07	<0.001	<0.001
Chicken Breast						
Millennial, heavy beef eater	7.0^{abc}	7.9^{cd}	7.5^{bcd}	7.6	7.4^{cdef}	7.4^{def}
Millennial, light beef eater	6.8^{ab}	7.6^{abc}	7.5^{bcd}	7.5	7.4^{cdef}	7.4^{def}
Non-millennial, heavy beef eater	7.5^{cde}	8.0^{cd}	7.7^{cde}	7.8	7.8^{f}	7.9^{g}
Non-millennial, light beef eater	7.5^{cde}	7.7^{bc}	7.6^{cde}	7.7	7.7^{def}	7.7^{f}
Pork Loin Chop						
Millennial, heavy beef eater	7.1^{abc}	7.5^{abc}	7.3^{bc}	7.2	7.1^{bcd}	6.8^{bcd}
Millennial, light beef eater	7.2^{abc}	7.4^{ab}	7.4^{bcd}	7.5	7.1^{cd}	6.9^{bcde}
Non-millennial, heavy beef eater	7.8^{de}	8.0^{cd}	7.8^{cde}	7.8	7.5^{cdef}	7.2^{bcdef}
Non-millennial, light beef eater	7.2^{bcd}	7.6^{abc}	7.4^{bc}	7.6	7.3^{cde}	7.2^{cdef}
Beef Bottom Round Roast						
Millennial, heavy beef eater	6.6^{a}	7.2^{a}	6.7^{a}	7.2	6.4^{a}	6.1^{a}
Millennial, light beef eater	6.6^{a}	7.4^{ab}	7.1^{ab}	7.4	7.0^{abc}	6.8^{bc}
Non-millennial, heavy beef eater	7.3^{bcde}	7.6^{abc}	7.1^{ab}	7.4	6.5^{ab}	6.5^{ab}
Non-millennial, light beef eater	7.2^{abc}	7.6^{abc}	7.3^{bc}	7.5	7.0^{bc}	6.8^{bcd}
Beef Top Loin Steak						
Millennial, heavy beef eater	7.4^{cde}	7.6^{abc}	7.6^{bcde}	7.8	7.4^{cdef}	7.1^{bcdef}
Millennial, light beef eater	7.4^{cde}	7.9^{cd}	7.8^{cde}	7.8	7.7^{ef}	7.3^{cdef}
Non-millennial, heavy beef eater	7.9^{e}	8.2^{d}	8.0^{e}	8.2	7.8^{f}	7.5^{ef}
Non-millennial, light beef eater	7.7^{de}	7.9^{cd}	7.9^{de}	7.9	7.6^{def}	7.4^{def}

RMSE	1.62	1.30	1.43	1.44	1.63	1.70

[abcdef]Mean values within a column followed by the same or no letter are not significantly different (*P* > 0.05).

Figure 17. Partial least squares regression biplot ($r^2 = 0.95$) for in-home consumer liking attributes (•), trained descriptive attribute sensory attributes (◆), and consumer group (■).

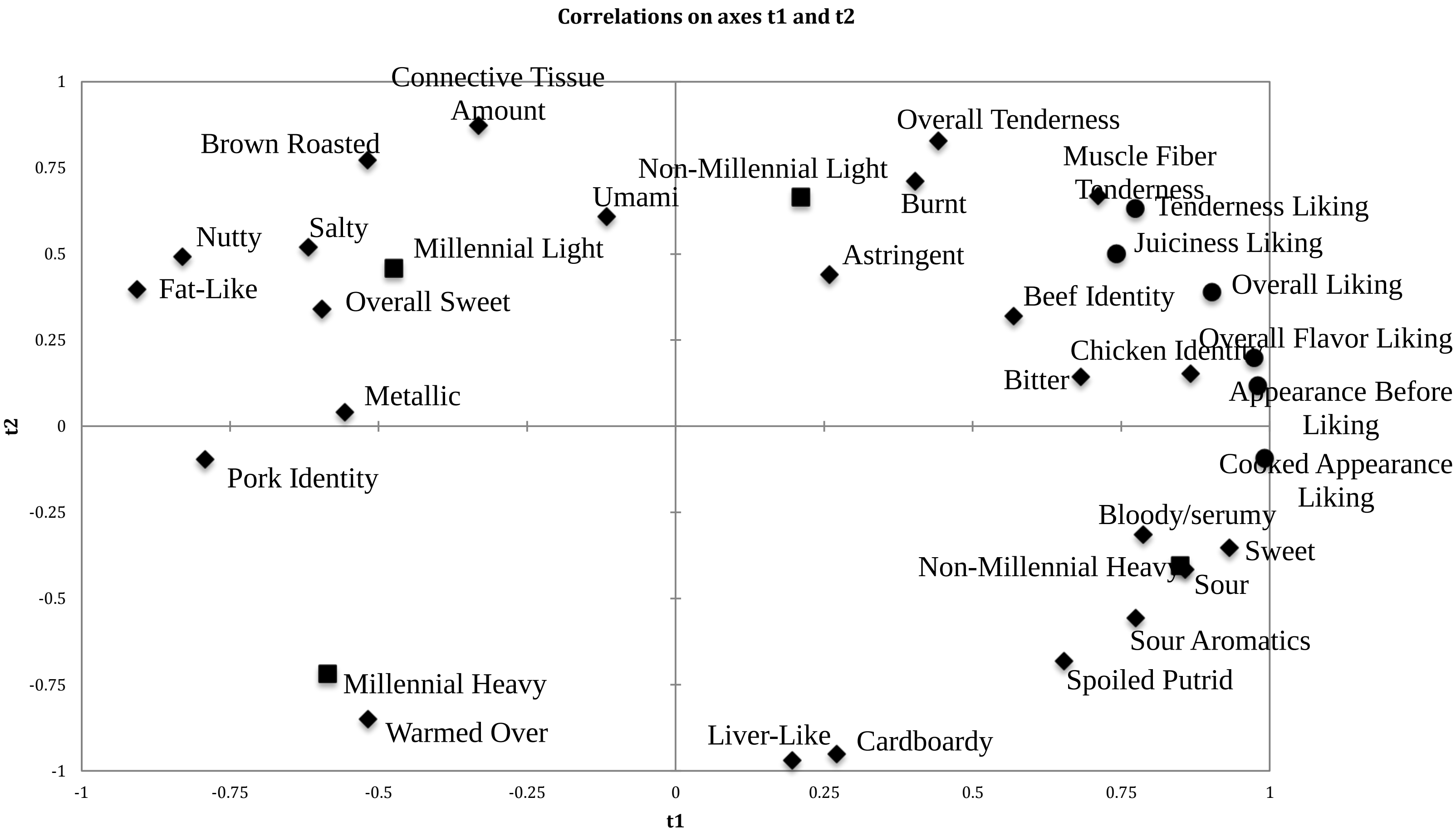


Table 28. Least squares means for in-home consumer attributes by city for consumer attributes where 1 = dislike extremely and 9 = like extremely from the in-home placement study.

Treatment	Raw Appearance liking	Cooked Appearance liking	Overall liking	Overall flavor liking	Juiciness liking	Tenderness liking
P-value	0.008	0.17	0.42	0.15	0.02	0.02
Griffin, GA	7.5[b]	7.8	7.6	7.8	7.6[b]	7.4[b]
Olathe, KS	7.3[ab]	7.7	7.6	7.6	7.2[a]	7.2[ab]
State College, PA	7.4[b]	7.7	7.6	7.6	7.2[a]	7.1[ab]
Portland, OR	7.0[a]	7.6	7.4	7.5	7.2[a]	6.9[a]
RMSE	1.61	1.30	1.43	1.44	1.63	1.70

[ab]Mean values within a column followed by the same or no letter are not significantly different (*P* > 0.05).

Figure 18. Percentage of in-home consumer responses to “How did you thaw the meat?” by city.

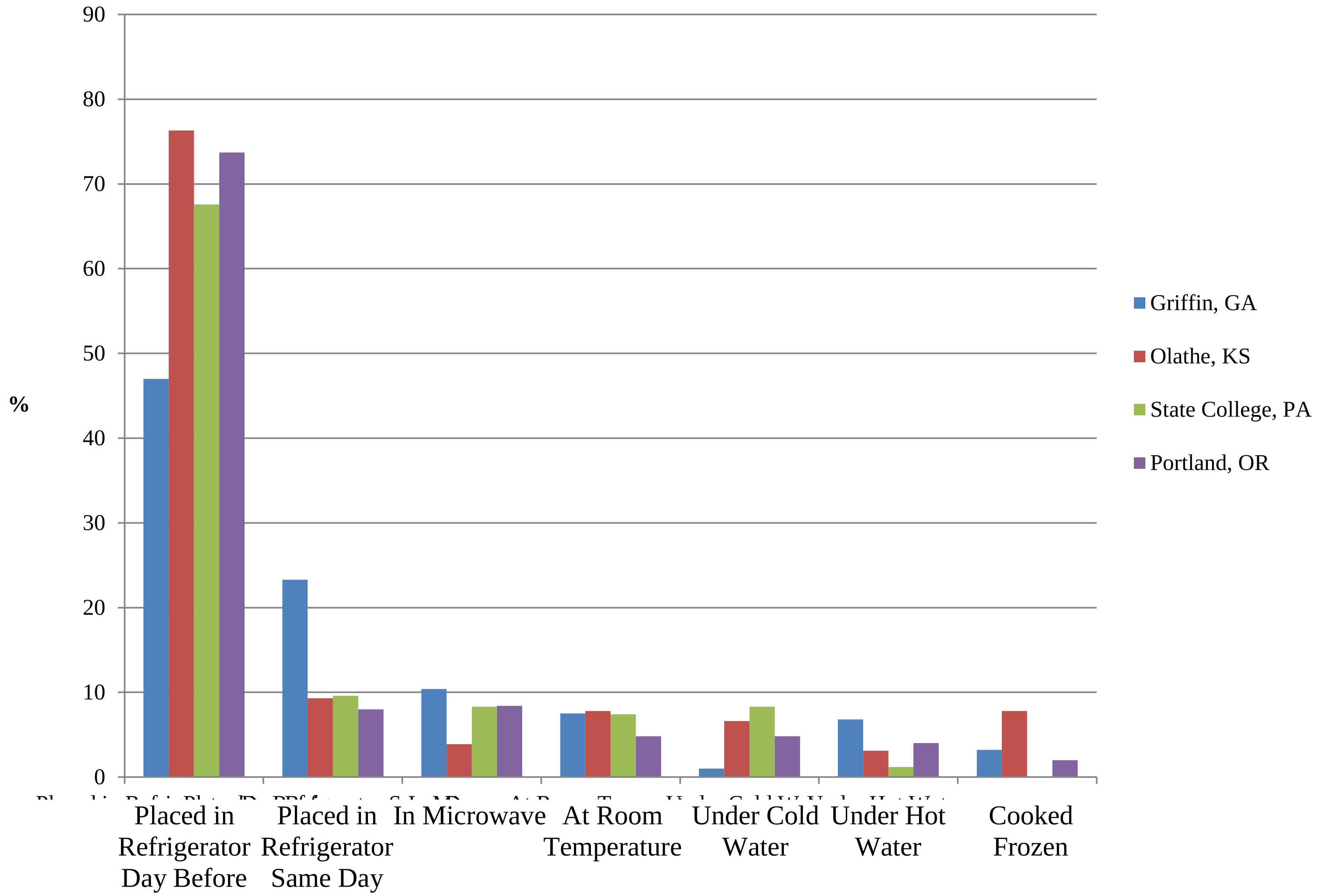


Figure 19. Percentage of in-home consumer responses to “Which of these, if any, did you do to the meat before cooking?” by city.

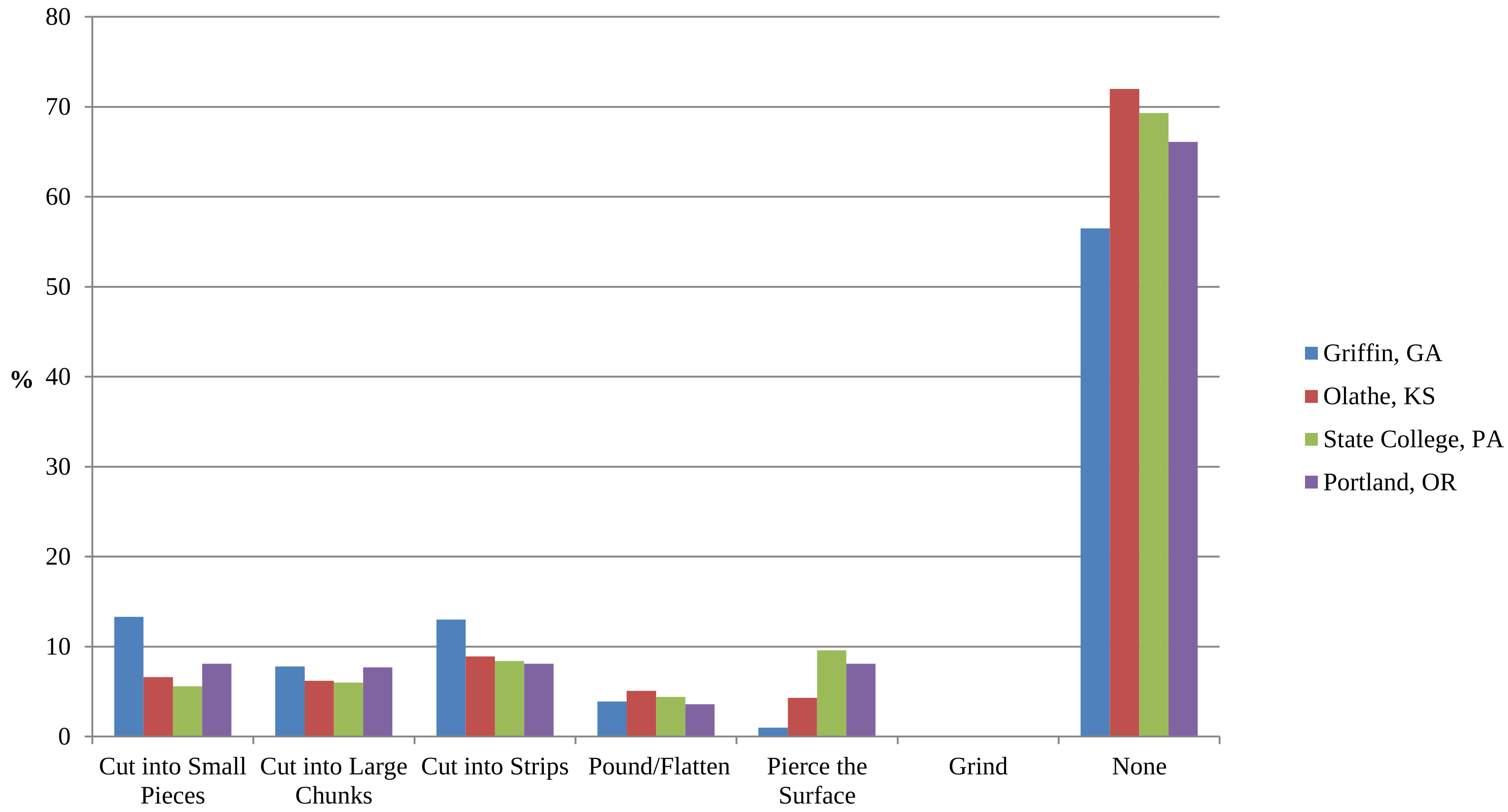


Figure 20. Percentage of in-home consumer responses to "What was added to the beef, pork or chicken, if anything, as it was prepared or cooked?" by city.

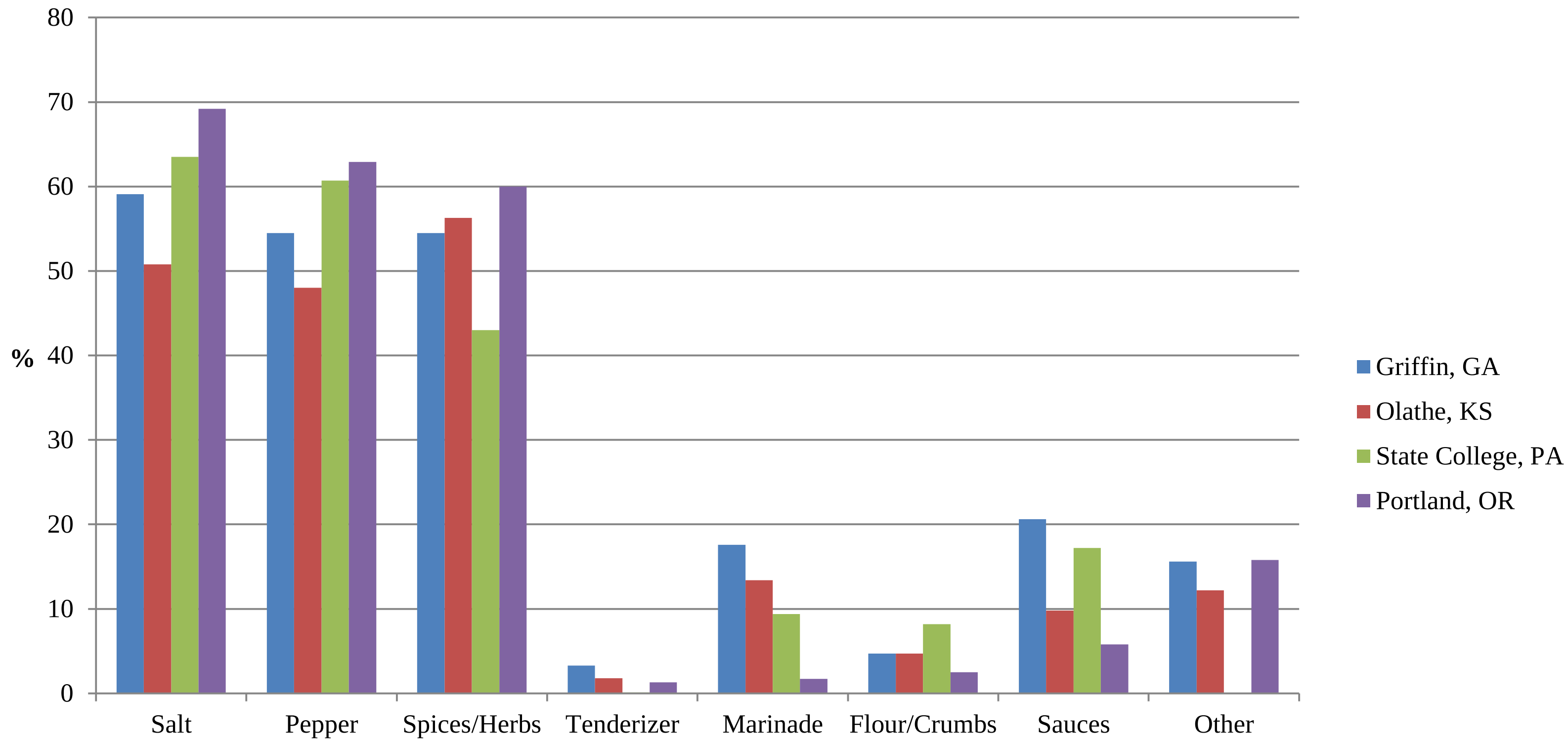


Figure 21 Percentage of in-home consumer responses to “How did you cook the meat?” by city.

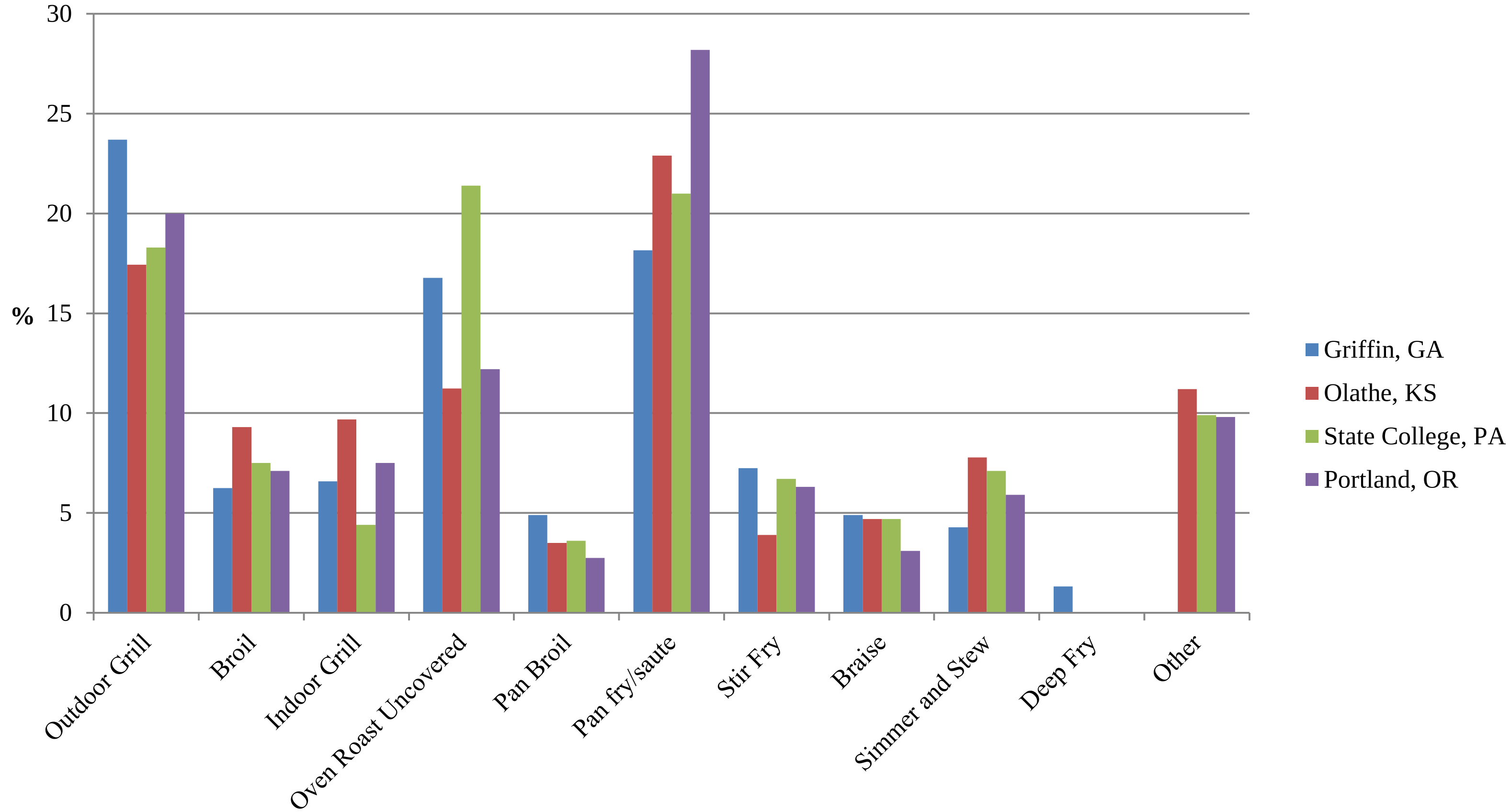


Figure 22. Percentage of in-home consumer responses to “What was the degree of doneness for the meat when you ate it?” by city.

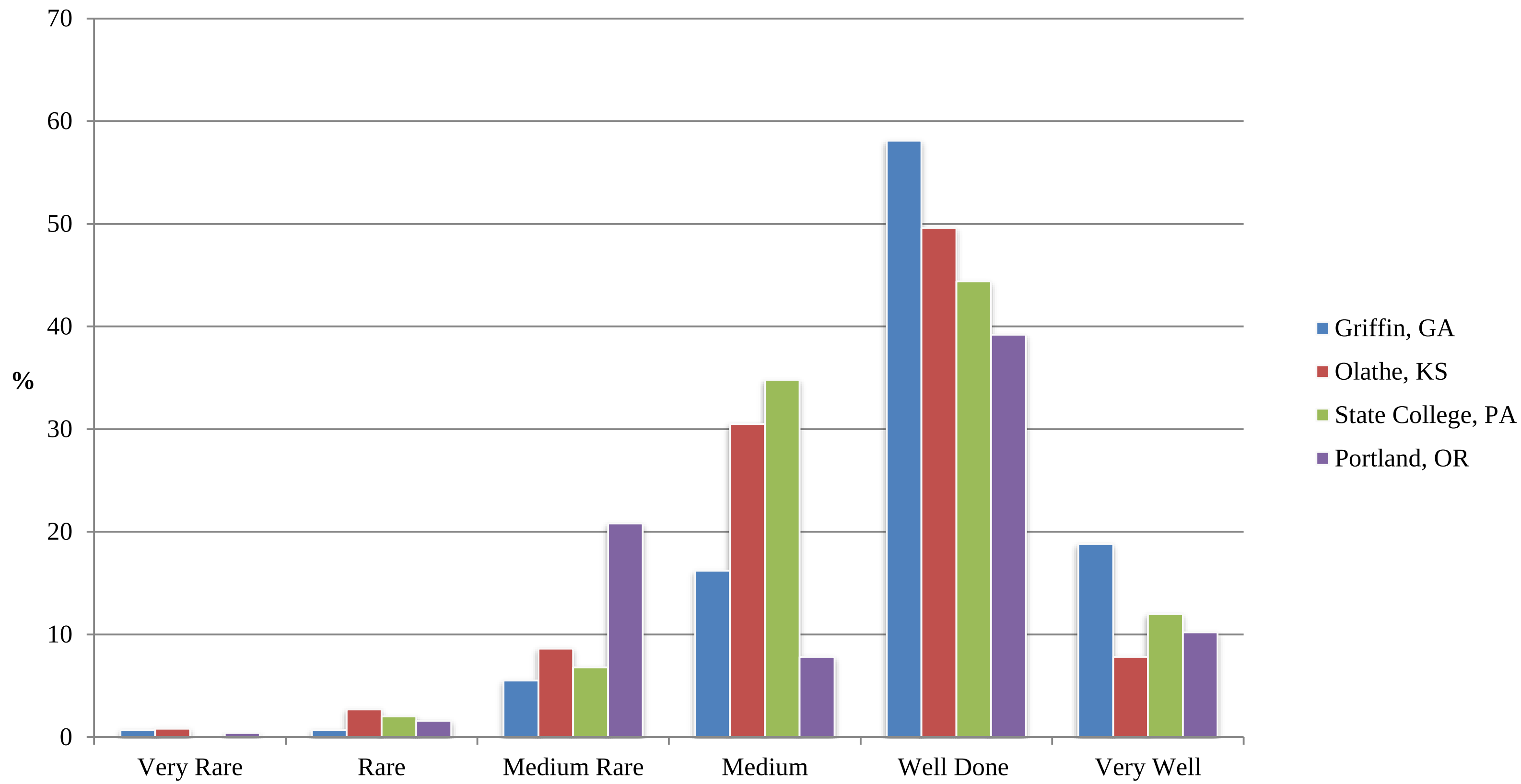


Figure 23. Percentage of in-home consumer responses to “Was this meat the main course of the plate, was it combined with other ingredients as the main course or was it a side dish?” by city.

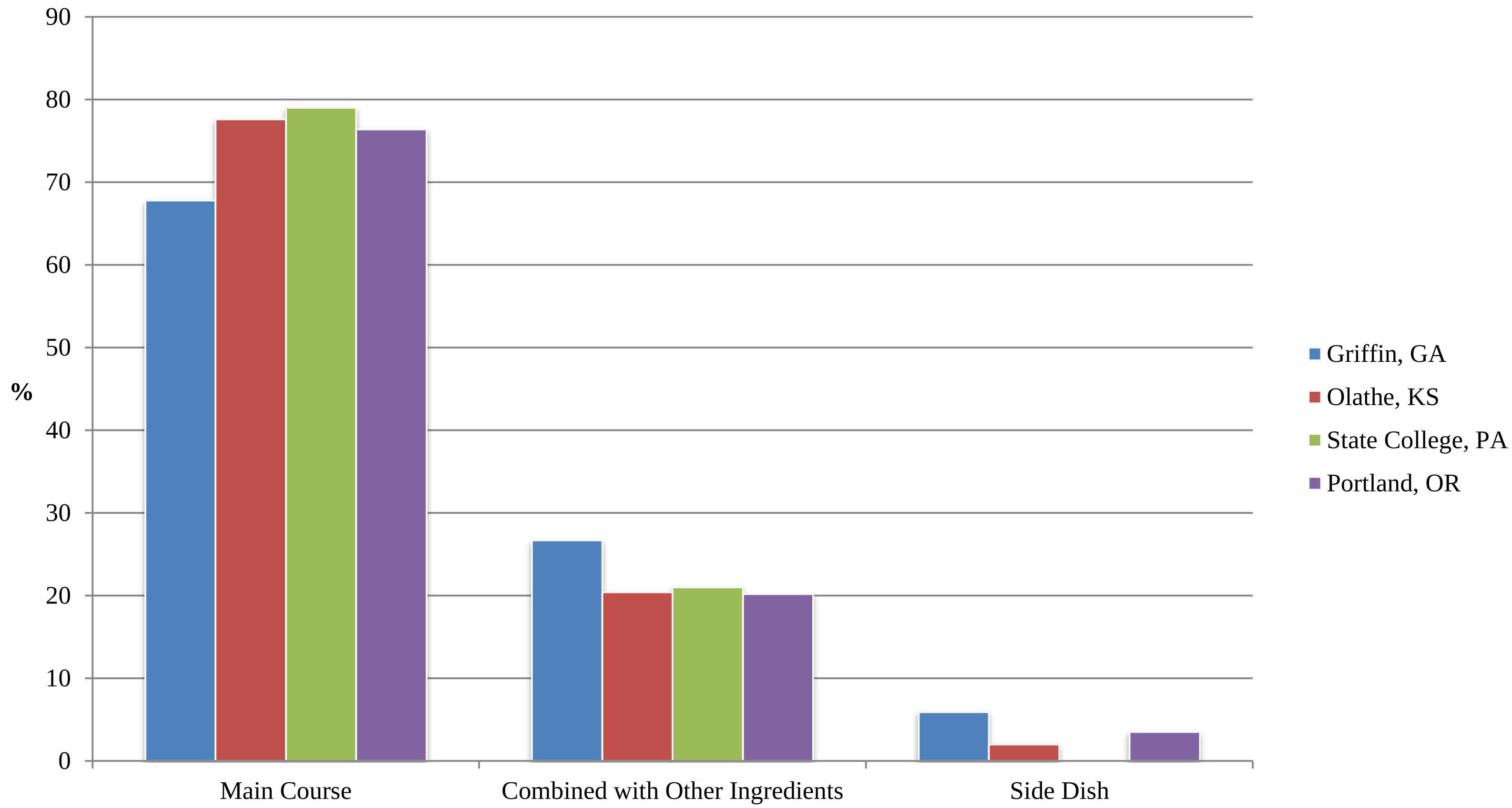


Figure 24. Percentage of in-home consumer responses to “Which of these did you add to the meal at the table before you ate?” by city.

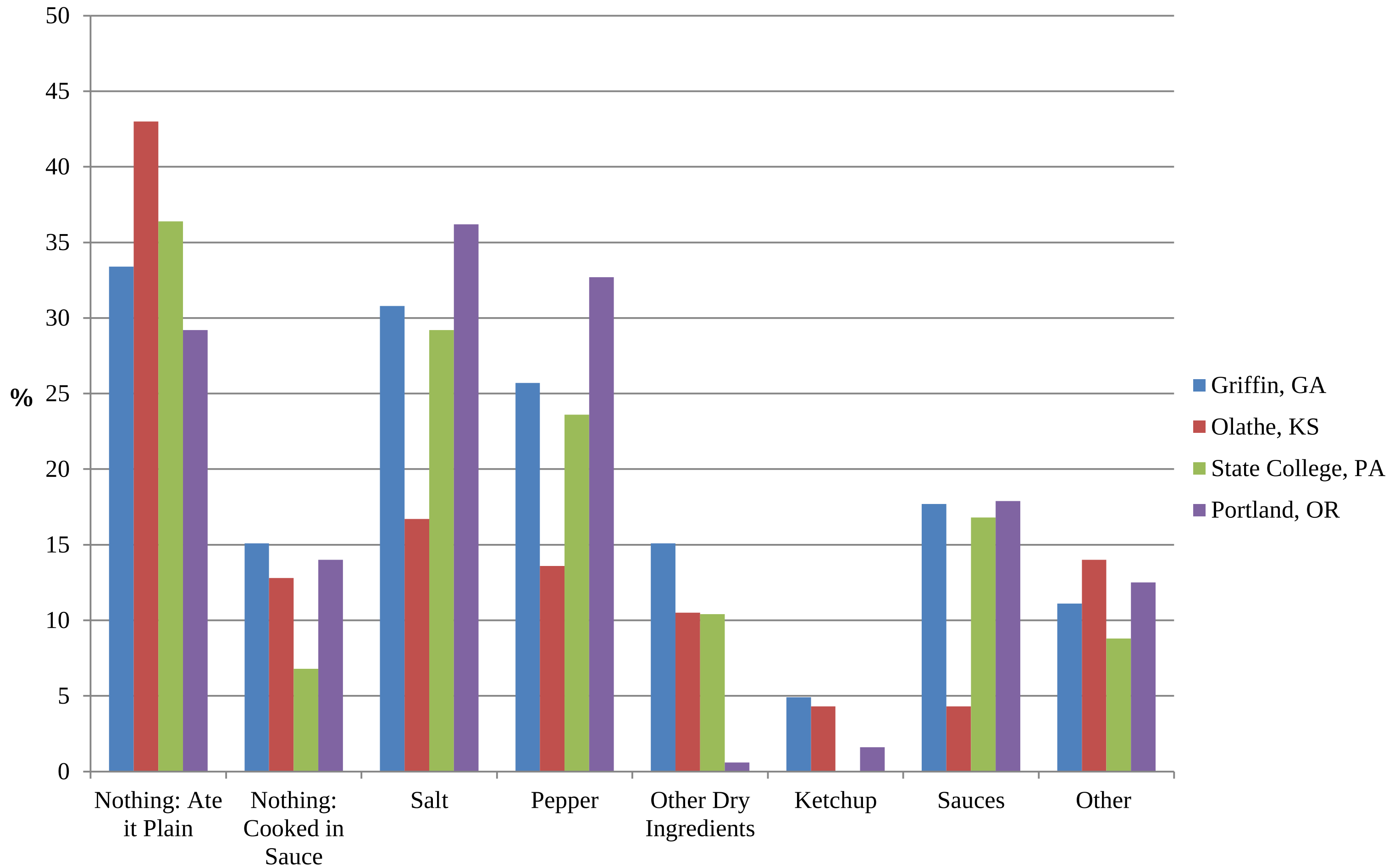


Table 29. Stepwise linear regression for prediction of in-home consumer overall liking[a] as the dependent variable and consumer attributes[a] as independent variables.

Step	Variables	Estimate[b]	Partial r^2	Equation r^2
	Intercept	0.64		
1	Overall flavor liking	0.50	0.66	0.66
2	Tenderness liking	0.25	0.09	0.75
3	Cooked appearance liking	0.15	0.01	0.76
4	Cooking method	-0.02	0.00	0.76
5	Degree of doneness	-0.06	0.00	0.77
6	Juiciness liking	0.05	0.00	0.77
7	Raw appearance liking	0.03	0.00	0.77

[a]Variables measured using 9-point hedonic and intensity scales were 1 = extremely dislike or none; 9 = extremely like or extremely intense.
[b]Estimates are the □-values for the final regression equation when the defined variable was included.

Table 30. Simple correlation coefficients[a] between in-home consumer sensory attributes where 1 = dislike extremely and 9 = like extremely and central location consumer sensory by cut where 1 = dislike extremely and 9 = like extremely.

Effects	HUT[b] Overall Liking	HUT Overall Flavor Liking	HUT Juiciness Liking	HUT Tenderness Liking
CLT[c]				
Chicken Breast				
Overall Liking	0.06	0.06	0.07	0.12
Overall Flavor Liking	0.07	0.09	0.11	0.13
Juiciness Liking	0.07	0.10	0.13	0.20
Tenderness Liking	0.07	0.10	0.10	0.18
Select Bottom Round Roast				
Overall Liking	0.07	0.00	0.02	0.05
Overall Flavor Liking	0.02	0.00	0.05	0.03
Juiciness Liking	0.07	0.03	0.11	0.11
Tenderness Liking	0.10	0.01	0.08	0.12
Choice Top Loin Steaks				
Overall Liking	0.13	0.22	0.14	0.09
Overall Flavor Liking	0.14	0.22	0.14	0.09
Juiciness Liking	0.17	0.13	0.16	0.15
Tenderness Liking	0.21	0.16	0.16	0.20
Pork Loin Chops				
Overall Liking	0.22	0.25	0.19	0.18
Overall Flavor Liking	0.19	0.24	0.17	0.16
Juiciness Liking	0.17	0.18	0.20	0.18
Tenderness Liking	0.25	0.29	0.22	0.23

[a] Simple correlation coefficients > 0.12 are significant ($P < 0.05$).
[b] HUT = Home use test.
[c] CLT = Central location test.

Table 31. Flavor, basic tastes and tenderness descriptive sensory attributes where 0 = none and 15 = extremely intense and Warner-Bratzler shear force (kg) least squares means by cooking treatments for in-home treatments.

Treatment	Beef identity	Pork identity	Chicken identity	Brown/ roasted	Bloody/ serumy	Fat-like	Metallic	Liver-like	Overall Sweet
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
<u>Chicken breasts</u>									
Grill, 62.7°C	0.0^{a}	0.1^{a}	5.1^{b}	1.1^{b}	0.1^{a}	0.5^{a}	1.7^{ab}	0.0^{a}	0.3^{a}
Grill, 80°C	0.0^{a}	0.0^{a}	5.1^{b}	1.4^{c}	0.0^{a}	0.5^{a}	1.7^{a}	0.0^{a}	0.2^{a}
<u>Pork loin chop</u>									
Grill, 62.7°C	0.0^{a}	4.7^{c}	0.6^{a}	1.1^{bc}	0.2^{ab}	1.0^{b}	1.9^{bc}	0.0^{a}	0.5^{b}
<u>Select bottom round roasts</u>									
Crock-pot®, 58.3°C	3.5^{b}	0.8^{b}	0.3^{a}	0.1^{a}	1.4^{d}	0.5^{a}	2.2^{e}	0.3^{b}	0.3^{a}
<u>Choice top loin steaks</u>									
Grill, 58.3°C	6.2^{c}	0.1^{a}	0.3^{a}	1.9^{d}	1.0^{c}	1.5^{c}	2.0^{d}	0.0^{a}	0.9^{c}
Grill, 80°C	6.9^{d}	0.0^{a}	0.2^{a}	2.6^{e}	0.4^{b}	1.4^{c}	1.9^{cd}	0.0^{a}	0.9^{c}
RMSE	0.73	0.78	0.59	0.48	0.47	0.30	0.26	0.15	0.25

Table 31 (con't.). Flavor, basic tastes and tenderness descriptive sensory attributes where 0 = none and 15 = extremely intense and Warner-Bratzler shear force (kg) least squares means by cooking treatments for in-home treatments.

	Basic Taste								
Treatment	Umami	Sweet	Sour	Salty	Bitter	Astringent	Burnt	Card boardy	Nutty
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chicken breasts									
Grill, 62.7°C	0.1[a]	0.5[ab]	1.9[c]	1.5[b]	2.1[b]	2.0[cd]	0.5[c]	0.1[a]	0.0[a]
Grill, 80°C	0.1[a]	0.4[a]	1.8[ab]	1.3[a]	2.3[b]	2.1[d]	0.7[c]	0.1[a]	0.0[a]
Pork loin chop									
Grill, 62.7°C	0.2[b]	0.6[b]	1.7[a]	1.5[b]	1.8[a]	1.8[ab]	0.0[a]	0.1[a]	0.2[b]
Select bottom round roasts									
Crock-pot®, 58.3°C	0.2[ab]	0.5[ab]	2.2[d]	1.3[a]	1.9[a]	1.9[bc]	0.0[a]	0.4[b]	0.0[a]
Choice top loin steaks									
Grill, 58.3°C	1.1[c]	0.8[c]	1.8[bc]	1.7[c]	1.8[a]	1.7[a]	0.0[a]	0.0[a]	0.0[a]
Grill, 80°C	1.2[c]	0.9[c]	1.7[ab]	1.7[c]	1.9[a]	1.8[abc]	0.3[b]	0.0[a]	0.0[a]
RMSE	0.23	0.22	0.29	0.18	0.32	0.29	0.34	0.22	0.08

Table 31 (con't). Flavor, basic tastes and tenderness descriptive sensory attributes where 0 = none and 15 = extremely intense and Warner-Bratzler shear force (kg) least squares means by cooking treatments for in-home treatments.

Treatment	Rancid	Spoiled Putrid	Juiciness	Muscle Fiber Tenderness	Connective Tissue Amount	Overall Tenderness	Warner-Bratzler Shear Force, kg
P-value	<0.001	0.002	0.001	<0.001	<0.001	<0.001	<0.001
Chicken breasts							
Grill, 145F	0.0[a]	0.0[a]	9.7[ab]	14.3[c]	14.3[e]	13.5[e]	1.7[a]
Grill, 80°C	0.0[a]	0.0[a]	9.4[a]	13.1[b]	13.9[e]	13.1[d]	1.9[a]
Pork loin chop							
Grill, 62.7°C	0.0[a]	0.0[a]	10.2[bc]	11.8[a]	12.7[c]	11.9[c]	2.2[b]
Select bottom round roasts							
Crock-pot®, 58.3°C	0.1[b]	0.1[b]	9.6[a]	11.1[a]	10.6[a]	10.7[a]	2.5[bc]
Choice top loin steak							
Grill, 58.3°C	0.0[a]	0.0[a]	10.6[c]	11.7[a]	12.3[bc]	11.7[bc]	2.3[b]
Grill, 80°C	0.0[a]	0.0[a]	9.2[a]	11.3[a]	12.0[ab]	11.2[ab]	2.8[c]
RMSE	0.06	0.05	1.05	1.97	0.96	0.87	0.61

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

Table 32. Simple correlation coefficients[a] between in-home consumer sensory attributes where 1 = dislike extremely and 9 = like extremely and trained descriptive sensory panel flavor attributes where 0 = none and 15 = extremely intense.

Effects	Raw Appearance liking	Cooked Appearance liking	Overall liking	Overall flavor liking	Juiciness liking	Tenderness liking
Beef identity	0.06	0.05	0.04	0.06	0.02	-0.04
Pork identity	-0.01	-0.06	-0.03	-0.05	-0.06	-0.05
Chicken identity	-0.02	0.03	0.03	0.02	0.10	0.14
Brown/roasted	0.12	0.12	0.18	0.14	0.20	0.14
Bloody/serumy	-0.05	-0.07	-0.10	-0.04	-0.14	-0.14
Fat-like	0.12	0.07	0.11	0.07	0.10	0.04
Metallic	-0.06	-0.08	-0.07	-0.04	-0.11	-0.11
Liver-like	-0.07	-0.10	-0.13	-0.12	-0.18	-0.14
Umami	0.10	0.09	0.11	0.09	0.09	0.03
Sweet	0.10	0.05	0.09	0.07	0.05	0.02
Sour	-0.07	-0.08	-0.08	-0.03	-0.09	-0.08
Salty	0.08	0.05	0.08	0.07	0.09	0.04
Bitter	-0.01	-0.01	0.00	-0.02	0.04	0.08
Overall sweet	0.12	0.09	0.11	0.09	0.09	0.03
Astringent	0.01	-0.02	-0.01	0.00	0.01	0.05
Burnt	0.03	0.02	0.07	0.03	0.10	0.11
Cardboardy	-0.10	-0.08	-0.09	-0.04	-0.05	-0.06
Nutty	0.05	0.03	0.03	0.01	0.04	0.04
Rancid	-0.06	-0.05	-0.08	-0.07	-0.10	-0.09
Spoiled Putrid	-0.05	-0.07	-0.07	-0.07	-0.09	-0.06
Juiciness	0.01	-0.03	-0.01	-0.01	-0.02	-0.02

Muscle fiber tenderness	-0.01	0.03	0.06	0.38	0.08	0.12
Connective tissue amount	0.03	0.05	0.10	0.07	0.13	0.15
Overall tenderness	0.00	0.04	0.08	0.06	0.10	0.15
Warner-Bratzler shear force	0.03	0.01	-0.04	-0.04	-0.02	-0.05

[a] Simple correlation coefficients > 0.13 are significant (*P* < 0.05).

Figure 25. Partial least squares regression biplot (r^2 = 95%) for in-home consumer sensory attributes (•), trained descriptive attributes (◆), and meat source (■).

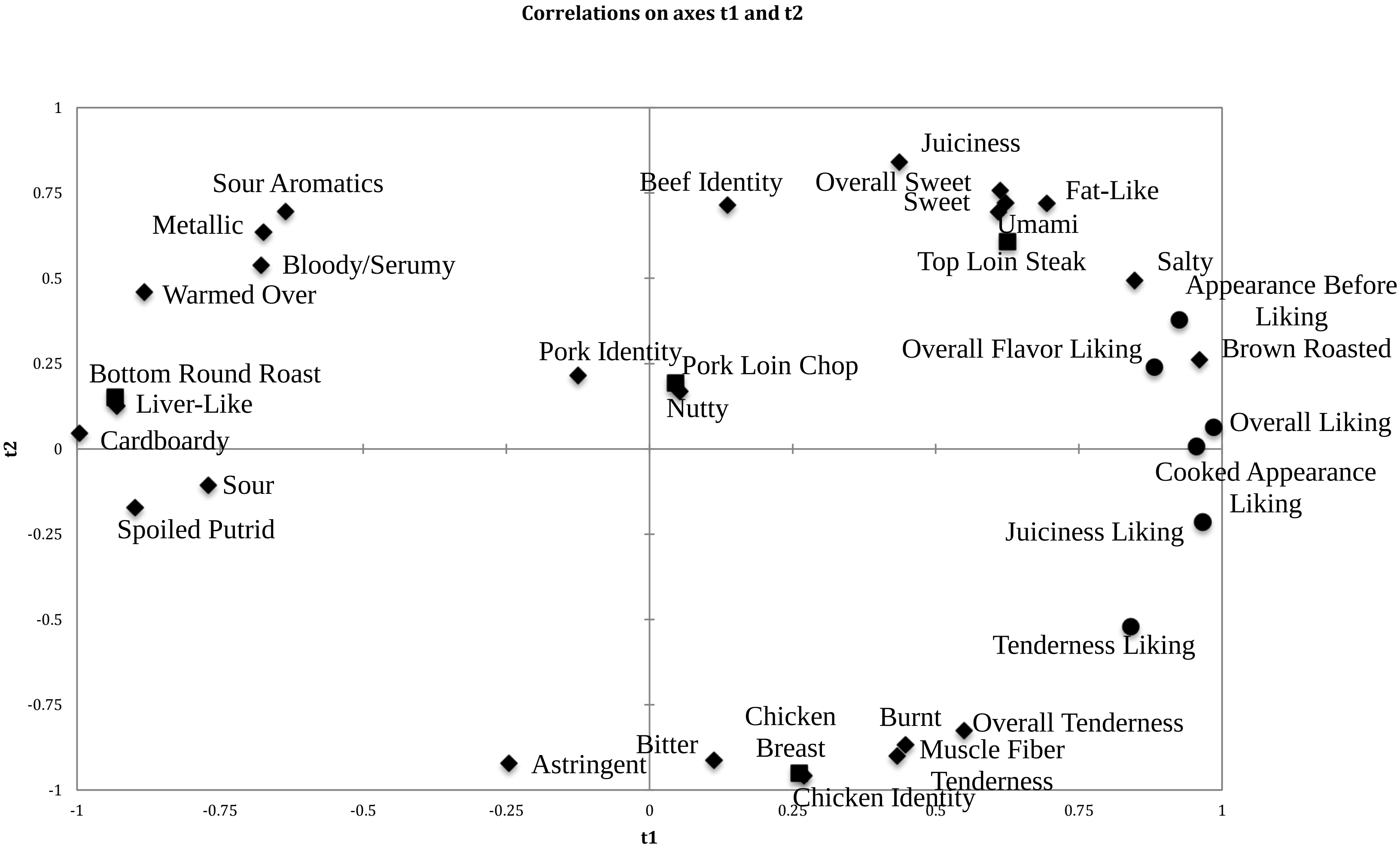


Table 33. Least squares means for chemical components of four meat sources used in-the in-home placement study.

Effect	pH	Non-Heme iron, mg/g	Myoglobin mg/g	Moisture %	Lipid %
p-value	<0.001	<0.001	<0.001	<0.001	<0.001
Chicken breasts	5.9^{c}	3.6^{c}	1.1^{a}	74.6^{c}	1.8^{a}
Pork loin chops	5.8^{c}	3.1^{b}	1.6^{b}	74.3^{c}	2.9^{b}
Select bottom round roasts	5.5^{b}	2.8^{b}	2.4^{c}	73.6^{b}	2.5^{b}
Choice top loin steak	5.3^{a}	2.3^{a}	2.2^{c}	69.8^{a}	7.2^{c}
RMSE	0.27	0.81	0.70	1.43	1.11

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

Table 34. Least squares means for fatty acid components of four meat sources used in an in-home placement study.

Effect	14:0	16:0	16:1	18:0	18:1	18:1 trans	18:2	18:3	20:4
p-value	<0.001	<0.001	<0.001	<0.001	0.009	<0.001	<0.001	0.001	<0.001
Chicken breasts	0.6^{a}	25.0^{b}	4.5^{c}	7.7^{a}	36.2^{a}	2.1^{b}	14.9^{d}	0.6^{b}	2.7^{c}
Pork loin chops	1.7^{b}	23.9^{a}	2.9^{a}	11.0^{b}	39.3^{c}	2.9^{c}	11.8^{c}	0.2^{a}	1.2^{b}
Select bottom round roasts	2.6^{c}	23.9^{a}	3.6^{b}	11.2^{b}	37.2^{ab}	2.1^{b}	6.4^{b}	0.2^{a}	1.5^{b}
Choice top loin steak	3.2^{d}	27.7^{c}	3.2^{ab}	12.6^{c}	38.6^{bc}	1.3^{a}	3.1^{a}	0.2^{a}	0.5^{a}
RMSE	0.86	1.71	0.88	1.65	3.56	0.73	2.87	0.26	0.49

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

Table 35. Simple correlation coefficients[a] between chemical measures and trained descriptive sensory panel flavor attributes where 0 = none and 15 = extremely intense for in-home treatments.

Descriptive Flavor Attributes	pH	Non Heme-iron mg/g	Myoglobin mg/g	Moisture %	Lipid %	14:0	16:0	16:1	18:0	18:1	18:1 trans	18:2	18:3	20:4
Beef identity	-0.61	-0.44	0.48	-0.70	0.72	0.69	0.15	-0.22	0.56	0.09	-0.48	-0.79	-0.28	-0.64
Pork identity	0.23	0.09	-0.13	0.29	-0.20	-0.09	-0.06	-0.24	0.05	0.19	0.49	-0.22	-0.22	-0.13
Chicken identity	0.40	0.39	-0.48	0.28	-0.44	-0.65	-0.06	0.41	-0.64	-0.25	0.05	0.65	0.46	0.72
Brown/roasted	-0.21	-0.12	-0.11	-0.41	0.55	0.11	0.09	-0.08	0.10	0.13	-0.26	-0.13	-0.05	-0.33
Bloody/serumy	-0.28	-0.26	0.44	-0.21	0.20	0.44	0.03	-0.11	0.36	0.11	-0.12	-0.52	-0.24	-0.36
Fat-like	-0.37	-0.28	0.13	-0.55	0.68	0.41	0.07	-0.26	0.40	0.18	-0.21	-0.39	-0.24	-0.54
Metallic	-0.23	-0.21	0.41	-0.14	0.16	0.38	0.01	-0.16	0.34	-0.03	-0.08	-0.37	-0.18	-0.32
Liver-like	-0.06	-0.01	0.32	0.00	-0.11	0.16	-0.03	-0.02	0.15	-0.11	0.04	-0.16	-0.21	-0.12
Umami	-0.49	-0.37	0.19	-0.69	0.84	0.51	0.16	-0.25	0.46	0.18	-0.40	-0.57	-0.21	-0.60
Sweet	-0.21	-0.27	0.10	-0.31	0.41	0.29	0.15	-0.18	0.27	0.03	-0.25	-0.36	0.01	-0.35
Sour	-0.05	-0.32	0.15	0.10	-0.17	0.01	0.01	0.19	-0.06	-0.03	-0.04	-0.06	-0.05	-0.24
Salty	-0.19	0.02	0.11	-0.42	0.55	0.17	0.09	-0.05	0.15	0.19	-0.29	-0.22	0.18	-0.35
Bitter	0.15	0.13	0.15	0.31	-0.26	-0.21	0.02	0.21	-0.31	-0.22	-0.07	0.24	0.23	0.38
Overall sweet	-0.40	-0.27	0.09	-0.53	0.69	0.49	0.20	-0.22	0.40	0.11	-0.32	-0.51	-0.19	-0.58
Astringent	0.11	0.17	-0.16	0.28	-0.28	-0.08	0.02	0.25	-0.31	-0.22	0.00	0.19	-0.04	0.36
Burnt	0.20	0.20	-0.31	0.26	-0.27	-0.35	-0.04	-0.26	-0.31	-0.28	-0.03	0.30	0.30	0.40
Cardboardy	0.09	0.00	0.32	0.13	-0.20	0.06	-0.06	-0.06	-0.34	-0.12	0.06	-0.08	-0.11	-0.01
Nutty	0.11	0.10	-0.16	0.18	-0.03	-0.05	-0.03	-0.16	0.08	0.04	0.28	0.12	-0.08	0.12
Rancid	-0.07	0.12	0.13	-0.10	-0.08	0.09	-0.02	0.01	0.09	-0.14	-0.05	-0.07	-0.04	0.08
Spoiled Putrid	-0.09	0.00	0.17	-0.04	-0.08	0.14	-0.03	-0.05	0.12	-0.19	0.01	-0.13	0.00	0.00
Juiciness	-0.06	-0.05	0.15	-0.09	0.12	-0.13	0.10	-0.07	0.06	0.12	0.16	0.07	0.06	-0.03
Muscle fiber tenderness	0.15	0.17	-0.25	0.16	-0.17	-0.29	-0.06	0.13	-0.28	-0.16	-0.05	0.33	0.18	0.33

Connective tissue amount	0.26	0.23	-0.51	0.22	-0.22	-0.50	-0.01	0.23	-0.48	-0.18	-0.03	0.56	0.41	0.50
Overall tenderness	0.25	0.23	-0.44	-0.49	-0.20	-0.49	-0.09	0.30	-0.51	-0.21	-0.05	0.55	0.43	0.50
Warner-Bratzler shear force	-0.21	-0.10	0.38	-0.26	0.22	0.29	0.01	-0.19	0.35	0.06	-0.08	-0.35	-0.31	0.28

[a] Simple correlation coefficients > 0.15 are significant (*P* < 0.05).

Table 36. Simple correlation coefficients[a] between chemical measures and consumer sensory attributes where 1 = dislike extremely and 9 = like extremely for in-home treatments.

Effects	Raw Appearance liking	Cooked Appearance liking	Overall liking	Overall flavor liking	Juiciness liking	Tenderness liking
pH	0.02	-0.02	-0.02	-0.01	0.04	0.04
Non-heme iron, mg/g	0.05	-0.01	0.00	0.00	0.05	0.05
Myoglobin, mg/g	-0.04	-0.05	-0.11	-0.07	-0.09	-0.13
Moisture, %	0.01	-0.04	-0.05	-0.01	-0.01	-0.01
Lipid, %	0.04	0.05	0.07	0.04	0.06	0.03
14:0	0.03	0.01	0.02	0.02	-0.02	-0.04
16:0	0.02	0.01	0.02	0.01	0.02	0.04
16:1	-0.00	-0.02	0.02	0.02	0.01	0.01
18:0	-0.01	-0.02	-0.04	-0.05	-0.07	-0.08
18:1	-0.04	-0.02	-0.01	-0.02	-0.03	-0.05
18:1trans	0.02	-0.04	-0.06	-0.05	-0.04	-0.08
18:2	0.03	0.03	0.01	0.01	0.01	0.10
18:3	0.07	0.06	0.08	0.10	0.10	0.13
20:4	-0.03	-0.01	-0.04	-0.02	0.00	0.04

[a]Simple correlation coefficients > 0.15 are significant ($P < 0.05$).

Table 37. Stepwise linear regression for prediction of in-home consumer overall liking where 1 = dislike extremely and 9 = like extremely as the dependent variable and chemical data as independent variables.

Step	Variables	Estimate[a]	Partial r^2	Equation[c] r^2
	Intercept	6.52		
1	14:0	-0.26	0.03	0.03
2	18:1	0.03	0.01	0.04

[a]Estimates are the □-values for the final regression equation when the defined variable was include

Figure 26. Partial least squares regression biplot ($r^2 = 0.95$) of in-home consumer sensory attributes (•), meat source (■), trained descriptive sensory attributes (◆), and raw chemical components (▲).

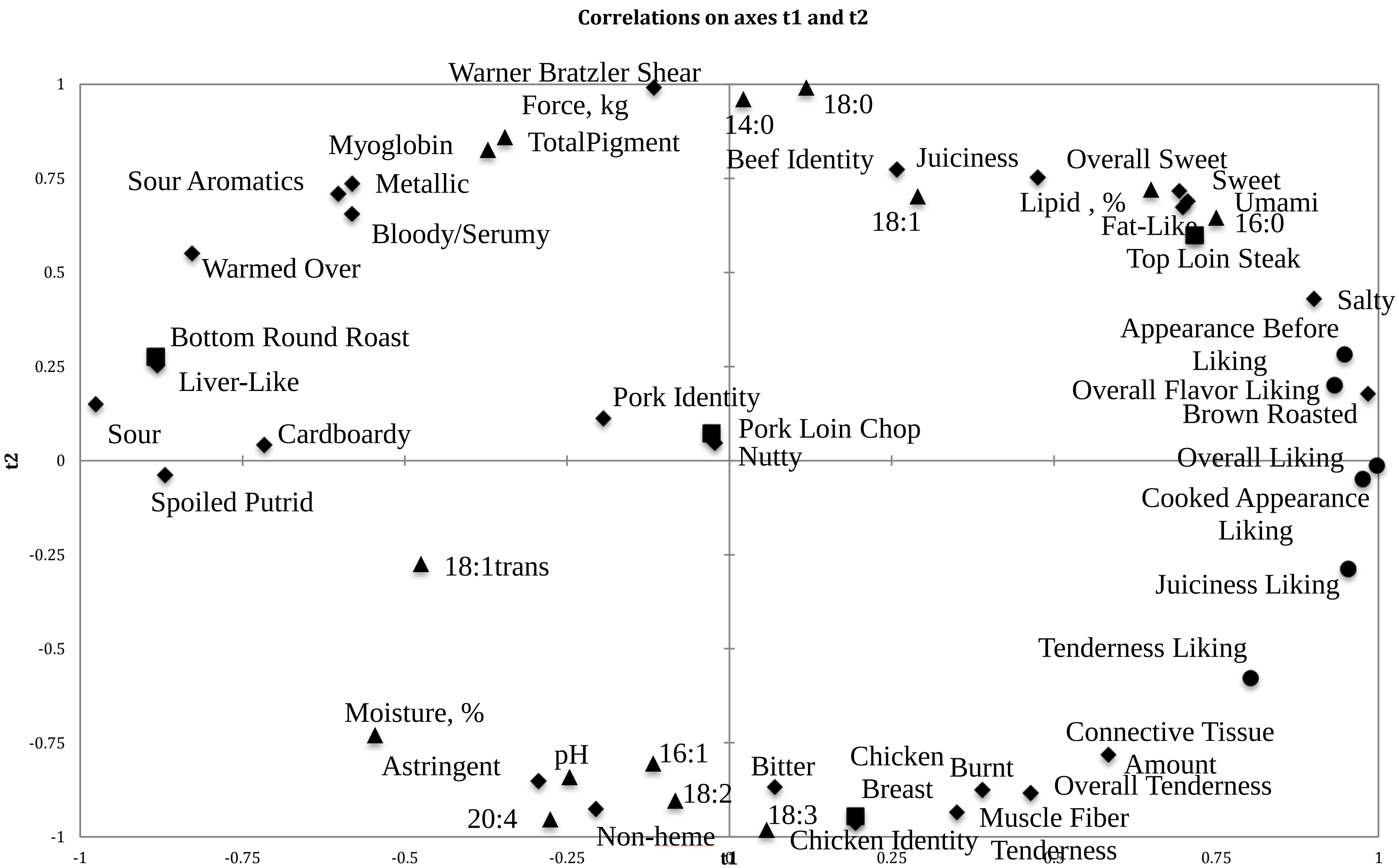
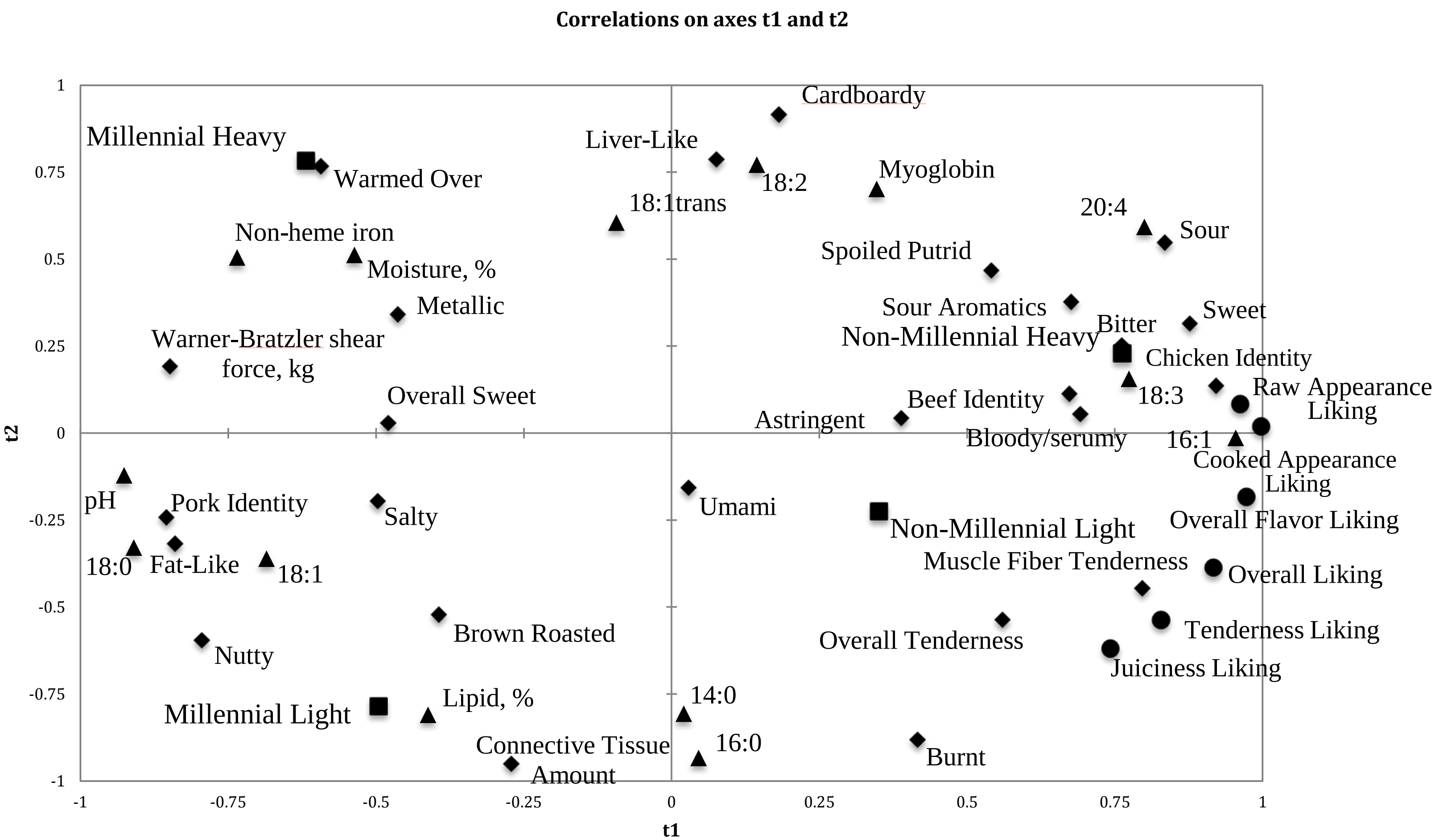


Figure 27. Partial least squares regression biplot (r^2 = 0.97) of in-home consumer sensory attributes (•), consumer treatment (■), trained descriptive sensory attributes (◆), and raw chemical components (▲).



APPENDIX II

REFERENCE MATIERAL

Appendix A. Percentage of in-home consumer responses to preparation information by city.

	Millennial, Light Beef Eaters	Millennial, Heavy Beef Eaters	Non-millennial Light Beef Eaters	Non-millennial Heavy Beef Eaters
How did you thaw the meat?				
Placed in refrigerator day before	64.8	73.0	67.6	66.1
Placed in refrigerator same day	13.5	10.4	9.6	16.1
In microwave	8.3	6.6	8.3	3.0
At room temperature	5.9	2.3	7.4	13.6
Under cold water	7.2	9.0	8.3	4.2
Under hot water	6.9	6.1	1.2	2.1
Cooked frozen	1.4	1.9	0.0	3.8
Which of these, if any, did you do to the meat before cooking?				
Cut it into small pieces	11.3	10.0	6.8	6.7
Cut it into large chucks	8.2	7.1	5.9	6.7
Cut into slices/strips	10.0	11.4	10.2	7.6
Pound it to flatten it	3.8	3.8	5.6	3.4
Use a fork or other utensils to pierce the surface	7.6	8.5	9.0	8.4
Grind it	0.0	0.0	0.0	0.0
None of these	62.9	63	65.1	71.4

What was added to the beef, pork or chicken, if anything, as it was prepared or cooked?				
Salt	61.6	65.9	56.2	59.9
Pepper	55.6	61.1	50.8	60.4
Spices/herbs, such as garlic, oregano	52.1	58.8	49.2	56.4
Tenderizer such as Adolph's	5.3	2.4	5.0	5.7
Marinade	11.6	18.0	13.6	10.6
Flour or crumbs to top and/or bottom	5.3	6.6	4.4	4.0
Sauces, such as soy, BBQ, etc.	19.7	15.6	16.7	11.0
Other	12.7	17.6	13.9	15.4
How did you cook the meat?				
Outdoor grill	17.7	16.9	22.3	22.4
Broil	4.8	3.4	10.7	10.0
Indoor grill	6.5	6.3	6.1	9.5
Oven roast uncovered	15.7	16.4	16.2	13.3
Pan broil	3.1	6.8	2.7	3.3
Pan fry/sauté	25.9	30.6	16.8	18.7
Stir fry	6.8	4.8	8.2	3.3
Braise	5.8	4.3	3.4	4.1
Simmer and stew	7.2	4.3	6.4	6.3
Deep fry	0.0	0.1	0.0	0.1
Other	9.9	9.2	9.5	10.7
What was the degree of doneness for the meat when you ate it?				
Very rare	0.0	1.4	0.0	0.0
Rare	0.1	1.4	1.5	3.3
Medium rare	6.8	12.0	12.2	10.0
Medium	26.6	23.4	26.2	30.5
Well done	50.2	47.4	49.4	45.2

Very well	15.0	14.4	10.4	10.9
Was this meat the main course of the plate, was it combined with other ingredients as the main course or was it a side dish?				
Main course on plate	70.9	67.9	73.5	82.0
Combined with other ingredients	26.7	23.1	20.8	16.4
Side dish	1.7	4.7	4.5	0.1
Which of these did you add to the meal at the table before you ate?				
Nothing: ate it plain	32.8	36.4	36.9	35.8
Nothing: it was cooked in sauce	4.3	23.9	11.9	10.8
Salt	25.6	22.5	30.2	24.2
Pepper	22.5	18.7	24.8	29.2
Other dry ingredients	16.0	7.7	14.0	7.9
Ketchup	2.1	1.9	2.7	3.8
Other sauces (soy or BBQ sauce, A-1, etc.)	19.5	14.4	20.7	9.6
Other	9.8	10.0	10.7	10.8
Other				

Appendix B. Percentage of in-home consumer responses to preparation information by city.

	Griffin, GA	Olathe, KS	State College, PA	Portland, OR
How did you thaw the meat?				
Placed in refrigerator day before	47.0	76.3	67.6	73.7
Placed in refrigerator same day	23.3	9.3	9.6	8.0
In microwave	10.4	3.9	8.3	8.4
At room temperature	7.5	7.8	7.4	4.8
Under cold water	1.0	6.6	8.3	4.8
Under hot water	6.8	3.1	1.2	4.0
Cooked frozen	3.2	7.8	0.0	2.0
Which of these, if any, did you do to the meat before cooking?				
Cut it into small pieces	13.3	6.6	5.6	8.1
Cut it into large chucks	7.8	6.2	6.0	7.7
Cut into slices/strips	13.0	8.9	8.4	8.1
Pound it to flatten it	3.9	5.1	4.4	3.6
Use a fork or other utensils to pierce the surface	1.0	4.3	9.6	8.1
Grind it	0.0	0.0	0.0	0.0
None of these	56.5	72.0	69.3	66.1
What was added to the beef, pork or chicken, if anything, as it was prepared or cooked?				
Salt	59.1	50.8	63.5	69.2
Pepper	54.5	48	60.7	62.9
Spices/herbs, such as garlic, oregano	54.5	56.3	43.0	60.0
Tenderizer such as Adolph's	3.3	1.8	0.1	1.3
Marinade	17.6	13.4	9.4	1.7

Flour or crumbs to top and/or bottom	4.7	4.7	8.2	2.5
Sauces, such as soy, BBQ, etc.	20.6	9.8	17.2	5.8
Other	15.6	12.2	14.3	15.8
How did you cook the meat?				
Outdoor grill	23.7	17.4	18.3	20.0
Broil	6.3	9.3	7.5	7.1
Indoor grill	6.6	9.7	4.4	7.5
Oven roast uncovered	16.8	11.2	21.4	12.2
Pan broil	4.9	3.5	3.6	2.7
Pan fry/sauté	18.2	22.9	21.0	28.2
Stir fry	7.2	3.9	6.7	6.3
Braise	4.9	4.7	4.7	3.1
Simmer and stew	4.3	7.8	7.1	5.9
Deep fry	1.2	0.0	0.0	0.0
Other	0.0	11.2	9.9	9.8
What was the degree of doneness for the meat when you ate it?				
Very rare	0.7	0.8	0.0	0.4
Rare	0.7	2.7	2.0	1.6
Medium rare	5.5	8.6	6.8	20.8
Medium	16.2	30.5	34.8	7.8
Well done	58.1	49.6	44.4	39.2
Very well	18.8	7.8	12.0	10.2
Was this meat the main course of the plate, was it combined with other ingredients as the main course or was it a side dish?				
Main course on plate	67.8	77.6	79.0	76.4
Combined with other ingredients	26.7	20.4	21.0	20.2
Side dish	5.9	2.0	0.0	3.5

Which of these did you add to the meal at the table before you ate?				
Nothing: ate it plain	33.4	43.0	36.4	29.2
Nothing: it was cooked in sauce	15.1	12.8	6.8	14.0
Salt	30.8	16.7	29.2	36.2
Pepper	25.7	13.6	23.6	32.7
Other dry ingredients	15.1	10.5	10.4	0.6
Ketchup	4.9	4.3	0.0	1.6
Other sauces (soy or BBQ sauce, A-1, etc.)	17.7	4.3	16.8	17.9
Other	11.1	14.0	8.8	12.5

Appendix C. Demographic questions included on the consumer ballot.

Please circle each appropriate response.

1. Please indicate your gender.
   Male Female
2. Which of the following best describes your age?
   20 years or younger
   21 - 25 years
   26 - 35 years
   36 - 45 years
   46 - 55 years
   56 - 65 years
   66 years and older
3. Please specify your ethnicity.
   African-American
   Asian/Pacific Islanders
   Caucasian (non-Hispanic)
   Latino or Hispanic
   Native American
   Other
4. Which of the following best describes your household income?
   Below $25,000
   $25,001 - $49,999
   $50,000 - $74,999
   $75,000 - $99,999
   $100,000 or more
5. How many people live in your household including yourself?
   1 2 3 4 5 6 or more
6. Please indicate your employment level.
   Not employed Part-time Full-time
7. Please circle any of the following proteins that you eat either at home or at a restaurant (away from home).

At Home	Away from Home/Restaurant
Chicken	Chicken
Beef	Beef
Pork	Pork
Fish	Fish
Lamb	Lamb
Eggs	Eggs
Soy Based Products	Soy Based Products

8. How many times a week total do you consume the following protein sources?

Beef	0	1-2	3-4	5-6	7 or more
Pork	0	1-2	3-4	5-6	7 or more
Lamb	0	1-2	3-4	5-6	7 or more
Chicken	0	1-2	3-4	5-6	7 or more
Fish	0	1-2	3-4	5-6	7 or more
Soy Based Products	0	1-2	3-4	5-6	7 or more

9. What cooking method do you prefer to use when cooking a beef steak? Circle any that apply.
   Pan-frying or using a skillet on the stove
   Grilling Outside
   Stir Fry
   Oven Broiling

Oven Baking Microwave
Electric Appliance (George Foreman Grill or other electric grill)

10. What cooking method do you prefer to use when cooking chicken? Circle any that apply.
    Pan-frying or using a skillet on the stove Stir Fry
    Grilling Outside Oven Broiling
    Oven Baking Microwave
    Electric Appliance (George Foreman Grill or other electric grill)
11. What cooking method do you prefer to use when cooking pork? Circle any that apply.
    Pan-frying or using a skillet on the stove Stir Fry
    Grilling Outside Oven Broiling
    Oven Baking Microwave
    Electric Appliance (George Foreman Grill or other electric grill)
12. What degree of doneness to you prefer your steak to be cooked to?
    Rare Medium Rare Medium Medium Well Well Very Well
13. When purchasing beef, what do you typically tend to buy at the retail store?
    Grass Fed Dry Aged Organic Traditional beef at the retail store
14. What flavor or types of cuisines do you like, please circle all that apply?
    American Barbeque Mexican/Spanish Indian
    Chinese Greek Japanese Italian
    French Thai Lebanese

Appendix D. Consumer ballot.

Respondent Number _____ Group Time_____
Sample Number________ Date___________

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

1. How much do you like or dislike this steak OVERALL?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — Neither Like or Dislike — Like Extremely

2. How much do you like or dislike of the OVERALL FLAVOR of this steak?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — Neither Like or Dislike — Like Extremely

3. How much do you like or dislike of the BEEFY FLAVOR of this steak?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — Neither Like or Dislike — Like Extremely

4. How much do you like or dislike of the GRILLED FLAVOR of this steak?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — Neither Like or Dislike — Like Extremely

5. How much do you like or dislike of the JUICINESS of this steak?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — Neither Like or Dislike — Like Extremely

6. How much do you like or dislike of the TENDERNESS of this steak?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — Neither Like or Dislike — Like Extremely

7. Please write any words that describe the POSITIVE or GOOD FLAVORS in this beef steak.

____

8. Please write any words that describe the NEGATIVE or BAD FLAVORS in this beef steak.

____

Appendix E. One-on-one interview questions

Reflection:
In the experience that you just had: Can you describe the meat that you like the best and why?
What were the good flavors?
What were the bad flavors?
Can you describe the meat that you liked the least and why?
What were the good flavors?
What were the bad flavors?

Beef: Think of the perfect raw steak in your mind.
Describe the raw appearance of that steak.
Describe the appearance of that steak after it is cooked.
What cut of meat would it be?
What are the most important characteristics in that steak for you?

Chicken: Think of the perfect raw chicken in your mind.
Describe the raw appearance of the chicken.
Describe the appearance of the chicken after it is cooked.
What cut of meat would it be?
What are the most important characteristics in chicken for you?

Pork: Think of the perfect raw pork in your mind.
Describe the raw appearance of the pork.
Describe the appearance of the pork after it is cooked.
What cut of meat would it be?
What are the most important characteristics in pork for you?

Purchasing Decisions:
What factors affect how often you eat or purchase beef?
What factors affect how often you eat or purchase chicken?
What factors affect how often you eat or purchase pork?
When you approach the meat case to purchase meat, what are you thinking, what is important to you?
What were your thoughts in regards to what meat to buy?
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.)
Is there any time that you do not select chicken and why?
Is there any time that you do not select pork and why?

Steak Preparation:

Are you familiar with Quality Grades of beef?

If you were to purchase any steak 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 beef when you cook it?

What seasonings do you typically add to chicken when you cook it?

What seasonings do you typically add to pork when you cook it?

Appendix F. In-home consumer ballot.

Instructions for Study Participants

Thank you for taking part in this important study. Your participation and opinions are valuable. Please read this page carefully. This package should contain 4 ballots, a stamped return envelope, and 2 degree of doneness charts. Call Hannah Laird at 979/845-3993 if you have any questions.

A. How to Handle the Meat

   1. Storage: Meat is perishable! Proper refrigerator and freezer storage is essential to maintain its quality and safety. Immediately place the beef in the freezer when you receive it. When you receive the meat it will already be vacuum packaged and frozen.

   2. Thawing: The best way to thaw meat is in the refrigerator, never at room temperature. A microwave oven also can be used for defrosting.

B. How to Prepare the Meat

   1. Please cook the samples in the order that is on the ballots and samples. The order number is located at the top of the ballot sheet and also the number is on the colored dot on your sample.

   2. Please cook the meat as you normally would.

C. How to Fill Out the Ballots

   1. Each ballot is the same color as the color dot placed on the meat. Please make sure you are filling out the correct ballot for each piece of meat. The front page of the ballot is about the preparation of the sample and the back page has questions for you while eating the sample.

D. Return

   1. Make sure you return 4 ballots in the stamped, self-addressed envelope and your return address. After we receive your 4 completed ballots, we will immediately send you a $20 gift card in return for your efforts.

Thank you so much for your participation. Please begin by answering the following questions about how you prepared the meat.

1. How did you thaw the meat? (Please select as many as apply)

☐ Placed in refrigerator day before	☐ Under cold water
☐ Placed in refrigerator same day	☐ Under hot water
☐ In microwave	☐ Cooked frozen
☐ At room temperature	

2. How much do you like or dislike the appearance of the sample before cooking?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely	Neither Like or Dislike	Like Extremely

3. Which of these, if any, did you do to the meat before cooking?

- ☐ Cut it into small pieces
- ☐ Cut it into large chunks
- ☐ Cut into slices/strips
- ☐ Pound it to flatten it
- ☐ Use a fork or other utensil to pierce the surface
- ☐ Grind it
- ☐ None of these

4. What was added to the beef, if anything, as it was prepared or cooked? (Please select as many as apply)

- ☐ Salt
- ☐ Pepper
- ☐ Spices/herbs, such as garlic, oregano
- ☐ Tenderizer such as Adolph's
- ☐ Marinade
- ☐ Flour or crumbs to top and/or bottom
- ☐ Sauces, such as soy, BBQ, etc.
- ☐ Other (Explain)

Please look at the meat before you eat & answer question 5. Now eat the meat & answer questions 6 to 15.

5. How much do you like or dislike the COOKED APPEARANCE of this meat?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — Neither Like or Dislike — Like Extremely

6. How much do you like or dislike this meat OVERALL?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — Neither Like or Dislike — Like Extremely

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

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — Neither Like or Dislike — Like Extremely

8. How much do you like or dislike of the JUICINESS of this meat?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — Neither Like or Dislike — Like Extremely

9. How much do you like or dislike of the TENDERNESS of this meat?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — Neither Like or Dislike — Like Extremely

10. Please write any words that describe the POSITIVE or GOOD FLAVORS in this meat.

____

11. Please write any words that describe the NEGATIVE or BAD FLAVORS in this meat.

____

12. How did you cook the meat? (See attached sheet for definitions)

- ☐ Outdoor grill
- ☐ Broil
- ☐ Indoor grill
- ☐ Oven roast uncovered
- ☐ Panbroil
- ☐ Pan/fry/sauté
- ☐ Stir fry
- ☐ Braise
- ☐ Simmer and stew
- ☐ Deep fry
- ☐ Other (Explain) ____________

13. What was the degree of doneness for the meat when you ate it? (Chart in the packet)

Very Rare Rare Medium Rare Medium Well Done Very Well

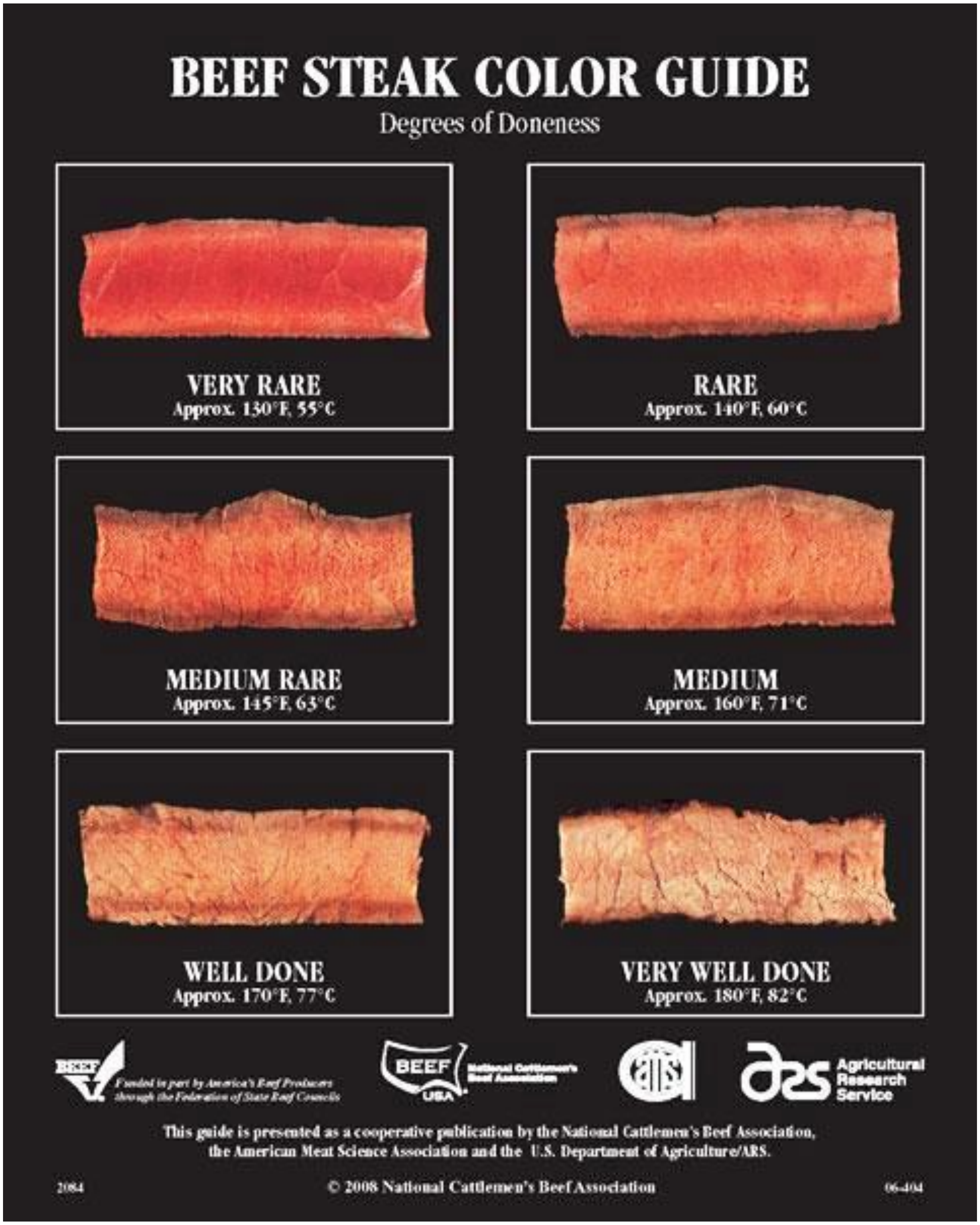
14. Was this meat the main course on the plate, was it combined with other ingredients as the main course or was it a side dish? (Please check just one)

- ☐ Main course on plate
- ☐ Combined with other ingredients
- ☐ Side dish

15. Which of these did you add to the meat at the table before you ate? (Select as many as apply)

- ☐ Nothing: ate it plain
- ☐ Nothing: it was cooked in sauce
- ☐ Salt
- ☐ Pepper
- ☐ Other dry seasonings
- ☐ Ketchup
- ☐ Other sauces (soy or BBQ sauce, A-1, etc)
- ☐ Other (Explain)

Appendix G. AMSA beef steak color guide.



Appendix H. Pork chop cooked color guide.

Pork Chop Cooked Color Guide

63°C (145°F), 3 minutes

66°C (150°F), 1 minute

71°C (160°F), 1 second

77°C (170°F), 1 second

Shown above are chops from loins that were typical in color, pH (5.6–5.8), and exudativeness cooked from the thawed state to four safe endpoint time/temperature combinations (FDA Food Code). Chops cooked to the lower endpoint temperatures will be slightly pink but will be more juicy, tender, and flavorful than chops cooked to 77°C or higher. Chops enhanced with a phosphate-salt solution had similar cooked colors of non-enhanced chops.

Raw Loin Quality Traits Pale, Soft, and Exudative (PSE)

71°C (160°F), 1 second

Raw Loin Quality Traits Dark, Firm, and Dry (DFD)

71°C (160°F), 1 second

Chops can vary in internal cooked color depending on pork quality, pigment color, and other factors. These chops show the color range in the chop interior, PSE chops (pH 5.3) are less pink and DFD chops (pH 6.6) are darker pink than normal chops, when cooked to a medium degree of doneness (71°C).

Take the guesswork out of grilling.

S. A. Hawthorne, R. Lien, M. C. Hunt, and D. H. Kropf, Department of Animal Sciences and Industry, Kansas State University, Weber Hall, Manhattan, Kansas 66506

Published by K-State Research and Extension in cooperation with the National Pork Producers Council and National Pork Board, P.O. Box 10383, Des Moines, Iowa 50306

Appendix I. Cooking method definitions

Outdoor grill: cooked on a grid or rack over coals, gas or wood)
Broil (Use the oven broiler)
Indoor grill (cooked indoors on range top or new appliances with dry heat)
Oven roast uncovered (cooked with dry heat in the oven and not covered)
Panbroil (to cook uncovered and ungreased in a skillet)
Pan/fry/sauté (oil is added to the pan prior to cooking)
Stir fry (similar to pan-frying but meat is stirred continuously)
Braise (meat is browned, moisture is added and cooked covered)
Simmer and stew (meat is cut into small pieces, browned, moisture added, covered, and simmered on low heat)
Deep fry (covered with egg/batter and crumbs and immersed in hot oil)
Other (Explain) ____
