BEEF FLAVOR AUDIT

A Thesis

by

CASSANDRA ANN PENA

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Chair of Committee	Rhonda K. Miller
Committee Member	Christopher R. Kerth
	Luis Cisneros-Zevallos
Head of Department	Cliff G. Lamb

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ABSTRACT

Consumer acceptability in meat flavor is one of the driving factors of consumer acceptability. Many factors have been found that affect beef flavor, but little is known about variability of major beef cuts in the retail meat case. In this study four beef cuts (chuck roast = 50, top sirloin steaks = 49, top loin steaks =50, and 80% lean ground beef = 50) were obtained from various retail stores in Miami, Los Angeles, Portland, New York, and Denver during a two-month period. No specific requirements such as quality grade, grain fed, or grass fed were used when purchasing cuts except ground beef was standardize to a 20 % fat level. A wide variety of samples that were from different production systems or contained claims that would be available to a customer during a shopping trip were documented. Two types of cooking methods were utilized; food service grill for top loin, top sirloin, and ground beef and oven roasting for chuck roast. Beef was cooked to an internal temperature of 71˚C.

An expert, trained descriptive flavor and texture sensory panel evaluated beef flavor, aroma and texture attributes. Principal component and partial least square biplots were conducted to relate flavor attributes and aromatic volatile compounds. Ground beef was more intense (*P* <0.0001) in brown, fat-like, green hay, and sour milk/sour dairy flavor aromatics; and salty and sweet basic tastes. Additionally, ground beef patties had the lowest levels (*P*<0.0001) of bloody/serumy, metallic, and liver-like flavor aromatics. Chuck roasts had the lowest (*P*< 0.0001) levels of beef flavor identity, brown, and roasted flavor aromatic and salt and umami basic tastes. Chuck roasts were closely associated with volatile compounds such as hexanal, 1-pentanol, 1-octen-3-ol, and 2-octenal, lipid degradation products. Top sirloin steaks were lowest (*P*< 0.0001) in fat- like flavor aromatics, and more intense (*P*< 0.0001) in burnt and cardboardy flavor aromatics and bitter and sour basic tastes. Top sirloin steaks and chuck roasts were more intense in metallic and liver-like (*P* < 0.0001) flavor aromatics. Top sirloin steaks were clustered near thiobis methane, ethyl ester acetic acid, and methyl ester butanoic acid. Top loin steaks were intermediate in flavor attributes, but possessed volatile products found from the Maillard reaction. Chuck roasts were closely associated with bloody/serumy flavor aromatics. Ground beef patties were clustered with fat-like, overall sweet, green hay, and buttery flavor aromatics. Top sirloin steaks were more highly associated with off-flavors, such as liver-like, cardboardy, and sour flavor aromatics. Top loin steaks were clustered with more positive attributes such as umami, beef flavor identity, brown, and roasted flavor aromatics. Therefore, flavor descriptive attributes of four beef cuts differed. Chuck roasts and top sirloin steaks were more closely associated with negative flavor attributes. Ground beef tended to contain more of the sweet, fat-like flavor attributes. Volatiles clustered around ground beef helped to explain the presence of green hay like flavor. Top loin steaks were associated with more positive beef flavor attributes.

DEDICATION

To my wonderful family members and friends, you know who are you

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CHAPTER I

INTRODUCTION

Once tenderness reaches an acceptable level, flavor is the driving factor for consumer preference (Huffman et al., 1996; Shahidi, 1994, Maughan et al., 2012; Glasscock, 2014, Lukemeyer, 2015, Laird, 2015). Locomotive and non-locomotive muscles have been found to effect tenderness (Henderson, 2016). Cooking methods and marination have been used to improve tenderness of tough cuts. There has been a shift to understanding the impact of degrees of doneness, cooking methods, and volatile aromatic compound development on beef flavor. Use of the beef flavor lexicon has helped to identify beef flavor attributes and their intensities (Adhikari et al., 2011). Consumer panels, such as central location test and home use test, in combination with expert trained panels provided greater insight into consumer preferences and how beef is cooked and consumed at home (Laird, 2015; Glascock, 2014).

By purchasing these cuts of meat in five cities (Denver CO, New York City NY, Portland OR, Miami FL, and Los Angeles, CA) across the United States, it understanding what flavors components are found in beef in the retail meat case, and how those components vary within meat. Cooking methods that mimic typical consumer in-home preparation would cook or foodservice cooking. A stove top grill for top loin steaks, top sirloin steaks, and 80% lean ground beef, and oven roast for chuck roasts were used. Ardeshiri et al. (2019) found that consumers purchased specific cuts during different times of the year. Roasts were primarily purchased during the winter months while steaks were purchased during the summer for grilling. Chuck roasts traditionally are cooked with moisture for a long period of time to allow for collagen break down. Final internal temperature of 71˚C was used for all beef cuts to ensure development of aromatic volatiles and flavors that came from non-enzymatic browning in the Maillard reaction and lipid heat degradation. An expert trained descriptive panel was utilized to identify flavor and aroma attributes present. This study was designed in order to generate a better understanding of what flavors are present in four different cuts found in the retail case which are chuck roasts, top loin steaks, top sirloin steaks, and 80/20 ground beef. With consumer studies, REIMS, and gas chromatography/mass spectrometry being done at Texas Tech and Colorado State University there will be a greater understanding on not only how consumers perceive flavor and preferences in these four cuts but also the flavor and aroma volatiles present and how it has affected the flavor perceived.

CHAPTER II

LITERATURE REVIEW

Flavor and Smell Perception

Perception is the understanding via visual, flavor, or taste senses and/or mind which is formed through things such as learning and experiences which have a tremendous impact on how or what we eat (Troy et al., 2010). Flavor perception is a deciding factor on whether or not a consumer rejects or accepts a certain type of food (Canon et al., 2018). Flavor is much more than just perceiving flavors on taste buds but rather a complex chemical interaction between olfactory sensations, taste receptors, and signalization to the brain. Beef flavor is not accredited to one specific attribute but really a combination of flavor aromatics, basic taste, feeling factors, and after tastes (Adhikari et al., 2011). The three main sensory system which contributes to flavor perception are known as the gustatory, trigeminal, and olfactory systems (Jelen, 2011).

However, gustatory and olfactory are the two systems used mainly when talking about beef flavor perception. The first step to identifying flavor compounds in meat is by mastication or smell. According to Spence (2015) it has been hypothesized that about 80 to 90 percent of what we perceive as taste comes the nose. Aromatic volatiles go through the nasal cavity and into the olfactory epithelium (Van Ruth et al., 1995). The olfactory epithelium contains three types of cells; basal, supporting, and olfactory receptor neurons. Basal cells help in division of olfactory receptor neurons or other types of cells. Supporting cells produce mucus while the olfactory receptor neurons transmit signals to the brain. Olfactory receptor neurons contain cilia which are bound to olfactory binding proteins; cilia come in contact with volatile molecules it travels through the olfactory receptor neuron (Jelen, 2011). Volatiles travel through the receptor neuron to the orbitofrontal cortex in order to identify compound (Rolls & Baylis, 1994). As for gustation, the tongue contains taste buds along dorsal surface and edge of tongue. Within taste buds are taste receptors that are unique to individual flavor compounds (Jelen, 2011). Flavor compounds are able to dissolve in saliva in order to travel to taste receptors. It has been shown that saliva can increase or decrease the perception of certain flavors (Canon et al., 2018). Once the flavor compounds have bound to taste receptors a single is sent to the orbitofrontal cortex for identification (Rolls & Baylis, 1994; Jelen, 2011).

Flavor Development

Raw meat is considered relatively flavorless with the exception of bloody/serumy flavors (Kerth & Miller, 2015; Shahidi, 1994). Flavor in beef was found to be mostly in the juice of the meat not so much the muscle fibers (Crocker, 1948). The heat-associated reactions with water-soluble and lipid component flavor precursors have been shown to be responsible for beef flavor development. The type of lipid found in meat produces species specific characteristics as well (Mottram and Edwards, 1983). Lipid precursors are mainly are fatty acids, phospholipids, and triglycerides. It has been shown that cattle diets can greatly affect the fatty acid profile which affects the overall flavor. Water soluble products include sugars, amino acids, salts, peptide, and nucleotides (Mottram, 1998). As well, cysteine, sulfur containing amino acids, and/or hydrogen sulfur contribute to meat like flavors (Morton et al., 1960). Water soluble precursors such as acids, salts, and minerals produce sour and salty flavors; 5’-

ribonucleotides help produce umami; 5'-ribonucleotides and peptides produce sour and bitter tastes; reducing sugars produce products such as aldehydes and ketones; tiamin produces heterocyclic aroma compounds (Dashdorj et al., 2015). Lipids can produce aldehydes, ketones, alcohols, and carboxylic acids (Mottram, 1998). These products produced from these precursors help attribute to positive flavor attributes that we find and that make up what we know as beef flavor.

Maillard Reaction

Consumer acceptance of meat is due to the aromas and flavors produced by cooked meat (Van Ba et al., 2012). These flavors that produced couldn't be developed without the help Maillard reaction and lipid thermal degradation. When thinking of the Maillard reaction one usually thinks of the browning of a fruit going old or the nice brown crust on the outside of beef. Browning from the Maillard reaction occurs in two types of ways; either through enzymatic or nonenzymatic browning. Nursten (2005) talks about how there are three reactions within the Maillard reaction; the reaction between a carbonyl compound (reducing sugar) and an amine. The second reaction is caramelization which is where we find the browning and crust formation of meat when placed on a hot surface. Browning happens from the formation of melanoidins during heating (Jousse et al., 2002). The third reaction which Nursten states is closest to an enzymatic reaction which is ascorbic acid oxidation. The Maillard reaction in beef occurs through non enzymatic browning of a carbonyl group (reducing sugar) and an amine group (amino acid, peptide, or protein) as well as caramelization of reducing sugars with the addition of heat (Nursten, 2005). In the initial step condensation of a reducing sugar and amino acid occurs which form N-glycosylamine which is a sugar attached to NR_2 which are known as Amadori products. Sugars can also go through direct degradation and produced carmelization (Jousse et al., 2002). The intermediate stage is where Amadori products are rearrangements which end up releasing amino acid groups and sugars. Dehyrdation and fragmentation occurs in the last stage (Van Ba et al., 2012).

Each step of the Maillard reaction is important to formation of flavor and aroma compounds. During dehydration of glucosamine by deoxyosones the formation of furural, furanone, and diacorbonyls occurs (Morttram, 1998; Hodgen, 2006). Once glucosamine is dehydrated it is rearranged to 1-amino-1-deoxy-2 ketose and rearranged again to form two isomers (Hodge, 1953). During the Maillard reaction another reaction called Strecker degradation occurs where amino acids are decarboxylated and deaminated to form a aldehyde; dicarbonyls form aminoketones and aminoalcohols (Mottram, 1998; Van Ba et al., 2012). When cysteine and systine is present it creates compounds such as sulfides (Mottrram, 1998). These sulfur containing products also produce H_2S and NH_3 compounds (Van Ba et al., 2012).

Major compounds formed during the Maillard reaction are aldehydes, ketones, furans, thiazoles, and pyrrols which lead to browned, roasted, and other meaty flavors (Dashdorj et al., 2015). Sugar dehydration and fragmentation produced furans, pyrones, cyclopentenes, and carbonyl compounds (Jousse et al., 2002). Compounds produced during degradation are hydrocarbons, alcohols, acid, aldehydes, and esters (Dashdorj et al., 2015; Mottram, 1998; Kerth & Miller, 2015). About 2,500 volatiles are produced during Maillard browning however, many of these volatiles have low sensory intensities (Reineccius, 1990). Heterocyclic compounds such as pyrazines and thiazoles are formed due to lipid and Maillard interactions which contain long chain alkyl substituents, nitrogen, and sulfur atoms (Whitfield & Mottram, 1992; Kerth & Miller, 2015).

Lipid Thermal Degradation

Lipid thermal degradation is the deterioration of neutral triglycerides and polar phospholipids due to the instability of energy during cooking (Kerth and Miller, 2015). Lipid degradation is often seen as more important than Maillard reaction and produces hundreds of volatiles (Mottram, 1998; Van Ba et al., 2012). Often times degradation begins at temperatures between 200˚C to 300˚C (Wasserman, 1972). Although lipid degradation aromas and flavors are predominately present in cooked beef once cooking temperatures rise to a certain extent, they are taken over by Maillard reaction compounds (Mottram, 1998). Large amounts of phospholipids are present in meat with what we know as marbling and within the lean tissue of meat (Mottram, 1998). Within phospholipids are made up of primarily unsaturated fatty acids. Fatty acids 18:2n-6 and 18: 3n-3 are present in high amounts in the muscle of cattle (Wood et al., 2008). Additionally, muscle in cattle contains longer n-6 and n-3 fatty acid chains (Wood et al., 2008). During lipid thermal degradation polyunsaturated fatty acids are broken down via oxidation faster due to double bonds during initial cooking and produce heterocyclic aroma compounds (Legako et al., 2015; Mottram, 1998). Often when meat is stored for long periods of time oxidation occurs which produces off flavors such as rancidity. However, oxidation during cooking produces positive flavors and aromas. The type of cooking can have a impact of how lipid degradation happens in meat. It has been found that meat that is roasted goes through high oxidation levels due to longer roasting times (Khan et al., 2015). Some compounds produced by lipid degradation as alphatic hydrocarbons, aldehydes, ketones, alcohols, carboxylic acids, and esters (Van Ba et al., 2012; Fors, 1983).

Lipid Maillard Interaction

Interactions between lipids and the Maillard reaction also occur during cooking which help produce more volatile compounds. Within adipose tissue are precursors for the Maillard reaction such as amino acids, proteins, sugars, and salts (Wasserman, 1972). Products from lipid degradation such as aldehydes, alcohols, ketones react with Strecker degradation products such as ammonia and hydrosulfide to produce additional compounds like thiols, thiopenes, and thiazoles (Van Ba et al., 2012). This would suggest that lipid and Maillard interaction occurs during Strecker degradation. Phospholipids help play an important role in the Maillard reaction because it helps determine what compounds are produced (Mottram, 1998). Sulfur heterocyclics compounds such as thiophenes, trithiolanes, and trithianes have been found to be most affected by phospholipids (Mottram, 1998). Phospholipids helped produced more meaty aromas and the number of compounds produced meaty aromas such as 1 -heptanethiol and 1 -octanethiol only found when phospholipids were present (Farmer et al., 1989). When phospholipids were removed an increase of pyrazines were present (Mottram and Edwards, 1983).

The formation of compounds can vary depending on what reaction is taking place. High amounts of heterocyclic compounds in glycine and ribose reactions which were mimicking reactions found in the Maillard systems while phospholipids which was mimicking lipid degradation produced higher amount of alcohols and aldehydes (Salter et al., 1988). It is important to keep in mind that compounds that are formed can vary in the flavors and aromas within their own chemical family (Reineccius, 1990). Important flavor classes such as pyrazines produce cooked, roasted, tasted, flavors and aromas when phospholipids were not present. Alkylpyrazines produce nutty and roasted flavors. Alkylpyridines produce negative notes such as green, bitter, and burnt. Furans, furanones, and pyranone form sweet, burnt, and caramel like. Oxazaoles form green, nutty, and sweet notes while thiphenes form meaty flavors (van Boekel, 2006). Hexane contributes to fatty flavors while 2-propanone related to livery and bloody flavors (Gorraiz et al., 2006).

Lipid Contributions to Flavor

Adipogenesis

As previously stated, degradation of fats produces volatiles that are found in beef so understanding how fat in produced in an animal is important. Adipogenesis is the process of cells differentiating to form fat cells. Fat cells first begin as a fibroblast which is a type of connective tissue cell. Fibroblast get transformed into mesenchymal cells which can differentiate to either myogenic or adipogenic cells (Du et al., 2013). Once a mesenchymal cell has a pathway it is developed into an adipoblast which contains a nucleus, mitochondria, and cytoplasm. These cells than are transformed into adioblast which begin to form lipid droplets. As the lipid droplets begin to increase in size the cell becomes rounder with all organelles getting pushed to the side of the cell until it is a mature adipose cell or adipocyte (Aberle et al., 1975). The body provide four major types of fat which are visceral, subcutaneous, intermuscular, and intramuscular. Visceral fat develops first in mid fetal stage to early postnatal stage (Robelin, 1980). Subcutaneous fat forms mid to late fetal stage (Hood and Allen, 1973). Intermuscular fat which is the fat between the muscles occurs late fetal-neonatal stage to 250 days of age (Du et al., 2013). Intramuscular fat is within the muscle what we know as “marbling” (Du et al., 2013). Marbling is deposited between muscle fiber bundles and in the connective tissue (Park et al., 2018). Marbling also tends to grow last in animals (Robelin, 1986).

Quality Grades

Marbling signifies the amount of intramuscular fat present in a piece of meat. Quality grades first appeared as a way to ensure that consumers have a consistent eating experience in the beef they are eating. Quality grades can be determined by measuring about of intramuscular fat within the muscle and looking at maturity by ossification of bones. Degree of marbling contains seven degrees having practically devoid as the lowest marbling to slightly abundant containing the highest amount. There are also five types of maturity ranging from A (9-30 months) to E (>96 months). Quality grades provide consumers valuable information on the amount of marbling within muscle. Intramuscular fat levels were the driving force of consumer acceptability (Corbin et al., 2015). As with steaks, higher amount of fat in ground beef produce higher flavor and juiciness scores (Cross et al., 1980; Berry, 1992; Troutt et al., 1992). *Longissimus lumborum* steaks with quality grades of Prime, Low Choice, and Standard found that Prime produced greater amounts of brown/roasted, beef ID, overall sweet, and umami which are considered positive flavor attributes Legako, et al., (2016). Steaks with quality grade of standard produced greater cardboardy flavors seen as negative. Consumer satisfaction tends to decrease as marbling decreases showing that marbling plays an important role in consumer acceptability (Quinn et al., 2012; Smith et al., 1986; Savell et al., 1989).

The presence of fat in muscle produces more a greater eating experience. The USDA (2014) use quality grade as a way to predict tenderness, juiciness, and flavor. The present of plays a significant role in flavor development of beef but even more with ground beef. With the average ground beef contain 20 to 30 percent fat more lipid derived components will be present in ground beef. Ground beef patties that contained 20 percent fat versus 4 percent fat expressed higher beef flavors (Berry, 1994). Ground beef containing 5 and 10 percent fat was lower in beef flavor than 20 to 30 percent fat patties (Troutt et al., 1992). Ground beef with 20 percent fat was found to have similar flavor acceptability by consumers compared to ground beef with higher amounts of fat (Miller et al., 1993). Beef with higher amount of marbling tended to be higher in tenderness, juiciness, and flavor (Philip, 2011; Bonny et al., 2016). The four marbling theories such as bulk density, lubrication, insulation, and strain explain how fat plays a role on how on we experience the beef we are eating (Smith and Carptenter, 1973). Bulk density describes fat as being less dense thus creating pocket within the lean like swiss cheese; when beef is bitten into it takes less force to bite down. As intramuscular fat increases tenderness by effecting the amount of connective tissue within the meat. Marbling fat in the perivascular cells in the perimysium connective tissue, decreases connective tissue toughness (Thompson, 2004). Prime *longissimus lumborum*, *infraspinatus,* and *serratus ventralis* were all rated more tender by consumers and trained panelists than choice and select quality grades (Nyquist et al., 2018). Suggestions of about 15 to 20 percent of marbling actually relates to tenderness in beef (Polkinghorne et al., 2008). In lubrication theory fat that has melted during cooking becomes the lubricant allowing for less pressure to be used thus perception in the mouth creates a more tender, juicier bite. Insulation suggests that fat in lean prevents meat from over cooking and/or cooking too quickly because it prevents less heat transfer throughout the lean. Strain theory like bulk and lubrication suggests that fat in the lean is used to increase tenderness; as the amount of fat increases there becomes less area for connective tissue to be present. In ground beef as fat level percentages increased tenderness decreased (Berry and Leddy, 1984). When fat increases so does flavor and juiciness ratings until percentages reach 14-20 percent it plateaus (Thompson, 2004). Although marbling is often a good indicator of how well a persons eating experience will be this isn't always the case. There are often consumer satisfaction ranges that each quality grade possesses; prime have the smallest range and standard having the largest range. However, there is a chance that a select steak could have the same or an even better customer satisfaction rating than a choice steak.

Breed Type

Factors that affect the amount of marbling developed in cattle range from weaning, breed type, castration, and amount of energy within the diet, age (Park et al., 2018). Weaning of cattle and introducing a high energy diet can impact the amount of marbling. Cattle that were weaned earlier produced higher amount of intramuscular fat (Wertz et al., 2002; Meyer et al., 2005). Breed type also plays a factor with Wagyu traditionally possessing 36.5 percent of fat content in the *longissimus dorsi* versus Herefords who have about 7.6 percent (Park et al., 2018). Angus cattle produced higher levels of stearic acids than Simental cattle (Itoh et al., 1999). As consumers become more aware of what they eat there has been a rapid shift towards consuming grass-fed cattle believing it to be more sustainable and healthier. Consumers from the United States preferred and rated grain fed beef higher in flavor, juiciness, and tenderness while rating grass fed beef the lowest in flavor and overall liking (Bjorklund et al., 2014). Feeding cattle concentrate diets for longer periods of time found to increase positive flavor intensities (Camfield et all, 1997). Changes in flavor were due to changes in fatty acid compositions (Dashdorj et al (2015). Grass fed cattle contained higher amount of saturated fatty acids and n-3 poly unsaturated fatty acids as well as differences in carbonyls. Grass fed cattle tend to have higher off flavors such as dairy, barny, gamey, grass and liver (Therkildsen et al., 2017; Dashdorj et al., 2015). Grain fed cattle tend to produce more fat like flavors while grass fed have green like flavors (Melton et al., 1982). Grass fed steaks tend to have lower concentrations of myristicoleic (C14:1), palmitoleic (C16:1), and oleic acid (C18:1) then grain finished steaks (Leheska et al., 2008).

Age Effects

As an animal ages and gains more fat, fat cells increase in size via hypertrophy (Robelin, 1985). As animals age fatty acids 16:0 and 18:0 tend to decrease (Wood et al., 2008). Cattle diets can also have an effect on how fat is produced. As energy level increased in the diet fat content increased twice as fat compared to actual growth rate (Robelin and Daenicke, 1980). Cattle fed a low energy diet produced low amounts of 18:1 cis and higher amounts of 18:2n (Wood et al., 2008). As well, fat percent increased from 16 to 42 percent as cattle weights increased from 200 to 500 kg. Sex classes can also have an effect on fat deposition. When weight gain was reduced by 10 percent there was a fat deposition reduction of 18 percent (Robelin, 1986).Steers and heifer produced 1.5 times more body weight compared to intact bulls (Robelin & Daenicke, 1985). Heifers tend to produce about 26-60 percent more fat than intact bulls (Robelin, 1980)..

Fatty Acids

The type of fatty acid present within the fat of the muscle can affect the rate of oxidation. There is the use of oxidation during lipid thermal degradation which helps degrade saturated fatty acids in order to produce positive flavors (Legako et al., 2015; Mottram 1998). Polyunsaturated fatty acids more susceptible to lipid thermal degradation (Legako et al., 2015). Most of the time oxidation is seen as a negative effect because on the negative flavors associated with it. Polyunsaturated fatty acids possess higher double bonds which have it at a higher risk to oxidation. As these fatty acids go through oxidation, they produce hexanal, pentanal, heptanal, and octanol (Ahn et al., 2007). Certain fatty acids can contribute negatively or positively flavor attributes in beef. Cowy flavor was negatively correlated with myristic (14:0), myristoleic (14:1(n-5)), palmitic (16:0), and margaric (17:0) while being positively correlated to vaccenic (18:11) and linoleic (18:2(n-6)) (Camfield et al., 1997). Saturated fatty acids tended to have a positive correlation with beefy flavors while unsaturated fatty acids had a positive correlation to undesirable flavors such as cowy, cardboardy, painty, and livery (Camfield et al., 1997). An increase in 18:1 tends to increase the amount of beefy flavor (Melton et al., 1982).

Muscle Aging

The primary usage of aging is to increase the tenderness of beef by the use of the enzymatic breakdown of the muscle fiber structure. However, aging can also change the types of flavors that are present in meat. Aging alterations occur to sugars, organic acids, peptides, and free amino acids which are considered the precursors to flavor (Spanier et al., 1997). As well, meat that was aged for 4 days tended to contain the optimum flavor. As post mortem aging increase there was an increase of free ribose due to the breakdown ribonucleotides and an increase in free amino acids and peptides from proteolysis (Lawrie and Ledward, 2006). When meat was stored for 21 days; reducing sugars increase by 15 percent, free amino acids increased between 7 to 14 days, and ribose was present due to the breakdown of 5'-monophosphate (Koutsidis et al., 2008). Loin steaks aged for 11 days tended to have optimal flavor however, past 11 days no flavor or tenderness enhancements occurred (Smith et al., 1978). Beef aged between 4 to 7 days was found to have increased in flavor due to fat degradation however, bulls tended to have higher liver and bloody flavors (Gorraiz et al., 2006). At 21 days of aging liver intensity was the highest because of nitrogen containing compounds (Campo et al., 1999).

The two most common types of aging we hear about is wet and dry aging. Dry and wet aging are both ways to increase tenderness and flavor. Dry aging is the process of hanging whole carcasses or subprimals in an environment where temperature, humidity, and air flow are controlled for about 10 to 35 days (Kim et al., 2017). Wet aging; the most common is taking sub-primals and placing them in vacuumed packaged bags to age (Smith et al., 2008). Wet aged beef tended to have more bloody/serumy and metallic flavor while dry aged had more beefy, brown, and roasted flavors (Warren and Kastner, (1992). However, there has been conflicting data that shows there is no impact on palatability from dry aged beef (Laster et al., 2008).

Muscle Comparison

Upon entrance of the meat section at stores there is a wide variety of cuts within the retail case however, not every muscle is created equal. It has been well established that tenderness various throughout muscles due its function whether it is locomotive, the amount of connective tissue, or the amount of calpain present (Wright et al., 2018; Fratzl, 2008; Belew et al., 2003; Henderson, 2016). Physicochemical components of beef differ based on the physiological requirements of that muscle therefore affecting the overall flavor of that muscle (Dashdorj et al., 2015).

Sections of the beef carcass that is the highest of interest to producers and consumers are the loin where the highest valued cuts are such as the strip loin and tenderloin (Lepper-Blilie et al., 2014). The *gluteus medius* (top sirloin) produced higher sour flavors than *infraspinatus* (top blade) and *psoas major* (tenderloin) (Yancey et al., 2005). Cuts commonly found in the chuck and round of beef are marked as low-end cuts due to not only tenderness but flavor as well (Seggern et al., 2005). Beef chuck muscle have a higher tendency to have amount liver like flavors (Wadhwani et al., 2010). Although studies have found negative flavor attributes in the chuck there has been contradicting reports that show certain muscles from the chuck such as *Supraspinatus* and *serratus ventralis* have had similar positive flavor attributes similar to higher end cuts like *longissimus* steaks found in the loin (Kukowski et al., 2005). However, the *Complexus* a muscle within the chuck had the lowest liver and highest beef flavor while the *rectus femoris* had the lowest beef flavor (Dashdorj et al., 2015; Stetzer et al., 2008). Other cuts within the chuck such as the *Triceps brachii* was more flavorful then *Serratus ventralis* and *Complexus* (Dashdorj et al., 2015).

The amount of myoglobin also plays a role in how meat flavor is expressed. Greater amounts of iron have been found iron and myoglobin have increased the amount of metallic flavors in beef. The *vastrus lateralis* had greater off flavor such as sour and oxidized due to higher heme-iron concentrations (Meisinger et al., 2006). Higher amounts of myoglobin tend to increase the liver flavor in beef (Yancey et al., 2006).

High pH is typically not favored in beef due to reduction in flavor (Dashdorj et al., 2015). Differences in pH can ultimately effect the type of flavor precursors that are expressed in meat (Madruga and Mottram, 1995). Beef muscle that contained a high pH tended to have less beef and brown flavors than muscles with normal range pH (Yancey et al., 2005). The amount of sulphur substituted furans and heterocyclic pyrazines increased as beef became more acidic (Zhang and Ho, 1991; Meynier and Mottram, 1995). However, pH changes did not have an effect on hydrocarbons, ketones, or alcohols; more acidic pH increased furanthiols, furans, aldehydes while pyrazines, and thiazoles decreased (Madruga and Mottram, 1995).

Cooking Methods

Different cook methods hold the most importance in how volatiles are expressed during cooking (Kerth and Miller, 2015; Gardner and Legako, 2018). Cooking methods can be distinguished between two conditions; dry or moist. Dry conditions are methods such as grilling, boiling, or pan frying (>177˚C) where the browning of the Maillard reaction is taking place on the surface of the meat. The Maillard reaction starts occurring in meat when high cooking temperatures are present which are at about 310˚F (Kerth, 2013). During dry conditions moisture and heat transfer is taking place by conduction between the grill and the piece of meat (Fabre et al., 2018). Pyrazines help contribute to 80 percent of the volatile compounds found in grilled meat (Khan et al., 2015). Moist conditions methods are roasting, boiling, or low temperature cooking (<100˚C) where the Maillard reaction cannot fully take place. This is because moisture that is released from cooking is held within the oven thus preventing caramelization on the outside (Kerth & Miller., 2015). Moist condition methods are described as having low humidity and high temperatures. Traditionally, tougher cuts like chuck roasts were cooked using the moist condition cooking in order to achieve higher tenderness acceptability but often times produced lower palatability (Jeremiah & Gibson, 2001; Jung et al., 2016). In roasted beef there tends to be high amounts of pyrazines, thiazoles, and oxazoles (Mottram, 1998). Roast were associated with greater negative flavors such as liver-like, green hay like, musty, and cardboard (Kerth and Miller, 2015). Steaks cooked on a grill were associated with greater positive flavors such as beef identity, brown, umami, burnt, salty, and fat like. When water percentage increased while keeping cooked temperature time constant meat tended to produce higher amounts of roasted, burnt, and pot-roasted flavors (Reineccius, 1990).

As discussed earlier different cooking methods change the physical and flavor characteristics of beef. As heat is applied during cooking myoglobin begins to denature producing beefy/brothy flavor (Phillip, 2011). Postive flavor attributes are those such as beefy, brown/roasted, bloody/serumy, fat-like, sweet, salty, and umami (Adhikari et al., 2011). Positive flavor attributes were also brothy, umami, roast beef, juicy, browned, fatty, and salty (Maughan et al., 2012). Negative flavor attributes included metallic, liver-like, sour, barnyard, musty/earthy, and bitter (Kerth & Miller, 2015). Words such as oxidized, bitter, barny, gamey, grassy, liver, metallic, and astringent were seen as negative attributes (Maughan et al., 2012). Roasted flavors came from carbonyl, sulfides, pyrroles, and pyridines (MacLeod & Coppock, 1977).

The addition of heat not only affects color, temperature, and digestibility of meat but also tenderness. At 60˚C collagen and shrink one quarter of its size, become heat soluble and be converted to gelatin improving tenderness (Light et al., 1985). At about 65˚C collagen shrinks increasing tension which makes fluid leave the muscle increasing the toughness of the meat. As heat is being added myosin heads begin to denaturation and as temperatures increase actin begin to denature (Purslow, 2018). Myosin heads begin to denature at about 40˚C and complete denaturation happens at 53˚C (Brüggemann et al., 2010). Actin begins to denature between 68 to 80˚C (Bertola et al., 1993). Additionally, at 35˚C to 40˚C protein begins to denature reducing the muscle fibers (Warner et al., 2017). Due to the variation of tenderness in different muscles within the beef carcass certain cooking methods are favored over another. Low temperature low-time cooking methods like in roasts do not lose water as much as cooking methods such as grill because shrinkage does not occur that much (Dominguez-Hernandez et al., 2018). Low temperature low- time cooking methods are ideal for cuts such as chuck, roasts, and muscles from older aged cattle that contain high amount of collagen in order for collagen to break down. Cooking meat from older animals for hours at 70 ˚C helped to gelatinize collagen (Purslow, 2018). Pan frying ground beef patties contributed to highest ratings for flavor and juiciness (McCormick et al., 1981). Pan frying ground beef tended to produce greater flavor ratings than broiled or microwaved ground beef (McCormick et al., 1981). Oven roasting of ground beef had the softest first bite characteristic while frying and microwave treatments produced the lowest juiciness, mastication hardness, cohesiveness of mass (Berry and Leddy, 1984).

Comminution of Beef

Ground beef is found to be the most common form of beef purchased at retail stores in the United States (Brewer, 2012). It has been seen that a portion of a families income goes towards buying beef (Berry & Leddy, 1984). A majority of beef found in the food service industry and at home is ground beef (Harbison, 2012).

Comminution of beef occurs due an excess of left-over muscle or muscle that is seen as lower quality. Comminution of beef can occur either through grinding, chopping, or flaking Berry et al., 1999).Cuts from the chuck and round which are seen as less tender are turned into ground product (Nyquist et al., 2018).Grinding of beef starts off by using a conveyor screw that allows meat to be packed into the instruments where a revolving blade allows meat to be cut into smaller pieces in order to go through the grinding plate. The grinding plate give ground meat that signature grounded look. Different grinding sizes can be used to achieve a certain type of look and thickness within the meat. Although tenderness and juiciness can be controlled through grinding and grinding size, variation within flavor can become a new problem. As ground beef passes through a grinder more oxygen is able to penetrate the fat within the ground beef. Beef that was held at longer aging times had greater off flavor scores indicating that fat is going through oxidation (Cleveland et al., 2014). Higher amounts of hexanal and 1-octen-3-ol are often times found in raw and cooked ground beef patties compared to raw and cooked beef steaks which was due to lipid degradation (Gardner and Legako, 2018). Lipid degradation products expressed were due to the oxidative status of the product (Gardner and Legako, 2018).

Utilization of Sensory Testing

Sensory testing has been used in the evaluation of consumer goods for as long as there have been consumer goods available to people. The use of people in sensory testing allows for producers to have a greater understanding of how a consumer would feel about a product or certain type of food. Sensory testing is often time used in product development and/or quality assessment of a food or consumer good (Civille and Oftedal, 2012). As explained in the previous sections multiple factors can affect the flavor development of beef. From sensory testing it has been found that the amount of fat effects quality grade which than produces greater positive flavors that consumers prefer (Legako et al., 2016). Tenderness differences of various cuts have been found using sensory testing (Nyquist et al., 2018). Trained and consumer panels have been used to determine flavor in beef (Laird, 2015). Trained panel has also been used to determine flavor between different cooking methods (Bamsey, 2017).

Within sensory testing there are the availability of multiple types of test to use when evaluating a product such as quantitative discriminative, descriptive, and consumer testing (Civille et al., 2015). The most often used tests in beef sensory are trained and consumer panel. Multiple studies have been done using descriptive and consumer testing on beef to understand its flavor (Laird, 2015; Glascock, 2014; Berto, 2015). Consumer testing are often times used when a larger population is being used to determine factors such as overall flavor, liking, and acceptability of a product. Descriptive test use expert trained panelists and a product lexicon on which they are trained on to determine differences in flavor and/or aromas of products (Civille et al., 2015). Descriptive panel testing is the most accurate tool for determining a products attribute and intensities (Suwonsichon, 2019). For descriptive testing panelists are often times recruited through things such as church groups or through word of mouth. Often times ideal panelists are those that follow direction, do not have any health problems, and have open schedules where they are able to make panel training and testing at different times. Once a person has showed interest in being a panelist, they go through a prescreening/ interview to see if they are the right fit for a panelist. Once they have passed the interview section they are given tests. A matching test is given where a person is given certain aromas and flavors that are commonly found where they then need to identify the flavor or aroma (Civille et al., 2015). The second test is known as detection/determination test where a person is given what is known as a triangle test. A triangle test consists of two products that are similar and one that is different. The person taking this test will need to determine which sample is different. If a person scores less than 60 percent they are often times rejected as a panelist (Civille et al., 2015). A ranking/rating test for intensity is used where a flavor, aroma, texture, or hardness is given with about four different intensities and are asked to rank them in ascending order (Civille et al., 2015). After all the test are completed they will either be accepted or rejected based on whatever criteria the person giving the test has set (Civille et al., 2015).

Gas Chromatography - Mass Spectrometry

Being able to identify the flavors and aromatics that are given off using a trained descriptive panel allows us to understand the quality of the product we are eating. For example, rancid flavors in a product signal to panelists that the product has gone bad. However, understanding what volatiles make up that rancid flavor in order to be able to combat the issue is very important. Although panelists are used to pick up certain flavors and aromas, the human nose is limited to what it can perceive and the concentration of the volatile (Zellner et al., 2008). A machine called gas chromatography can be highly used by multiple industries such as the coffee, produce and meat industry for rapid analysis of components (Dong et al., 2019; Roasa et al., 2019; Cuevas et al., 2017). Gas chromatography is used to understand flavor profiles, distinguish between odor and non-odor active compounds, and be a representation of the product that is being test in order to identify quality differences (Zeller et al., 2008).

The initial step because a sample can be put on a gas chromatography is the collection of volatiles from the product. Multiple methods can be used to extract volatiles from products such as solvent extraction (SE), direct thermal desorption (DTD), or solid phase microextraction (SPME) (Zeller et al., 2008). A solid phase microextraction are essentially modified solid phase extraction but with chemically modified fused silica fibers that are highly flexible and durable in order to extract analytes (Bartle and Myers, 2002). Solid phase microextractions allows for a reduction in time, blanks, and product variation (Arthur and Pawliszyn, 1990). Using a SPME is considered to be a non-exhaustive approach due to the small collection volume compared to the actual volume of the sample (Pawliszyn, 2011). The section injected into a vial is the septum piercing needle. Within that septum piercing needle is the fiber attachment tubing, and within that is the fused silica fiber that acts as a sponge for organic analytes (Kataoka et al., 2000). Fiber SPME's are most widely type when using SPME's, which are injected into a supporting vial that contains sample and is absorbed until equilibrium has been reached (Ouyang and Jiang, 2017). This step is commonly known as the extraction step. This type of extraction application is commonly called headspace (HS-SPME) because it is above the sample compared to direct immersion (DI)-SMPE which is immersed in a liquid sample. During the extraction step temperature is often increased in order to absorb more analyte from the sample (Kataoka et al., 2000). While HS-SPME is used for more volatile samples using high performance liquid chromatography together allows for greater extraction of less volatile and thermally liable samples (Kataoka et al., 2000). Within the fiber of the SPME a barrier is present in order to reduce the amount of high molecular analytes, humic acids, or non-volatile compounds which could reduce the sensitivity of high volatile compounds because non-volatile compounds like the gas phase in the gas chromatograph (Pawliszyn, 2011).

The type of fiber within a SPME is dependent on what product is being used for extraction. Within a fused silica fiber there is a polymeric phase that helps to extract volatile, semi volatile, and nonvolatile analytes to be further identified in a gas chromatography (Pawliszyn and Mani, 1999). There are now multiple types of fibers that contain different types of coatings. The first initial type of fiber was a non-polar polydimethylsiloxane (PDMS) used for the extraction on non-polar analytes (Kataoka et al., 2000). PDMS is most commonly used coating for SPME (Risticevic et al., 2009). Polar fiber coatings such as carbowax/divinylbenzene (CAR-DVB) and carbowax/templated resin (CW-TPR) (Kataoka et al., 2000). Polyacrylate (PA) a polar coating has used for extraction of phenols (Risticevic et al., 2009). Semi polar coatings such as polydimethylsioxane/divinylbenzene (PDMS/DVB) are also available. Coatings commercially available can de divided into two categories: homogeneous polymer and porous particles imbedded in a phase. Within the homogeneous coating there are polydimethylsiloxane and polyacrylate. Polydimethylsiloxane can be bonded or nonboned; bonded produces higher thermal stability which can reach 320˚C while nonbonded can reach 270˚C. Pourous particles imbedded within a SPME allows for higher selectivity and retains analytes (Pawliszyn and Mani, 1999). Coating thickness also greatly effects how the analyte is absorbed within a SPME. The thicker the coating is the greater amount of retention and separation occurs which leads to a more accurate identification (Pawliszyn and Mani, 1999).

The desorption step is where the SPME can then be put into the injection port of the gas chromatograph to be further analyzed. The heating of the fiber within the injection allows for analyte to be transferred to the analytical column to start the process of analyzing (Kataoka et al., 2000). The advantage of using a direct injection of the sample allows for less sample loss (Bartle and Myers, 2002). Split mode injection can also be done where there is a ratio of sample being used to the rest going to waste while a splitless mode is used to determine involatile analytes. During splitless mode injection the column is initially heated below the solvent boiling point in order to concentrate the sample (Bedson et al., 2003). The usage of programmed temperature vaporizer (PTV) injection allows for more operating options to choose from such as split or splitless; hot or cold temperatures in order to main the best conditions during testing (Bedson et al., 2003; Bartle and Myers, 2002).

With the addition of heat, the analyte within the SPME gets turned into a vapour. It is important to choose the correct injection temperature because too high temperature can destroy your analyte but too low of a temperature may not give you accurate results (Bedson et al., 2003). The analyte gets combined with a carrier gas in the first column and is known as the mobile gas phase. A carrier gas often times helium or hydrogen uses pressure to push the analyte out to the next phase where it can be further analyzed (Bartle and Myers, 2002; Sparkman et al., 2011). Carrier gases should have a purity percentage of 99.995 in order to remove any contaminants that can affect the detection and reading of compounds (Bedson et al., 2003).

The analyte and carrier gas get sent to a chromatographic column which is used to separate compounds. This step is known as the stationary phase. The stationary liquid phase is the most commonly used when using a combination of gas chromatography and mass spectrometry (Bedson et al., 2003). The faster a compound passes through the stationary phase shows the variation of chemical and physical components that make up that compound (Bedson et al., 2003). Packed columns were originally used to separate compounds but the invention of capillary columns allowed for faster separation and lower temperatures that reduce the risk of analyte degradation (Bartle and Myers, 2002). Various capillary columns are available such as wall coated, support coated, and porous layer open tubular columns (Bedson et al., 2003). The most common wall coated column is thin walled which are made of fused silica. Fused silica allows for greater mechanical strength yet enough coiling ability as well as less contaminations from metals (Poole and Poole, 2008). The usage of porous layer open tubular columns had advantages of greater efficiency and faster separation times (Ji et al., 1999). It has been suggested that long and narrow columns are ideal in order to produce higher separation of compounds (Bedson et al., 2003).

Detection methods of compounds vary throughout the GC. A popular low cost detection method called the flame ionization detection (FID) contains a hydrogen air or hydrogen oxygen flame which carbon hydrogen bonds pass through and has a high sensitivity to organic compounds (Bedson et al., 2003). Electron capturing detector (ECD) uses beta radiation as a way to capture free electrons (Bartle and Myers, 2002). ECD is highly sensitive to halogenated, nitro, and organometallic compounds (Bedson et al., 2003). Flame photometric detector (FPD) is used in order to detect compounds containing phosphorus, and halogens, but mainly Sulphur (Zainullin and Berezkin, 1991). Another commonly known detection method of compounds is mass spectrometry. In MS when the carrier gas and analyte compounds pass through the first column the carrier gas gets separated out in the interface zone while the analyte compounds go to the isolation zone of the mass spectrometer (Bedson et al., 2003). The analyte compounds enter the isolation zone a filament which produces electrons gets turned on at 70 ev. These electrons ionize molecules and causes fragmentations and formation of solute ions. Solute ions get sent to electron multiplier detector where they are measured by molecular weight (Bedson et al., 2003;

Thompson, 2017). A peak is created with each compound analyzed and is compared to compounds found in reference libraries.

The accuracy of the analytes collected in a SPME for identification can vary due to what is known at the “matrix effect”. The “matrix effect” is when coextracted matrixes are absorbed and block active sites in the injector resulting in inaccurate results (Tsuchiyama et al., 2017). The use of standard in pure solvent and or within a matrix are best used for calibration during testing (Garrido-Frenich et al., 2009). There are three types of standards that can be used for SPME calibration; external, standard addition, and internal (Pawliszyn, 2011). External calibrations are often used when there is little variability within testing samples. Standard addition is when known quantities of a target are added to a matrix with unknown concentrations and a range is made up from that concentration to go off of. An internal standard possesses similar properties and extraction behavior of the analyte that is being analyzed however, is different in that when both are analyzed for calibration multiple concentrations of the analyte can be compared to the constant peak of the standard being used (Pawliszyn, 2011).

Conclusion

Beef flavor is a complex system that has tremendous influence on the acceptability of consumers. Impact of beef flavor starts long before it is eaten by the consumer with multiple intrinsic and extrinsic factors such as muscle type, fatty acid profile, and cooking methods effecting the final flavor. However, never has a study been done that uses specific cuts from over the retail case to understand flavor. This study is broken up between three universities; Texas A&M University, Texas Tech University, and Colorado State University using multiple sensory tests such as trained descriptive and consumer panel along with gas chromatography mass spectrometry and rapid evaporative ionization mass spectrometry to help create a baseline for flavor, see how flavor varies between each cut, and find how the impact of these flavors effect consumer acceptability.

Texas A&M's objective of this study was to evaluate beef aroma and flavor attributes top loin steaks, top sirloin steaks, chuck roasts, and 80 percent leanground beef using an expert trained descriptive panel. As well as using similar gas chromatography mass spectrometry methods as Texas Tech University to identify volatile compounds found in cuts.

Hypothesis is that each cut will have distinct and unique flavor volatiles present that will distinguish themselves from one another. Top loin steaks, top sirloin steaks, and 80 percent lean ground beef will have higher amounts of Maillard reaction volatile compounds compared to chuck roasts due to the fact that the final volatile profile is affected the most by cooking method.

CHAPTER III

MATERIALS AND METHODS

Sample Selection and Preparation

Top loin steaks (n= 50), top sirloin steaks (n= 49), chuck roasts (n= 50), and 80% lean ground beef (n= 50) were selected int the Miami FL, Denver CO, Portland OR, New York City NY, and Los Angeles CA from August 29th to September 25th. Meat selection occurred between six to eight retail and high volume retail stores in each city. Any available packaging information was recorded by Texas Tech University. No specific quality grade, package type, or claim was favored over another. After meat was selected, meat was then shipped to Texas Tech University to be repackaged with a four-digit identification code (3.5 mil thermoform vacuum packaging with moisture vapor transmission: 4.8 g/m2127 /d; Multivac F100; Kansas City, MO. The first digit in the code identified what city it came from while the second digit identified the type of cut. The last two digits represented the cut number selected. Meat was shipped frozen with dry ice to Texas A&M University via coolers. Once at Texas A&M all samples were provided a random three-digit code, cook date, and order and organized in each individual box that was for a specific date. Any packages that were open were noted and repackaged with vacuum packaged bags (B2470, Cryovac Sealed Air Corporation, Duncan, SC) with an oxygen transmission rate of 3-6 cc at 4°C (m2, 24 h atm @ 4°C, 0% RH) and 0.5-0.6 g at 38°C (100% RH, 0.6 m2, 24 h) for water vapor transmission. Once sorted samples were held at -9˚C in the sensory testing facility at Texas A&M.

Twenty-four hours prior to cooking meat was defrosted in a 4˚C cooler making sure no samples were stacked on top of each other. Due to the fact that chuck roasts varied in thickness each roast was cut into 10.16X12.7 cm sections from the center of the roast ensuring that all muscles would have an equal chance of representation. Each ground beef sample was formulated into three 150g patties and flattened using a patty press (07-0301,Weston Burger Patty Press). The press patty was used to have consistent thickness for all ground beef samples. Each sample raw weight was taken and recorded. After raw weights were taken samples were placed on a plastic tray, covered with plastic wrap and placed back into the cooler until cooked. Plastic wrap was used to prevent meat from drying out and because panel was two hours long placing meat in cooler prevented microbial growth. All cuts except for ground beef patties had a thermocouple probe (Omega Engineering, Stamford, CT) placed in the geometric center of the sample to monitor cooking temperature. Ground beef patty temperatures were taken using a thermocouple probe (Omega Engineering, Stamford, CT) to monitor cook temperature.

Cooking

Chuck roasts were placed in a 35cmX26cm roasting pan with a roasting rack filled with two cups of water in order to mimic how roasts would be traditionally cooked at home. Beef steaks and ground beef patties were cooked on a stove top grill (StarMax 536GF 36 inch Countertop Electric Griddle, Star Manufacturing International, Inc., St. Louis, MO) with a grill surface temperature of 177˚C. Grill and oven were turned on 15 minutes before the start of panel. All internal temperatures and time were recorded as samples went on grills or in ovens. Temperature of grill was checked to ensure the grill temperature was being met. All samples were cooked until reaching an internal temperature of 71˚C; steaks and patties were flipped when internal temperature reached 35˚C. Final internal temperature, time, and cooked weight were recorded and then samples were wrapped in foil and placed in a Bain Marie warmer (APW Wyott W-3Vi 12"x20", Alan,TX). The warmer contained water held at 145˚F with warmer pans (Royal Industries, 6"x10", Brooklyn, NY) and lids (Royal Industries 6"x10", Brooklyn, NY). Samples were held in the Bain Marie warmers for no more than maximum of 20 minutes. The maximum of 20 minutes was used to ensure that temperature of sample did not decrease too drastically and to ensure potential flavor changed would not occur. Chuck roasts were cut into 1.27 cm cubes with no visible connective tissue, fat, or outside browning. Steaks were cut into 1.27 cm cubes with no connective tissue or visible fat. Panelists were served either two wedges or two 1.27 cm samples for evaluation. Cubed samples for evaluation were randomly chosen within the sample to ensure that panelist did not get one specific section or edge of the sample.

Descriptive Panel Training

For this project five trained panelists that were experts in beef flavors and texture attributes were used. We used the same panelists that helped to create the beef lexicon we were using for this study. The Institutional Review Board for Use of Humans in Research at Texas A&M University approved the sensory protocal (IRB2018-0958M). Training took 13 days with the first 11 days introducing new flavor and texture attributes from the beef lexicon and the last 2 days retraining on those attributes. Table 1 provides flavor and aroma definitions defined by Adhikari et al. (2011) that were used for evaluation. AMSA (2015) provided the definitions for the juiciness and tenderness attributes used in this study. There were a total of 43 aroma, flavor, and texture attributes used for evaluation of the beef samples . Although all panelists have been expertly trained, the universal scale and basic taste were introduced on the first day of training. On the first day of training panelists were trained on the major attributes found in meat, such as beef flavor identity, fat-like, brown, and roasted. As training continued, training proceeded from the major flavor and aroma attributes to minor attributes, and lastly on texture attributes. During training and testing texture attributes such as cohesiveness of mass, hardness, initial juiciness, particle size, and springiness were only evaluated for ground beef patties while juiciness, connective tissues, and muscle fiber tenderness were evaluated for top loin steaks, top sirloin steaks, and chuck roasts. Any attributes that panelists struggled with were reintroduced during the next day of training until panelists were confident in ratings. For training, a reference and cook sheet (Appendix B) was prepared that contained all references made for that day and how to make them along with a sample evaluation page that panelists and group leader would evaluate for specific attributes. A separate individual training sheet that were given to panelists contained attributes that were going to be introduced along with an evaluation sheet that had all attributes listed along with a three digit code that were used. After references were made, they were put into soufflé cups and covered with lids (translucent cups and lids, Georgia-Pacific, Asheboro, North Carolina) with a label identifying the attribute. All panelists were seated around a table so they would be able to discuss attributes and samples. Panelists were provided a spit cup, double-distilled water, napkins, saltless saltine crackers (Premium Unsalted Tops Saltine Crackers, Nabisco, East Hanover, NJ) as a palate cleanser were replenished every two weeks to ensure freshness

Expert, Trained Descriptive Analysis

For testing, panelist evaluated steaks, ground beef, and roast (n=199) for 17 testing days. Panelists evaluated 12 samples with a two-hour period having a ten-minute break to prevent fatigue after evaluation of 6 samples. Fifteen minutes before each testing session a “warm up” sample was given to panelists and group leader. Panelists and group leader individually evaluated each attribute in the sample, discussed and came to consensus using a score between 0

= none and 15 = extremely intense in order to calibrate. The warm up was rotated between a top sirloin steak, top loin steak, ground beef, and chuck roast and served as it would be given if it was a testing sample. Each panelist was seated in separate breadbox style booths that contained red lights (44.2 lux) to mask any color differences in samples. Saltless saltine crackers, a napkin, two toothpicks, double-distilled water, a spit cup, and box with each panelist's references were placed inside their booths. Samples were cut 1.27 cm X1.27 cm cubes and served in soufflé cups that would not impart any flavor to the sample and that contained a random three-digit code. Five minutes were given in between samples in order for panelists to cleanse their palate. Panelists recorded their scores using a 16-point scale from 0= none to 15=extremely intense on an electronic excel ballot (Appendix C) on an iPad (Apple Inc, Cupertino, CA). After panel was finished, excel documents containing the panelists score sheet were saved and uploaded onto the computer desk top (iMac Pro, Apple Inc, Cupertino, CA).

Cooked Beef Volatile Flavor Evaluation

Volatiles were evaluated from the samples the trained panelists evaluated during sensory testing. Once samples were given to panelists two 1.25 cm cubes were frozen in liquid nitrogen at -196˚C and kept frozen at -80˚C until time for GC/MS analysis. For GC evaluation samples was blended into a fine powder using a coffee grinder with 5g +/- 0.01g weighed out and placed in 20 mL glass GC vials with Teflon lids. Samples were placed in a heating block heated at 65˚C to mimic cooking temperatures given to sensory panelists. An aliquot of a10 µL internal standard of 1,2-dichlorobenzene, was pipetted into each GC sample vial (2.5 µg/ml). A solid-phase microextraction (SPME) sampler (Supelco 504831, 75 µm carboxen/polydimethylsiloxane [CAR/PDMS], Sigma-Aldrich, St. Louis, MO) was interested through the lid and held for 25 minutes in order to collect the headspace. During the 25 minutes SPMEs were able to absorb any analytes that were coming off of the sample. After the 25-minute collection, the SPME were taken out of the jar and interested into the injection port of the gas chromatograph (GC; Agilent Technologies 7920 series GC, Santa Clara, CA) for 3 minutes at 280˚C. Total run time for injector was 28.25 minutes while the internal standard retention time was 18.8 minutes. The sample was then loaded into a gas chromatograph column (Agilent VF 5MS 30m × 0.25mm ID/1µ film thickness, SGE Analytical Sciences, Austin, TX), first being held for 1 minute at an initial temperature of 40˚C then increasing to 145˚C at 5˚C/min than increasing at a rate of 20˚C/min for a total run time of 28 minutes until reaching a final temperature of 250˚C and held for 1 minute. Separation occurred due to the boiling points of different compounds. Compounds were then separated by molecular weight and polarity. The compounds were sent to the mass spectrometer detector (MS; Agilent Technologies 5975 series MS, Santa Clara, CA) for quantification and identification using the Wiley Chemical Library.

Statistical Analysis

Proc Means by SAS (version 9.4, SAS Institute, Cary, NC) was used with an alpha of ($P<0.05$) to statistically analyze data collected from trained sensory panel. Sensory testing day and order were labeled as a random effect while cut was determined as a main effect. All sensory data was then averaged across panelists after analysis for panelists effects in order to indict panelists efficiency. Analysis of Variance was used to determine main effect differences and least square means were calculated to determine differences between means when amounts were considered significant by using Fishers least significance differences in SAS. XLSTAT (v2013, Microsoft Corporation, Redmond, WA) was used for principal component analysis (PCA) and partial least squares regression (PLS) and results were presented as biplots.

CHAPTER IV

RESULTS AND DISCUSSIONS

Packaging information

Means, standard deviation, minimum, and maximum for the four cuts are reported in table 5. For top loin steaks the mean price per pound was $12.97 with a mean total price of $16.27. Top loin steaks were the highest priced cut. Although total price mean was similar to that of chuck roast which was $16.65 the mean weight of a chuck roast was almost twice as much as a top loin steak. The second most expensive cut the top sirloin steaks which traditionally is a higher valued cut compared to ground beef and chuck roasts (Nyquist et al., 2018). Top sirloin steaks in 2017 had a price range of $11.25 to 12.48 (Yeh et al., 2018). Consumers were willing to pay more for cuts found in the loin due to increased tenderness, juiciness, and flavor (Jung et al., 2016). Ground beef was the least expensive of the four products (Mise, 1972). This is due to the fact that different type of cuts of beef are blended together with about 50 percent of beef used for ground beef (Cross et al., 1980). Chuck roasts was one of the two lowest priced beef due to its lack of desirability based on tenderness and flavor (Nyquist et al., 2018; Belew et al., 2003). In a span of five years beef chucks and rounds decreased in value by 25 percent (Meisinger et al., 2006). There is about an eight to ten dollar difference between top loin steaks and cuts from the chuck with chuck shoulder clod selling at about 4.41 dollar per kilogram and a chuck roll selling at about $6.31 dollars per kilogram from 2018 (Nyquist et al., 2018). For the amounts of cuts per package the means ranged from 1.00 to 1.57 lbs. It is important to note that not all cuts had cuts/package information. Table 3 provided the frequencies for package types, label claims, cuts per package, quality grade, brand, and store for top loin steaks, top sirloin steaks, ground beef, and chuck roasts. For package type the majority of top loin steaks were contained in overwrap packaging 54%. The second most common packaging type was vacuum packaging 26%. The third most common packing type was modified atmosphere packaging 16%. And 2% of modified atmosphere packaging contained carbon monoxide and overwrap packing with a modified atmosphere. Top sirloin steaks followed the same trend with the majority of overwrap packaging 67.3% followed by vacuum packaging (18.4%), modified atmosphere packaging (8.2%), overwrap with modified atmosphere packaging (4.1%), and modified atmosphere packaging with carbon monoxide (2 percent). In ground beef samples the majority of packages were in overwrap packaging (38%), vacuum packaging (26%), modified atmosphere packaging (16%), chub packaging (10%), modified atmosphere packaging with carbon monoxide and unknown packaging (4%), and overwrap with modified atmosphere packaging (2%). Chuck roasts were mostly packaged with overwrap (80%) and vacuumed packaged (20%). For all four cuts the majority of packages used were overwrap and vacuumed packaged. Overwrap packaging is the most common type of packaging used for fresh meat due to color visibility available to consumers. Over wrap packaging is commonly used for short term shelf life in the retail meat case while modified atmosphere packaged is used for long term storage (McMillin, 2017). Vacuum packaging and modified atmosphere packaging are widely utilized although it only has moderate shelf life. Vacuum package helps in extending storage life and quality. With vacuum packaging reduction in color quality, off flavor and odor development along with less water loss due to evaporation (Jeremiah, 2001). At about 34 days off odors began to appear in meat (Ericksen et al., 1981). About 88 percent of consumers bought ground beef in overwrapped packaging while 54 percent intended to buy ground beef in chub form (McMillin, 2017).

For label claims there were thirty- eight different claims with an additional section for cuts that did not contain a label at all. Within label claims factors such as the type of breed, country of origin label, religious slaughtering type, how the animal was raised, and factors that effected the cuts after slaughter were all identified. Within each cut the number of claims that were present on a packaged varied from none to seven claims. In top loins claims that were present. For top loins the top five claims included Angus with 40 percent, hormone free and natural with 26 percent, country of origin label with 22 percent, and antibiotic free with 20 percent. Other claims with top loins included grain fed, fresh never frozen, regional/local, hand cut, blade tenderized, CL, grass fed, organic, never ever, vegetarian fed, no GMO, dry aged, no additives, USA, sustainable, environmentally friendly For top sirloins angus (28.6 percent), country of origin label (20.4 percent), grass fed (14.3 percent), and natural, antibiotic and hormone free all at 12.2 percent. Other claims present were grain fed, fresh never frozen, regional/local, hand cut, blade tenderized, CL, organic, never ever, vegetarian fed, NP, certified angus, humanely raised, and no GMO. For ground beef 42 percent did not possess claims. Thirty percent had a natural claim followed by hormone free (16 percent), antibiotic free (14 percent), grass fed (12 percent), and country of origin label (10 percent). Claims that were found in ground beef that were not previously state on top loins and sirloins were fresh never frozen – no water, 100 percent beef, 100 percent pure, no additives, chuck, fresh quality, HALAL, and free range. For chuck roasts 28 percent did not have a claim; 26 percent had angus as the claim, 18 percent had CL, country of origin, and natural both had 14 percent. A lot of these claims are known as "buzzwords" presented on packages will make it seem more attractive to consumers In the United States about 60 percent of cattle contain some kind of angus influence (Drouillard, 2018). Consumers often times see Certified Angus Beef cuts as being more flavorful, tender, and juicy

(Nelson et al., 2004). Consumers are becoming more concerned of where their meat is coming from and how its grown. The shift to more hormone free, natural, and antibiotic free beef is increasing (Drouillard, 2018; Garrison and Gazdziak, 2017).

In cuts per packages majority all had one cut per package with the frequency being at least 60 percent. Ground beef majority did not have much information on how many “cuts” in a package were present; with 60 percent being unavailable. However, 40 percent did have identification of 1 cut per package. Ground beef is not marketed as a cut so there is really no corrected way to identify what it is. For brands found on packages of cuts, not all were available. However, the ones that did have brands we found the frequencies as well; presented on Table 4. For top loins 42 percent did not have an identification. The second highest was Sutton and Dodge; Kirkland Signature and Simple Truth had 10 percent. Additional brands present for op loins were Black Angus, Colorado Angus, Kirkland, Members Mark, Meyers Natural Angus, Publix Premium, Simple Truth, Strauss Feed Raised, Thousand Hills, and White Oak. Like top loins majority of top sirloins brands were not identified (55 percent). The second highest was Kirkland Signature (10.2 percent) and Members Mark with 6.1 percent. Similarly, to the previous two ground beef did not contain brand information (54 percent). Second highest were Signature Farm (8 percent) and third highest All Natural (6 percent). Twenty – eight percent of chuck roasts did not possess a brand. However, Publix Premium was the second highest at 12 percent, and Walmart and Kirkland Signature at 10 percent.

For stores we have 24 different types of stores however, not all stores are presented in each cut. For top loins Costco and Target had the highest frequencies with 12 percent. King Kullen, Safe’s Way, Sam’s Club, and Walmart had frequencies of 8 percent. For top sirloins Safe Way had the highest frequency with 12.2 percent. Sam’s Club and Costco had the second highest frequencies at 10.2 percent. For ground beef majority came from Target and Walmart with 14 percent. The third highest group was for those that did not have store information. Chuck roasts majority came from Walmart with majority with 18 percent. The second highest store was Fred Meyer at 14 percent and Publix is third highest at 12 percent.

Flavor Analysis of Trained Panel

Beef flavors attributes used by panelists during this study are outlined on Table 1. All flavor and texture attributes were evaluated by using a 16-point scale, 0 = none to 15 = extremely intense. By using least square means found on Table 3 we found that cuts (top loin steaks, sirloin steaks, chuck roasts, and ground beef) varied between flavor attributes using a P value less than 0.05. Flavor attributes shows differences between cuts were beef flavor ID, brown, roasted, bloody, fat like, bitter, salty, sweet, sour, umami, metallic, overall sweet, barnyard burnt, buttery, cardboardy, cooked milk, green, green hay, leather, liver, smoky charcoal, and sour milk/sour dairy. Of these flavor attributes that showed significant differences with cut, beef flavor ID, brown, roasted, bloody, fat like, sweet, salty, and umami are seen as positive flavors (Berto, 2015; Miller and Kerth, 2012; Glascock, 2014). While in cuts, metallic, barnyard, bitter, burnt, cardboardy, leather, liver, sour milk/sour dairy are seen as negative flavors (Berto, 2015; Adhikari et al., 2011; Glascock, 2014). Flavor attributes that did not different between cuts (P >0.05) animal hair, beet, chemical, cocoa, rancid, smoky wood, sour aromatics, warmed over, soapy, floral, petroleum, cumin, and dairy.

From looking at Table 3 top loins and ground beef were highest (P<0.0001) in beef ID, roasted, umami while lowest in liver. Figure 1 found that flavors such as bitter, burnt, brown, roasted, beef ID, smoky charcoal, and umami were clustered around top loins. When comparing ribeyes, top loins, and strip loins and found that top loins were rated highest in beef identity, brown, and roasted (Wall, 2017). Comparing top loin to top sirloin top loins had higher sensory scores for beef ID, umami, and overall sweet (Wall, 2017). A lot of these flavors that are associated with this cut are also associated with the Maillard reaction and the way it was cooked (Dinh et al., 2018). Ground beef by itself was lowest ($P<0.0001$) in bloody, metallic, cardboardy, and leather ($P<0.05$). Fat like ($P<0.0001$), salty, sweet, overall sweet, buttery, smoky charcoal, green hay, green ($P<0.05$), and cooked milk ($P<0.05$) were highest in ground beef samples. Figure 1 shows that flavors closely related to ground beef were sweet, overall sweet, fat like, green hay, and buttery. Ground beef containing 20 percent fat were high is buttery, fat-like, smoky charcoal, and sweet (Beavers, 2017). Top sirloin steak was highest in bitter ($P<0.0001$), sour ($P<0.05$), and cardboardy ($P<0.0001$). Figure 1 shows that top sirloins possessed undesirable flavors such as metallic, liver, leather, cardboardy, sour milk/sour diary, and sour and table 3 shows top sirloins along with chuck roasts having the highest liver like scores. The *gluteus medius* tends to be ranked highest in sour flavor (Yeh et al., 2018). The *gluteus medius* ranked the highest in liver like flavor compared to 10 different muscles throughout the round, chuck, and loin (Stetzer et al., 2008). A high amount of iron has been found in the *gletus medius* which has been said to increase liver like flavors (Yancey et al., 2006). Chuck roast were lowest $P<0.0001$) in beef ID, brown, roasted, bitter, and umami. When comparing the top sirloin and chuck roast although the top sirloin possessed greater undesirable flavors it ranks higher in beef ID, brown, and roasted. The *gluteus medius* possessed more beefy flavors like brown and roasted (Carmack et al., 1995). Undesirable off flavors such as bloody, cardboardy, and barnyard ($P<0.0001$) were highest in chuck roast. Looking at PCA figure 1 chuck roast contained bloody and barnyard flavors.

From looking at Table 3 and Figure 1 it is safe to say that our top sirloins and chuck roasts had the majority of negative flavors. The main reason why top sirloins and chuck roasts had such negative flavors could be due to the type of muscle. Top sirloin (*gluteus medius)* showed to contain more beef intensity flavors although Table 4 in this study shows the opposite (Carmack et al., 1995). Chuck roast is considered a locomotive muscle that helps that animal move. Locomotive muscles tend not to have as much intramuscular fat compared to cuts in the loin (Belew et al., 2003). A lot of these flavors that are found in beef are due to lipid thermal degradation (Mottram, 1998; Van Ba et al., 2012). As for chucks, they are cooked in an oven roast which of course is limited to the amount of Maillard reaction products being created. When chuck roasts were served to panelists it wasn't possible to have every sample contain an outside crust so the decision was made to trim all crust which could be a reason why the presence of certain flavors like beef ID and browned were missing. However, with that much lipid present degradation can only happen to an extent. Cooking types such as grilling versus roasting creates obvious differences in the types of flavors produced. Cuts cooked on stove top grills produced higher amount of Maillard reaction products (Kerth and Miller, 2015. The stove top grill was heated at 350˚F and Maillard reaction begin to appear at 310˚F (Kerth, 2013).

Cooked Meat Volatile Flavor Evaluation

Volatile aromatic compounds (n = 157) were found in samples used in this study (Table 6). From these compounds they could then be separated by their functional group; alcohols that contained 21 compounds, 25 compounds for aldehydes, 39 alkanes, 6 hydrocarbons, 26 ketones, 9 pyrazines, 8 sulfur containing compounds, and 23 other types of compounds. For partial least square regression biplot 39 volatiles which were considered the most influential on flavor and odor can be found in figure 2.

Chuck roasts were clustered around 2,5-dimethyl- nonane, 2,5-hexandione, pentanal, hexanal, 2-hexenal, 1-pentanol, benzene, (E)-2-octenal, 2-heptenal, 2,3-octanedione. As expected Maillard reaction volatiles were not found in chuck roasts due to the cooking method of roasting with two cups of water creating a moist heat cooking environment. Due to moisture in the environment the initial stages of the Maillard reaction which is dehydration cannot take place preventing compounds such as pyrazines which are more closely related to top loin steaks and ground beef samples (Kerth and Miller, 2015). Without Maillard reaction more lipid degradation products are able to be expressed which we find in chuck roasts. Volatiles such as 1-pentanol, hexanal, 2-hexenal, 1-octen-3-ol, 2,3-octanedione, and 2-octenal were volatiles derived from lipid degradation found in beef (Elmore et al., 2002). Hexanal and 2-octenal were products produced from lipid degradation (Zamora et al., 2015). Hexanal was associated with green aromas (Shahidi, 2009; Brewer, 2006). Higher amounts of hexanal in steaks from cattle that were present in grass fed beef suggesting that lipid thermal degradation plays a role in the production of these volatiles (Gardner and Legako, 2018). Hexanal is often times associated with the phosolipid arachidic acid (Blank et al., 2001). (E)-2-octenal is associated with green, nutty, and fatty aromas while 2-heptenal were associated with soapy, fatty, almond, and fishy aromas (Calkins and Hodgen, 2007). 1-pentanol can give off a fermented, bread, cereal aroma. Liver - like flavors were positively correlated with pentanal, hexanal, 1-pentanol and 1-octen-3-ol were liver like flavors associated with chuck roasts and top sirloin steaks (Calkins and Hodgen, 2007; Maughan et al., 2012). Liver – like flavors tend to be related to chuck roast muscles (Yancey et al., 2006). When looking to the left of figure 2 chuck roasts and top sirloins were clustered closer to these volatiles 2,3- octanedione was closely associated with green aromas and flavors (Calkins and Hodgen, 2007). Pentanal and Benzene often times has been associated with fermented, bready, fruity, and nutty aromas and flavors (Shahidi, 2009; Burdock, 210). 2-hexenal was found to produce green, apple, bitter, and almond aroma (Kerth and Miller, 2015).

Top sirloin steaks were closely associated to thiobis-methane which gives off sulfurous, creamy, vegetable, fruity aroma (Burdock, 2010). Thiobis methane was present in top sirloin steaks and close to metallic. Thiobis methane was the major volatile contributor to metallic flavor found in beef samples (Laird, 2015).Thiobis methane to be highest in top sirloin steaks (Wall, 2017). 3-methyl-acetate-butanol an alcohol was closely associated with top sirloin steaks that give off fruity, banana, and sweet aromas (Burdock, 2010). Table 7 shows 3-methyl-acetate-butanol was statisticaly the same for top sirloins and chucks roasts coupled with the volatile being clustered near sour which could indicate why sensory panelists rated these two cuts highest in sour. Methyl-ester-butanoic acid is known to give off an apple like odor with a sweet, fruity, almond, buttery, and nutty taste; often times these volatiles is known to be a product of lipid thermal degradation (Gardner and Legako, 2018). 3-heptanone was found and fruity, spicy, cinnamon, and banana like aromas; ethyl-ester-hexanoic acid is known to give off fruity aromas (Burdock, 2010). Ethyl-ester acetic acid was more closely clustered near top sirloins and gives off a sour, vinegar like aroma which could possibly explain the high sour scores for this cut. Specific products that were found in lipid thermal degradation such as acetic acids, methyl ester-butanoic acid were found to be associated with off flavor (Gardner and Legako, 2018). Although in the top left corner of the top loin steaks quadrant acetic acids and methyl ester-butanoic acid can be found these compounds are in fact clustered closer to top sirloins steaks which can attribute to off flavors being found in figure 1.

Top loin steaks were the only cut that was associated with pyrazines such as trimethyl-pyrazine, 2-methyl-pyrazine, 2-ethyl-3,5-dimethyl-pyrazine, 2,5-dimethyl-pyrazine, methyl-pyrazine, 3-ethyl-2,5-dimethyl-pyrazine. Majority of all pyrazines found gave off roasted, nutty, potato, musty, brown, earthy, cocoa aromas which is associated with attributes to high sensory scores for brown/roasted, beef identity, and umami (Kerth and Miller, 2015; Gardner and Legako, 2018; Mottram, 1998; Shahidi, 2009). 2-methyal-propanal was more closely related to bitter which gives off a sharp pungent odor and tends to be associated with a product produced by the Maillard reaction (Gardner and Legako, 2018). Additionally, 2-methyl-butanal and 3-methyl-butanal have found to give off meaty, oily aromas also created by the Maillard reaction. 2-ethyl-3,5-dimethyl pyrazines tend to give off pleasant odors in beef (Specht and Baltes, 1994). 3-(methylthio)-propanal tended to give off meaty aromas as well (Burdock, 2010). Top loin steaks that were about 3.81 cm similar to the thickness of top loins in this study had higher amounts of 3,5-dimethyl-pyrazine, 2-methyl-butanal, 2,5-dimethyl-pyrazine, 3-methyl-butanal, and methyl-pyrazine similar to the results found in figure 2 of this project (Kerth, 2016). Principal component analysis done in a beef study found that majority of top loins regards of quality grade were more closely associated with pyrazine volatiles while the gluteus medius muscle was associated with more negative volatiles (Legako et al., 2015).

The aldehyde volatile (E)-2-decenal a waxy orange aroma and 2,3-pentanedione a ketone with a sweet aroma and buttery taste were clustered near ground beef in figure 2. Lipid thermal degradation attributed to a high amount of (E)-2-decenal due to the fact that beef cuts with higher marbling produced more of this volatile compound (Dashdorj et al., 2015). The presence of 2,3-pentanedione could possibly be the reason why butter was highest in sensory scores of ground beef. Dl-limonene was found to have lemon, citrus, and sweet like aromas (Kerth and Miller, 2015; Ramalingam et al., 2019). The presence of this volatile could explain why ground beef sensory scores were highest in sweet. Both dl-limonene and (E)-2-decenal have been found in higher amounts in cattle that have been grass fed and have given off (Calkins and Hodgen, 2007). With higher amounts of (E)-2-decenal this may be why higher sensory score for green and green hay-like occurred.

CHAPTER V

CONCLUSION

Beef flavor is now considered to be the most important factor in consumer acceptability in meat. With multiple types of cuts, a consumer can purchase at the retail case it is important to understand what flavors are being expressed and how those flavors can ultimately impact purchasing decisions. By identifying both positive and negative flavors through trained descriptive sensory panel and gas chromatography mass spectrometry for top loin steaks, top sirloin steaks, chuck roasts, and 80 percent learn ground beef it will allow for a profile creation of each cut and how each cut varies in flavor. Along with the data that will be eventually collected by Texas Tech University and Colorado State University using consumer testing and REIMS a better understanding of how flavors found in these cuts will effect consumer acceptability.

Results indicated that chuck roasts and top sirloin steaks tended to be associated with negative flavor attributes. Lipid thermal degradation volatiles products were found primarily in chuck roasts due to the cooking environment where moisture was present preventing Maillard reaction products. The absence of Maillard reaction products overall effected flavors expressed during sensory testing with chuck roasts scoring lowest in beef identity, brown, roasted, and umami. Top sirloin steaks were closely associated with flavors such as sour, metallic, and cardboardy and found that certain volatiles such as thiosbis methane and ethyl ester acetic acid attributed to these flavors.

Top loin steaks tended to be associated with more positive flavor attributes as well as the production of more Maillard reaction products. Pyrazines which help give off a roasted flavor and aroma were clustered around top loins. On the other hand, 80 percent lean ground beef had a combination of positive and negative flavors found. Sweet and fat like flavors were identified by sensory panelists and volatiles found by GC/MS supported these findings. Negative attributes like green and green hay like were also associated with ground beef.

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APPENDIX A

TABLES AND FIGURES

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

Attributes	Definition	Reference
Flavor		
Animal hair	The aromatic perceived when raw wool is saturated with water	Caproic acid (1 drop) on cotton ball = 12.0 (a)
Asparagus	The slightly brown, slightly earthy green aromatics associated with cooked green asparagus	Fresh asparagus (40 g) diced in water (200 mL) microwave (3 min) = 7.5 (a), 6.5 (f)
Barnyard	Combination of pungent, slightly sour, hay-like aromatics associated with farm animals and the inside of a horn.	White pepper (0.45g) steeped in water (30 min). Filter = 4.5 (a), 4.0 (f)
Beef Flavor ID	Amount of beef flavor identity in the sample.	Swanson's Beef Broth = 5.0 80% lean ground chuck = 7.5 Beef brisket (160˚F) = 11.0
Beet	A dark damp-musty-earthy note associated with canned	Food club slice beets and water red beets. (1:2) = 6.0 (a), 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 metallics	Choice strip steak (140˚F) = 5.5 (a), (f) Beef brisket (160˚F) =6.0 (a), (f)
Brown	A round, full aromatic generally associated with beef suet that has been broiled.	Beef suet (broiled) =8.5
Burnt	The sharp/acrid flavor note associated with over roasted pork muscle, something over baked or excessively browned in oil	Arrowhead mills puffed barley cereal = 3.0
Buttery	Sweet, dairy-like aromatic associated with natural butter	Land O' Lakes unsalted (1/2 tbsp) = 7.0 (f)

Cardboardy	Aromatic associated with slightly oxidized fats and oils, reminiscent of wet cardboard packaging.	Dry cardboard (1 in square) = 5.0 (f) Wet cardboard soaked in water (1 cup) for 30 min. = 7.0(f)
Chemical	The aromatics associated with garden rose, hot Teflon pan, plastic packaging and petroleum-based product such as charcoal liter fluid.	Clorox (1 drop) in water (200 mL) = 6.5 (a)
Cocoa	Aromatic associated with cocoa beans, powdered cocoa, and chocolate bars; brown, sweet, dusty, often bitter aromatics.	Hershey's ® cocoa (1/2 tsp) water (1/2 cup) = 3.0 Hershey's ® chocolate kiss = 7.5 (a), 8.5 (f)
Cooked milk	The combination of sweet, brown flavors notes, and aromatics associated with heated milk.	Mini babybel original swiss cheese regular = 2.5 Whole milk microwaved (2 min) = 4.5
Cumin	The aromatics commonly associated with cumin and characterized as dry, pungent, woody, and slightly floral.	McCormick ground cumin (1/4 tsp) = 10.0 (a), 7.0 (f)
Dairy	Aromatics associated with products made from cow's milk, containing milk butter fat such as cream, milk, sour cream or butter milk.	Reduced fat 2% serve ½ oz = 8.0
Fat-like	Aromatics associated with cooked animal fat	Hillshire farms lit'l beef smokies = 7.0 Beef suet (broiled) = 12.0 (a, f)
Floral	Sweet light, slightly perfume impression associated with flowers.	Welch's white grape juice in water (1:1 parts) = 5.0 Geraniol (2 drops) on cotton ball = 7.5 (a)
Green	Sharp, slightly pungent aromatics associated with green/plant/vegetable matters such as parsley, spinach, pea pod, fresh cut grass, etc.	Fresh parsley (25g) steeped in in water for 15 min than drained = 9.0
Green Hay	Brown/green dusty aromatics associated with dry grasses, hay, dry parsley and tea leaves	Dry parsley (1/4 tsp) in 2 oz cup = 5.0 (a)
Heated oil	The aromatics associated with oil heated to a high temperature	Wesson vegetable oil (1/2 cup) microwaved (3 min) = 7.0 (a) Lays potato chips = 4.0 (a)
Leather	Musty, old leather (like old book bindings)	Leather cord in medium snifter = 3.0 (a)
Liver like	Aromatics associated with cooked organ meat/liver.	Beef liver (1 in) = 7.5 (a, f) Brauschweiger liver sausage = 10.0 (a, f)
Metallic	The impression of slightly oxidized metal, such as iron, copper, and	0.10 potassium chloride

	silver spoons.	solution = 1.5 Choice strip steak (140˚F) =4.0 Dole canned pineapple juice = 6.0
Overall Sweet	The combination of sweet taste and sweet aromatics	Post shredded wheat spoon size = 1.5 Hillshire farms lit'l beef smokies = 3.0 Lorne done cookies = 5.0
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 fats and oils. these may include cardboard, painty, varnish, and fishy.	Wesson vegetable oil (1/2 cups) microwave (3 min) = 7.0 (a)
Refrigerator Stale	Off-flavor associated with a product that has absorbed odors from the refrigerator.	Ground beef (165˚F) stored overnight = 4.5 (a), 5.0 (f)
Roasted	A round, full aromatic generally associated with beef that has been broiled/roasted.	80% lean ground chuck = 10.0 Hormet potroast =6.0 Wesson vegetable oil (1/2 cup) microwave (5 min) = 9.0
Soapy	An aromatic commonly found in unscented hand soap	Clorox liquid (.12 oz) in water (4 oz) = 3.0 (a) .5g Ivory bar soap in water (100 mL) = 6.5 (a)
Smokey charcoal	An aromatic associated with meat juices and fat drippings on hot coals which can be acrid, sour, burned, etc	Wright's natural (1/4 tsp) in water (100 mL) = 9.0 (a)
Smokey wood	Dry, dusty aromatic reminiscent of burning wood.	Wright's natural hickory seasoning (1/4) tsp in water (100 mL) = 7.5 (a)
Sour aromatics	Aromatics associated with sour substances.	Buttermilk (1/2) oz = 5.0
Sour milk/sour dairy	Sour, fermented aromatics associated with dairy products such as buttermilk and sour cream	HEB swiss cheese = 3.0 (a), 7.0 (f) Buttermilk = 4.0 (a), 9.0 (f)
Warmed Over	Perception of a product that has been previously cooked and reheated.	Reheated ground beef (165˚F) = 6.0

Table 2. Definition and reference standards for beef and ground beef texture attributes and their intensities where 0 = none and 15 = extremely intense from AMSA (2015).

Tenderness		
Connective tissue	The structural component of the muscle surrounding the tissue amounts during mastication.	Brisket steak cooked to 70˚C = 7.0 Tenderloin cooked to 70˚C = 14.0
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 cooked to 70˚C = 9.0 Tenderloin cooked to 70˚C = 14.0
Ground beef textures		
Cohesiveness of mass	The amount to which sample deforms rather than crumbles, cracks, or breaks.	Licorice (1 piece) = 0.0 Carrots (1/2 in)= 2.0 Mushrooms (1/2 in)= 4.0 Hebrew national frankfurter cooked (5 min) = 7.5 Yellow American cheese (1/2 in) = 9.0 Little Debbie soft brownie (frosting removed) = 13.0 Pillsbury/country biscuit dough = 15.0
Hardness	The force to attain a given deformation, such as: force to compress with the molars, as above; force to compress between tongue and palate; force to bite through with incisors.	Philadelphia cream cheese = 1.0 Yellow American cheese = 4.5 Goya foods olive = 6.0 Hebrew national frankfurter cooked 10 min = 7.0 Planters peanut = 9.5 Carrot (1/2 in) = 11.0 Life savers = 14.5

Initial juiciness	The amount of perceived juice that is released from the product during the initial 2-3 chews.	Carrot (1/2 in) = 8.5 Mushroom (1/2 in) = 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
Particle size	The degree to how big the particle is.	Small pearly tapioca = 4.0 Boba tea tapioca = 8.0
Springiness	The degree to which samples returns to original shape or the rate with which sample returns to original shape.	Philadelphia cream cheese (1/2 in) = 0.0 Hebrew national frankfurter cooked 10 min = 5.0 Marshmallow = 9.5 Gelatin dessert = 15.0

Table 3. Beef flavor and basic tastes attributes least square means by 4 beef cuts

Effect	P-Value	Top Loin Steaks	Top Sirlon Steaks	Chuck Roast	80% Lean Ground Beef	RMSE
Beef Identity	<.0001	9.2[c]	8.7[b]	7.2[a]	9.1[c]	0.7
Brown	<.0001	9.9[b]	9.9[b]	3.3[a]	10.5[c]	1.03
Roasted	<.0001	7.6[bc]	7.4[b]	5.9[a]	7.7[c]	0.75
Bloody	<.0001	1.4[b]	1.5[b]	2.0[c]	1.1[a]	0.48
Fat Like	<.0001	2.1[b]	1.8[a]	2.3[b]	5.4[c]	0.56
Bitter	<.0001	2.5[b]	2.7[c]	2.1[a]	2.3[b]	0.40
Salty	<.0001	1.8[a]	1.6[a]	1.5[a]	1.9[c]	0.28
Sweet	<.0001	1.1[b]	0.8[a]	0.7[a]	1.4[c]	0.40
Sour	.0002	2.5[a]	2.9[b]	2.5[a]	2.4[a]	0.56
Umami	<.0001	4.2[c]	3.5[b]	2.7[a]	4.3[c]	0.76
Metallic	<.0001	2.1[b]	2.2[c]	2.2[c]	1.9[a]	0.26
Overall Sweet	<.0001	0.5[b]	0.3[a]	0.3[a]	0.7[c]	0.25
Burnt	.0007	0.2[ab]	0.4[c]	0.0[a]	0.2[bc]	0.46
Buttery	<.0001	0.1[ab]	0.2[a]	0.2[b]	0.6[c]	0.29
Cardboardy	<.0001	1.6[b]	2.0[d]	1.8[c]	1.4[a]	0.42
Cooked Milk	.0012	0.0[a]	0.0[a]	0.0[a]	0.1[b]	0.08
Green	.0057	0.0[a]	0.0[a]	0.0[a]	0.1[b]	0.14
GreenHay	<.0001	0.0[ab]	0.0[a]	0.2[b]	1.1[c]	0.32
Leather	.0033	0.2[b]	0.2[b]	0.2[b]	0.0[a]	0.22
Liver	<.0001	1.6[a]	2.0[b]	1.9[b]	1.5[a]	0.45
Smokey Charcoal	<.0001	0.3[b]	0.3[b]	0.0[a]	0.5[c]	0.33
Sour Milk/ Sour Dairy	.0320	0.2[a]	0.4[bcd]	0.3[ac]	0.4[ad]	0.45

Barnyard	<.0001	0.1[a]	0.1[a]	0.3[b]	0.1[a]	0.22

[abcd]Mean values within a row and cut followed by the same letter are not significantly different (P>0.050)
[e]Flavor measured where 0 = none and 15 = extremely intense.
Flike – Fat like.
Osweet – overall sweet.
Cmilk – cooked milk.
SCharcoal – smoky charcoal.

Table 4. Package information frequencies of top loins, top sirloins, ground beef, and chuck roasts

	Top Loin		Top Sirloin		GBeef		Chuck Roast	
Package Type	n	%	n	%	n	%	n	%
Over wrap	27	54	33	67.3	19	38	40	80
Over wrap-MAP	1	2	2	4.1	1	2	0	0
Vacuum Packaged	13	26	9	18.4	13	26	10	20
Chub	0	0	0	0	5	10	0	0
MAP	8	16	4	8.2	8	16	0	0
MAP-CO	1	2	1	2	2	4	0	0
Unknown	0	0	0	0	2	4	0	0
Label Claim								
Angus	20	40	14	28.6	0	0	13	26
COOL	11	22	10	20.4	5	10	7	14
Grain Fed	2	4	3	6.1	0	0	3	6
Fresh Never Froz.	4	8	4	8.2	2	4	3	6
FNF-No Water	0	0	0	0	2	4	0	0
Natural	13	26	6	12.2	15	30	7	14
Regional/Local	2	4	2	4.1	0	0	1	2
Hand Cut	2	4	2	4.1	0	0	1	2
Blade Tender.	5	10	3	6.1	0	0	6	12
CI	6	12	3	6.1	0	0	9	18
Grass Fed	6	12	7	14.3	6	12	4	8
Organic	1	2	3	6.1	0	0	0	0
Antibiotic Free	10	20	6	12.2	7	14	3	6
Hormone Free	13	26	6	12.2	8	16	3	6
No Grain Fed	0	0	0	0	0	0	1	2
Never Ever	5	10	1	2	0	0	4	8
Vegetarian Fed	5	10	1	2	4	8	2	4
NP	2	4	2	4.1	3	6	1	2
None	9	18	0	0	21	42	14	28
100% Beef	0	0	0	0	2	4	0	0
100% Pure	0	0	0	0	2	4	0	0
No Additives	0	0	0	0	2	4	0	0
Chuck	0	0	0	0	4	8	0	0
Fresh Quality	0	0	0	0	1	2	0	0
HALAL	0	0	0	0	1	2	0	0
Free Range	0	0	0	0	1	2	0	0
Certified Angus.	0	0	3	6.1	0	0	0	0
Humanely Raised	0	0	2	4.1	0	0	0	0
No GMO	1	2	3	6.1	0	0	0	0
Dry Aged	1	2	0	0	0	0	0	0

No Additives	1	2	0	0	0	0	0	0
USA	2	4	0	0	0	0	0	0
Sustainable	1	2	0	0	0	0	0	0
Eniv.Friendly	2	4	0	0	0	0	0	0
ANA	0	0	0	0	0	0	0	0
A	0	0	1	2	0	0	0	0
NA	0	0	1	2	0	0	0	0
NH	0	0	1	2	0	0	0	0
Cuts/Package								
1	34	68	30	61.2	20	40.0	39	78
2	9	18	14	25.6	0	0	11	22
3 or more	6	12	5	10.2	0	0	0	0
N/A	1	2	0	0.00	30	60.0	0	0
Grade								
Standard	0	0	0	0	0	0	0	0
Select	0	0	0	0	1	2	0	0
Choice	26	52	26	53.1	0	0	40	80
Choice +	1	2	0	0	0	0	0	0
Choice Not designated	0	0	5	10.2	0	0	0	0
Prime	6	12	3	6	0	0	0	0
N/A	17	34	15	30.6	49	98	10	20
Brand								
All Natural	0	0	0	0	3	6	0	0
Black Angus	1	2	0	0	0	0	0	0
Butcher Shop	0	0	1	2	0	0	0	0
CO Angus	2	4	2	4.1	0	0	1	2
Fred Meyer	0	0	1	2	0	0	2	4
Greenwise	0	0	0	0	2	4	0	0
Kirkland	1	2	0	0	0	0	2	4
KirklandSig.	5	10	5	10.2	0	0	5	10
Kroger	0	0	0	0	2	4	0	0
Members Mark	2	4	3	6.1	2	4	3	6
Market	0	0	1	2	0	0	0	0
Market Side butcher	0	0	0	0	1	2	1	2
Meyers Nat. angus	1	2	0	0	0	0	0	0
Meyers Nat. beef	0	0	0	0	2	4	0	0
Nat. Beef	0	0	0	0	1	2	0	0
Publix	0	0	0	0	1	2	0	0
Publix Prem.	1	2	0	0	0	0	6	12

Panorama	0	0	1	2.0	0	0	0	0
Private Selection	0	0	1	2.0	0	0	0	0
QFC	0	0	0	0	0	0	2	4
SC Grocers	0	0	0	0	0	0	1	2
Sig. Farm	0	0	0	0	4	8	0	0
Simple Truth	5	10	2	4.1	0	0	2	4
Straus Feed raised	2	4	0	0	0	0	0	0
Sunfed Ranch	0	0	0	0	2	4	0	0
Sutton &Dod.	6	12	0	0	0	0	4	8
Thou. Hills	2	4	0	0	0	0	1	2
Walmart	0	0	0	0	0	0	5	10
Thomas Farms	0	0	0	0	2	4	0	0
White Oat	1	2	2	4.1	0	0	0	0
WD Brand	0	0	0	0	1	2	1	2
N/A	21	42	27	55.1	27	54	14	28
<u>Store</u>								
Aldi	1	2	1	2	0	0	0	0
Best Mkt.	2	4	1	2	2	4	0	0
Costco	6	12	5	10.2	0	0	7	14
Fred Meyer	2	4	2	4.1	2	4	2	4
Fresco y Mas	0	0	0	0	0	0	1	2
King Kullen	4	8	2	4.1	0	0	0	0
King Sooper	2	4	1	2	1	2	4	8
Nat. Grocers	2	4	0	0	2	4	1	2
North Shore	0	0	0	0	1	2	0	0
Pavillions	0	0	2	4.1	2	4	1	2
Publix	1	2	3	6.1	3	6	6	12
QFC	1	2	0	0	1	2	2	4
Ralph’s	2	4	4	8.2	4	8	2	4
Safe Way	4	8	6	12.2	2	4	1	2
Sam’s Club	4	8	5	10.2	2	4	3	6
Shop Rite	0	0	3	6.1	4	8	2	4
State Bros.	1	2	1	2	0	0	0	0
Stop & Shop	0	0	1	2	1	2	0	0
Target	6	12	4	8.2	7	14	4	8
Trader Joe	2	4	1	2	1	2	0	0
Vons	1	2	0	0	1	2	1	2
Walmart	4	8	3	6.1	7	14	9	18
Whole Foods	0	0	1	2	0	0	0	0
Winn Dixie	3	6	3	6.1	2	4	1	2
N/A	2	4	0	0	5	10	3	6

GBeef – Ground beef.

Table 5. Mean, standard deviation, minimum, and maximum for top loin, top sirloin, ground beef, and chuck roast

	Top Loin				Top Sirloin				GBeef				CRoast			
	$\bar{X}$	SD	Min	Max	$\bar{X}$	SD	Min	Max	$\bar{X}$	SD	Min	Max	$\bar{X}$	SD	Min	Max
Package Wt.(lb)	1.22	0.97	0.50	3.97	1.44	1.00	0.50	5.99	1.21	0.46	0.96	3.00	2.97	1.33	1.33	6.66
Cuts/Package	1.52	1.53	1.00	4.00	1.57	0.94	1.00	5.00	1.00	0.00	1.00	1.00	1.22	0.42	1.00	2.00
Price/lb	12.97	4.06	4.99	24.99	8.15	2.41	1.29	12.99	4.52	0.83	3.19	5.99	5.81	1.06	3.99	7.99
Total Price	16.27	12.38	4.19	51.57	11.68	6.13	3.86	31.07	7.27	2.52	3.06	11.68	16.65	6.00	7.70	39.77

GBeef – ground beef.
CRoast – chuck roast.

Table 6. Overall means and standard deviation value for volatiles, aromatics chemicals (n = 157) identified by Gas Chromatograph/ Mass Spectrometry.

Code	Volatile Chemical compound	Mean Total Ion	Standard Deviation	Retention Time	Standard Deviation
C1	alpha.-Pinene	86218.23	52481.06	15.36	0.57
C2	(S)-2-Methylbutanal	45468.67	15408.07	14.62	0.02
C3	1-Butanol, 3-methyl-	495907.11	1073168.52	7.55	0.02
C4	1-Butanol, 3-methyl-, acetate	329128.25	160546.40	12.55	0.02
C5	1-Hexanol	412212.79	670184.20	12.35	0.02
C6	1-Hexanol, 2-ethyl-	1407479.86	1581658.78	18.36	0.03
C7	1-Octen-3-ol	439333.79	463855.34	16.56	0.03
C8	1-Octene	127705.66	117470.90	9.41	0.31
C9	1-Pentanol	502520.00	701074.67	8.63	0.02
C10	1-Pentanol, 2-methyl-	85463.00	42796.91	8.16	0.15
C11	1-Penten-3-ol	92459.96	44456.77	5.95	0.02
C12	1-Propanol	508377.50	704175.82	3.19	0.01
C13	1,2-Propanediol	43721423.40	29670019.67	0.01	0.31
C14	1,3-Octadiene	126231.17	100888.14	10.78	0.01
C15	2 - hydroxy – butanedial	12107.00	10619.74	15.70	0.13
C16	2 ETHYL HEXANOL	284084.33	212204.43	18.39	0.02
C17	2 OCTENAL	168762.43	62453.23	19.55	0.03
C18	2-Butanone	3096649.04	4222949.59	3.85	0.02
C19	2-Butanone, 3-hydroxy-	2588827.79	3159363.21	6.93	0.23
C20	2-Butenal, 2-methyl-	235612.25	534423.62	7.90	0.02
C21	2-Decanone	40482.50	37.47	23.58	0.03
C22	2-Decenal, (E)-	166022.25	85993.91	25.00	0.01
C23	2-Furancarboxaldehyde	27897.00	10105.97	11.17	0.01
C24	2-Heptanone	210231.17	235128.92	13.28	0.78

C25	2-heptenal	115927.71	95704.84	15.82	0.02
C26	2-Hexanone, 5-methyl-	114285.75	129571.25	13.19	0.03
C27	2-Hexenal	107823.29	64429.62	11.91	0.01
C28	2-methyl pyrazine	169052.71	234910.86	10.93	0.04
C29	2-Nonanone	98920.33	46669.45	20.58	0.03
C30	2-Nonenal	65924.44	36289.82	22.19	1.49
C31	2-Octanone	65496.63	35954.17	16.94	0.02
C32	2-Octenal, (E)-	205814.00	184520.68	19.55	0.03
C33	2-Octene, (E)-	551605.33	462610.33	10.11	0.27
C34	2-Octene, (Z)-	422297.93	199941.58	10.21	0.21
C35	2-Pentanone	124082.11	66057.28	6.06	0.04
C36	2-Pentanone, 3-methyl-	291574.00	364654.87	4.84	1.40
C37	2-Pentanone, 4-methyl-	87630.58	153807.26	7.71	0.03
C38	2-Penten-1-ol, (E)-	31051.50	34165.28	6.33	0.03
C39	2-Penten-1-ol, (Z)-	41527.60	10684.71	5.97	0.01
C40	2-Propanol	219931.75	155615.80	7.88	0.34
C41	2-Propanol, 1-butoxy-	238834.25	323932.39	15.06	0.04
C42	2-Propanol, 1-propoxy-	365508.50	373495.98	11.35	0.03
C43	2-Propanone	1700248.79	1485874.04	2.39	0.02
C44	2-Propenoic acid, 2-methyl-,methyl ester	295746.80	252178.52	6.75	0.01
C45	2,3-Butanediol	1126866.13	1861414.44	9.62	0.18
C46	2,3-Butanedione	630308.46	816456.12	3.73	0.05
C47	2,3-Octanedione	566438.15	872986.95	16.65	0.02
C48	2,3-Pentanedione	56040.85	32904.84	6.31	0.02
C49	2,3,5-trimethyl pyrazine	88995.00	50799.60	17.61	0.02
C50	2,5-Hexanedione	1070372.20	765044.86	16.65	0.03
C51	2,5-Octanedione	659472.00	933537.84	16.65	0.03
C52	2(3H)-Furanone, dihydro-	189055.32	353835.46	14.20	0.05
C53	2(3H)-Furanone, dihydro-3,5-dimethyl-	207204.00	232196.90	8.67	0.00

C54	2(3H)-Furanone, dihydro-4-hydroxy-	2560.00	2768.38	17.70	3.55
C55	2(5H)-Furanone	53379.33	57801.34	14.11	0.03
C56	3-Buten-2-ol, 3-methyl-	112255.40	46783.47	6.06	0.01
C57	3-Ethyl-2-hexene	59774.80	23319.16	9.69	0.01
C58	3-Heptanone	52241.00	54995.73	13.04	0.00
C59	3-Heptene, 3-methyl-	93737.00	51142.36	9.66	0.04
C60	3-Hexanone	57360.80	21729.13	6.30	0.02
C61	3-Octene, (Z)-	229615.25	203103.09	9.92	0.46
C62	3-Pentanone	29970.80	17912.65	6.34	0.01
C63	3-Pentanone, 2-methyl-	54858.67	21769.28	6.28	0.03
C64	3-Piperidinol	23952.53	17336.77	23.08	0.54
C65	3,3-Dimethyl-2-pentanol	115593.40	104560.15	8.25	0.21
C66	3,4-Dihydropyran	21747.54	17608.84	8.39	1.74
C67	3(2H)-Furanone, dihydro-2-methyl-	34365.88	13723.99	6.13	0.51
C68	4-Octene, (E)-	64952.60	40425.72	9.63	0.02
C69	4-Pentenal	166225.08	97402.92	12.37	0.03
C70	Acetic acid ethenyl ester	387815.31	357672.77	3.69	0.09
C71	Acetic acid, 2-ethylhexyl ester	107897.75	69017.51	22.35	0.01
C72	Acetic acid, ethyl ester	1782753.67	2893176.04	4.50	1.32
C73	Acetic acid, methyl ester	128047.65	139761.37	2.79	0.01
C74	Benzaldehyde	746917.83	459210.42	16.32	0.04
C75	Benzene	54458.80	26580.25	5.46	0.02
C76	Benzene, 1,2-dimethyl-	157027.67	45813.29	12.82	0.37
C77	Benzene, 1,3-bis(1,1-dimethylethyl)-	122376.49	92161.09	24.83	0.02
C78	Benzene, 1,4-dimethyl-	92959.15	87529.27	12.84	0.36
C79	Benzene, ethyl-	47709.11	39390.24	12.33	0.02
C80	Benzene, methyl-	461369.52	304522.65	8.82	0.02

C81	Butanal	409249.90	769711.70	3.46	0.30
C82	Butanal, 2-methyl-	1998369.06	1858879.25	5.51	0.02
C83	Butanal, 3-methyl-	1463370.17	1613746.97	5.59	0.51
C84	Butanoic acid	587661.11	487507.31	8.96	0.24
C85	Butanoic acid, 3-hydroxy-,methyl ester	228965.65	326382.69	7.11	0.02
C86	Butanoic acid, 3-methylbutyl ester	803250.88	1123531.76	14.12	4.91
C87	Butanoic acid, ethyl ester	738155.00	297983.21	9.77	0.02
C88	Butanoic acid, methyl ester	1066594.65	1524344.86	7.11	0.02
C89	Carbon disulfide	2010895.20	1436588.62	3.03	0.02
C90	Decanal	150435.86	147627.85	23.95	0.02
C91	Dimethyl sulfide	320058.00	374013.33	2.73	0.02
C92	Dimethyl tetrasulphide	78967.25	69636.54	2.09	0.06
C93	Dimethyl trisulfide	157728.17	79491.45	16.75	0.04
C94	Dimethyldisulfide	183264.27	157799.54	8.23	0.99
C95	dl-Limonene	105239.77	75450.72	18.70	0.03
C96	Dodecanal	86337.50	37628.69	26.90	0.00
C97	Furan, 2-pentyl-	193662.44	201074.96	17.03	0.03
C98	Heptanal	917776.71	782173.48	13.68	0.10
C99	Heptane, 2-methyl-	179162.50	172546.18	8.54	0.02
C100	Heptane, 2,2-dimethyl-	121968.18	141930.88	9.11	0.02
C101	Heptane, 2,2,4-trimethyl-	74291.38	77601.77	12.87	0.11
C102	Heptane, 2,3-dimethyl-	68325.82	24282.95	11.90	0.03
C103	Heptane, 2,4-dimethyl-	1345377.11	1027919.50	10.55	0.02
C104	Heptane, 2,4,6-trimethyl-	113412.94	128182.62	17.72	0.03
C105	Heptane, 2,5-dimethyl-	39384.25	12210.58	11.07	0.02
C106	Heptane, 4-methyl-	121731.96	92988.75	8.36	0.10
C107	Hexanal	8491304.81	11083767.98	9.86	0.06
C108	Hexane, 2,4-dimethyl-	84703.57	49150.20	7.36	0.04

C109	Hexane, 3-ethyl-	107553.47	109160.16	12.11	0.06
C110	Hexanoic acid	693394.00	467665.63	16.04	0.05
C111	Hexanoic acid, ethyl ester	130409.33	163086.47	17.13	0.03
C112	Hexanoic acid, methyl ester	711316.28	879032.98	14.40	0.03
C113	ISO BUTYRALDEHYDE	792175.04	704069.34	3.27	0.12
C114	Methane, thiobis-	344644.89	416320.49	2.73	0.02
C115	Methanethiol	114672.39	85365.43	1.92	0.01
C116	N HEPTANAL	656399.69	381432.52	13.67	0.02
C117	Nonanal	877868.05	609751.76	21.12	0.03
C118	Nonane, 2-methyl-	122843.30	97332.31	15.94	0.03
C119	Nonane, 2,5-dimethyl-	70301.56	66340.89	17.91	0.02
C120	Nonane, 2,6-dimethyl-	208194.46	101823.37	18.05	0.03
C121	NONENAL	82819.00	30735.35	22.95	0.01
C122	Octanal	620978.31	502954.82	17.48	0.02
C123	Octane, 2,2-dimethyl-	69810.00	70151.71	12.89	0.10
C124	Octane, 2,3-dimethyl-	64575.50	6264.26	15.83	0.02
C125	Octane, 2,6-dimethyl-	122820.74	69470.19	18.06	0.02
C126	Octane, 2,7-dimethyl-	40425.80	19057.64	14.63	0.01
C127	Octane, 3,3-dimethyl-	19176.43	12788.99	13.45	0.02
C128	Octane, 4-methyl-	282954.45	229365.61	12.13	0.02
C129	Octanoic acid	128389.00		22.80	
C130	Octanoic Acid	369179.50	13547.46	22.82	0.01
C131	Pentanal	1383834.41	1413558.21	6.40	0.04
C132	Pentane, 2-methyl-	426154.78	444422.79	3.37	0.29
C133	Pentane, 2,3,3-trimethyl-	233872.05	213976.30	8.37	0.02
C134	Pentane, 2,3,4-trimethyl-	175093.11	112071.40	8.11	0.04
C135	Pentane, 3-ethyl-	126910.00	63879.55	8.15	0.12
C136	Pentane, 3-ethyl-2-methyl-	144737.29	53476.96	8.38	0.02
C137	Pentanoic acid, methyl	186077.13	151087.43	10.66	0.20

	ester				
C138	Propanal, 2-methyl-	828939.51	842260.73	3.28	0.13
C139	Propanal, 2,2-dimethyl-	36778.29	20465.04	6.22	0.17
C140	Propanal, 3-(methylthio)-	53949.79	32189.43	14.00	0.02
C141	Propanoic acid, 2-methy l-, methyl ester	180878.50	253105.93	5.96	0.03
C142	Propanoic acid, 2-methyl -, pentyl ester	3202849.22	2329249.75	17.65	0.03
C143	Propanoic acid, methyl ester	68316.86	72513.77	4.58	0.01
C144	Pyrazine, 2-ethyl-3-methyl-	91973.00	67909.19	17.65	0.04
C145	Pyrazine, 2-ethyl-3,5-dimethyl-	80898.75	20010.83	20.42	0.19
C146	Pyrazine, 2,5-dimethyl-	408558.88	329569.86	14.25	0.03
C147	Pyrazine, 2,6-dimethyl-	117860.55	78262.42	14.26	0.05
C148	Pyrazine, 3-ethyl-2,5-dimethyl-	95864.10	57002.28	20.27	0.05
C149	Pyrazine, methyl-	164795.94	134023.89	10.94	0.03
C150	Pyrazine, trimethyl-	305012.47	208567.07	17.60	0.03
C151	Styrene	169598.18	107134.32	13.53	0.02
C152	Toluene	595079.42	745630.62	8.82	0.02
C153	trans-1-Butyl-2-methylcyclopropane	108131.56	66874.35	9.46	0.03
C154	Tridecane	79098.13	103603.12	25.41	0.22
C155	Undecane, dimethyl	153883.41	68493.85	17.75	0.03
C156	Undecane, 2-methyl-	16070.00	7190.50	22.88	0.02
C157	XYLENE	165570.17	108034.24	13.12	0.50

Table 7. Least square means of total ion counts for volatile aromatic compounds present for top loin steaks, top sirloin steaks, chuck roasts, and 80% lean in ground beef.

Volatile	Top Loin	Top Sirloin	Chuck Roasts	80% Lean Ground Beef	SEM*	*P*>F
Alcohol						
1-Pentanol	122642[a]	220983[a]	742038[b]	224467[a]	567463	<.0001
2-Hexenal	0[a]	0[a]	15403[b]	0[a]	22146	.001
(E)- 2-Octenal	0[a]	0[a]	26140[b]	3196[a]	49180	.02
3-Piperidinol	0[a]	334[b]	103[a]	3871[b]	7729	.02
1-Octen-3-ol	158210[a]	371766[bc]	383255[c]	225210[ac]	419747	.02
3-Methyl-acetate-1-butanol	0	22434	4890	0	50144	.09
Aldehyde						
(E)-2-Decenal	0[a]	0[a]	0[a]	13281[b]	25308	.02
2-Heptenal	0[a]	0[a]	43911[b]	5656[a]	43744	<.0001
2-Methyl-butanal	2653361[c]	2226821[c]	45210[a]	1439433[b]	1564309	<.0001
3-Methyl-butanal	1786114[bc]	1509436[b]	246104[a]	2142985[c]	1452346	<.0001
Hexanal	3933888[a]	5540758[a]	19687803[b]	4908676[a]	9058740	<.0001
Pentanal	187289[a]	250644[a]	1644402[b]	230095[a]	96295	<.0001
2-Methyl-propanal	754280[bc]	914556[c]	198139[a]	560915[b]	769035	<.0001
3-(Methylthio)-propanal	33757[c]	23361[bc]	0[a]	17187[b]	29626	<.0001
Alkane						
1,3-Octadiene	0	6526	9063	0	26974	.23

2-Methyl-nonane	26104	10934	0	10733	74524	.38
2,5-Dimethyl-nonane	3381[a]	2938[a]	14898[b]	1693[a]	26259	.047
4-Methyl-octane	275089[b]	278017[b]	258012[b]	133252[a]	228330	.004
2,3,4-Trimethyl-pentane	69238[bc]	41816[ab]	23894[a]	98324[c]	101919	.002
Hydrocarbon						
Benzene	3355[a]	4750[a]	19565[b]	5585[a]	21292	.001
1,3-bis(1,1- dimethylethyl)- benzene	71904[a]	123807[b]	82006[a]	61737[a]	92992	.01
Ketone						
2,5-Hexanedione	0	52209	132631	33974	28497	.13
2,3-Pentanedione	9627	6293	10741	18636	26768	.13
2,3-Octanedione	29915[a]	52709[a]	513598[b]	118540[a]	521929	<.0001
2(5H)-Furanone	0	448	0	2772	8767	.33
3-Heptanone	0	2411	295	432	8498	.50
Pyrazine						
2-Methyl-pyrazine	34824	23814	35469	5727	65245	.08
2-Ethyl-3,5-dimethyl- pyrazine	6471[b]	0[a]	0[a]	0[a]	11446	.009
2,5-Dimethyl-pyrazine	335846[b]	239421[b]	0[a]	251425[b]	286963	<.0001
3-Ethyl-2,5-dimethyl-						

pyrazine	43163[b]	36186[b]	0[a]	14127[a]	47083	<.0001
Methyl-pyrazine	83135[c]	51531[bc]	0[a]	42077[b]	96890	.001
Trimethyl-pyrazine	72512[b]	19782[a]	0[a]	0[a]	94479	.0003
Sulfur Containing						
1,2-Propanediol	0[a]	0[a]	0[a]	4372142[b]	7925584	.01
Carbon disulfide	2600850[b]	2482872[b]	2309566[b]	634926[a]	1203087	<.0001
Thiobis-methane	120381[a]	548351[c]	293416[b]	44445[a]	336318	<.0001
Other						
Ethyl ester-hexanoic acid	1515	12742	0	1900	34290	.24
Ethyl ester-acetic acid	216520	355280	12458	71992	994378	.33
Ethyl ester-butanoic acid	13855	31701	0	0	95341	.31
Methyl ester-butanoic acid	248489[a]	553914[b]	0[a]	9032[a]	747790	.001
dl-Limonene	32909[a]	49556[a]	37509[a]	78502[b]	72148	.001

Figure 1. Principal component analysis biplot for descriptive sensory attributes and cuts.

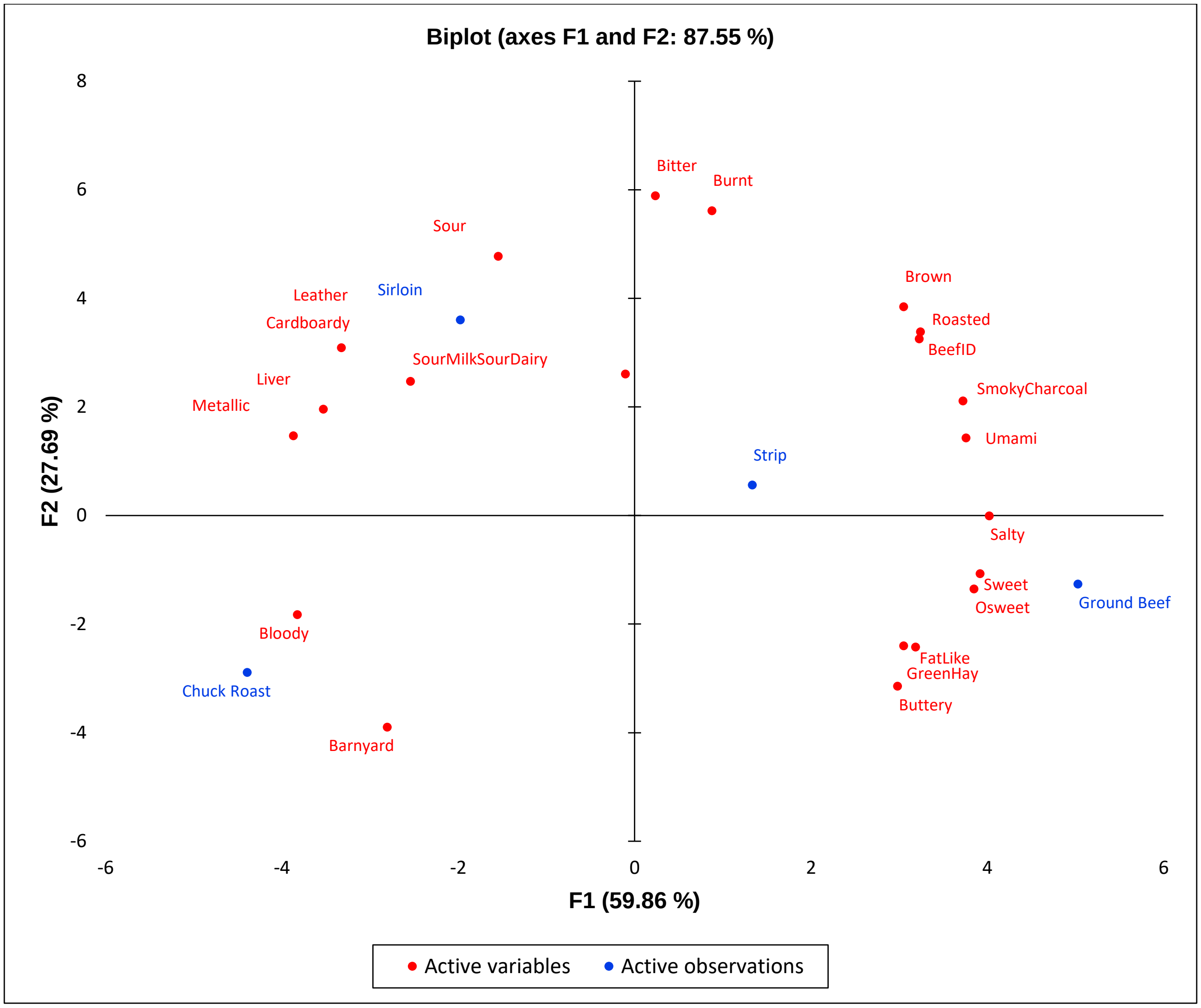
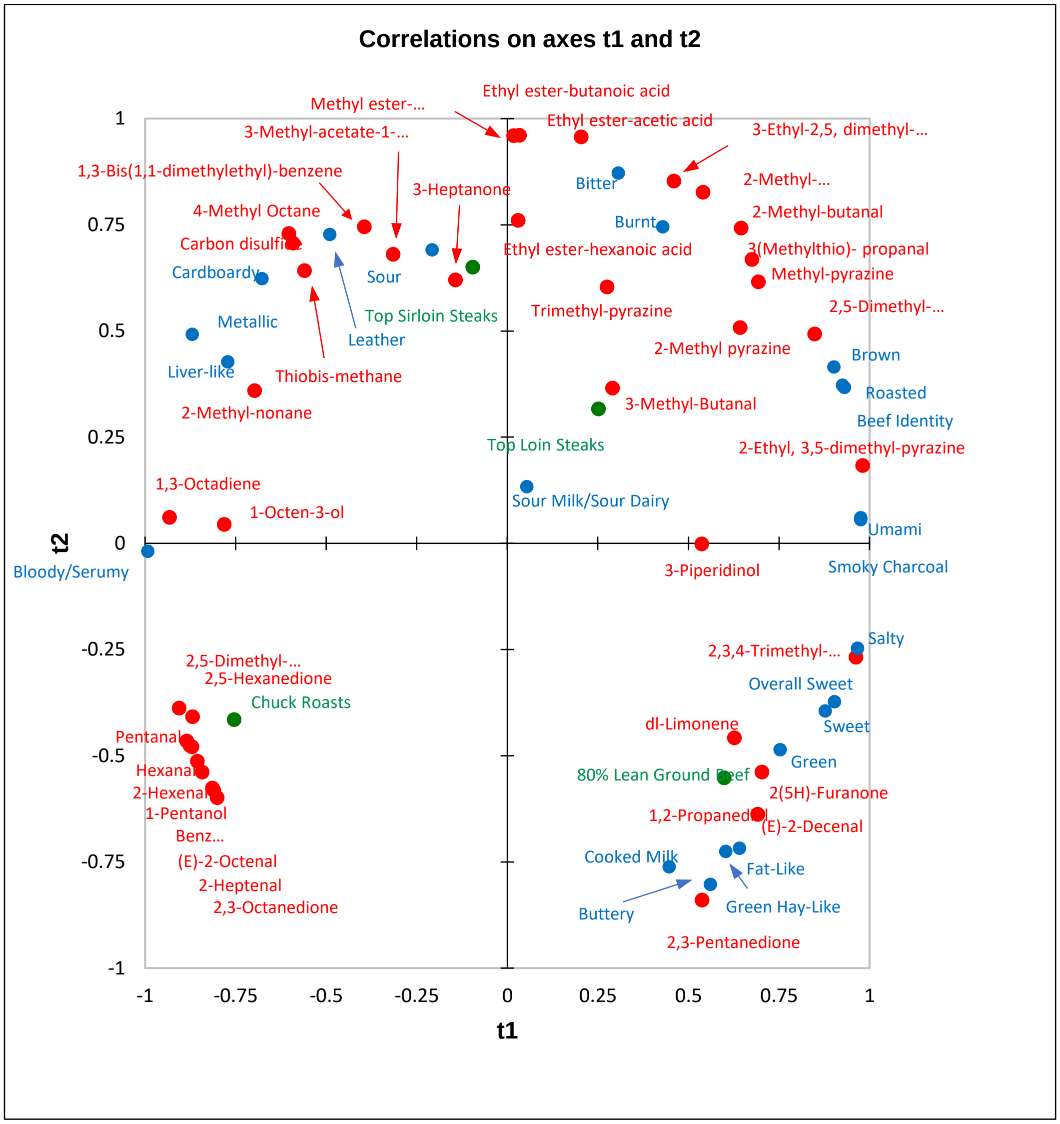


Figure 2. Partial least square means biplot for trained descriptive flavor and volatile aromatic compounds.



APPENDIX B

COOK SHEET

Beef Flavor Audit
CAP/RKM

Day	Order	Cut	City	QCode	Cook	DOD	Code	RawWeight	Timeon	TempOn	TimeOff	TempOff	CookWeight
1	1	Strip Steak	NY	2211	Grill	71C	**215**						
1	2	Chuck Roast	MIA	4108	Roast	71C	**873**						
1	3	Chuck Roast	PD	5117	Roast	71C	**084**						
1	4	Strip Steak	MIA	4217	Grill	71C	**154**						
1	5	Ground Beef	PD	5414	Grill	71C	**671**						
1	6	Sirloin	DV	1329	Grill	71C	**946**						
1	7	Sirloin	PD	5302	Grill	71C	**295**						
1	8	Chuck Roast	LA	3123	Roast	71C	**450**						
1	9	Ground Beef	MIA	4405	Grill	71C	**648**						
1	10	Strip Steak	LA	3223	Grill	71C	**108**						
1	11	Ground Beef	DV	1417	Grill	71C	**796**						
1	12	Sirloin	LA	3326	Grill	71C	**401**						

Recorded: ______________ **Entered:**______________ **Checked:**____________

Date:________________ **Date:**______________ **Date:**______________

APPENDIX C

TRAINED PANEL BALLOT

Sample	Beef Flavor ID	Brown	Roasted	Bloody/Serumy	Fat-Like	Bitter	Salty	Sweet	Sour	Umami	Metallic	Overall Sweet	Other Notes	Animal Hair	Asparagus	Barnyard	Beet	Burnt	Buttery	Cardboardy	Chemical	Cocoa	Cooked Milk	Cumin	Dairy	Fat Like	Green	Green Hay	Heated Oil	Leather	Liver-like	
Warm Up																																
745																																
203																																
957																																
681																																
843																																
554																																
BREAK																																
558																																
998																																
350																																
796																																
613																																
247																																