THESIS

CONSUMER PREFERENCES FOR BEEF FLAVOR

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ABSTRACT

CONSUMER PREFERENCES FOR BEEF FLAVOR

For consumer satisfaction to occur, beef retailers and producers must continuously provide beef that contributes to desirable beef flavor. The objectives of this research was: 1) determine the consist of preference for beef flavors resulting from various production practices among beef consumers, 2) develop a true ranking of preference via best-worst (B/W) scaling, and 3) identify the proportion of preference for beef product categories resulting from various production practices. Nine consumer panels were conducted in three different geographical locations (eastern, central and western US). Consumer beef flavor preference was determined using B/W scaling, multinomial logit, and random parameter logit models in SAS® MDC. Proximate analysis and consumer ranking of attributes when making beef purchases was analyzed using an ANOVA, then means were separated using least squares means in SAS® and consumer demographic information was analyzed using PROC GLIMMIX. Overall, the four samples with the greatest percentage of lipid, F-1 Wagyu x Angus (20.2%), wet-aged upper two-thirds USDA Choice (15.6%), USDA Prime (14.7%), and dry-aged upper two-thirds USDA Choice (13.7%) resulted in a greater percentage of preference for flavor than product categories with a lower percent lipid, low USDA Choice (12.5%), USDA Select (11.9%), beef derived from domestic grass-fed cattle (6.8%); and beef derived from Uruguayan grass-fed cattle (4.5%). Results suggest the incorporation of Wagyu genetics, breeding cattle for a greater propensity of lipid, and grain finishing market beef cattle should result in a more preferred beef flavor characteristic. Results from demographic preference show females, Millennials (18 - 34 years of age), and respondents with an average or higher household income are more likely to consider

beef derived from Uruguayan grass-fed cattle as their least preferred sample. Results from consumers making beef purchasing decisions show marbling level (3.8) and USDA grade of product (4.2) are moderately important and if the product was grass-fed vs. grain-fed (7.5) is the least important beef characteristic. Demographic information shows Baby Boomers (over 50 years of age) prefer beef derived from domestic grass-fed cattle (10.3%) more than both Generation X (6.0%; 35 - 50 years of age) and Millennials (7.1%; $P < 0.05$). Baby Boomers (18.6%) also prefer dry-aged upper two-thirds USDA Choice more than Millennials (13.6%; $P < 0.05$).

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

Beef consumption per capita in the US declined from 1976 (42 kg.) to 2012 (25 kg.; USDA-ERS, 2014b). In June 2014, ground beef prices on average were $3.88 and average uncooked steak prices were $6.97 per .454 kg. (1 lb.; USDA-ERS, 2014c). In order to improve beef consumption, the beef industry should adapt to produce beef at the correct proportion and target the correct consumer market (preference dependent on demographic information) to result in a desirable eating experience and continued beef purchases. Cross and Savell (1994) stated that the beef industry lacked the knowledge base to produce beef at the correct target market. Recently O'Quinn (2012) documented differences in preference for beef flavor when generated from cattle and carcasses of differing pre and post-harvest production methods. An increased quantity of marbling and subsequent quality grade has been an established indicator of preferred eating satisfaction (Platter et al., 2003; Tatum, 2008; Emerson et al., 2012; O'Quinn, 2012). An understanding of beef flavor consumer preference and in what proportion can help the industry decided what product categories are worth pursuing. For the first time, the 2011 National Beef Quality Audit (NBQA) concluded that beef flavor was the most important characteristic of eating satisfaction for those closest to consumers (Igo et al., 2013). Retailers described eating satisfaction as flavor, 70% and tenderness, 66.7% and food service also described flavor (62.5%) to be more important than tenderness (52.1%; Igo et al., 2013). However, eating satisfaction was described more by tenderness for beef allied industries (tenderness, 63.8% and flavor, 57.5%), packers (tenderness, 65.4% and flavor, 53.8%), and feeders, who ranked eating satisfaction as least important comprising of tenderness (44.1%) and marbling (25.4%; Igo et al., 2013). The beef industry has room for improvement to breed, produce, and retail beef that supports consumer preferences. Consistent delivery of a desirable eating experience is fundamental for sustainable beef demand (Schroeder and Mark, 2000). Therefore, the objectives of this study were to determine the proportion of preference for beef categories based upon carcass merit (USDA grades), aging technique (wet vs. dry-aging), and production management practices such as breed (F-1 Wagyu x Angus) and animal diet (grass-fed vs. grain-fed) factors that result in different beef flavor characteristics. Additionally, preferences of beef flavor related to specific targeted consumers will provide the beef industry knowledge to successfully market beef.

CHAPTER II

REVIEW OF LITERATURE

Development of Flavor

People have multiple sensory systems that vary among persons; this factor creates challenges when deciphering flavors during consumption. Human ability to detect flavor is comprised of the olfactory, gustatory, and trigeminal sensory systems (Farmer, 1994; Auvray and Spence, 2008). Detecting flavor outside of the mouth is 'to smell' while to detect substances inside the mouth is 'to taste'; together, they are known as the perceptual system (Auvray and Spence, 2008). However, there is likely confusion between the sensed taste and smell. A study conducted by Davidson et al. (1999) found that the taste of mint-flavored gum originated from the sugar content, while the menthol gave rise to olfactory and trigeminal components. Results documented from this research determined that when the sugar was high, consumers noticed an intense flavor yet over five minutes of chewing, the flavor was found to decline rapidly while menthol levels were still consistent. The conclusion of this research determined that consumer's perception of intensity for the menthol flavor was actually being driven by the release of sugar (Davidson et al., 1999).

Overall flavor is detected by several attributes including appearance, odor, consistency of texture, aromatics, and chemical feelings (Meilgaard et al., 2007). Odor and aromatics are detected as volatiles in the mouth by posterior cilia nares located on the roof of the nasal passageway; this sense is referred to as olfactory sensation or orthonasal olfaction (Meilgaard et al., 2007; Auvray and Spence, 2008; Ba et al., 2012). In the mouth, low molecular weight volatile compounds stimulate the nasopharynx by retronasal olfaction. The olfactory receptors are stimulated either by sense (orthonasal olfaction) or by taste during eating, drinking, or inhaling volatile components, called retronasal olfaction (Auvray and Spence, 2008).

Like olfactory, during gustation the chemical substances are dissolved in water, oil, saliva, and ultimately absorbed by taste buds that are primarily located on the surface of the tongue and mucosa of the throat and palate (Meilgaard et al., 2007). Gustatory perceptions occur when the taste substances are detected by non-volatile and water-soluble substances including: inorganic salts, sodium salts, hypoxanthine, peptides, sugars that are sweet, and amino acids that are bitter and sour (Moody, 1983; Meilgaard et al., 2007). The four senses are sweet, sour, salty, and bitter. A fifth sense, 'umami' is known as a major flavor contributor to meat and is commonly recognized as "savory" (Maga, 1994).

The trigeminal system detects "chemical feeling factors," these chemical feelings are stimulated by nerve endings of the nasal cavity and are commonly referred to as astringency, pungency, temperature, spice, heat, cooling, bite, metallic, and umami (Idolo Imafidon and Spainer, 1994; Meilgaard et al., 2007). The most important organ to the trigeminal system is the tongue, followed by the taste buds located on the hard and soft palate, throat, cheeks, and floor of the mouth.

Tactile properties are a measure of geometric size, texture, and consistency of food particles that decipher amounts of juicy, oily, greasy, and wetness found in each food sample (Meilgaard et al., 2007). To analyze the slipperiness, smoothness, and roughness of food, the surface texture is sensed during mouth palpation (Auvray and Spence, 2008). Chewing method accounts for viscosity, consistency, and amount of solids or semisolids in foods to assess tactile softness, hardness or brittleness (Meilgaard et al., 2007; Auvray and Spence, 2008). Multiplicity between taste and smell determine the extent to which flavor can be defined by the perceptual system. It is important to also note that visual and auditory cues also play a role in flavor perception and has led to more research focusing on the relationship between vision, audition, touch, taste, and smell (Auvray and Spence, 2008). Overall, there are multiple interactions that occur between taste, smell, temperature, touch, and visual clues to determine flavor (Auvray and Spence, 2008).

Beef Flavor Development

The 2006 National Beef Tenderness Survey determined that the majority of cooked beef was tender (Voges et al., 2006). This illustrates the importance of flavor when tenderness has reached an acceptable level, and flavor becomes the most important factor for consumer acceptability (Goodson et al., 2002; Killinger et al., 2004; Calkins and Hodgen, 2007). In raw uncooked beef, there is no desirable aroma until after the thermalization process (Mottram, 1998). In 1912, non-enzymatic browning was described as reactions between amines and carbonyl compounds, especially reducing sugars (Maillard, 1912). The Maillard reaction is non-enzymatic browning reaction that occurs throughout cooking, drying, and storing (Fay and Brevard, 2005). Amino compounds consist of amino acids, peptides, and proteins, which react to form the maillard reaction (Fay and Brevard, 2005). A Maillard peptide is a flavor enhancer known to increase taste intensity and duration of flavor (Orgasawara et al., 2005). The Maillard reaction is important for flavor formation, and occurs during cooking between amino acids (peptides) and reducing sugars (Farmer, 1994; Mottram, 1994; Fay and Brevard, 2005). The reaction is complex yielding a formation of high molecular weight, brown-colored products and volatile aroma compounds (Farmer and Patterson, 1991; Fay and Brevard, 2005). This reaction is responsible for unique aromas and taste during the thermal processing of foods (Orasawara et al., 2005). The effect of the maillard peptide is referred to as a “simmered taste” or in Japan “koku” (Orasawara et al., 2005). A chemical reaction occurs to reduce carbohydrates (sugars) and amino acids (peptides) in three primary phases: condensation, intermediate, and dehydration (Boekel, 2006). A few low molecular weight compounds (volatiles) result during condensation and enhance beef flavor. The intermediate stage results in released amino groups (amines, amino acids, aldehydes, hydrogen sulfide, and ammonia) after sugar fragmentation (Calkins and Hodgen, 2007). The third phase results in fragmentation after condensation between amino groups and sugars yield *n*-glycosylamine and hundreds of volatiles (Farmer et al., 1994; Calkins and Hodgen, 2007). The combination of dehydration, cyclization, and polymerization result in beef flavor or ‘meaty’ flavor formation during cooking (Boekel, 2006). Once amino groups react, carmelisation occurs (Boekel, 2006). The final stage of the Maillard reaction is the formation of brown high molecular weight melanoidin polymers after condensation forms pyrroles in the primary phase (Fay and Brevard, 2005). Other volatiles generated can include furans, pyrazines, oxazoles, thiazoles, and other heterocyclic compounds (Elmore et al., 1999; Fay and Brevard, 2005). Elmore et al. (1997) found more than fifty alkylthiazoles and alkyl-3-thiazolines in cooked beef. Farmer et al. (1994) identified aroma formation was due to *trans*-2-noneal, *trans, trans*-2-4-decadienal and 1-octen-3-one after thermal oxidation of (methional, phenylacetaldehyde, and 2-acetyle-1-pyrroline) polyunsaturated fatty acids. Gasser and Grosch (1988) identified 2-methyl-3-furanthiol and the disulfide bis-(2-methyl-3-furanyl) disulfide, as ‘meaty’ aroma contributors. In a study conducted by O’Quinn (2012), twenty-four volatiles were identified from cooked beef. O’Quinn documented that dry-aged samples exhibited the greatest percentage of diacetyl (2,3 butanedione) when cooked and dry-aged USDA Prime and upper two-thirds USDA Choice produced high concentrations of acetonin (3-hydroxy-2-

butanone). The research determined that the formation of diacetyl and acetonin was highly correlated to flavor desirability. Conversely, ketone 3-methylbutanal was negatively correlated with beef flavor producing metallic and livery flavor notes (O'Quinn, 2012).

Oxidation of lipids is the second major reaction that can change the flavor profile of meat to reflect a desirable or undesirable eating experience. Oxidation of fatty acids during cooking, particularly of unsaturated fatty acids, results in aliphatic aldehydes, ketones, and alcohols that exhibit unique flavors (Elmore et al., 1997). Lipids can be broken down during thermal oxidation and result in odor compounds or volatiles that can contribute to either desirable or undesirable flavor attributes (Farmer et al., 1994; Mottram, 1998; Calkins and Hodgen, 2007). Autoxidation during storage or refrigeration can occur and form rancidity or a "warmed-over" flavor (Farmer 1994; Mottram 1998). Lipid oxidation gives off many aliphatic saturated and unsaturated hydrocarbons, alcohols, aldehydes, ketones, acids, and esters (Farmer, 1994; Mottram, 1998). Polyunsaturated fatty acids are the most susceptible to oxidation (Gasser and Grosch, 1988; Mottram 1998). Cooking beef at a slower rate and holding it for a longer time can allow volatiles to evaporate and reduce undesirable flavor intensity of beef with greater amounts of polyunsaturation (Calkins and Hodgen, 2007). Phospholipids are also known to be highly vulnerable to oxidation due to their high level of unsaturation (Farmer, 1994). However, phospholipids are important to the meaty flavor and result in a loss of flavor when removed. Thus, phospholipids promote meat flavor and are important to the Maillard reaction (Farmer, 1994; Mottram 1998). The proportion of salt, sugar, acid, and phospholipids contribute to the flavor of cooked beef (Farmer, 1994). Overall beef flavor is determined by amino acids, peptides, vitamins, sugars, phosphate, nucleotide-bound sugars, and nucleotides contribution to the Maillard reaction. Consumers purchase beef because they enjoy the aroma and flavor of beef after thermalization (Hornstein, 1971; Farmer, 1994; Ba et al., 2012).

Beef Flavor Importance

Consumers have difficulty evaluating meat quality, which may result in eating dissatisfaction (Grunert et al., 2004). In order to provide consumers with an enjoyable beef eating experience; producers, processors, and retailers must understand the relationship between flavor and tenderness to provide a favorable product that is consistent (Calkins and Hodgen, 2007). Adhikari et al. (2011) developed the beef flavor lexicon of twenty-six descriptors for beef sensory attributes. Further research is needed to develop a better understanding of consumer preferences for beef flavor in relation to production impacts on flavor and identify differences in preference dependent on demographic information. It is widely understood that beef is an important source of nutrients, however this is probably not the reason why most people eat it; those who eat beef do so because they like the characteristic aroma, flavor, and texture (Farmer, 1994). It is important to identify beef categories that consumers prefer and target those consumers according to demographic differences in preference for beef flavor.

Factors Influencing Beef Flavor

Degree of Marbling

The United States Department of Agriculture-Agricultural Marketing Service (USDA-AMS) provides a voluntary service to apply beef grading standards to carcasses at beef processing plants to market and add value to beef. Intramuscular fat (IMF) or marbling, is a known predictor of eating satisfaction in cooked beef (Hankins and Ellis, 1939; Cole and

Badenhop, 1958; Blumer, 1963). Palatability-indicating characteristics of the lean muscle to evaluate marbling and the skeleton to determine maturity are used to assign a "quality grade," the percentage of boneless, closely trimmed, major retail cuts are assessed to determine the "yield grade." Federal grade standards compensate for the adverse effects of carcass maturity by requiring a higher degree of marbling with advancing maturity for a given grade (Romans et al., 1965). The bulk density or lubrication effect occurs due to the presence of lipid (Savell and Cross, 1988). The amount of lipid is determined by the abundance and distribution of marbling. The lubrication theory is that marbling, or IMF, present around muscle fibers, lubricate the muscle fibrils and result in a tender and juicy beef eating experience (Savell and Cross, 1988). Thus, marbling level is an important part of quality grade determination. As marbling scores increase from Practically Devoid to Moderately Abundant, flavor desirability increases (Smith et al., 1984). Degree of marbling affects beef flavor in two ways: (1) volatiles that are released when fatty acids are heated, and (2) oxidation that occurs during storage (Hornstein, 1971). Marbling score indirectly assesses concentration of flavor/aroma compounds in carcasses that result in a greater likelihood of producing meat that tastes "beefy" (Smith et al., 1983). The effect of marbling on tenderness, juiciness, flavor, and overall eating experience is widely studied. Emerson et al. (2012) found that marbling evaluated by instrument grading cameras was closely correlated ($r = 0.84$) with sensory panel rank for intensity of buttery and beefy fat flavors. In the same study, consumer panel ratings between marbling and juiciness were moderately strong ($r = 0.67$). Overall, increased marbling scores were attributed to greater juiciness, tenderness, meaty/brothy, flavor intensity, and buttery/beef fat flavor and accounted for 61% of variation in overall sensory experience (Emerson et al., 2012). The 2011 National Beef Quality Audit analyzed (N = 9,802) carcasses and determined the national benchmark for animal age, sex, breed, HCW, carcass discounts, and certified marketing program. This audit determined the national USDA quality grade (assessed by Meat Grading and Certification Branch, AMS, USDA) distribution was Prime, 2.1%; Choice, 58.9%; Select, 32.6%; Standard, 5.1%; Commercial, 0.9%; and Utility, 0.3% (Moore et al., 2012). Least squares mean marbling score was Small^{40} and USDA Quality Grade was Select^{93} (Moore et al., 2012). The 2005 National Beef Quality Audit analyzed a maximum of 49,330 carcasses and determined the USDA Quality Grade distribution was Prime, 2.6%; Choice, 51.9%; Select, 40.2%; Standard, 4.4%; Commercial, 0.7%; and Utility, 0.3% (Garcia et al., 2008). The 2000 National Beef Quality Audit analyzed (N = 43,595) carcasses and determined the USDA Quality Grade distribution was Prime, 2.0%; Choice, 49.1%; Select, 42.3%; Standard, 5.6%; and Commercial, Utility, Cutter, and Canner, 0.9% (McKenna et al., 2002). Conclusions from the National Beef Quality Audits from 2000 to 2011 indicate an increase in the number of cattle that produce USDA Choice and higher quality grades.

Sensory research conducted by O'Quinn (2012) evaluated discriminating beef consumer's (culinary students and chefs) flavor preference for USDA Select, Low Choice, upper two-thirds USDA Choice, USDA Prime, and beef derived from grass-fed cattle. O'Quinn (2012) documented that beef derived from ≥ 50% Wagyu cattle (USDA Prime), that were corn-fed, had superior flavor desirability (O'Quinn, 2012). Untrained consumer panelists from Lubbock, Texas evaluated upper two-thirds USDA Choice and USDA Select steaks for tenderness, juiciness, liking of flavor, and overall liking on a continuous line scale (Hunt, 2013). Sensory analysis results from Hunt (2013) determined upper two-thirds USDA Choice to be most preferable for flavor and overall desirability. In regard to beef flavor and overall desirability, both studies suggest that cattle operations should focus on improving herd genetics by emphasizing deposition of IMF. Carcasses with greater amounts of IMF should result in more desirable beef flavor characteristics.

Grain versus Grass-fed

Generally, red meat consumers consider the flavor of beef from cattle raised on pasture to be different from beef of cattle raised on concentrates (Melton et al., 1982). Perhaps consumers may be accustomed to and prefer the flavor of beef produced from traditional grain-feeding practices (O'Quinn, 2012; Cox et al., 2006). However, consumers are seemingly pressured by media, the image of sustainability, and marketing practices to source grass-fed beef. Beef produced from cattle in grass-finishing systems is generally darker in color, leaner appearing, and tends to have a higher pH (Prilo et al., 2001). Research has proven that animal diet has an effect on beef flavor. The greatest difference between grass versus grain-beef is the fatty acid concentration (Melton 1982; Ba et al., 2012). Beef flavor noted from beef derived from cattle solely fed grass has been referred to as having a fishy, off-flavor due to greater amounts of polyunsaturated fatty acids (O'Quinn, 2012). Beef from grain-fed cattle contains higher amounts of phospholipids, more *n*-6 fatty acids, and less *n*-3 fatty acids, resulting in the more favorable flavor (Farmer, 1994; Elmore et al., 1999). Forage-finished cattle result in beef containing greater concentrations of linolenic and other *n-3* polyunsaturated fatty acids (PUFA), while cattle finished on grain generate beef containing greater proportions of oleic acid and *n-6* PUFA, particularly linoleic acid (Calkins and Hodgen, 2007). The PUFA in beef may have different oxidative double bonds and this could be why different flavor formations are experienced (Elmore et al., 1999). Aliphatic alcohols reflect levels of PUFA in cooked beef and the greater prevalence of aldehydes and alcohols in beef containing greater amounts of PUFA (Elmore et al., 1999). Volatiles from cooked grass-fed beef are more recognizable than volatiles of grain-fed beef due to the higher levels of low molecular weight aldehydes (Larick and Turner, 1990). Consumers in the U.S. are able to detect flavor differences between grain-fed and grass-fed beef and overall, prefer flavor characteristics of grain-finished beef (O'Quinn, 2012). Grass-fed beef flavors have been described as grassy, gamey, livery, fishy, and sour (Larick and Turner, 1990; Farmer, 1994; Adhikari et al., 2011; O'Quinn, 2012). Discriminating beef consumers in the research conducted by O'Quinn (2012) described grain-fed beef as beefy, browned, and buttery, and ranked grain-fed beef overall greater for flavor desirability (O'Quinn, 2012).

Fatty Acids Effect on Beef Flavor

Differences in beef production method result in unique fatty acids that play a primary role in beef flavor development. Westering and Hedrick (1979) found that beef flavor preference was positively correlated with both saturated (SFA; C16:0 and C18:0) and unsaturated (UFA; C18:1) fatty acid. Meat MUFA have a desirable effect on beef flavor (Larrick and Turner, 1990; O'Quinn, 2012); O'Quinn (2012) determined that MUFA (C12:1; C14:1; C16:1 c9 and C18:1 c9) were most correlated ($P < 0.05$) to overall flavor desirability (beefy, brothy, browned/grilled, buttery and sweet flavors) and negatively correlated to bloody/metallic, grassy, gamey, livery, fish, and sour flavor intensities. Of the monounsaturated fats identified by O'Quinn (2012), 18:1 c9 concentration in the *longissimus* muscle and was more closely correlated with beefy/brothy ($r = 0.52$), browned/grilled ($r = 0.55$), buttery/beef fat ($r = 0.45$), and sweet flavors ($r = 0.34$) than all other MUFA identified and resulted in the most positive impact on desirability of beef flavor (O'Quinn, 2012). American F-1 Wagyu was found to contain the greatest percentage of C18:1

c9; C12:1; C14:1; C16:1 c9 and low USDA Choice contained similar levels, while USDA Select and organic grass-fed beef contained the lowest percentage of MUFA (O'Quinn, 2012).

The C18:1 has a positive impact on desirability of beef flavor (Westerling and Hedrick, 1979; Melton et al., 1982; O'Quinn, 2012). In a study analyzing seven breeds (Angus, Hereford, South Devon, Limousin, Jersey, Wagyu, and Belgian Blue crosses) weak genetic correlations (-0.25 to 0.28) were reported between fatty acid composition and carcass traits, however, palmitic (0.43) and oleic acids (-0.48) were more strongly correlated to carcass weight, fat depth, IMF, and fat color (Pitchford et al., 2002). O'Quinn (2012) detected seven saturated fatty acids in his analysis, but only stearic acid (C18:0) was found to be negatively correlated ($r = -0.44$) with flavor desirability. In the same study, corn-fed beef had a greater intensity for beefy/brothy and buttery/beef fat and was rated more desirable ($P < 0.05$) for overall flavor when compared to grass-fed beef flavor intensity of ($P < 0.05$) grassy/hay like, gamey, livery, fishy, sour, and bitter (O'Quinn, 2012). Organic grass-fed beef was also found to be greater in stearic acid (Westerling and Hedrick, 1979; O'Quinn, 2012), which was also negatively correlated ($r = -0.60$) to flavor desirability of cooked LM samples (Westerling and Hedrick, 1979). In a different study, flavor scores were negatively associated with both saturated and unsaturated fatty acids (C14:1, C18:0, C18:3; Melton et al., 1982).

From a nutritional standpoint, increasing the content of *n*-3 PUFA, conjugated linoleic acid (CLA), and reducing SFA with the net effect of increasing PUFA:SFA is important to beef nutrition (Scollan et al., 2006b). *Trans-octadecenoic* acid and CLA are produced in the rumen as intermediates in the biohydrogenation of dietary linoleic acid to stearic acid (Bauman et al., 1999). An anticarcinogen, CLA is known to decrease the growth of tumors (Ha et al., 1987, Chin et al., 1992). In a study conducted by Chin et al. (1992), CLA concentration was more prevelant in ruminants vs. nonruminants. Forage fed diets benefit in *n-3* PUFA, SFA, and CLA; however, flavor may be compromised and result in gamey, livery, and fishy flavors (Scollan et al., 2006; O'Quinn 2012).

Diets rich in concentrates normally have greater amounts of unsaturated fatty acids (Enser et al., 1998). The greatest difference in fatty acid profile between grain and forage-fed cattle is the type of fatty acids present. Grass-fed beef is lower in MUFA (Leheska et al., 2008). Greater proportions of PUFA contribute to the flavor profile observed in grass-fed beef. Unsaturated linolenic acid (C18:3) does not undergo ruminal biohydrogenation and is greater in grass-fed beef (Larick and Turner, 1989). Linolenic acid results in increased amounts of *n*-3 fatty acids synthesized from C18:3 (Young et al., 1999). Eicosapentaenoic acid (EPA; 20:5) and docosalhexaenoic acid (DHA; 22:6) are derived from linolenic acid and are restricted to phospholipids, which can impact beef flavor during cooking (Elmore et al., 1999; Elmore et al., 2000). Priolo et al. (2001) found that grazing cattle for six months on pasture increased intramuscular linolenic acid content of beef by 50%. During thermalization, fatty acids become oxidative. This occurs faster for polyunsaturated fatty acids (PUFA) than saturated or unsaturated fatty acids (Elmore et al., 1999; Elmore et al., 2000). It has been proposed by Young et al. (1999) that linolenic acid in grass-fed beef produces 4-heptenal during cooking, causing a very unpleasant odor.

The fatty acid profile of Wagyu beef differs from that of in comparison to British and Continental European beef breeds. Wagyu cattle are known to have greater prevelance of C16:1, C18:1, and a lower prevalence of C16:0 and C18:0 than Angus cattle (May et al., 1993). Oleic acid (C18:1 c9) is known to be the most beneficial for beef flavor. Research conducted on Angus and Wagyu steers to assess lipid characteristics found that muscle of Wagyu cattle that consumed corn/grain based diets for 8 and 16 months contained greater amounts of C18:1 c9 than Angus steers (Chung et al., 2006).

Volatiles Associated with Beef Flavor Attributes

The role of fatty acids in beef flavor is related to the low molecular weight of volatiles and liberation of the compounds during cooking. There are over 1,000 volatile compounds related to beef flavor that can be detected in the headspace during cooking or when consuming cooked meat products. Volatiles known to produce desirable beef flavor characteristics include organic compounds diacetyle and acetoin (2, 3 butandione; 3-hydroxy-2-butanone; O'Quinn, 2012). Some of the compounds can be influenced based upon diet. Primary compounds that contribute to beef flavor include aldehydes, ketones, alcohols, and sulfur containing compounds (McHenry, 2013). Volatile compounds can develop from either the maillard reaction during cooking or lipid oxidation during storage where free iron is unlikely to remain in its reduced (Fe^{2+}) state and readily converts into its oxidized (Fe^{3+}) form resulting in free radical conversion (Love, 1987).

Effect of Aging on Beef Flavor

In the US, the term "aging" is generally recognized by consumers as having a positive effect on beef tenderness and flavor. Considerable research has been conducted to evaluate the effects of aging on beef tenderness, but more research should be conducted to better understand its effect on beef flavor. Postmortem aging of beef has been associated with desirable palatability attributes that improve beef flavor (Hodges et al., 1974; Diles et al., 1994). The two most common forms of aging beef are wet and dry-aging. Wet aging is used most frequently by commercial purveyors and foodservice industries and requires beef to be vacuum packaged in a moisture-impermeable bag and stored under refrigeration for some amount of time. The wet-aging method is commonly used due to its convenience and yield advantage (DeGeer et al., 2009). Dry-aging exposes meat to cooler conditions that require frequent monitoring and strict temperature, humidity, and air-flow control (Warren and Kastner, 1992; Smith et al., 2008). Dry-aging beef causes excessive yield and trim loss generally resulting in a loss of saleable value (Warren and Kastner, 1992; Smith et al., 2014). However, dry-aged beef is frequently seen in high-end retail and food service venues as a premier product with perceived quality.

There are some discrepancies regarding which aging type is the most desirable for flavor. O'Quinn (2012) wet-aged upper two-thirds USDA Choice beef for 46 days to evaluate the affect of extended aging on sensory analysis and concluded that the treatment produced sour, livery, and bitter flavor notes. However, in the same study, dry-aged (30 days) USDA Prime beef generated greater flavor notes of beefy, browned/grilled, and buttery/beef fat (O'Quinn, 2012). Some research has shown that wet-aged USDA Prime samples were rated higher for flavor than dry-aged samples (Sitz et al., 2005). Other research found wet-aged beef to be juicier than dry-aged beef (Laster et al., 2008; Smith et al., 2014). However, Dikeman et al. (2012) found that aging method did not affect juiciness. Consumer panels conducted by Sitz et al. (2004) detected no differences between the desirability of wet versus dry-aged beef when analyzing USDA Prime and USDA Choice (NAMP 180) strip loins that were dry-aged for 30 days and wet-aged for 7 days compared to solely wet-aged (37 days) samples. Flavor of dry-aged beef provides desirable beef flavor that is more intense (Campbell et al., 2001; O'Quinn, 2012; Xin et al., 2014). Flavors that are anticipated to be produced from dry-aged beef include: beefy, brown-grilled, nutty, roasted, and earthy (Campbell et al., 2001; O'Quinn, 2012; McHenry, 2013; Smith et al., 2014). However, O'Quinn (2012) documented discriminating beef consumers have a greater flavor desirability for 14 day wet-aged upper two-thirds USDA Choice when compared to upper two-thirds USDA Choice that was initially wet aged for 17 days then, dry-aged for 30 days and 46 day wet-aged upper two-thirds USDA Choice. An economic study on beef flavor research found consumers who prefer dry-aged beef (29.3%) to be willing to pay more for the product (Sitz et al., 2004; Sitz et al., 2005).

Breed

Research over the past 50 years has determined that a positive eating experience begins at the producer level and requires collaborative effort along the entire beef supply chain where management decisions impact differences in flavor (Tatum, 2008). Published and peer-reviewed research demonstrated the effect of breed on beef flavor. A recent study reported that breed affects volatiles and influences cooked beef flavor (Ba et al., 2012). Elmore et al. (2000) found that fifty-four volatile compounds were affected by breed. Flavor characteristics have been shown to be moderately heritable (h^2 = 0.26 to 0.40; Wheeler et al., 2004) and a moderate to strong association for marbling heritability has been demonstrated (Wheeler et al., 2001; 2004; Riley et al., 2003).

Marshall (1994) summarized breed differences and genetic heritability estimates for thirty-three breeds and found that Jersey, Red Angus, Angus, Shorthorn, and South Devon ranked highest for marbling and Chiania, Charolais, Brahman, Limousin, and Sahiwal breeds ranked lowest. Research has shown that *Bos indicus* breeds consistently produce lower palatability scores while *Bos taurus* breeds have a greater degree of marbling (Marshall, 1994). Heritability for marbling was determined to be strongly positive to slightly negative between fat thickness and phenotype (Marshall, 1994). A study conducted by Dikeman et al. (2005) evaluated carcasses and beef palatability traits for fourteen cattle breeds (Angus, Brahman, Brangus, Charolais, Gelbvieh, Hereford, Limousin, Maine-Anjou, Red Angus, Salers, Shorthorn, Simbrah, Simmental, and South Devon). Dikeman (2005) documented correlations between marbling, flavor, and juiciness; and determined that as marbling score increased, flavor and juiciness, also increased. Gregory et al. (1994) evaluated nine breeds (Red Poll, Hereford, Angus, Limousin, Braunvieh, Pinzgauer, Gelbvieh, Simmental, and Charolais) and determined that breed and marbling score were correlated ($r = .61$).

Beef from Wagyu cattle has had more extensive research conducted to analyze marbling and beef flavor. Duarte et al. (2013) evaluated the adipogenesis and fibrogenesis in skeletal muscle of the Wagyu and found Wagyu to express more adipogenic markers than Angus cattle. In the same study, a reduced number of larger muscle fibers were determined due to the propensity of mesenchyme progenitor cells that form adipose and connective tissue (Duarte et al., 2013). Wagyu beef may be lower in saturated fatty acids (SFA) and higher in monounsaturated fatty acids (MUFA) than other North American breeds (Sturdivant et al., 1992). Duckett et al. (1993) concluded that beef from Wagyu cattle had a greater proportion of MUFA. Duckett (1993) also noted that bacterial biohydrogenation was reduced because of the effects of high-concentrate diets on ruminal pH, resulting in a greater proportion of unsaturated fatty acids that can enter the small intestine for absorption during the longer period on feed. Wagyu cattle are traditionally long-fed for at least 300 days in order to reach full marbling capability. Lunt et al. (1992) compared growth and carcass characteristics of long-fed (552 days) American Wagyu (10 carcasses) and Angus (10 carcasses) carcasses to the Japanese quality grading system; one Angus versus five American Wagyu steers qualified for the highest

Japanese marbling grade (5). American Wagyu cattle were determined to have the genetic ability to marble more than Angus and as much as Japanese Black cattle raised in Japan; however, variation in marbling score was found among both the American Wagyu and Angus breeds (Lunt et al., 1992). Research conducted by Wheeler et al. (2004) evaluated breed (Hereford, Angus, Hereford x Angus, Norwegian Red, Swedish Red and White, Friesian, and Wagyu) effects on carcass yield and palatability traits. Wheeler et al. (2004) determined that at a constant weight, LM steaks from Wagyu-sired steers produced steaks that were rated more intense ($P < 0.05$) for beef flavor; however, the magnitude of difference was of little practical importance. Wheeler (2004) concluded that Wagyu steers resulted in carcasses with the greatest proportion of USDA Choice grades and Yield Grades 1 and 2 when compared to British sire breeds (Wheeler et al., 2004). Trained consumer sensory panels evaluated beef from Angus and crossbred Wagyu cattle that were long-fed. Trained sensory panel trials documented the inability to detect differences in flavor intensity; however, consumers could differentiate the crossbred Wagyu beef in a triangle test (May et al., 1993). O'Quinn (2012) fed discriminating beef consumers, who ranked intensity for flavor on a 10 cm unstructured line scale with 0 cm representing very low intensity and 10 cm representing high intensity. O'Quinn (2012) determined that dry-aged American Wagyu resulted in the greatest (6.65) rating for overall flavor, desirability, beefy/brothy, and nutty/roasted flavors. Generally Wagyu beef is preferable in flavor when compared to other beef categories. Beef from Wagyu genetics could offer a distinctive marketing opportunity due to the greater amount of MUFA without losing desirable beef flavor. Currently, the American Wagyu Association has nearly 15,000 head registered in the National database (personal communication with Michael Beattie, Executive Director of the American Wagyu Association, communicated in July 2014). The current research determined that in comparison to the cattle production in the US, there is a stronger demand for the flavor of Wagyu than what is produced. Limited research regarding beef flavor differences has been conducted for other breeds, perhaps this is because there is already knowledge regarding breed effects on tenderness.

Statistical Procedures

To determine the preference of each beef category a B/W rank was used. The ordinal scale procedure allows researchers to see the number of consumers who preferred a beef category versus those consumers who least preferred the same beef category. This assessment determined the number of values preferred as best (+1) and worst (-1). The final rank is determined by each consumer's response when selecting his or her most and least preferred beef sample. Using mathematical subtraction, the B/W rank was ascertained. An advantage of this scaling method is that it allows researchers to see the numeric "votes" per product category and easily determine if there were major discrepancies among consumers. However, this scale is limited and does not provide statistical significance for treatment preference. Thus, additional statistical analyses were also conducted.

The MDC procedure in SAS® (SAS Inst. Inc., Cary, N.C.) was used to develop multinomial logit (MNL) and random parameter logit models (RPL) to assess consumer "shares of preference" and determine the proportion of consumers who preferred a specific beef category. The MNL model constructs comparisons to determine a measurement for discrete empirical disruptions and predicts the spread of preference by an estimate value (Poe et al., 2005). Unlike the MNL model that places equal importance on each value selected, the RPL model allows for random preference variation of the population, is free from assumption of independent of irrelevant alternatives, and allows for correlation of unobserved factors (Pruitt et al., 2014). After a resampling using Monte Carlo simulations, a shares of preference for each beef category was determined by $j = e^{\lambda_j} / \sum_{k=1}^{j} e^{\lambda_j}$. The preference, or the number of times a product category was chosen, as best (*j*) and worst (k) (Poe et al., 2005). Both the MNL and RPL models developed in SAS® MDC determined a proportion of preference for each product category.

In the current study, consumers were given four randomized samples of the eight total product categories in sessions one through eight and consumers were given all eight consecutive product categories in session nine. During sessions one through nine in all of the respective nine panels, consumers were asked to select their most favorite and least favorite sample in each session based on flavor preference. The benefit of this analysis over other ranking approaches is that it does not force participants to make trade-offs between important issues. This type of analysis avoids ordinal scale measurements. However, the challenge that presents itself with the MNL model is scalar inequivalence. Scalar inequivalence is how relatively important variable traits are to specific individuals. The relative importance becomes evident when there are differences in response style, or “tendencies to respond systematically to questionnaire items on some basis other than what the items were specifically designed to measure” (Paulhus, 1991). This refers to differences in reaction and strategies of elimination. Pairwise comparisons were derived to determine if there was significance between treatments.

Unfortunately, the MNL model assumes that all individuals place the same level of importance on each value (Lusk and Briggeman, 2009). The MNL procedure restricts standard deviations to equal zero implying significant homogeneity with regard to beef flavor. Characterization of discrete heterogeneity is important because preferences could be influenced dependent upon a person's demographic or response strategy (Wolf and Tonsor, 2013). The use of RPL or mixed logit can overcome this weakness according to $\lambda_{ij} = \lambda_j + \sigma\mu_{ij}$, where λ_j and σ_j are the mean and standard deviation of λ_j in the population respectively, and μ_i is a random term normally distributed with mean zero and unit standard deviation. This implies that preference *j* follows a normal distribution with a standard deviation, σ_j and mean, λ_j (Pruitt et al., 2014). Thus, the importance of beef flavor follows a normal distribution yielding a probability statement that depends on the random term μ_{ij} (Lusk and Briggeman, 2009). The assumption of RPL is that the variance or error (ε_{ij}) is assumed to be equal to one. Due to the normalization of the variance, the model accommodates for differences in the potential scale over alternatives (Train, 2003). The RPL can produce good estimates of predicted probabilities even if there is misspecification in the choice model (Lusk and Briggeman, 2009).

Both MNL and RPL parameter estimates were used to calculate shares of preference to forecast probabilities of preference for beef categories chosen as most preferred. The difference between the two statistics is small (Train, 2003). The result indicates the probability that a preference is chosen more frequently than the other comparisons. Parameter estimates from both the MNL and RPL models were used to derive covariance and variance matrices. Beef product category estimates and variance terms were simulated 1,000 times using Monte Carlo simulation following procedures illustrated by Poe et al (2005) and an ANOVA was derived to assess pairwise comparisons. Pairwise comparisons were conducted to determine statistical difference among consumers' shares of preference for beef flavor using both the MNL and RPL models.

CHAPTER III

IDENTIFYING CONSUMER PREFERENCES FOR DIFFERENT BEEF CATEGORIES BASED ON FLAVOR

SUMMARY

This study was conducted to determine the proportion of consumer preference for beef derived from production-related beef flavor differences associated with the affects of USDA grade, cattle type, finishing diet, and postmortem aging. Beef categories (treatments) evaluated include: beef derived from domestic grass-fed cattle, beef derived from Uruguayan grass-fed cattle, USDA Select, low USDA Choice, upper two-thirds USDA Choice, upper two-thirds (dry-aged) USDA Choice, USDA Prime, and beef derived from F-1 Wagyu x Angus cattle. Beef categories were evaluated to determine the most preferred and least preferred product categories by untrained consumer panelists (N = 335) collected from Colorado, Ohio, and California. Proximate analysis was conducted on each beef category, consumer demographic information was obtained, and consumers were asked to rank the importance of ten traits when making purchasing decisions to complete the research analysis. A better understanding of consumer preference is needed to determine the most suitable proportion of market opportunity for various beef categories with differences in production, breed, and post-harvest aging. Results from this analysis show that beef derived from F-1 Wagyu x Angus cattle is the most preferred with a likelihood of preference of 20.2%. Upper two-thirds USDA Choice has a likelihood of preference of 15.6%; USDA Prime, 14.7%; and upper two-thirds USDA Choice (dry-aged), 13.7%. These four product categories are consistently preferred out of the eight beef categories analyzed. Results suggest that the incorporation of Wagyu genetics, breeding cattle for a greater

propensity of percent lipid, and grain finishing market beef cattle should result in more preferred beef flavor characteristic and improve eating satisfaction.

INTRODUCTION

The US beef industry has a value of $85 billion and is comprised of a total of 89.3 million cattle (USDA-ERS, 2014). Total US beef consumption in 2002 was 27.9 billion lbs. and was most recently reported as 25.5 billion lbs. (USDA-ERS, 2014b). The decline in beef consumption (-2.4 billion lbs.) from 2002 to 2014 highlights the importance to maintain and build beef demand during record high prices. For the first time, the 2011 National Beef Quality Audit (NBQA) concluded that beef flavor was the most important characteristic of eating satisfaction for those closest to consumers (Igo et al., 2013). Retailers described eating satisfaction as flavor, 70% and tenderness, 66.7% and food service also described flavor (62.5%) to be more important than tenderness (52.1%; Igo et al., 2013). Beef Checkoff funded consumer retail marketing data determined that "taste of beef" was the most commonly selected reason for eating more beef in 2013 (Richardson, 2013).

Despite this, it is not clear what proportion of beef product categories (e.g. grass-fed, grain-fed, dry-aged, wet-aged, breed etc.,) consumers demand. Eight product categories were chosen to represent beef flavors associated with differences in USDA grade (Prime, upper two-thirds Choice, low Choice, and Select), cattle breed (Wagyu), production methods (grass-fed, grain-fed), grazing systems (Uruguayan grass-fed, domestic grass-fed), and postmortem aging method (wet-aged, dry-aged). The objectives of this research were to 1) determine the consist of preference of beef flavors resulting from various production practices among beef consumers 2) develop a true ranking of preference for product categories via B/W scaling methods and 3) identify the proportion of preference for various product categories of beef resulting from various production practices. The conclusion of this research will assist the beef supply chain manage market opportunity through beef production and post-harvest practices.

MATERIALS AND METHODS

Experimental Beef Categories and Sample Preparation

Beef strip loins (IMPS #180; NAMP, 2010), representing 8 different beef product categories (Table 3.1) were purchased for this study. Product specifications were verified by (CSU) personnel using official USDA grades, and personal communication with individual suppliers consent on verified origin of production practice include: 1) 14-d wet-aged, domestic (US) grass-fed (DGF); 2) 56-d wet-aged (due to transportation), Uruguayan grass-fed (UGF); 3) 14-d wet-aged, USDA low Choice (small marbling; LCH); 4) 14-d wet-aged, USDA Select (slight marbling; SE); 5) 14-d wet-aged, USDA Prime (≥ slightly abundant marbling; PR); 6) 14-d wet-aged, upper two-thirds Choice (modest-moderate marbling; PCH); 7) 14-d wet-aged, and 21-d dry-aged, upper two-thirds Choice (modest-moderate marbling; DA); and 8) 14-d wet-aged, F-1 Wagyu x Angus cross (≥ slightly abundant marbling; W; Table 3.1).

Three batches were independently created for each treatment using an equal number of strip loins for each batch. Fifteen beef strip loins (IMPS #180; NAMP, 2010) for treatment groups SE, LCH, PCH, DA, and PR were used in this study. Twelve strip loins (IMPS #180; NAMP, 2010) were used for W due to the heavier weight of each strip loin. Twenty-seven strip loins (IMPS #180; NAMP, 2010) were used for DGF and UGF due to the lower strip loin weight. Colorado State University (CSU) personnel selected strip loins representing SE, LCH, PCH, DA, and PR from a commercial beef processing plant in northern Colorado and DGF strip loins were obtained from a beef wholesale distributor in western Colorado. Strip loins representing W were collected from a commercial beef processing plant in the northwest US. The UGF strip loins were collected through a US distributor to obtain beef from a Uruguayan beef processing plant. All strip loins were transported under refrigeration (2°C) to the Colorado State University Meat Laboratory where they were immediately stored in the absence of light at 2-4°C for the specified aging period. Strip loins were checked daily throughout the aging period to ensure the vacuum seal was maintained.

Following postmortem wet-aging period of 14-d, DA was aged at a commercial dry-aging facility at 1 to 2°C and approximately 77% relative humidity for 21-d. Once aging specified procedures were complete, the DA treatment batches were processed immediately upon arrival at the CSU Meat Laboratory without further aging.

For all strip loins, all exterior fat, connective tissue, *gluteus medius*, and *multifidus dorsi* were removed, leaving only the *longissimus dorsi*. Within each treatment, three batches of an equal number of strip loins per batch per treatment were used. Each batch was first coarse ground using a grinder (Model 84186, Hobart, Troy, OH) with a 1 cm plate. Batches then were mixed thoroughly by hand for approximately 1 minute. After mixing, each batch was fine ground using a 4 mm grinder plate to obtain a homogenous mixture.

Ground product from each batch was stuffed into 6.4 cm in diameter cellulose casings using a vacuum stuffer (Model Vf50, Handtmann, Germany). Filled casings were placed in a freezer (-20°C) and allowed to freeze at least 18h before cutting into patties. After freezing, casings were removed from the samples, and a band saw (Model 400, AeW-Thurne, AEW Engineering Co. Ltd., Norwich, UK) was used to slice samples into 28.35 g patties. Patties were randomly selected per batch to be weighted on a gram scale to ensure consistency of size. Per treatment and batch ends from each cellulose casing were obtained to be used for objective proximate analysis. Remaining patties from each batch per treatment were randomly assigned to predetermined cooking and serving orders, vacuum packaged, and stored frozen (-20°C).

Sensory Analysis

Untrained consumer sensory panels were conducted in Colorado, California, and Ohio. Approximately 40 consumers participated in each of the three panels per location, for a total of nine panels and N=335 panelists. Each panel lasted approximately 1 ½ h. Individual panelists were given a ballot, packaged plastic utensils containing a napkin, expectorant cup, and bottles of purified water, as well as bottles of apple juice, and unsalted crackers to serve as palate cleansers. Verbal instructions were provided before the start of each panel. Panelists were instructed to ignore variations in texture and juiciness between samples and to focus only on the flavor attributes for each sample. Panelists were instructed to cleanse their palate between each sample.

Samples were thawed at 2 to 4°C for 48 and 72 h before sensory evaluation. All samples were cooked using 30.48 cm in diameter, pre-seasoned cast-iron skillets (Lodge Logic) that were specified, unique for each product category. Skillets were heated to 232°C before sample cooking. Patties were cooked one minute per side to an internal temperature of 74°C. Temperature was monitored by a meat thermometer (SPLASH-PROOF SUPER-FAST ® THERMAPEN ®, ThermoWorks, Lindon, UT). Samples were cooked by treatment, seven patties at a time with two skillet repetitions for a total of 14 cooked patties per sample served. Cooked patties were cut into four equally-sized quarters, immediately placed into a heat stable environment, and stored until served at 50°C.

Each panelist was asked to fill out a brief demographic questionnaire before the panel began. Individual panelists were asked to provide the following demographic information: a) gender; b) household size; c) marital status; d) age; e) ethnic origin; f) annual household income; g) education level; h) amount of beef consumed per week. Consumers were also asked to rank the importance from 1 to 10 (1 = most important and 10 = least important) of ten factors when purchasing beef. The factors included: a) brand name of product; b) breed of animal that produced the product; c) marbling level; d) nutrient content; e) taste/eating experience; f) USDA grade of product; g) visual appearance; h) where and how the animal was raised; i) whether or not the animal received growth promotants and/or antibiotics.

Consumer sensory panels were designed to mimic a wine tasting session to compare flavor profile. Consumers were randomly served and asked to evaluate 4 product categories in sessions 1-8 and 8 product categories in session 9. Panelists were asked to wait to evaluate samples until all samples were present on their plate. Each of the panelist plates were divided into four quadrants to allow each panelist to identify samples 1 through 4 for sessions 1-8 and samples 1-8 (two plates issued) for session 9. Panelists were asked to mark their most and least favorable beef sample during each of the randomized sessions per panel on their ballot. Panelists identified their most preferable sample by placing a circle around the sample number and their least preferable sample by placing an X on the sample number on their ballot for each session. After each panel and completion of ballot marking, any remaining samples were discarded and a new quartered plate was provided. After panels in each location were conducted, ballots were tabulated to determine B/W scaling and demographic data was entered and saved on a computer file.

Proximate Analysis

Sixteen frozen patties from each batch per product category were analyzed for proximate composition. Approximately 1 kg of each sample was broken into (1 cm x 1 cm x 1 cm) pieces, and submerged into liquid nitrogen. Following complete freezing of each sample, samples were homogenized into a fine powder using a commercial food processor (Blixer 4V, Robot Coupe USE, Inc., Ridgeland, MS). Homogenized samples were individually identified and double bagged in Whirl-Pak bags (Nasco, Ft. Atkinson, WI) and stored at -80°C.

Total lipid content was determined using the method described by Folch and Stanley (1957) and modified by Bligh and Dyer (1959). To determine percent lipid (on a wet-weight basis), 1 g of homogenized beef from each batch per product category was analyzed. The lipid-containing fraction was dried under N_2 gas and placed into a 100°C drying oven for 3 h. Samples were allowed to cool to room temperature (22°C) in a desiccator for 30 minutes before weighing. The cooled samples were weighed, and total percent lipid was determined by dividing the final weight of the residual sample by the initial sample weight and multiplying by 100.

Moisture content was determined using the moisture removal process described by AOAC (1995). Approximately 2 g of each sample was weighed into an aluminum tin (low form, aluminum, fluted; Fisher Scientific, Pittsburg, PA) and dried for 24 h in a forced air drying oven (Thelco lab oven, Mandel Inc., Guelph, Ontario, Canada) set at 100°C. Samples were allowed to cool to room temperature (22°C) in a desiccator before weighing. Samples were re-weighed and weight loss was reported as the percent moisture computed as the difference between initial and final weight.

Nitrogen content was determined using the combustion method (TruSpec CN Carbon/Nitrogen Determination Instruction Manual, December 2004, Leco Corp., St. Joseph, MI) and a conversion factor of 6.25 was used to determine crude protein content (Merrill and Watt, 1973).

Ash content was determined using the AOAC ashing method (AOAC, 1995) where 1 g of sample was placed in a pre-weighed, dry crucible before being placed in a Thermolyne box furnace (Thermo Fisher Scientific, Pittsburgh, PA) at 600°C for 24 h. After removing the samples from the furnace, samples were allowed to cool to room temperature (22°C) in a desiccator before re-weighing. Samples were weighed and the percentage ash was calculated by dividing the quantity of material remaining in the crucible post-incineration by the initial quantity sample placed into the crucible and multiplying by 100.

Statistical Methods

All analyses, except B/W scaling were conducted using statistical procedures of SAS (SAS Inst. Inc., Cary, NC). All comparisons (SAS® MDC and GLIMMIX) were tested using level of $\alpha = 0.05$. Means were compared using the PDIFF option when F-tests were significant ($P < 0.05$) and analyzed to determine GLIMMIX results. A randomized, repeated measure, design was used to determine consumer preference for beef flavor. The SAS® 9.3 PROC OPTEX function was used to determine the number of samples served per session and the randomized sample serve order. Eight product categories were randomized into sets of four, for sessions 1-8, and all eight product categories were represented in session 9. Each of the eight product categories appeared randomly five times per panel and were compared to each other product category the same number of times.

The B/W scaling procedure was designed to quantify the importance of 8 product categories. An orthogonal fraction 2^8 was used to create 9 sets of comparisons; each panelist was asked to choose 1 product category as most preferable, and 1 product category as least preferable, in regard to flavor. By using this approach, there was only one way to choose something, limiting bias from alternative rating methods (Cohen and Neira, 2003).

The MNL and RPL models were constructed using SAS® MDC to estimate the "shares of preference" or percentage of preference for each of the eight product categories (Wolf and Tonsor, 2013). The MNL and RPL models construct comparisons to determine a measurement for discrete empirical disruptions and predict the spread of preference by an estimate value (Poe et al., 2005). Estimates derived from both models were simulated 1,000 times using Monte Carlo simulation following procedures illustrated by Poe et al. (2005) and an ANOVA was derived to assess pairwise comparisons. Pairwise comparisons allowed researchers to determine statistical difference among consumers' shares of preference for beef flavor for both models. The estimated coefficients for both the MNL and RPL models have little to no economic interpretation, so the shares of preference probability conveys the product categories importance. A share of preference is a forecasted probability in which a question is preferred as most important. The equation for shares of preference is $j = e^{\lambda_j} / \sum_{k=1}^{j} e^{\lambda_j}$ (Wolf and Tonsor, 2013). This procedure provides the exact measure of difference for multiple distributions (Poe et al., 2005).

The MNL procedure provides a maximum difference and flexibility in the estimation procedure dependent on the extreme value of the type I error (Pruitt et al., 2014). If the assumption of the error term holds, the model takes form of a MNL model that places equal importance on each value selected, otherwise a random parameter logit (RPL) or mixed logit model may be estimated (Pruitt et al., 2014).

Due to the MNL model's restriction of standard deviation (SD = 0), homogeneity is placed on preference. A RPL model was conducted to determine if there were potential differences in preference. The RPL model allows for random preference variation of the population, is free from assumption of independent of irrelevant alternatives, and allows for correlation of unobserved factors (Pruitt et al., 2014). The RPL model can overcome weaknesses of the MNL model according to ($\lambda_{ij} = \lambda_j + \sigma_j \mu_{ij}$) where λ_j and σ_j are the mean and standard deviation of the population respectively, and μ_i is the random term normally distributed with a mean zero and a standard deviation (Pruitt et al., 2014). The results of the RPL imply that *j* (choice options) follows a normal distribution with a mean (λ_j) and a standard deviation (σ_j) (Pruitt et al., 2014). The use of RPL model allows for correlation of unobserved factors; and it allows the surveyed population to have a random preference variation (Train, 2003). The RPL can report overlap in respondents' preference. Lusk and Briggeman (2009) concluded that food safety was the most important factor in both the MNL (26.8%) and RPL (34.2%) models. Consumers were nearly two times more likely to prefer food safety over nutrition (13.9%) and taste (17.2%) when purchasing food. However, of the eleven questions asked, there were differences in rank of preference comparing the RPL model to MNL suggesting heterogeneity. The diverse populations sampled in the current research had no heterogeneous affects on preference due to the consistency in product category rank and preference. In a different study analyzing USDA market data, Pruitt et al. (2014) found both MNL and RPL model's rank of preference to be constant and shares of preference to be similar, thus having no heterogeneity influence. Simulation and correlation procedures of the RPL model estimates can allow researchers to understand the relationship in preference in comparison to the other factors in the choice set (Pruitt et al., 2014).

A final analysis was conducted to determine the probability of untrained consumer panelists preference (most preferred and least preferred) for each beef category based upon the response variable per consumer preference coded as 0 and 1 using SAS® PROC GLIMMIX. The analysis was conducted using fixed effects including gender, age, and household income. The random effect was accounted for by panelists (N = 335). The distribution was binomial and the logit link function was specified as options.

RESULTS AND DISCUSSION

Participant Demographics and Rank of Importance When Purchasing Beef

Demographic information was obtained from consumer panelists (N = 335; Table 3.2). Sensory analysis in the current study was performed by male (54.9%) and female (45.0%) consumers. The "Baby-Boomer" generation (over 50 years of age) accounted for the greatest percent (42.9%) of the sample population, while "Millennials" (ages 18 to 34) accounted for the second highest participation with (35.2%) and "Generation X" respondents (ages 35 to 50) accounted for the lowest percent (22.0%) of the sample population. All of the study participants were atleast light beef consumers (Richardson, 2013b), while 56.7% of participants indicated that they consumed beef between 1 to 3 times weekly, and 37.3% of panelists consumed beef 4 to 6 times per week. Therefore, 94% of consumers analyzed in this study were moderate to heavy beef eaters (Richardson, 2013b).

Panelists were asked to rank the importance of ten considerations when making beef purchasing decisions by ranking them from 1 to 10, results are reported in Table 3.3. Taste/eating experience and visual appearance are the most important characteristics to consumers when purchasing beef ($P < 0.05$). The second most important traits are marbling level and grade of product ($P < 0.05$); the fifth most important trait is nutrient content ($P < 0.05$). Four of the bottom five characteristics include: breed of animal/product, where and how the animal was raised, if growth promotants and/or antibiotics were used, and brand of product, which are not statistically different ($P > 0.05$), but do rank higher in importance compared to the feeding history (grass-fed vs. grain-fed animals) of the cattle from which the beef is derived ($P < 0.05$).

Resulting rank of importance demonstrates that the beef industry needs to continue to provide a positive eating experience in combination with producing a product that is visually appealing. The least important trait to beef consumers when making beef purchases is if the animal was grass-fed or grain-fed. A disparity between the lack of prioritization of grass-fed vs. grain-fed production methods and flavor profile preferences of a primarily grain finished beef product identifies the knowledge gap of a majority of beef consumers. Regardless of flavor preference, consumer education is needed to ensure purchases reflect a positive beef eating experience.

Proximate Composition of Beef Categories

Least squares means for percent lipid, protein, moisture, and ash are summarized in Table 3.4 for the eight experimental treatments. As expected, treatments containing a higher percentage of lipid are also comprised of a lower percentage of protein and moisture. Beef originating from W has the greatest percent lipid (14.44%; $P < 0.05$) while both DGF (14.44%) and UGF (4.15%) are comprised of the smallest percentage of lipid ($P > 0.05$). The UGF (4.15%) percentage of lipid is not different ($P > 0.05$) from DGF (3.39%). The SE has a greater percent lipid than both DGF and UGF ($P < 0.05$), but a smaller percent lipid than all other product categories ($P < 0.05$). Although not different ($P > 0.05$), PR contains 0.17% greater percent lipid than PCH, however LCH has 1.23% less lipid than PR ($P < 0.05$). Of the product categories, DA has the second greatest percent lipid (11.64%; $P < 0.05$), the greatest percent protein (25.85%; $P < 0.05$) and smallest percent moisture (60.42%; $P < 0.05$) likely due to significant levels of moisture loss resulting in a concentration of lipid and protein. Furthermore, percent moisture is greater for both DGF (74.28%; $P < 0.05$) and UGF (72.38%; $P < 0.05$).

Best-Worst Ranking of Beef Flavor as Quantified by Untrained Consumer Panelists

In this analysis, B/W scaling was used to determine consumer preference when their most preferred (best) and least preferred (worst) sample was indicated from all samples consumed in each session per panel. Although the treatments were randomized across all panels, each product category was fed an equal number of times in each panel, resulting in a possible numeric value of 1,675 that a product category could have been selected as best or worst. However, this could only be the case if all consumers (N = 335) preferred the same treatment across all sessions.

Results indicated in Table 3.5 showed that W is the most preferred (best = 615) beef product and generates the lowest frequency of being the worst preferred (worst = 171). Overall, the B/W rank aggregates to 444, and results in a rank of first, or most preferred. Consumers in a study conducted by Busboom (1993) rated strip loin steaks from imported purebred black Japanese cattle greater in juiciness, flavor desirability, flavor intensity, and overall palatability when compared to North American cross-bred Wagyu.

The DA B/W scaling results in a rank of fourth overall, while the dry-aged treatment is ranked second for best = 444 (B/W scaling), there is a greater number of discriminating consumers who selected the product as “worst” more often (worst = 358) compared to the other grain-fed product categories. Studies conducted by Campbell et al. (2001) in Kansas and Stenström et al. (2014) in Sweden showed that dry-aging accentuated a more desirable beef flavor, but this was not found in other studies (McKeith et al., 1985; Oreskovich et al., 1988; Smith et al., 2014). Sensory analysis conducted by McHenry (2013) found consumers to prefer 50% fresh and 50% dry-aged ground beef patties; consumers noted that samples contained more beefy/brothy and buttery/beef fat flavor attributes. However, in the same study, the 100% dry-aged treatment resulted in more browned/grilled, earthy/mushroom, nutty/roasted, livery, sour, acidic and bitter flavor notes. The presence of off or undesirable flavors could explain the higher ranking of PCH and lower ranking of upper DA in this analysis.

The UGF is less preferred than DGF and ranked 8^{th} overall (B/W = -592). The UGF long aging period of 56 d was due to transportation, which may have attributed to less overall flavor desirability. O'Quinn (2012) found 46 d wet-aged premium Choice to produce more undesirable flavors described as sour, grassy/hay like, gamey, livery, and bitter, resulting in 1 of 2 least favorable product categories. Karney (2014) also found the intensity of oxidized and sour/acidic flavor attributes to be significantly greater in beef strip loins (IMPS #180; NAMP, 2010) wet-aged in a vacuum sealed bag for 35 or more days. In regard to extended wet-aged Uruguayan grass-fed beef, Resconi et al. (2010) reported that beef from cattle solely fed a pasture diet and wet-aged in a vacuum sealed bag for 20 days (designed to mimic transportation duration during exportation), was found to statistically ($P < 0.001$) produce a high intensity of strange odors, denoted by trained panelists in Spain. Although, wet-aging beef in a vacuum sealed bag slows the anaerobic development of lactic acid bacteria, during extended aging, a sour taste can be produced (Parrish et al., 1991). It is noteworthy, that in the current research the less preferred UGF flavor is likely attributed to the extended 56d wet-aging.

In the current research, beef from grass-fed cattle is less preferred, which may be attributed to the low lipid percent found in DGF and UGF, respectively. Research conducted by O'Quinn (2012) found beef derived from grass-fed cattle was the least favorable product category analyzed. The current study results also agree with Sitz et al. (2005) that demonstrated consumers rated domestic grass-fed beef overall more acceptable in flavor and preferred it (64.5%) more often than imported grass-fed beef. Research conducted by Emerson et al. (2012) concluded that grass flavor intensity was influenced ($P < 0.001$) by marbling degree, decreasing gradually as marbling degree increased. The current research, and previous research mentioned, demonstrates that less percent lipid results in less flavor desirability by the consumer.

Overall, in the present study, the product categories with a greater lipid percentage rank greater for flavor preference. However an exception was determined for PCH (best = 201), which is more preferred than PR (best = 136). Unique to percent lipid, PR was found to have the same percent lipid as PCH ($P > 0.05$). Perhaps this result is explained by variations within the USDA grading scale as product was collected after USDA grade (determined by USDA Agricultural Marketing Service standards) was assigned at a commercial beef plant. Upper two-thirds Choice (Mt-Md 0-99) has been determined to have an 82% to 88% positive sensory experience and USDA Prime (Slab-Ab 0-99) has been determined to provide a 99% chance of an acceptable eating experience (Emerson et al., 2012). Previous research has found that as degree of marbling increases, the likelihood of increased juiciness and improved flavor increases (Smith et al., 1984; Platter et al., 2003; Emerson et al., 2012).

Shares of Preference for Beef Flavor

In order to determine the proportion of consumers who prefer a specific beef category, SAS® MDC was used to construct MNL and RPL models to intuitively provide a share of preference. Preferences were combined from consumer panels in Colorado, Ohio, and California. Results in Table 3.6 show W is forecasted to have the greatest likelihood of preference (19.0%; $P < 0.05$). The W is also ranked first in B/W scaling and is consistently the most preferred product category in this analysis. Intramuscular (IM) fat of the *longissimus dorsi* contains more than one-third oleic acid (C18:1 c9), a MUFA known to have the most beneficial effect on beef flavor desirability (Dryden and Marchello, 1970; Westerling and Hedrick, 1979; Garmyn et al., 2011; O'Quinn, 2012).

The likelihood of preference for PCH is 15.2% ($P < 0.05$); and PR is 14.4% ($P < 0.05$). Additionally, DA (13.5%) is less preferred ($P < 0.05$) by 1.7% than PCH ($P < 0.05$). Results from Sitz et al. (2004) using an experimental auction found consumers in the auction to prefer wet-aged Choice (39.2%) more than dry-aged Choice (29.3%). Perhaps, consumers preferred wet-aged, upper two-thirds Choice more often because consumers recognized the flavor, whereas, only a small percentage of consumers may be accustomed to the flavor profile of dry-aged beef. O'Quinn (2012) concluded that consumers identified mixed results for dry-aged beef flavor, some consumers preferred the brown/roasted and dry-aged flavor notes whereas others reported no flavor difference (O'Quinn, 2012).

In the current study, SE (12.0%) is different from and preferred less than LCH (12.6%; $P < 0.05$). Consumers generally rate low Choice samples greater for flavor intensity when compared to USDA Select, and distinguish more positive flavor attributes (Philip, 2011;

O'Quinn, 2012). Fuez et al. (2004) indicated that consumers would pay more for the preferred flavor of USDA Choice steaks when compared to USDA Select steaks.

In the current study, UGF (5.5%) is consistently less preferred than DGF (7.5%; P = 0.002). Fuez et al. (2000) provided similar results for domestic grass-fed preference. However, Lin et al. (2013) found that consumers prefer and were willing to pay more for international grass-fed beef. Umberger et al. (2002) concluded that 23% of consumers were willing to pay a premium for Argentina forage-finished beef vs. corn-fed beef. Cox et al. (2006) reported that blinded retail consumers preferred to purchase forage-finished beef (34.1%), indicating that more than one-third of consumers preferred the taste of beef from forage-fed cattle in comparison to beef from grain-fed cattle. Although the current research found the DGF and UGF combined flavor preference to be 13.1%, this result is much less than results (53.7%) reported by Cox et al. (2006). The current results more closely agree with O'Quinn (2012), which found beef derived from grass-fed cattle to be less desirable for overall flavor than all other product categories analyzed. Discriminating consumer panelists in O'Quinn (2012) found beef from grass-fed cattle to have greater resignation of fishy, livery, gamey, grass/hay like, and bloody/metallic attributes. Although DGF is more preferred than UGF in the current analysis, US grass-fed beef production may be variable due to genetic variety, forages, and management practices which affect the fatty acid composition of the beef (Leonhardt and Wenk, 1997; Baublits et al., 2009). However, some preference for beef raised domestically on forage is determined in this study.

Relative Importance of Specific Beef Category

The results for both B/W scaling, SAS® MNL, and RPL models were consistent. Table 3.6 illustrates results from B/W scaling, the MNL model (determines homogeneity of preference), and RPL model (determines heterogeneity of preference) were consistent in rank for beef flavor preference. The W has the greatest share of preference of 20.2% ($P < 0.05$), which is more than the previous MNL model (19.1%). Duarte (2013) determined that Wagyu cattle form larger adipocytes and fibroblasts cells leading to their hypertrophy and richness of beef flavor. Also O'Quinn (2012), showed Wagyu to contain high amounts of oleic acid (C18:1 c9), which was closely correlated to positive flavor attributes including: beefy/brothy (r = 0.52), browned/grilled (r = 0.55), buttery/beef fat (r = 0.45), and sweet flavors (r = 0.34; O'Quinn, 2012). Xie (1996) found oleic acid content of the F-1 Wagyu x Angus to result in decreased ruminal biohydrogenation and have a greater proportion of MUFA and less SFA.

Second most preferred is PCH ($P < 0.05$), and is slightly more preferred ($P < 0.05$) in the RPL model by 0.3% versus the MNL model ($P < 0.05$). Third most preferred is PR (14.7%; $P < 0.05$), slightly more preferred than the MNL model (14.4%). The PR has the highest grade designation within the USDA grade standards for carcass beef and may be preferred, due to consumers past experience and probability of a positive sensory experience (98% to 99%; Emerson et al. 2012). The RPL model determined DA to be the fourth most preferred (13.7%) treatment ($P < 0.05$). Results from Stenström et al. (2014) found dry-aging to bring out pleasant flavors and dry-aged beef to have a greater overall liking for flavor (64.9%) versus vacuum aged beef (31.6%). Smith et al. (2014) found dry-aged beef to be exposed to mold growth and the exposure, may have caused the less desirable sensory experience and noted metallic flavors. Dry-aged treatments resulted in less juicy samples and loss of saleable yield (Smith et al., 2014).

In the present study, W, PCH, PR, and DA are slightly more preferred in the RPL model than the MNL model however, all beef categories are ranked consistently and each product category is different ($P < 0.05$). The RPL model illustrates a likelihood of preference for LCH to be 12.5%; SE, 11.8%; DGF, 6.8%; and UGF, 4.5%, slightly less preferred in the RPL versus MNL; however, the product categories mentioned are different ($P < 0.05$) from each other in both models.

Pairwise Comparisons

Pairwise comparisons were conducted for both MNL and RPL models. A mean and standard deviation for each product category was determined and an ANOVA derived a *P*-value for all comparisons. Pairwise comparisons for both the MNL and RPL models show significance between all product categories. Impressively, the more restrictive RPL model shows significance for each product category. Difference between product category is signified by differing superscripts in the same columns of Table 3.6 ($\alpha = 0.05$).

Probability of Consumer Demographic Information on Preference

Demographic information shows difference in preference (probability of choosing a product category as best) for DGF ($P = 0.009$) and DA ($P = 0.019$; Table 3.7) and no other differences are found when panelists select the most preferred product category. Beef from DGF is preferred more (10.3%) by Baby Boomers (10.3%) than both Generation X (6.0%) and Millennials (7.1%; $P < 0.05$). However, Millennials and Generation X show the same preference ($P > 0.05$) for DGF. Baby Boomers (18.6%) also prefer DA more than Millennials (13.6%; $P < 0.05$). Generation X (14.7%) respondents do not differ from Baby Boomers or Millennials for flavor preference of DA ($P > 0.05$).

Demographic information shows difference in preference when consumers select for the least favorable product category, gender ($P = 0.049$), age ($P = 0.013$), and household income (*P*

= 0.014; Table 3.8). Females are more prone to identify UGF as least preferred (25.3%) compared with males (21.9%; $P < 0.05$). Millennials show the greatest likelihood of having UGF as their least preferred (27.8%) sample ($P < 0.05$), while both Generation X (21.9%) and Baby Boomers (21.3%) do not differ in preference ($P > 0.05$). Consumers with a household income between $25,000 to $34,999 are less likely to denote UGF as the least favorable sample when compared to all other income categories ($P < 0.05$). Household income does not show a difference in flavor preference for UGF for those with incomes below $25,000 and above $35,000 for preference ($P > 0.05$). In summary, females, Millennials, and respondents with an average or higher household income are more likely to consider UGF as their least preferred sample.

Conclusions

Cross and Savell (1994) stated that the beef industry did not know the most suitable proportion for effective marketing of USDA Prime, upper two-thirds Choice, low Choice, Select, and other major beef brands. This research quantified the likelihood of preference for beef flavor of different product categories and determined optimal market share potential for beef flavor preference. Overall, W, PCH, PR, and DA were consistently preferred in the top half of the treatments analyzed with preference ranging from 13.5% to 20.2% between both MNL and RPL shares of preference models. Consumers in this study (MNL) preferred W (19.1%) compared to the seven beef product categories and ranked it 1^{st} (B/W scaling). The consumer prediction model (RPL) determined it to be slightly more preferred (20.2%). These results do not agree with Savell and Cross (1988) that reported beef derived from Wagyu cattle contained too high of IM fat content that was outside the window of consumer acceptability. Although, it is apparent that there are discrepancies in flavor preference. However, the four samples with the greatest percentage of lipid (W, PCH, PR, and DA) resulted in a greater percentage of preference for flavor than product categories with a lower percent lipid (LCH, SE, UGF and DGF). It is obvious that lipid content has a large affect on flavor and overall preference of beef. Across all analyses, grain-fed beef treatments are likely to be more preferred in flavor than grass-fed treatments.

Beef originating from F-1 Wagyu x Angus cattle has the opportunity to be recognizable by brand and deliver an acceptable eating experience. Highly marbled beef from domestic breeds, e.g. USDA Prime and upper two-thirds Choice, fared well with consumer beef preferences for flavor reinforcing the importance of genetic selection and management of cattle that produce higher quality grades. There is market opportunity for the beef flavor produced from dry-aging of beef; however, consumers have a tendency to either strongly prefer or strongly dislike the more distinguishable flavor. An ideology is that variation among beef flavor preference may exists due to consumer background and perception (Daley, et al., 2010). Research has shown that consumers are willing to pay a premium for a quality attribute that is desired allowing it to be feasible to market (Hebb, 2011). Marketing of beef needs distinction based on desirable attributes to return profitability to the meat industry (Purcell and Lusk, 2003). Though less preferred than the grain-fed product categories, beef derived from grass-fed cattle can provide a niche market opportunity for grass-fed beef suppliers.

Consumers in this research concluded that taste/eating experience and visual appearance were most important when making beef purchasing decisions. Consequently, it is important that beef originating from various production methods are marketed clearly with animal diet, breed composition, marbling content, and postmortem aging method that may result in beef flavor profile differences. Consumers ranked marbling level (3.8) and USDA grade of product (4.2) moderately important when making beef purchasing decisions, yet research has shown that degree of marbling and subsequent USDA quality grade is an accurate predictor of beef flavor preference and overall eating satisfaction. Consumers ranked grass-fed vs. grain-fed (7.5) as the least important beef characteristic to beef purchasing decisions. There is an evident disconnect in supply chain communication. This can be interpreted that consumers do not put emphasis on seeking out grass-fed beef, as a majority in the retail case is considered grain finished, or that they perceive animal diet to be a lower priority in purchased beef products. Awareness of beef flavor intensity profile differences from beef originating from grass-fed animals should be communicated to the end consumer as this research indicated grass-fed beef was overall less preferred for flavor. Consumers should be provided educational resources that offer knowledge about differences in products they purchase and expected flavor attributes. Consumer demographic analysis indicates that targeting Millennials and Generation X as the preferred group for grass-fed beef may not be the best target market. Females and Millennials are shown to most dislike UGF. However, Baby Boomers have the greatest preference for DGF. Also it appears that Baby Boomers and Generation X may have a more developed taste and preference for DA than Millennials.

This study determined that overall flavor preference is preferred for beef that is raised in US commercial feeding systems. Despite this, there is a niche market opportunity for domestic grass-fed beef (6.8%) and Uruguayan grass-fed (4.5%). However, the influence of the Wagyu breed in cattle production may be more beneficial for increased market opportunity and meeting beef flavor preferences. Of the 89.3 million head of US cattle (USDA-ERS, 2014) less than 15,000 consist of Wagyu and Wagyu cross cattle (personal communication with Michael Beattie, Executive Director of the American Wagyu Association, communicated in July 2014). The USDA upper two-thirds Choice and USDA Prime were preferred when compared to lower marbling treatments although percent lipid content and flavor preference may not be as pronounced as compared to F-1 Wagyu x Angus. At the retail level, dry-aging beef can change flavor profile and provide another market alternative that some consumers prefer. The 2011 NBQA concluded that feeders placed the least importance on eating satisfaction. Perhaps more emphasis needs to be focused on genetic selection and animal diet to obtain full market value capitalization. Focusing on genetics, optimization in the feedyard, and value-adding at retail with quality in mind will allow market opportunity to expand to beef flavor preferences of US consumers. Quinn (1999) describes, "The end-product is taste…people will pay more for greater satisfaction, and taste is their measure of satisfaction in food…meat producers who are customer-driven must seek to influence the factors that affect taste all the way from the field to the table."

Table 3.1. Treatment, product type, treatment abbreviations, marbling scores, and aging specifications

Trt. #	Product Type	Treatment Abbreviation	Marbling Score	Postmortem Aging Time and Method
1	Domestic Grass-Fed	DGF	-	14-d wet-aged
2	Uruguayan Grass-Fed	UGF	-	56-d wet-aged
3	Choice	LCH	Small	14-d wet-aged
4	Select	SE	Slight	14-d wet-aged
5	Prime	PR	≥ Slightly Abundant	14-d wet-aged
6	Upper two-thirds Choice	PCH	Modest/Moderate	14-d wet-aged
7	Upper two-thirds Choice (dry-aged)	DA	Modest/Moderate	14-d wet-aged, 21-d dry-aged
8	F-1 Wagyu x Angus	W	≥ Slightly Abundant	14-d wet-aged

Table 3.2. Demographic characteristics of study participants (N = 335)

Characteristic	Response	Percentage of participants
Sex	Male	54.9
	Female	45.0
Age	18-34	35.2
	35-50	22.0
	Over 50	42.9
Income	Under $25,000	20.9
	$25,000 to $34,999	4.5
	$35,000 to $49,999	9.0
	$50,000 to $74,999	24.5
	$75,000 to $100,000	13.1
	$100,000 or more	25.1
Marital Status	Single	32.5
	Married	62.1
	Divorced	2.1
	Widowed	3.0
Education	Non-high school graduate	1.7
	High school graduate	8.1
	Some college or technical school	36.7
	College graduate	32.0
	Post graduate	20.0
Household Size	1 person	13.4
	2 persons	36.7
	3 persons	15.5
	4 persons	22.7
	5 persons	6.3
	6 persons	4.8
	More than 7 persons	0.1
umber of times beef is consumed per week	None	0.0
	1 to 3	56.7
	4 to 6	37.3
	7 or more	5.4

Table 3.3. Consumer ranks of the importance of various beef characteristics when purchasing beef

Characteristic	Rank
1 Taste/eating experience	2.9^{e}
2 Visual appearance	3.2^{e}
3 Marbling level	3.8^{d}
4 USDA grade of product	4.2^{d}
5 Nutrient content	5.6^{c}
6 Breed of animal/product	6.7^{b}
7 Where and how the animal was raised	6.8^{b}
8 Growth promotants and/or antibiotics	6.9^{b}
9 Brand of product	6.9^{b}
10 Grass-fed vs. grain-fed	7.5^{a}

Consumers rank of importance of the ten traits (1-10) where 1 = most important and 10 = least important

^{abcde} Least squares means lacking a common superscript differ ($P < 0.05$)

Table 3.4. Least squares means for percent lipid, protein, moisture, and ash determined by proximate analysis of raw samples

Treatment	Lipid, (%)	Protein, (%)	Moisture, (%)	Ash, (%)
Domestic Grass-Fed, 14-d wet-aged	3.39^{f}	22.96^{b}	74.28^{a}	1.00^{b}
Uruguayan Grass-Fed, 14-d wet-aged	4.15^{f}	22.46^{b}	72.38^{b}	1.00^{b}
Choice (Sm 0-99), 14-d wet-aged	8.73^{d}	22.38^{b}	68.65^{d}	1.00^{b}
Select (Sl 0-99), 14-d wet-aged	6.08^{e}	22.81^{b}	70.55^{c}	1.03^{b}
Prime (Slab-Ab 0-99), 14-d wet-aged	9.96^{c}	21.46^{c}	66.76^{e}	0.99^{b}
Upper two-thirds Choice (Mt-Md 0-99), 14-d wet-aged	9.79^{cd}	21.93^{bc}	67.01^{e}	0.98^{b}
Upper two-thirds Choice (Mt-Md 0-99), 14-d wet-aged, 21-d dry-aged	11.64^{b}	25.85^{a}	60.42^{g}	1.18^{a}
F-1 Wagyu x Angus cross (≥Slab 0-99+), 14-d wet-aged	14.44^{a}	20.53^{d}	62.63^{f}	0.88^{c}
SEM[1]	0.41	0.22	0.28	0.03
P-value	< 0.0001	< 0.0001	< 0.0001	< 0.0001

[1] SE of the least squares mean

[abcdefg] Least squares means in the same column lacking a common superscript differ ($P < 0.05$)

Table 3.5. Consumer best-worst ranking of beef preference

Attribute	Best[1]	Worst[2]	Best-Worst	Rank[3]
F-1 Wagyu x Angus cross (≥Slab 0-99+), 14-d wet-aged	615	171	444	1
Upper two-thirds Choice (Mt-Md 0-99), 14-d wet-aged	427	226	201	2
Prime (Slab-Ab 0-99), 14-d wet-aged	397	261	136	3
Choice (Mt-Md 0-99), 14-d wet-aged & 21-d dry-aged	444	358	86	4
Choice (Sm 0-99), 14-d wet-aged	377	313	64	5
Select (Sl 0-99), 14-d wet-aged	312	308	4	6
Domestic Grass-Fed, 14-d wet-aged	230	573	-343	7
Uruguayan Grass-Fed, 14-d wet-aged (T2)	177	769	-592	8

[1] Number of responses chosen as best
[2] Number of responses chosen as worst
[3] Ordinal scale of consumer rank

Table 3.6. Coefficient estimates and shares of preference relative to F-1 Wagyu x Angus

	Econometric Estimates		Shares of Preference (%)	
Beef Category[1]	MNL	RPL	MNL	RPL
W	0.000	0.000	19.068[4a]	20.168[a]
	(0.000)[2]	(0.000)	[0.000]	[0.656]
	[0.000][3]	[0.000]		
PCH	-0.222*	-0.260*	15.275[b]	15.557[b]
	(0.051)	(0.055)	[0.000]	[0.566]
	[0.000]	[0.067]		
PR	-0.277*	-0.314*	14.449[c]	14.740[c]
	(0.050)	(0.053)	[0.000]	[0.530]
	[0.000]	[0.008]		
DA	-0.344*	-0.384*	13.521[d]	13.741[d]
	(0.049)	(0.059)	[0.000]	[0.581]
	[0.000]	[1.000]		
LCH	-0.416*	-0.475*	12.574[e]	12.543[e]
	(0.051)	(0.054)	[0.000]	[0.452]
	[0.000]	[-0.100]		
SE	-0.463*	-0.530*	12.001[f]	11.872[f]
	(0.050)	(0.054)	[0.000]	[0.441]
	[0.000]	[-0.064]		
DGF	-0.930*	-1.081*	7.521[g]	6.847[g]
	(0.051)	(0.063)	[0.000]	[0.335]
	[0.000]	[0.800]		
UGF	-1.227*	-1.494*	5.590[h]	4.532[h]
	-0.052	(0.074)	[0.000]	[0.273]
	[0.000]	[-1.115]		
N individuals	335	335		
N Choices	2979	2979		
Log likelihood	-7475	-7422		
Pseudo R^2	0.055	0.062		

[1] Eight beef categories (NAMP 180) include: 1) DGF (14-d wet-aged domestic grass-fed beef); 2) UGF (14-d wet-aged Uruguayan grass-finished beef); 3) LCH (14-d wet-aged USDA Choice); 4) SE (14-d wet-aged USDA Select); 5) PR (14-d wet-aged USDA Prime); 6) PCH (14-d wet-aged upper two-thirds Choice); 7) DA (14-d wet-aged and 21-d dry-aged upper two-thirds Choice); and 8) W (14-d wet-aged F-1 Wagyu x Angus cross)

[2] Numbers in ( ) are standard errors

[3] Numbers in [ ] are standard deviations

[4] Mean of simulated shares of preference of 1,000 observations drawn from a multivariate normal distribution parameterized by using the coefficients and variance-covariance terms estimated by the MNL and RPL models in SAS® MDC

* implies that the mean importance of the coefficient estimate is different from W when ($P < 0.05$)

[abcdefgh] Percentages in the same column lacking a common superscript differ ($P < 0.05$)

Table 3.7. Probability of consumer demographic most preferred product category (mean ± SEM)

		Beef Category[2]							
Effect	N	DGF	UGF	LCH	SE	PR	PCH	DA	W
Gender		*P* = 0.414	*P* = 0.335	*P* = 0.811	*P* = 0.300	*P* = 0.778	*P* = 0.667	*P* = 0.780	*P* = 0.446
Male	184	0.072 ± 0.007	0.065 ± 0.007	0.130 ± 0.010	0.097 ± 0.008	0.134 ± 0.100	0.130 ± 0.010	0.200 ± 0.011	0.207 ± 0.017
Female	151	0.081 ± 0.009	0.056 ± 0.008	0.134 ± 0.011	0.122 ± 0.011	0.130 ± 0.011	0.121 ± 0.010	0.160 ± 0.013	0.189 ± 0.013
Age[1]		*P* = 0.009	*P* = 0.814	*P* = 0.686	*P* = 0.346	*P* = 0.622	*P* = 0.629	*P* = 0.019	*P* = 0.363
Millennial	118	0.071 ± 0.010[b]	0.056 ± 0.009	0.143 ± 0.013	0.102 ± 0.011	0.134 ± 0.013	0.137 ± 0.013	0.136 ± 0.013[b]	0.212 ± 0.015
Generation X	74	0.060 ± 0.011[b]	0.061 ± 0.011	0.121 ± 0.014	0.137 ± 0.016	0.140 ± 0.015	0.114 ± 0.014	0.147 ± 0.016[ab]	0.212 ± 0.018
Baby Boomers	144	0.103 ± 0.011[a]	0.064 ± 0.081	0.132 ± 0.011	0.093 ± 0.010	0.120 ± 0.011	0.124 ± 0.011	0.186 ± 0.014[a]	0.171 ± 0.012
Household Income		*P* = 0.062	*P* = 0.965	*P* = 0.679	*P* = 0.701	*P* = 0.927	*P* = 0.587	*P* = 0.811	*P* = 0.741
Under $25,000	70	0.049 ± 0.010	0.064 ± 0.012	0.125 ± 0.015	0.109 ± 0.015	0.139 ± 0.017	0.137 ± 0.016	0.160 ± 0.019	0.212 ± 0.019
$25,000 to $34,999	15	0.119 ± 0.030	0.066 ± 0.022	0.167 ± 0.032	0.110 ± 0.028	0.110 ± 0.027	0.113 ± 0.027	0.152 ± 0.033	0.157 ± 0.031
$35,000 to $49,999	30	0.091 ± 0.018	0.061 ± 0.015	0.117 ± 0.020	0.127 ± 0.021	0.134 ± 0.021	0.106 ± 0.019	0.167 ± 0.024	0.189 ± 0.025
$50,000 to $74,999	82	0.078 ± 0.011	0.062 ± 0.009	0.144 ± 0.014	0.103 ± 0.012	0.131 ± 0.013	0.134 ± 0.013	0.138 ± 0.014	0.203 ± 0.016
$75,000 to $100,000	44	0.075 ± 0.014	0.058 ± 0.012	0.122 ± 0.017	0.119 ± 0.017	0.138 ± 0.018	0.112 ± 0.016	0.151 ± 0.020	0.219 ± 0.022
> $100,000	84	0.063 ± 0.009	0.052 ± 0.008	0.122 ± 0.012	0.090 ± 0.011	0.138 ± 0.013	0.153 ± 0.014	0.164 ± 0.015	0.211 ± 0.016

[1] Consumers identified age as either Millennial (18-34), Generation X (35-50), or Baby Boomers (over 50)

[2] Eight beef categories (NAMP 180) include: 1) DGF (14-d wet-aged domestic grass-fed beef); 2) UGF (14-d wet-aged intensely managed Uruguayan grass-finished beef); 3) LCH (14-d wet-aged USDA Choice); 4) SE (14-d wet-aged USDA Select); 5) PR (14-d wet-aged USDA Prime); 6) PCH (14-d wet-aged upper two-thirds Choice); 7) DA (14-d wet-aged and 21-d dry-aged upper two-thirds Choice); and 8) W (14-d wet-aged F-1 Wagyu x Angus cross)

[ab] Least square means in the same column within an effect lacking a common superscript differ ($P < 0.05$)

Table 3.8. Probability of consumer demographic least preferred product category (mean ± SEM)

Effect	N	Beef Category[2] DGF	UGF	LCH	SE	PR	PCH	DA	W
Gender		*P* = 0.871	*P* = 0.049	*P* = 0.488	*P* = 0.567	*P* = 0.642	*P* = 0.281	*P* = 0.810	*P* = 0.337
Male	184	0.193 ± 0.011	0.219 ± 0.013[b]	0.116 ± 0.009	0.095 ± 0.008	0.093 ± 0.008	0.087 ± 0.008	0.125 ± 0.010	0.056 ± 0.006
Female	151	0.190 ± 0.013	0.253 ± 0.015[a]	0.103 ± 0.010	0.086 ± 0.009	0.085 ± 0.009	0.064 ± 0.008	0.128 ± 0.011	0.072 ± 0.008
Age[1]		*P* = 0.414	*P* = 0.013	*P* = 0.368	*P* = 0.538	*P* = 0.595	*P* = 0.938	*P* = 0.409	*P* = 0.491
Millennial	118	0.179 ± 0.014	0.278 ± 0.018[a]	0.094 ± 0.011	0.101 ± 0.011	0.082 ± 0.010	0.074 ± 0.010	0.123 ± 0.013	0.056 ± 0.008
Generation X	74	0.219 ± 0.019	0.219 ± 0.019[b]	0.104 ± 0.014	0.076 ± 0.011	0.087 ± 0.012	0.077 ± 0.017	0.140 ± 0.016	0.060 ± 0.011
Baby Boomers	144	0.182 ± 0.013	0.213 ± 0.015[b]	0.132 ± 0.011	0.095 ± 0.010	0.010 ± 0.010	0.073 ± 0.009	0.117 ± 0.011	0.077 ± 0.009
Household Income		*P* = 0.658	*P* = 0.014	*P* = 0.617	*P* = 0.800	*P* = 0.819	*P* = 0.543	*P* = 0.345	*P* = 0.527
Under $25,000	70	0.214 ± 0.020	0.252 ± 0.021[a]	0.105 ± 0.015	0.087 ± 0.013	0.085 ± 0.014	0.062 ± 0.011	0.125 ± 0.016	0.062 ± 0.012
$25,000 to $34,999	15	0.145 ± 0.031	0.135 ± 0.030[b]	0.164 ± 0.032	0.097 ± 0.025	0.112 ± 0.027	0.056 ± 0.019	0.173 ± 0.035	0.118 ± 0.029
$35,000 to $49,999	30	0.176 ± 0.024	0.232 ± 0.028[a]	0.099 ± 0.018	0.099 ± 0.018	0.099 ± 0.080	0.114 ± 0.020	0.115 ± 0.021	0.059 ± 0.014
$50,000 to $74,999	82	0.211 ± 0.016	0.250 ± 0.018[a]	0.102 ± 0.012	0.081 ± 0.010	0.084 ± 0.011	0.079 ± 0.010	0.133 ± 0.014	0.054 ± 0.009
$75,000 to $100,000	44	0.206 ± 0.021	0.307 ± 0.026[a]	0.093 ± 0.015	0.079 ± 0.014	0.075 ± 0.014	0.069 ± 0.013	0.117 ± 0.017	0.051 ± 0.011
> $100,000	84	0.204 ± 0.015	0.268 ± 0.018[a]	0.102 ± 0.011	0.098 ± 0.011	0.086 ± 0.011	0.079 ± 0.010	0.104 ± 0.012	0.053 ± 0.008

[1] Consumers identified age as either Millennial (18-34), Generation X (35-50), or Baby Boomers (over 50)

[2] Eight beef catagories (NAMP 180) include: 1) DGF (14-d wet-aged domestic grass-fed beef); 2) UGF (14-d wet-aged intensely managed Uruguayan grass-finished beef); 3) LCH (14-d wet-aged USDA Choice); 4) SE (14-d wet-aged USDA Select); 5) PR (14-d wet-aged USDA Prime); 6) PCH (14-d wet-aged upper two-thirds Choice); 7) DA (14-d wet-aged and 21-d dry-aged upper two-thirds Choice); and 8) W (14-d wet-aged F-1 Wagyu x Angus cross)

[ab] Means in the same column within an effect that do not share a common superscript letter differ ($P < 0.05$)

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APPENDIX

Table A.1. Least squares means for percent lipid, protein, moisture, and ash determined by batch for proximate analysis of raw samples

Treatment	Lipid, (%)	Protein, (%)	Moisture, (%)	Ash, (%)
DGF	3.39[f]	22.96[b]	74.28[a]	1.00[b]
Batch 1	3.47	23.00	74.08	0.93
Batch 2	3.77	22.17	74.1	1.06
Batch 3	2.93	22.19	74.64	1.00
SEM[1]	0.05	0.19	0.22	0.02
P-value	0.0042	0.0897	0.2822	0.0535
UGF	4.15[f]	22.46[b]	72.38[b]	1.00[b]
Batch 1	4.30	23.05	72.62	1.12
Batch 2	4.06	22.72	71.96	0.96
Batch 3	4.14	23.09	72.55	0.92
SEM[1]	0.19	0.39	0.29	0.03
P-value	0.7665	0.7838	0.3457	0.0514
LCH	8.73[d]	22.38[b]	68.65[d]	1.00[b]
Batch 1	7.25	22.60	69.30	1.03
Batch 2	8.88	22.60	68.19	1.01
Batch 3	10.06	21.92	68.48	0.96
SEM[1]	0.27	0.41	0.28	0.03
P-value	0.0130	0.4968	0.4072	0.03677
SE	6.08[e]	22.81[b]	70.55[c]	1.03[b]
Batch 1	7.31	22.26	69.46	1.09
Batch 2	5.26	23.43	70.72	0.97
Batch 3	5.66	22.75	71.45	1.03
SEM[1]	0.16	0.24	0.08	0.03
P-value	0.0055	0.0923	0.0012	0.1006

Table A.1. Continued

Treatment	Lipid, (%)	Protein, (%)	Moisture, (%)	Ash, (%)
PR	9.96[c]	21.46[c]	66.76[e]	0.99[b]
Batch 1	10.45	21.14	66.92	1.05
Batch 2	10.19	21.20	66.40	0.97
Batch 3	9.23	22.04	67.00	0.96
SEM[1]	0.31	0.15	0.21	0.04
P-value	0.2253	0.0216	0.2515	0.4600
PCH	9.79[cd]	21.93[bc]	67.01[e]	0.98[b]
Batch 1	10.16	21.58	67.52	1.03
Batch 2	10.74	21.62	66.0	0.91
Batch 3	8.47	22.58	67.49	1.02
SEM[1]	0.25	0.67	0.26	0.03
P-value	0.1012	0.1856	0.0415	0.1818
DA	11.64[b]	25.85[a]	60.42[g]	1.18[a]
Batch 1	12.25	25.54	60.60	1.17
Batch 2	12.80	25.53	59.56	1.22
Batch 3	9.89	26.49	61.10	1.16
SEM[1]	0.17	0.17	0.15	0.05
P-value	0.0026	0.0463	0.0108	0.6795
W	14.44[a]	20.53[d]	62.63[f]	0.88[c]
Batch 1	13.77	20.66	63.27	0.98
Batch 2	15.68	20.17	61.61	0.80
Batch 3	13.69	20.76	63.00	0.88
SEM[1]	0.30	0.41	0.20	0.07
P-value	0.4333	0.0764	0.0179	0.2916

Panel: 1
Panelist: 1

About Yourself

(Please circle the answer that best describes you for each item)

Gender	Household Size	Marital Status	Age	Ethnic Origin
Male	1 person	Single	Under 18	African-American
Female	2 people	Married	18-34	Asian
	3 people	Divorced	35-50	Caucasian/White
	4 people	Widowed	Over 50	Hispanic
	5 people			Native American
	6 people			Other
	Over 6 people			

Annual Household Income	Education Level
Under $25,000	Non-high School graduate
$25,000 - $34,999	High school graduate
$35,000 - $49,999	Some College/Technical School
$50,000 - $74,999	College graduate
$75,000 to $100,000	Post graduate
more than $100,000	

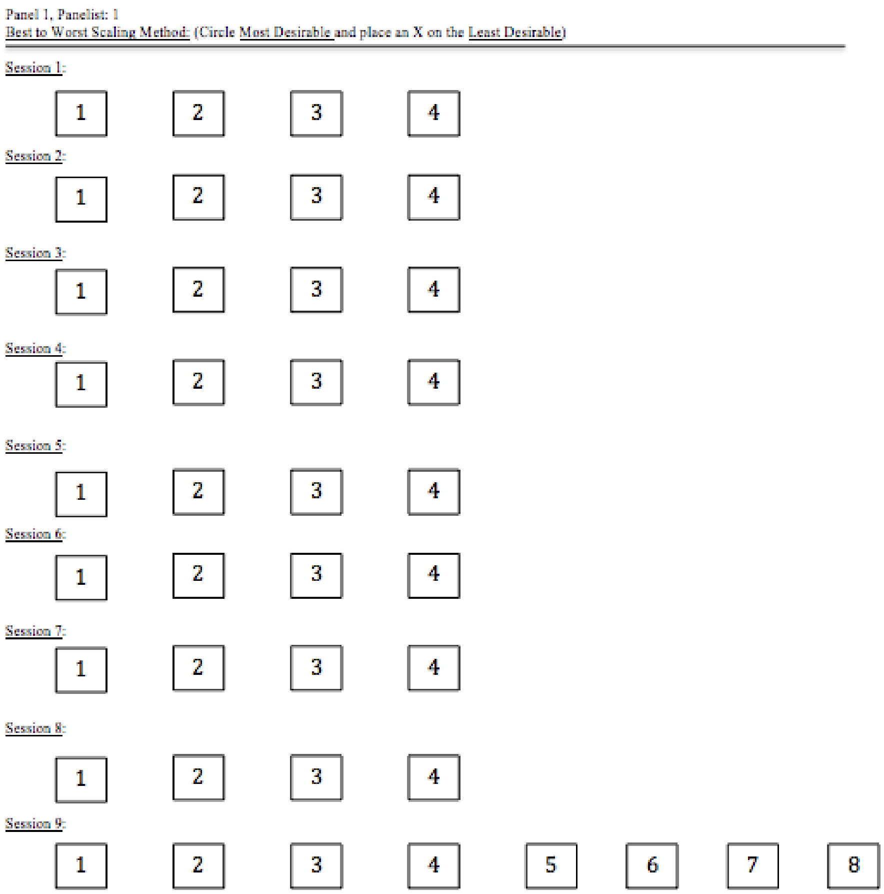
How many times a week do you consume beef?

None 1 to 3 4 to 6 7 or more

Please rank the importance of the following 1 through 10 (1= Most important; 10 = Least important):

________ brand name of the product
________ breed of the animal that produced the product
________ marbling level (fresh meat)
________ nutrient content
________ taste/eating experience
________ USDA grade of the product
________ visual appearance (fresh meat)
________ where and how the animal was raised
________ whether or not the animal received growth promotants and/or antibiotics
________ whether or not the animal was raised exclusively on pasture or fed grain in a feedlot for any period of time

Figure A.2. Consumer ballot, front



Panel 1, Panelist: 1

Best to Worst Scaling Method: (Circle Most Desirable and place an X on the Least Desirable)

Session 1:

1 2 3 4

Session 2:

1 2 3 4

Session 3:

1 2 3 4

Session 4:

1 2 3 4

Session 5:

1 2 3 4

Session 6:

1 2 3 4

Session 7:

1 2 3 4

Session 8:

1 2 3 4

Session 9:

1 2 3 4 5 6 7 8

Figure A.3. Consumer ballot, back