MOUTH BEHAVIOR AND CONSUMER PREFERENCES IN GROUND BEEF PATTIES

A Thesis

by

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ABSTRACT

Food texture attributes have been used in sensory science for testing or predicting consumer acceptability of a product. Within meat products, ground beef texture has been related to consumer acceptance. However, consumers respond differently to texture attributes. A concept was developed that classified consumers into four texture categories (crunchers, chewers, smooshers, or suckers) based on mouth behavior. The objective of this study was to determine if consumers classified into four mouth behavior (MB) categories using the Jeltema Beckley Mouth Behavior® (JBMB®) graphic tool responded differently to ground beef differing in texture attributes. Differences in ground beef texture attributes were evaluated mechanically by Texture Profile Analysis (TPA) where hardness 1, adhesion, hardness 2, cohesiveness, springiness, gumminess, and chewiness were calculated. Descriptive texture attributes of surface roughness, firmness, springiness, hardness, initial juiciness, mouthcoating, connective tissue amount, cohesiveness, cohesiveness of mass, particle size, particle amount, chewiness, toothpacking, and sustained juiciness were evaluated by a 5-member expert descriptive attribute panel. Qualitative consumer workshops were used to determine consumer attitudes toward differing ground beef patty texture attributes. In Phase 1, four 227 g ground beef patty treatments (three treatments were machine formed patties containing either 7, 20 or 27% fat; and one treatment was bowl chopped, machine formed, containing 20% fat) and two 110 g patty treatments were bowl chopped and either hand-formed into patties or formed into balls and smashed during cooking. One ground beef patty was served to each consumer across each MB category (Crunchers n=7, Chewers

n=5, Smooshers n=5, Suckers n=2). Phase II, stimuli consisted of seven foodservice commercially prepared patties (Wayback Burgers, Five Guys, Koppe Bridge, Whataburger, McDonald's, Sonic, and Freddy's) weighing approximately 110 g and six ground beef products hand-formed round, sirloin and chuck that were purchased in chubs, hand-formed brisket and chuck patties purchased in over-wrap trays; and chuck patties machine formed at the retail location) were purchased from H-E-B. Patties were presented as in Phase I (Crunchers n=4, Chewers n=7, Smooshers n=3, Suckers n=7).

Patties in both phases differed in texture. In Phase I, ground beef patties differed ($P<0.05$) in the descriptive texture attributes of surface roughness, firmness, connective tissue amount, cohesiveness of mass, particle size, and chewiness; and TPA values of hardness 1, adhesion, gumminess, chewiness, and hardness 2. Phase II treatments differed ($P<0.05$) in descriptive sensory attributes of surface roughness, firmness, springiness, hardness, mouthcoating, cohesiveness, particle size, chewiness, and sustained juiciness; and TPA values of hardness 1, hardness 2, cohesiveness, springiness, gumminess, and chewiness. Qualitative consumer sensory results from Phase I indicated that consumers across mouth behavior groups perceived differences in fat level and processing method differently. During Phase II consumer perceptions of foodservice ground beef patties differed from their perception of casual dining burgers across the four mouth behaviors. These results indicated that mouth behavior classification impacted consumer acceptance of ground beef patties based on differences in beef patty texture.

DEDICATION

This work is dedicated to my family, friends, peers, and colleagues that have supported me along the way and helped me grow into the person I am today. Most importantly it is dedicated to my Papa. Your unconditional love and support have guided me through this period of life even from above.

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NOMENCLATURE

MB	Mouth Behavior
TPA	Texture Profile Analysis

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1. INTRODUCTION

Texture analysis is a complex and critical attribute used in sensory science for testing or predicting a product's acceptability by consumers (Munoz, 1986; AMSA 2022; Miller, 2022). Texture research was not studied seriously until the 1950's when Alina Szczesniak started developing a texture lexicon. In 1963 Szczesniak published the foundational articles on the measure and classification of food texture (Jeltema, Beckley, & Vahalik, 2014). These texture attributes have been used to evaluate processed meat texture (Munoz, 1986, 1988). Texture is a key driver of consumer acceptance and a major contributor to the rejection of a food (Drenowski, 1997; Jeltema, Beckley, & Vahalik, 2015). Texture and its relationship to consumer liking and acceptance has been extensively evaluated (Miller, 2020). There is minimal research that focuses on the drivers and differences of texture preferences and ultimate consumer acceptance or rejection.

Mouth behavior is defined as the preferred way an individual manipulates food in their mouth as they eat (Jeltema et. al., 2014). Individuals can be placed into one of four broad categories based on their oral processing behaviors: Crunchers; Chewers; Smooshers; and Suckers (Jeltema, 2015). The four categories were created based on two primary modes of mouth actions. Chewers and Crunchers prefer to use their teeth to break down their foods (Jeltema, Beckley, & Vahalik, 2015), while Smooshers and Suckers manipulate their food between the roof of their mouth and their tongue. Crunchers prefer foods that break or fracture easily. Chewers like products that require increased mastication (Jeltema et al., 2015). This does not mean that individuals of one

mouth behavior type reject foods that are categorized in another. According to Jeltema (2015) there are increased levels of satisfaction when consuming foods that are categorized into an individuals' preferred mouth behavior type.

Since its discovery in the 1980's, mouth behavior has been investigated in relation to a wide variety of food and beverage items (Kokini, Kadane, & Cussler, 1977). Over the past 15 years, qualitative research has explored individuals mouth behaviors and concluded that it is a factor that drives consumer food decisions, purchases, and overall satisfaction of products (Jeltema et al., 2015). Interestingly, the influence of mouth behavior on acceptability of food has not been evaluated in meat products. Therefore, the objective of this study was to evaluate the impact of mouth behavior on consumer acceptance of ground beef patties varying in texture attributes.

Phase I of this study focused on textual differences and effects from ground beef patties that varied in grind size, fat content, lean source and processing method. Phase II included commercially processed and cooked foodservice ground beef patties available for takeout or delivery in Bryan and College Station, TX area, and fresh retail ground beef that was then hand pressed into patties. Within each phase, qualitative consumer sensory, descriptive texture sensory, and mechanical texture analyses were conducted. For qualitative consumer sensory, four consumer workshops ($n \leq 9$) per phase were conducted so that consumers with similar mouth behavior classification were used within each qualitative group session. Texture Profile Analysis (TPA) and an expert texture descriptive attribute sensory panel were utilized to evaluate ground beef texture from each phase.

2. LITERATURE REVIEW

2.1 Mouth Behaviors

Jeltema et al. (2015) introduced the idea that consumers perceive textures in different ways. The JBMB® graphic tool (Figure 1) is used to characterize an individual's food/texture preferences based on how they manipulate food inside their mouth. Development of the JBMB® graphic tool is based on research that shows that individuals have preferred oral manipulation methods and that oral processing behaviors determine textural preferences (Jeltema et al., 2015). Brown and Braxton (2000) identified four groups based on chewing efficiency and breakdown of almonds and chewing gum. Individuals were separated into group based on their low or high efficiency to breakdown each product. Major conclusions from their research were that there are differences in the mechanisms individuals use during mastication, and that these differences may be drivers of personal preferences. The JBMB® graphic tool was developed as a new model for understanding what drives texture preferences and can be utilized to optimize product development (Jeltema et al., 2015). Additionally, the JBMB® graphic tool development suggested that Brown and Braxton's conclusion of manipulation mechanisms are a key driver of preference (Jeltema et al., 2015). This translates to the idea that textures that fit an individual's mouth behavior is key to understanding textural preferences (Jeltema et al., 2015).

Mouth behavior was discovered in the 1980s when scientists observed participants in a ready to eat cereal bowl-life study poured vastly different proportions of milk into their bowl. Some participants had more milk for the cereal to sit in, allowing it

to get soggy; while others used substantially less, to prevent the texture change. Further investigation was done to find ways to explain the different oral behaviors and preferences qualitatively and quantitatively (Jeltema et al., 2015). The question 'what do people want to do with products in their mouths' arose from an observation involving consumer interest in a product that was meant to be held in the mouth for a prolonged time period Most of the participants were uninterested due to the lack of desire to suck on the product and were overall unsure of what to do with the product (Jeltema et al., 2015). Additional research solidified the idea that people use and interact with products differently in their mouths and this heavily drives consumer acceptability (Jeltema et al., 2015). Chewing behavior varies by individual, it has been found that food manipulation and mastication affects sensory sensations (Jeltema et al., 2015). Additional research has shown that reception of attributes changes with mastication length, suggesting that specific oral movements enhance how consumers experience their foods (De Wijk et al., 2006; De Wijk, Polet, Bult, & Prinz, 2008; Jeltema et al., 2015)

The four different mouth behavior categories were distinguished through mastication behaviors (Guinard & Mazzucchelli, 1996). Sensory physiology features have four distinct functions: discriminative touch, proprioception, nociception, and temperature sense (Guinard & Mazzucchelli, 1996). Discriminative touch refers to the physical recognition of shape, shape, and texture of foods. Proprioception is the movement or static positioning of the jaws. There are three physical modalities inside the structure of the oral structure that further the decoding of texture of foods once they have entered the mouth. Mechanoreceptors in the superficial dental structures; the hard

and soft palates, tongue, and gums. There are mechanoreceptors in the periodontal membrane that surrounds the roots of each tooth. Finally, the mechanoreceptors present in the tendons and muscles that are directly involved and responsible for mastication (Guinard & Mazzucchelli, 1996). Product development has demonstrated more failures than successes, due to the lack of understanding the consumer (Resurreccion, 2003). Upon review of the meat science literature, the influence of consumer mouth behavior has not been examined.

2.2 Oral Processing

During mastication food is evaluated for palatability, and the decision to swallow or reject is made (De Wijk, 2006). Liquids are low viscosity and require minimal oral processing to be swallowed (De Wijk, 2006). Solid foods are fractured into particles by teeth and mixed with saliva to form a bolus (Hutchings, 1988; Prinz, 1997). Oral manipulation increased surface area of a product and coats the inside of the mouth during mastication (Liu, 2000). If intense enough, aromas are released, and flavor is intensified during mastication (Liu, 2000).

Oral processing movements can be varied depending on the set task (De Wijk, 2006). Chewing pace and the masticatory pattern have been found to be consistent within individuals across multiple days but are variable across individuals (Po, et al. 2011). When sensory panelists are asked to evaluate specific attributes there will be subtle differences in their food manipulation movements (De Wijk, 2006). De Wijk et al. (2003) discussed the various phases of oral processing and the different sensations resulting from each. Initial perceptions are from external appearance or touch. As food is

fragmented during mastication and physically deforms, attributes relating to the food are assessed. First chew mainly detects attributes such as hardness, softness, and sponginess. As more saliva is added, attributes relating to the physical structure, and consistency are evaluated (De Wijk, 2003). Previous information has included jaw movements, muscle activity and particle size distribution using products such as colored chewing gym, wax-wafers and facial movements tracked though video-fluorography (De Wijk 2003). De Wijk (2003) outlines the commonly found movements in the steps of oral processing; these assumptions and findings have not been studied with consumer perception of meat.

2.3 Factors Effecting Ground Beef Patties

Ground beef accounts for a major portion of beef sales within the United States (Kerth, 2015). In 2001, burgers made up 75% of all beef entrees served in commercial restaurants and ground beef represented 63% of the total volume in of beef in the food service industry (Kerth, 2015). In 2018, ground beef was 64% of the total volume of beef purchased and generated 37% of total beef value (National Cattlemen's Beef Association, 2019). The COVID-19 pandemic resulted in a major shift in the trends for consumer behavior. Rapid shutting down of restaurants and an increased discomfort eating in public spaces resulted in consumers to exhibiting "stocking-up" behaviors. With over 50% of consumers reporting to have surplus ground beef products in their home (National Cattlemen's Beef Association, 2021b). Between 2018 and 2019 there were no changes in the billions of pounds of ground beef in the retail and foodservice sectors. However, in 2020 there was a 6.8% increase in the amount of ground beef purchased in the retail space (National Cattlemen's Beef Association, 2021b). There are

numerous factors that impact the palatability of ground beef patties, including fat source, grind size, marbling, the use of specific muscle blends and the way patties are formed and handled during cooking (Blackmon et al., 2015; Kerth et al., 2015; Roth et al., 1999).

2.3.1 Lean Source

Ground beef is often derived from trimmings fabricated from various areas on a beef carcass. Trimmings from cattle between 12-18 months of age and major cuts from cattle 4 years of age and older are common sources of lean for ground beef (Cross et al., 1980b). Lean from carcasses of C, D and E maturity (42 months and older) has been extensively studies and there are notable correlations in older animals have increased amount of connective tissue (Berry, et al., 1995). Additionally, differences in the raw material source for ground beef have concentrated on flavor attribute differences. It has been previously estimated that approximately 58% of beef used for ground beef comes off of cow carcasses (National Cattlemen's Association, 1991). More recently, consumers are seeing more muscle specific marketing of ground beef and ground beef products in both the retail and foodservice spaces. For the foodservice industry, this has come to fruition with the increase in prevalence of a gourmet burger culture. It has been found that specific muscle blends result in differences in mouth feel sensory attributes (Gilmore et al., 2011). While roughly 70% of all ground beef sold in the retail space is not marketed as a specific primal, chuck derived ground beef is responsible for 20% of all ground beef on the market (National Cattlemen's Beef Association, 2021a). Gredell, et al., (2018) investigated the of palatability on ground beef patties when using a dry

aged lean source. Three blends (fresh, dry aged, 50% blend) were evaluated by a sensory panel. Dry aged ground beef patties resulted in higher sensory scores for browned/grilled, earthy/musty and musty/roasted, sour/acidic and bitter flavors, and higher hardness scores (Gredell, et al., 2018). Fresh ground beef patties were more tender even with no differences in connective tissue scores when compared to the dry aged ground beef (Gredell, et al., 2018). Based on these studies, lean source impacts palatability of ground beef patties.

2.3.2 Fat Content

Beef demand has previously been linked to health concerns as it relates to fat content. Since the 1980's there have been negative associations with the effects that beef fatty acid composition can have on human health. The United States marketing scheme form beef has changed minimally in the past twenty years (Resurreccion, 2003). However, the development of low-fat meat products has been a strategy to increase meat consumption (Resurreccion, 2003). Lusk (2009) discussed the relationship between beef composition, total human fat consumption and content of ground beef fatty acid composition and coronary heart disease. It was shown that information on cholesterol had a more significant impact on consumers decision to purchase beef than the price factor (Kinnucan et al., 1997). Huffman's group developed the first commercial low-fat formulations (Egbert, 1991). They concluded that juiciness, tenderness, and flavor intensity are directly related to fat content (Resurreccion, 2003). Several studies have concluded that a certain level of fat is necessary to ensure overall consumer acceptability of texture, mouthfeel, tenderness of ground beef products (Baublits et al., 1960, 2006;

Cross et al., 1980a; Liu & Berry, 1998, Troutt et al., 1992). In 2020, over half of the ground beef available in the retail space was between 20-30% fat while roughly 20% of ground beef was 90% lean or greater (National Cattlemen's Beef Association, 2021a). Most ground beef available in the retail space is considered high in monounsaturated fatty acids (MUFAs) (Blackmon, 2015). When compared to ground beef produced from grass fed cattle, with a MSFA: Saturated Fatty Acid (SFAs) ratio of 0.75, cattle that were fed a high-grain diet had a MUFA:SFA ratio of 1.10 (Blackmore 2015; Gilmore et al., 2011). It has been noted that ground beef palatability attributes decreased when fat content was less than 20% (Roth et al., 1999). Furthermore, Cross et al (1980a) concluded that when fat content increased to 28% there was a positive correlation to descriptive sensory tenderness and juiciness attributes. Berry (1984;1992) concluded that sensory scores for tenderness, juiciness and flavor are lower were lower when fat level decreased.

2.3.3. Grind Size

When evaluating ground beef it has been documented that meat source particle size (grind size) influenced sensory attributes both negatively and positively (Berry, et al., 1999; Roth, et al., 1999; Suman, et al., 2003). Egbert et al. (1991) found that beef ground using larger grinder plate sizes (3 mm and 5 mm) had slightly increased overall palatability (Roth et a. 1999). Roth et al. (1999) used three different size grinder plates (2, 3 and 5 mm) for final lean grind size of lean used for ground beef patties. The initial grind of all lean and fat was 2.54 cm. Sensory scores for rubberiness were significantly impacted by grinder plate size. Ground beef patties were rubberier as grind size

increased. Additionally, meat ground with a 2 mm plate resulted in ground beef patties with lower sensory hardness scores, lower Kramer shear force values and lower cook loss (Roth, 1999). Suman et al. (2003) had similar results when comparing grind size to instrumental texture measurements. They reported increased sensory scores for tenderness on patties (buffalo) that were processed with a 3 mm plate and there were no statistical differences in texture, juiciness or overall palatability for patties made with 4- or 6-mm plates (Suman et al. 2003).

2.3.4. Processing Method

Texture characteristics differ in whole muscle meats and processed meats (Miller 2022). Cross et al. (1980b) investigated eight grinding methods (2.54 cm x 0.32 cm, 2.54 x 0.64 cm x 0.32 cm, 1.90 cm x 0.32 cm, 1.90 cm x 0.64 cm x 0.32 cm, 1.27 cm, 0.32 cm, 0.64 cm x 0.32 cm, 0.32 cm x 0.32 cm, silent cutter x 0.32 cm). This study was conducted to understand if changing grinder plate size could improve consumer palatability in ground beef patties formulated using low quality beef lean sources. Low quality beef lean sources contained greater amounts of connective tissue (Cross et al., 1976). Cross et al. (1980b) confirmed the initial hypothesis that quality grade played an important role in ground beef patty tenderness. Additionally, there were no differences between treatments of patties made from USDA Choice quality grade carcasses even with noticeable trends. However, there were significant differences in tenderness for treatments when evaluating lower quality (USDA Utility) grade carcass meat used for ground beef patties. Patties ground with an initial grind size of 2.54 or 1.90 cm resulted in scores that reflected consistently tougher patties regardless of if it was ultimately used

in a double or triple grind system (Cross, et al., 1980b). U.S. Utility ground beef patties were found to be unacceptably tough regardless of grinding treatments with 0.32 x 0.32 .cm and SC x 0.32 cm grinding methods (Cross, et al. 1989b). Berry (1980) evaluated three processing methods (grinding, chopping, combination of grinding and chopping). Sensory scores were higher for juiciness, initial and final tenderness and lower for initial and final connective tissue amount for chopped ground beef patties. Furthermore, it was concluded that chopping was a viable substitute for grinding for initial comminuting of carcass trim (Berry, 1980).

2.3.5. Forming Method

Forming method is used to ensure that the ground beef patties have the correct weight, size, and/or desired shape. Across the food service sector, there is a large variation in ground beef patty thickness and shape. Although, impacts of forming method on palatability attributes have not been extensively documented in the scientific literature, there has been evidence supporting the relationship between forming method and texture attributes.

Liu and Berry (1998) investigated two patty thicknesses with two differing formaing methods. They examined two machine forming types, traditional gravity fill equipment and twisted and forced through holes going into the mold machine. This study concluded that patties created from product forced through holes before the mold resulted in softer patties that were masticated more rapidly into smaller particle sizes compared to patties formed using the traditional gravity fill method.

Roth et al. (1999) evaluated ground beef patties formed with three pressures using an Instron Universal Testing Machine (Model 1122, Instron Corp., Canton, Mass.) at 50, 100 and 150 kg of pressure. The full fat patties that were formed at 50 kg pressure had the lowest breaking value when compared to all other fat and pressure combinations (Roth et al., 1999). Furthermore, patties formed at 50 kg of pressure were less cohesive than patties formed at 100 or 150 kg (Roth, et al., 1999). Sensory characteristics rubbery, hardness, shear and break forces were the highest when evaluating patties formed at 150 kg (Roth, et al., 1999). These studies document that forming methods affected ground beef patty sensory texture attributes.

2.4 Texture Profile Analysis (TPA) as an Instrumental Texture Measurement

Texture is comprised of numerous different sensation and parameters (Szczesniak, 1975). Additionally, TPA was based upon the idea that texture is a sensory property and is a combination of force, time and temperature as influenced by saliva (Szczesniak, 1975). Texture Profile Analysis was designed to simulate the chewing action of the mouth by applying two compression cycles to a 'bite size' piece of a product (Bourne et al., 1978). Significant thought was put into how to evaluate fundamental rheological principles in food product research (Szczesniak, 1975). What resulted was classification of these rheological principles into three main categories: mechanical, geometrical and 'others' categories. The other categories included attributes such as texture, moisture, and fat content within the food (Szczesniak, 1975). Mechanical factors were separated into primary parameters: hardness, cohesiveness, springiness (formerly named elasticity), adhesiveness and three secondary parameters:

fracturability, chewiness and gumminess (Szczesniak, 1975). Bourne et al. (1975), outlined the standard reference attribute scales for hardness, fracturablity, chewiness, gumminess, adhesiveness, and viscosity. Wilfong et al, (2016) observed increased instrumental scores for hardness, cohesiveness, gumminess, and chewiness for ground beef patties with low-fat formulations. These methods have not commonly been applied to ground meat or ground meat products based on the literature.

3.1. Sensory Analysis

3.1.1. Descriptive Analysis

Sensory profiling of products has been traditionally evaluated using trained sensory panels (Meat Quality Analysis, 2020). Descriptive sensory analysis has been utilized in meat quality research with major meat sensory attributes being defined as tenderness, juiciness, and flavor (Miller, 2022). The American Meat Science Association has defined how trained panelists are used (AMSA 1987, 1995). Descriptive attribute analysis has primarily focused on tenderness and flavor. Multiple attributes are components of flavor (Adhikari et al., 2011) and texture. Use of attributes that describe varying components of flavor and texture provide clarity and strength to sensory results (Miller, 2022). Lexicons are defined as a group of terms where attributes are defined, and scaling is clarified with references (Miller, 2022). When conducting trained descriptive analysis, the panelists are provided intensity scores for specific attributes that are repeatable. Unlike consumer acceptance panels where overall acceptability or liking of products are measured, scales are used in conjunction with references provided from lexicons to anchor the panel during training to ensure when assessing the data is both accurate and precise (AMSA, 2015). Results and individual panelists scores are not

typically discussed. During quantitative descriptive analysis, the panel leader is a conversation facilitator and does not influence the scoring in any way (Miller, 2022). Training methodologies are discussed extensively in AMSA (2015). This process is critical to ensure the accuracy of panel scoring and essential during panel training sessions (ASTM, 1981;. Meilgaard et al., 2015)

3.1.2. Qualitative Consumer Analysis

Qualitative research simplest definition is any form of data collection that produced a narrative or non-numeric information (Bowling, 2005). Marketing research has utilized focus groups to gather consumer information (Byers & Wilcox, 1991). Focus groups have been used to create an environment for consumers to express themselves and researchers receive beneficial information (Byers & Wilcox, 1991). Focus group setting is successful due to the flexibility and comfort participants have (Byers & Wilcox, 1991). Focus group data contains a variety of responses but, the protentional correlations are easier to explore (Byers & Wilcox, 1991). Rust et al. (1994) discussed the importance of the framework of focus groups and how this impacts qualitative data reliability. Qualitative data from focus groups is commonly used to gain further understanding of consumers regardless of the field of research (Calder, 1977). However, this method of data collection has been viewed as ‘unscientific’ by many in the social sciences (Calder, 1977). This is due to the ambiguity of the information to everyday knowledge derived from quantitative data analysis (Calder, 1977). Qualitative data collection has been paired with quantitative data across many fields of study. However, this method has not been adopted in meat science investigation methodology.

3. MOUTH BEHAVIOR TYPE AND CONSUMER PREFERENCES ON GROUND BEEF PATTIES

3.1 Materials and Methods

Descriptive panelist training and testing procedures were approved by the Texas A&M Institutional Review Board (IRB2021-0346M).

3.1.1. Phase 1 – Ground beef patty formulation

Treatments for Phase I are defined in Table 1. Commercial coarse ground beef was purchased from Ruffino's Meats in Bryan, TX at 20% fat content. Additionally, frozen batches of 7 and 27% fat (6.35mm fine grind; IMPS 136) were purchased so all material for each fat content treatment were from the same commercial processing day. The 20% fat ground product was processed on March 08, 2021. The 27% and 7% were processed on 03/24/2021 and between 03/23 and 03/30/2021, respectively. Ground beef was stored at approximately 1.7 °C and thawed in The Rosenthal Meat Science and Technology Center, Texas A&M University at 2.2°C overnight. All patties were processed on one day to remove processing day effects. The 7 and 27% final grind raw material was formed into 226.8-gm patties using a Hollymatic JET-FLOW Super (Supermodel 54 Food Portioning Machine, Hollymatic Corporation, Countryside, IL) patty forming machine. The 20% fat coarse ground beef was separated into three batches, 72,773 gm each. One third of the meat was processed through a 6.35 mm grinder plate and 226.80-gm patties were manufactured using a Hollymatic JET-FLOW Super patty forming machine. The remaining ground beef was processed using a three bladed bowl chopper (Seydelmann Model K-64, Maschinenfabrik Seydelmann KG,

Stuttgart, Germany), at 2000 RPM for 40 seconds. Following this, the chopped beef was separated into two batches. One batch was formed into 113.40 gm balls to be used later as a 'smash burger' style patty. The remaining product was also weighed into 113.40 gm balls and hand pressed into patties using a Cuisinart adjustable burger press (Cuisinart, The Fulham Group, Newton, MA). Patties were held at -40 °C overnight to freeze before vacuum packaging (10 x 12 in STD curved Sealed Air Food Care, Charlotte, NC). After packaging, patties were stored at approximately -18°C until 24 hours prior to cooking when they were thawed by storing at a 4.5°C for 24 h.

At the time of cooking, iron-constantan thermocouples (Omega Engineering, Stanford, CT) were inserted into the geometric center to measure internal temperature before, during, and after cooking. Patties were cooked on a commercial flat top grill (Star Max 536TGF Countertop Electric Griddle with Snap Action Thermostatic Controls, Star International Holdings Inc. Company, St. Louis, MO) with a surface temperature of 176.7°C. Patties were flipped once at an internal temperature of 35 °C and removed from the flat top grill at the final internal temperature of 70 °C. Cooked patties were covered and held at approximately 49°C internal temperature in a holding oven (HATCO Chef System CSC-10, HATCO Corporation, Milwaukee, WI) wrapped in aluminum foil for up to 20 minutes prior to serving.

3.1.2. Phase II – Food service and Retail ground beef patties

Retail ground beef and pre-made ground beef patties from the retail counter were purchased from a local H-E-B. Ground beef labeled from varying carcass locations in differing package forms were utilized to provide differences in textures (Table 2.). Pre-

made 226.8 gm ground beef made in store chuck patties were purchased in PVC overwrap packaging from H-E-B in College Station, TX. Ground round and ground sirloin purchased in chub packaging and were weighed into 113.4-gm portions then hand pressed into patties with the Cuisine adjustable burger press. Ground chuck from both chub and loose PVC overwrap packing were weighed into 226.8-gm, to match the weight of the premade patties made in store, before being hand pressed into patties. The weight difference was due to the predetermined weight of the premade chuck patties made in store from H-E-B, and the goal of providing uniform size of samples to consumers within a 'flight' during the qualitative sessions (Table 2). Patties made from retail ground beef and pre-made patties purchased form H-E-B were cooked to an internal temperature of 70°C.

Foodservice patties for Phase II were purchased as outlined in Table 2. While all patties were considered either 'fast food' or 'casual dining' style burgers, patties represented a variety of ground beef type. Establishments were selected based on discussion by consumers at the end of Phase I qualitative groups as. Patties were pre-ordered online or over the phone. Orders consisted of plain ground beef patties from each location. Patties were either picked up at the store or delivered via food delivery services on day of analysis. All foodservice patties were transported in thermoregulating / heat insulating bags or in ice chests containing a pre-heated clay brick to maintain warm temperatures when being delivered to Kleberg Animal and Food Sciences Center. Patty temperature was checked upon arrival, then held in a warming oven at 60°C for up to 20 minutes before serving. Care was taken to serve pre-cooked patties within 30

minutes of purchase to ensure food safety and maintenance of sensory attributes. Foodservice patties were served between 44 and 52°C.

Phase II of the ground beef patty study was designed to further examine and understand the texture descriptors that were provided by the participants in discussion during Phase I.

3.2.1. Descriptive Texture Attribute Analysis

Ground beef patties were evaluated by an expert trained descriptive panel that aided in development of the beef flavor lexicon (Adhikari et al., 2011) for Phases I and II . The panel was trained for 10 d using 14 texture attributes (Table 3). Texture attributes were measured using 15-point scales. Panelists were provided samples daily for the duration of training. Products from within and outside the study material were randomized to demonstrate a variety of texture attributes. At the conclusion of d 10, the panel was validated in the testing booth conditions to ensure accuracy and precision of training. Panelists were given eight randomized samples after calibrating with a warm-up.

Phase I patties were thawed in a cooler (4°C) roughly 24 hours prior to testing. Prior to cooking, raw weights, and internal temperature were recorded. Time on the grill, time off the grill, end point temperature and cooked product weight were recorded. Patties were cooked on a commercial flat top grill (Star Max 536TGF Countertop Electric Griddle with Snap Action Thermostatic Controls, Star International Holdings Inc. Company, St. Louis, MO) to an internal temperature of 70°C.

During descriptive analysis of Phase I patties, panelists were given a warm-up sample at the beginning of each testing session to calibrate before each sensory session. When the panel moved into evaluating samples for Phase II (foodservice and retail ground beef patties) two warm-ups were provided. Each session started off with one randomly chosen foodservice patty and one retail ground beef patty warm up. Each sample was given a random three-digit code and served in a 177 ml glass custard cup (Anchor Hocking, OH, United States) covered with a watch glass containing four to five 1.27 cm cubes of meat to evaluate each sample. Upon arrival of foodservice patties, internal temperature was checked, then patties that were being used for descriptive sensory were held in the warming over for up to twenty minutes. Before serving the foodservice patties, the internal temperature was checked, all patties were served between 45 and 52°C internal temperature. Panelists were seated in individual booths under white light separated from the sample preparation area. Panelists were served six samples within a two-hour session to evaluate Phase I ground beef patties and 10 samples when evaluating Phase II. Samples were served at least 5 minutes after completion of the previous sample. Palette cleansers of double distilled deionized water and unsalted tops saltine crackers were used before evaluation of each sample.

3.2.2. Texture Profile Analysis

After cooking the beef patties to an internal temperature of 70°C in Phase I, for retail patties in Phase II and for precooked foodservice patties in Phase II, patties were covered with plastic wrap (Food Service Film Roll, Members Mark, Bentonville AR) and allowed to equilibrate to room temperature for a minimum of 1 h. Patties for TPA

analyses were evaluated on the same day as samples were evaluated for descriptive sensory texture analysis. Once all samples reached room temperature a minimum of one core, measuring 2.54 cm in diameter, was taken from the geometric center of each patty. If additional surface area allowed, a second 2.54 cm core was taken from the side of patties. Cores were used for Texture Profile Analysis (TPA) on a Food Technology Corporation TL-Pro Texture Analyzer (Mecmesin Ltd., West Sussex, United Kingdom) for a two cycle compression with each being compressed to 50% of its original height at a rate of 0.5 mm/s using a 250 kg load cell. This analysis is used to measure hardness, springiness, fractuablity, cohesiveness, gumminess and adhesiveness as defined in Bourne (1978).

3.2.3 Qualitative Consumer Workshops

Consumers were recruited through a Qualtrix survey that was distributed through an email sent to Texas A&M University employees and participants in the Bryan College Station area. Qualitative consumer groups were conducted at the Kleberg Animal and Food Science center. Using a central location allowed for more control over ground beef patty preparation and conducing of each consumer session. A maximum of 9 consumers were recruited to participate in each of the sessions. Consumers were selected based on their mouth behavior type and availability. Selected consumers received a follow up email with instructions and homework to think about to prepare for their session.

The objective of Phase I focus groups was to understand the terminology used by the 4 mouth behavior groups to describe their burger, specifically the ground beef patty,

eating experience. Phase I focus groups evaluated patties in Table 1. Ground beef patties were manufactured in the Rosenthal Meat Science and Technology Center with materials purchased from Ruffino's Meats in Bryan, TX. The goal of these formulations was to give consumers ground beef patties with texture differences to gather a wide scope of descriptors from each Mouth Behavior group. To isolate the effect of the ground beef patty, buns (H-E-B seeded hamburger buns), toppings (green leaf lettuce, sliced tomato, slices red onion), and condiments (Heinz mustard, Heinz mayonnaise, Heinz ketchup, H-E-B brand salt and pepper) were standardized and provided to each participant. Each consumer was given a plate of lettuce, red onions, sliced American cheese, sliced tomato and choice of ketchup, mustard, mayonnaise, salt, and pepper for condiments during all sessions. Each workshop began with discussing the homework provided to participants during recruitment. During discussion of the participants good and bad burger eating experiences, the U&I Collaborations team was listening for terminology used when describing each. Additionally, they were listening for the role the ground beef patty played compared the toppings and condiments. Following homework discussion, participants were asked what attributes were the most important to a burger. These discussions occurred in each mouth behavior group session. Each Mouth Behavior session had varying attributes that were deemed as most important, resulting in a unique landscape (biplot) axes for each Mouth Behavior that was based on their two most critical organizing factors (Figure 2). Before being served any patties, consumers identified where their ideal burger would fall on the landscape map.

Phase I sessions consisted of 3 flights of stimuli, each consisted of 2 ground beef patties. Flight 1 focused on if any texture differences were perceived when fat content was manipulated (7%, 20% 27%). Flight 2 showcased differences in ground beef patty formation (machine formed, hand pressed, smashburger style) and flight 3 provided differences in ground beef processing methods (fine grind, chopped). As each ground beef patty was sampled, the research team observed how people built their burger as the hypothesis going to the session was that topping, and amount would be critical in gaining insight into each mouth behaviors preference. Notes were taken on the language used to describe each patty provided as well as the 'corrections' made to each patty, including whether or not consumers made changes to their burger build after tasting. It was also important for understanding each mouth behavior to listen for what, if anything, was missing for people to have an enjoyable eating experience. After evaluating all samples in each flight, a facilitated discussion took place each patty was positioned were participants felt it best fit within the axes of their session's landscape map. At the conclusion of all flights, discussion was shifted to the wrap up portion, which was designed to gather any final thoughts, favorite and least favorite products and identify any foodservice burgers the consumers liked or disliked that had not been previously discussed to gather product ideas for Phase II focus workshops.

Phase II utilized foodservice patties and retail ground beef products (Table 2). The objective of Phase II was to further understand the language used to describe the burger eating experience by the 4 mouth behavior categories. More specifically to gain insight on the role the patty plays compared to toppings and condiments. Expanding to

foodservice products provides descriptors for a patty experienced on a ‘typical’ day for consumers. However, the provided buns, toppings and condiments allowed for the preference of the ground beef patty specifically from each foodservice establishment. Retail ground beef products were introduced to explore the protentional impact of packaging types in conjunction with lean source and fat content differences. These patties represented the type of burger build consumers would get from making patties at home with store bough ground beef.

Workshops for Phase II were structured similarly to sessions conducted in Phase I. The homework asked participants to provide a visual representation or story that was associated with their mouth behavior type. Additionally, consumers were asked to define their ‘perfect burger’. During this discussion, the U&I Collaboration team was listening for characteristics and terminology used to describe the eating experience and the role the patty played. Common axes for the landscape maps were provided during these sessions taking language and attributes from Phase I. Phase II workshops consisted of 4 primary flights, 2 with foodservice patties and 2 with retail product. Objectives were similar to Phase I. During foodservice flights, there were specific additional observations. The discussion was driven towards discovering how consumers described the differences between a smashed; patty compared to a thicker, non-smashed patty. Likewise, any differences that were associated with perceptions of foodservice patties when participants were not in the typical car or restaurant environment and if the foodservice patties were more identifiable on those standardized builds rather than establishment specific materials. Retail ground beef products were subject to afore

mentioned general listening topics as well as how preferences were impacted by lean source and fat content. Furthermore, the impact of raw material packaging type, ground beef patty weight and different patty formation methods of the same raw material was discussed. At the conclusion of all flights for Phase II, wrap up discussion again asked for consumer final thoughts of each product and began an ideation session on desired attributes for whole muscle beef steak products for future research initiatives.

3.2.4. Statistical Analysis

Data were analyzed using Analysis of Variance effects in a factorial arrangement using the General Linear Model procedure of SAS (v9.4, SAS Institute, inc., Cary, NC) with $\alpha < 0.05$. The main effect of six patty formulations (ground machine formed 93%, ground machine formed 80%, ground machine formed 73%, chopped machine formed 80%, chopped hand pressed 80%, chopped 80% smashburger) for Phase I. Phase II main effects included thirteen ground beef patties from retail product or food service establishment (loose chuck, chub chuck, premade chuck patties, loose brisket, chub sirloin, chub round, Koppe Bridge, Freddys, Five Guys, Whataburger, Wayback Burgers, McDonalds, Sonic) were included in the model. Sensory day was included as a fixed effect in the model and order was included as a random model effect. Least squares means were calculated for significant ($P > 0.05$) main effect. For main effects that were significant, ($P > 0.05$), differences in least squares means were determined using the pdiff function in SAS. Texture Profile analysis data were analyzed similarity. Least squares means were calculated and differences between least squares means were determined using the pdiff function when differences were significance ($P < 0.05$) in the

Analysis of Variance table. Principal component analysis (PCA) was conducted using XLSTAT (v2013, Addinsoft, New York, NY). Data were presented in a bi-plot (Figure 4).

3.3 Results and Discussion

3.3.1 Descriptive Sensory Analysis for Phase I

Ground beef patties in Phase I did not ($P>0.05$) differ in initial or sustained juiciness, toothpacking, springiness, hardness, mouthcoating, particle amount, cohesiveness, or cohesiveness of mass texture attributes (Table 4). However, ground beef patties did differ ($P<0.05$) in surface roughness, firmness, particle size, amount of connective tissue, and chewiness texture attributes. The ground, machine formed patties, regardless of lean content, were similar in firmness, surface roughness, connective tissue amount, chewiness, and particle size. Compared to patties where the lean source was chopped, ground patties were firmer, less rough on the surface, smaller in particle size, and less chewy, except hand-formed chopped patties with 80% lean that were similar in chewiness to ground lean source patties. For chopped lean source patties, the smashed and hand pressed patties were similar in surface roughness, firmness, and particle size. When chopped lean source patties were machine formed, surface roughness and connective tissue amount was similar to the ground machine formed patties.

These results indicate that chopping as defined in this study resulted in patties that differed in some texture attributes compared to commercial pre-ground lean source patties. Chopped lean source patties had larger particle size and more detectable connective regardless of patty formation compared to ground lean source patties. The compaction or manipulation of machine forming resulted in smoother, softer patties.

The impact of grind size on texture of ground beef patties has been evaluated. Patties made using lean ground beef manufactured using a 3 mm or higher final grind

size plate were more rubbery (Roth et al., 1999; Suman et al., 2003). Suman et al. (2003) also reported that buffalo ground patties manufactured using 4 to 6 mm final grind plates were drier and less desirable in texture and acceptability than patties made using a 3 mm final grind plate. However, Egbert et al. (1991) evaluated low fat (8% fat) ground beef patties and found that palatability was improved when a 4.8 mm final grind plate was used compared to a 3 mm final grind plate. As final grind size increased, rubberiness increased. Additionally, Cross et al. (1980b) concluded ground beef patties processed through a 2.54 cm initial grind plate were consistently tougher than patties from a 1.90 cm initial grind plate, even after undergoing double or triple grinding. Contrary to our results, Berry (1980) reported that patties made from a chopped lean source were juicier, more tender and had lower amount of connective tissue. Moreover, the ground beef patties where the lean source was chopped then ground were similar in texture attributes to patties made from a ground lean source (Berry, 1980).

Fat content of ground beef patties have been shown to impact ground beef texture. Low fat ground beef patties (< 10% fat) were harder, drier, and less tender than full fat ground beef patties (20% fat) (Berry & Leddy, 1984; Egbert, 1991;Troutt, et al., 1992b). Furthermore, Berry (1984) evaluated ground beef patties with 16, 19 and 24% fat and found that increasing fat level resulted in increased tenderness. Unlike our results, Berry (1984) reported that ground beef patties containing 24% fat were juicier than those with 14% fat. Similarly, Troutt et al. (1992a) found that low fat (5 or 10% fat) patty formulations were not comparable to 20% fat ground beef patties for juiciness.

Formation methods of ground beef patties have been shown to impact texture attributes across multiple studies (Liu & Berry, 1998; Roth, 1999). An alternative method of forcing ground lean through holes before filling a patty mold resulted in patties that tended to be softer and juicier than using the traditional gravity fill method (Liu & Berry, 1998). Patties from the alternative filling methods also were broken down quickly into smaller particle sizes. Additionally, Roth et al. (1999) compared sensory texture attributes in ground beef patties at 50, 100, and 150 kg of pressure during filling in a patty filling machine. They concluded that patties formed under higher pressure (150 kg) were tougher and harder than patties created using lower pressure. Furthermore, patties formed using the 50 kg of pressure were more tender and had the lowest breaking force values. Our results indicated that some texture attributes were affected by the grind size, fat content and patty forming method used in the study. Therefore, as treatments in our study resulted in ground beef patty texture differences, these patties would be acceptable to use to understand how consumers differing in Mouth Behavior reacted to differences in ground beef texture.

3.3.2. Texture Profile Analysis for Phase I

Rheological texture was evaluated using the TPA method and attributes were reported in Table 5. Ground beef patties did not differ ($P>0.05$) in springiness and cohesiveness. However, patties across the six treatments did differ ($P<0.05$) in adhesion, gumminess, chewiness, hardness 1, and hardness 2. Ground machine formed patties containing 90 and 73% lean were hardest during the first compression cycle. Conversely, patties made with 80% lean and that were either ground, machine formed, or chopped

and smashed during cooking were the softest at both peak compression points, hardness 1 and hardness 2. Regardless of fat percentage, ground, machine forms patties were less chewy compared to patties made with the chopped lean source and were either machine formed or smashed during cooking. Hand pressed, chopped 80% lean ground beef patties were intermediate in chewiness and similar to other treatments. Additionally, chopped, smashed patties had higher adhesiveness in relation to all other ground beef patties regardless of fat percentage, processing, or formation method. These results indicate that lean source, somewhat regardless of fat contnet, and forming method impacted texture of ground beef patties.

Roth et al. (1999) examined full fat (24%) and low fat (8%) patties that were machine formed with 50, 100 or 150 kg of pressure. They found that the full fat patties formed with 50 kg of pressure were the easiest to break. Contrary to this study's findings, Berry (1980) stated chopped patties produced lower shear force values when compared to the ground lean source and lean that was chopped. Most likely, chopping methods differed. Furthermore, Roth et al. (1999) concluded that ground beef patties made from lean that had been ground using a smaller plate (2 mm) had lower hardness 1 and hardness 2 values than patties made form leans using 3- or 5-mm plate size. Additionally, Kramer shear force vales differed ($P<0.05$) for ground beef patties made from lean ground through different grinder plate sizes (Roth, et al., 1999). Troutt et al. (1991b) found Warner-Bratzler shear force values for ground beef patties with 5% fat were higher and these findings confirmed conclusions made in Berry and Leddy (1984).

These studies align with our results for texture profile analysis as it relates to hardness 1 values of 93% lean ground, machine formed patties.

3.3.3. Qualitative Consumer Analysis for Phase I

Phase 1 qualitative consumer workshops provided a range of descriptors associators with an 'ideal burger' for each mouth behavior category. Across mouth behavior groups there were some general takeaways regarding consumers eating experience of burgers. Consumers can distinguish between a good juiciness and bad juiciness, or a burger that is very greasy. When participants were asked if juiciness was more important than flavor in the burger eating experience, they stated that juiciness was the more critical attribute. This is primarily due to the usage of additional toppings on a built burger that can mask any off or unpleasant flavors or enhance burgers that are perceived as 'bland'. None of the stimuli provided in Phase 1 were close to the 'ideal' for Chewers, Smooshers and Suckers who placed high priority on flavor. However for juiciness and tenderness, ground beef samples were close to ideal for all Mouth Behavior classifications, specifically the 80% and 73% lean ground beef patties.

Chewers want 'a little bit of fight' with noticeable texture differences in the texture of their ground patties. They also want their ground beef patty to stand alone when compared to a fully built burger and prefer to use condiments for 'correction' of dryness or undesirable flavors. Crunchers think a good burger should be characterized by a ground beef patty that does not stick to their teeth and breaks apart easily but is not too intensely crumbly, and in the middle range for thickness. Chewers view toppings as a critical element for implementing flavor, texture, and temperature differences. Unlike

Chewers, Crunchers do not emphasize the need for a ground beef patty to ‘stand-alone’ without extra condiments. There was more willingness to use condiments to ‘fix’ a burger that does not fall into their definition of an ‘ideal’ eating experience. Smooshers viewed the use of condiments in the same capacity as Chewers; however, ground beef patty thickness was a priority in their description of ‘ideal burger’ characteristics. Smooshers also verbalized their dislike of greasy films that coat their mouths and ground beef patties that fall apart too quickly during mastication. Across mouth behavior groups it was noted that the addition of seasoning after the cooking process did not impart the same flavors or enjoyment during eating as when it is added prior to cooking. This was of most importance to Suckers. They pressed the significance of adding seasonings to the raw ground beef patty to maximize the pleasure of the eating experience, especially when preparing and forming their ground beef patties at home. Suckers described the desire to have differences in every bite and piled on condiments and extra toppings for extra flavor.

Landscape map axes for the Cruncher Mouth Behavior were focused on juiciness (x) and patty thickness (y) (Figure 2). Crunchers mapped the 80/20 chopped, machine formed, and 80/20 ground machine formed (228 gm) patties the closest to the ideal zone for the majority of participants in the workshop. Ground beef patties that were hand pressed and ‘smashed’ during cooking from 80/20 chopped lean were close to the ideal zone for juiciness attributes; however, were perceived as too thin. Conversely, ground machine formed patties with 27% fat were on the same plane as the ideal zone in regard to patty thickness; however, Crunchers perceived them to be ‘too dry’. Moreover, the

ground machine formed patty with 7% fat was the furthest from the Crunchers ideal zone between these axes. Conversely, Chewers placed all stimuli a considerable distance away from their ideal zone. Axes for Chewers were in relationship to tenderness (y) and amount of seasoning (x) (Figure 2). Smooshers and Suckers had similar axes, (y) characterized juiciness, while (x) was regarding amount of seasonings (Figure 2). Neither of these Mouth Behavior group placed any of the ground beef patties provided in or near their ideal zone. For both, many of the patties were placed toward the 'bland' direction. Even with addition of salt, pepper and provided condiments, none of the stimuli were preferable.

Phase II qualitative groups focused on retail and food service ground beef patties. Rather than created textural differences, expanding to retail and foodservice products allowed for understanding differences in patties readily available to consumers. Crunchers placed Koppe Bridge ground beef patties the closest to their ideal zone between theses axes during their ideation session. Chewers placed fast food patties from Sonic and Koppe Bridge in their ideal zone when asked what burgers they like the most. Smooshers though Freddys 'smashburger' fit their ideal zone while Suckers leaned toward Sky Rocket and Mojo Burger for food service patties.

3.3.4. Descriptive Analysis for Phase II

As ground beef patties differed in descriptive attributes in Phase I, ground beef patties where the lean source was final ground beef, commonly presented to consumers at a local retail store and cooked ground beef patties from foodservice establishments that consumers had defined in the qualitative workshops as differing in texture were

used. Retail ground beef patties derived from the retail store in Phase II differed ($P<0.05$) in surface roughness, hardness, mouthcoating, particle size, chewiness, and sustained juiciness (Table 6a). However, retail ground beef patties did not result in differences ($P>0.05$) for initial juiciness, toothpacking, cohesiveness of mass and amount of connective tissue. Ground beef patties in Phase II were analyzed across retail and foodservice treatments. Results are reported in Tables 6a and 6b with mean separations within a row across both tables as patties were randomized and served across all treatments. For retail ground beef, loose, ground chuck purchased in PVC overwrap packaging was rougher, stayed in larger particle size during mastication, and left more residues in the mouth after swallowing compared to chuck patties pre-made in the store at H-E-B. There were no differences ($P>0.05$) in texture attributes for loose, ground and chub packaged chuck patties. Ground beef patties made into 113-gm portions from chub packaged chuck were similar across texture attributes when compared to the 228-gm H-E-B pre-made chuck patties. Additionally, loose ground chuck and loose ground brisket patties also differed ($P<0.05$). Brisket patties were smoother on the surface, less chewy, broke into smaller particles and left less residue than chuck loose ground patties. Overall, patties made from loose, ground brisket were the softest 113-gm patties.

Ground beef patties from the chuck and round were evaluated by Fruin and Van Duyne (1961) and concluded that patties from the chuck were more preferable than those from the round, However, there was no palatability differences across quality grades (U.S. commercial or standard). Wilfong et al, (2016) found in blind palatability testing

that consumer rated 10% fat Certified Angus Beef ground beef from the sirloin similar in tenderness and juiciness to 20% fat Certified Angus Beef patties made form the chuck. However, consumers scored the 10% fat Certified Angus Beef ground beef from the sirloin superior to the 20% fat Certified Angus Beef for tenderness during informed testing. There were no differences between the 20% fat ground chuck or Certified Angus Beef ground chuck patties for tenderness or juiciness in either blind or informed sections (Wilfong, et al., 2016).

When comparing texture attributes across retail and food service ground beef patties there are noticeable trends. McDonalds quarter pound patties were firmer than other retail patties, except patties formed from chuck in chub packaging. The McDonalds quarter pound patties were different ($P<0.05$) than Wayback Burgers and Sonic ground beef patties in hardness. Additionally, McDonalds quarter pound patties were springier than patties made from retail ground beef products regardless of lean source or packaging type. Chewiness was similar ($P>0.05$) for loose and chub packaged chuck when compared to food service ground beef patties, except Whataburger patties. Wayback Burgers, Sonic, loose, ground chuck, sirloin and brisket patties were softer than the McDonalds quarter pounder, but still harder than the loose, ground brisket patties

3.3.5. Texture Profile Analysis for Phase II

Retail ground beef patties differed in hardness 1, hardness 2, chewiness, and gumminess (Table 7a). Loose, ground chuck patties tended to be softer at both peak load points during the TPA double compression cycle. Patties (133 gm) made form sirloin,

chuck and round from chub packaging performed similarly with respect to all texture measurements. With regards to ground products from different lean sources in chub packaging, there were no differences ($P>0.05$) observed in hardness 1, and hardness 2 values for sirloin, round and chuck patties. Between the loose ground brisket patties and chuck patties, there were differences in ($P<0.05$) gumminess and chewiness. Chuck patties (226.8 gm) were chewier but less gummy, compared to the loose brisket patties (113 gm).

Foodservice ground beef patties differed in hardness 1, hardness 2, springiness, gumminess, cohesiveness and chewiness (Table 7b). Comparing texture measurements in foodservice patties, differences ($P<0.05$) were apparent, Whataburger patties were chewier and gummier than Five Guys, Koppe Bridge, Wayback Burgers and Sonic ground beef patties. Likewise, Whataburger, Koppe Bridge and McDonalds patties were the hardest for hardness 1. Conversely, Wayback Burgers, Five Guys and Freddys 'smashburger' had lower TPA values for hardness 1. These trends continued when evaluating measurements from hardness 2, except for Whataburger patties that were intermediate in hardness 2. Wayback burgers were less springy when compared to the McDonalds quarter pound patties ($P<0.05$). Other treatments were similar ($P>0.05$) in springiness. Whataburger ground beef patties were chewier than Five Guys, Koppe Bridge and Sonic products. Likewise, Whataburger patties resulted in similar values to McDonalds quarter pounder and Freddys 'smashburger' for surface roughness, firmness, springiness, hardness, cohesiveness and chewiness texture attributes. Despite the

exacerbated patty thickness differences in the ‘smashburger’ from Freddys, it fell intermediate for all measurements except hardness 2.

Wilfong et al. (2016) concluded that texture profile analysis values were higher for hardness, cohesiveness, gumminess and chewiness in low-fat ground beef patties. This aligns with our results, specifically for the retail ground sirloin patties, that were 10% in fat content based on the package information.

3.3.6. Qualitative Consumer Analysis for Phase II

Qualitative group participants were given standardized axes for landscape mapping. Texture attributes placed on X and Y axes were derived from attributes that were discussed during Phase I groups. Standardized axes allowed maps from each Mouth Behavior group to be directly compared.

Phase I groups ideal zones were evaluated and used to form hypothesized sones on the standardized axes for Phase II groups. Phase II workshops revealed more overlap across mouth behavior categories than expected for ‘ideal’ ground beef patty characteristics (Figure 5). The overlap with the Phase II axes indicated there was potential for a ground beef patty that provided an enjoyable eating experience for each Mouth Behavior category.

Fast casual patties from Koppe Bridge were close to, or in, the ‘ideal’ zone for Chewers. However, it was too tough for Crunchers, Smooshers and Suckers. Crunchers found 5 Guys burger was the closest to providing an ‘ideal’ eating experience. Fast food patties from Whataburger, Sonic and McDonalds were placed the closed to the ‘ideal’ zone mapped by consumers (Figure 5). It was clear that there are differences in

perceptions even from within mouth behavior categories, this is reflected by the variation in placement of McDonalds patties when evaluating tenderness (Figure 9). Smooshers and Suckers stated that none of the foodservice ground beef patties were thick enough to ‘smoosh’ or suck during the eating process.

Across the mouth behaviors, there was a lot of variation in the placement of ground beef patties made from different raw materials (Figure 8). Overall, Chewers viewed this set of patties tougher than all other Mouth Behavior types. Thus, suggesting that Chewers use vastly different cues during mastication to rate tenderness. Ground beef patties created from the round and brisket were closest to the ‘ideal’ zone for Crunchers and Chewers, respectively. Smooshers and Suckers did not place any of the raw material patties near their ‘ideal’ zones. This series map displays that Chewers placed these patties the opposite of Crunchers.

Chuck, in all forms was the closest to ‘ideal’ for all mouth behaviors, except Suckers (Figure 11). None of the chuck patties were as tender as desired for Suckers. Crunchers placed the hand pressed patties from chub packaging around the exterior of their ‘ideal zone (Figure 11). Smooshers also preferred the hand pressed, from both a chub or PVC overwrap packaging; unlike Chewers who preferred the machine formed ground beef patties from H-E-B.

4. CONCLUSIONS

4.1. Relationship between Texture attributes and Mouth Behavior Classification Preferences of Ground Beef Patties Differing in Formation Method, Processing method, Lean Source, Fat Content from Commercial, Retail and Foodservice Ground Beef Patties.

Consumers across the four Mouth Behavior categories responded differently to ground beef patties with varying texture attributes, especially in Phase I. Descriptive sensory analysis resulted in patties made from chopped meat, regardless of patty formation method, were (P<0.05) firmer, chewier, had larger particle size and more detectable amount of connective tissue. Within machine formed patties from ground lean with different fat contents, the 80% lean patties tended to have more detectable amount of detectable connective tissue. Texture Profile Analysis confirmed that patties from chopped meat were chewier. Machine formed patties from 73% and 93% lean, chopped 80% lean machine formed patties and hand pressed 80% lean patties were similar in hardness 1 and hardness 2 values, tending to be harder when compared to the ground, machine formed 80% lean patties and chopped ‘smashburger’ 80% lean style patties.

Qualitative workshop landscape maps differed on perception and preferences for resulted from the varying modes of mouth action utilized across each category. Chewers and Crunchers mode of mouth action is to use their teeth to break down foods during mastication (Jeltema et al., 2015). Crunchers eat food forcefully and often use this more aggressive mouth action even with softer foods (Jeltema et al., 2015). Chopped, machine formed and chopped hand pressed ground beef patties were rated closer to the ideal

ground beef patty of Crunchers. Crunchers perceived the 93% lean ground, machine formed patties very dry, but mapped the 80% and 73% fat machine formed patties and the chopped 80% lean machine formed patties as juicy and just right on the patty thickness axes. Chewers perceived the chopped, machine formed and chopped hand pressed ground as too tough and too difficult to chew down on. To Chewers, chopped patties were tough and lacked flavor. Smooshers and Suckers exhibit modes of mouth action that reflect a desire to manipulate their food between the tongue and palate. Neither group enjoys the act of chewing and, spend more time eating smaller pieces of food (Jeltema et al., 2015). None of the ground beef patties presented to Smooshers and Suckers in Phase I fit into or near their ideal zone. Smooshers had varied perceptions for treatments, except the 93% lean ground, machine formed patty was viewed as not seasoned well. This eating experience was likely due to the low-fat content of the patty. Especially because all patties were seasoned the same, with no seasonings. Lower fat content likely prevented Smooshers from extracting the fat flavor that is present in patties with higher fat content. Suckers rated patties as bland, but the ground machine formed patties, regardless of fat content, were considered juicy. Each Mouth Behavior groups placed patties on different axes, however, attributes on each map represented the most important attributes when eating a burger. The difference axes showed patty thickness was important to Crunchers, while tenderness was important to chewers. Smooshers and Suckers prioritized seasoning and flavor of the ground beef patty. Juiciness was an important attribute to Smooshers, Suckers and Crunchers, but was perceived differently by the Crunchers. In summary, firmer, chewier patties with larger

particle size and more connective tissue negatively impacted Chewers. Crunchers and Smooshers responded to low fat patty formulations. Texture Profile Analysis differences appeared to only impact Chewers. Connective tissue differences that were present in patties did not impact consumer perception during qualitative workshops.

In Phase II, descriptive sensory for the retail ground beef patties showed loose hand pressed brisket patties were softer, less springy, and less chewy while retaining the most juiciness after 10 to 15 chews. Foodservice patties resulted in differences in springiness, hardness, and chewiness scores. Wayback burger patties were softer compared the Freddys 'smashburger' and McDonalds quarter pound patty. Wayback burger patties were also different than McDonalds patties when comparing hardness scores. Sonic, Wayback burgers, Five Guys, and Koppe Bridge patties differed in chewiness scores compared to Whataburger with the highest chewiness scores. Texture Profile Analysis supported the descriptive sensory scores for the hand pressed brisket patties. TPA also resulted in the lowest hardness 1 and hardness 2 values the loose chuck (228 gm) patties. Foodservice patties differed in hardness 1 and hardness 2. Koppe Bridge and McDonalds quarter pound patties were harder at both compression points compared to Wayback burgers. Springiness values reflected the same trends shows in descriptive sensory analysis. Whataburger patties were the chewiest and gummier when compared to other foodservice patties. Freddys 'smashburger' and McDonalds quarter pound patty were similar and springier than Wayback burger patties.

Qualitative groups for Phase II landscape maps were on standardized axes. Attributes on either side were picked from the attributes that were discussed during

Phase I groups. Hypothesized ideal zones for each Mouth Behavior groups had less overlap than the actual landscape of ideal zone in Figure 5. Hand pressed patties (113 gm) made from retail ground beef from different lean sources were perceived as tough and varied in cohesiveness for Chewers. Crunchers, Smooshers and Suckers resulted in overlap when mapping patties in this flight, however none were perceived as very hard to bite though by these Mouth Behaviors. With Chewers perceiving these patties virtually opposite of the other Mouth Behaviors, it suggests they are using different indicators during oral processing to dictate tenderness attributes. Landscape mapping for casual dining foodservice burgers (Koppe Bridge, Five Guys, and Wayback) showed varying placements for Smooshers and Crunches. Most Smooshers rated these patties higher for staying together and tough. Crunchers rated the casual dining patties at variable locations for cohesiveness attributes and from tough to just past 'a little bit of fight', but none were considered near tender. Chewers perceived all causing dining patties as tender. Once again, Chewers were the opposite when rating when compared to the other Mouth Behavior groups. Fast food patties were mapped with the most variation of all patties presented to participants in Phase II. Across all Mouth Behavior groups, participants had an enjoyable eating experience with the chuck patties (226.8 gm) even though they were not clustered around a singular groups ideal zone. None of the Mouth Behaviors perceived the chuck patties as 'very hard to bite through'. The hand pressed, loose or chub packaged chuck (226.8 gm) patties were the only Phase II patties preferable to Smooshers. Furthermore, none of the Phase II patties were mapped near the Suckers ideal zone or were considered desirable. Phase II did not result in the same

patterns that were seen in Phase I. This variation could be attributed to the standardized axes that were provided in Phase II. The attributes that were chosen from the discussion in Phase I qualitative groups may not have held equal importance to all groups. Additionally, there could have not been enough perceivable textural differences in the patties chosen for Phase II contributing to the variation in landscape maps. Future research should gain insight across Mouth Behavior groups before standardizing axes to allow for equal representation of important attributes for a all sessions to be comparable but align with priorities of each group. Understanding how different Mouth Behavior groups perceive different foodservice patties can lead to fast food establishments serving their own versions of different types of patties rather than creating polarizing products. This would allow for a greater customer base to be captured within a single restaurant.

4.2. References

AMSA. 1978. Research guidelines for cookery, sensory evaluation and instrumental measurements of fresh meat. 1st Ed. Chicago, IL: National Livestock and Meat Board and American Meat Science Association.

AMSA. 1995. Research guidelines for cookery, sensory evaluation and instrumental measurements of fresh meat. 2nd Ed. Champaign, IL: American Meat Science Association.

AMSA. 2015. Research guidelines for cookery, sensory evaluation and instrumental measurements of fresh meat. American Meat Science Association. Champaign, IL. Accessed at meatscience.org/sensory.

AMSA. 2016. Research guidelines for cookery, sensory evaluation and instrumental tenderness measurements of meat. Am. Meat Sci. Assoc. Champaign, Illinois

ASTM. 1981. Guidelines for the selection and training of sensory panel members. STP758. West Conshohocken, PA: ASTM International.

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

Berry, B.W., (1980). Effects of Chopping versus Grinding on Palatability, Shear, Chemical and Cooking Properties of Beef Patties. Journal of Animal Science, 51(3). 615-619

Berry, B.W., & Leddy, K.F., (1984). Effects of Fat Level and Cooking Method on Sensory and Textural Properties of Ground Beef Patties. Journal of Food Science, 48870-875.

Berry, B.W., (1992). Low Fat Effects on Sensory, Shear, Cooking and Chemical Properties on Ground Beef Patties. Journal of Food Science, 57(3), 537-540

Berry, B.W., & Abraham, H.C., (1995). Sensory, Shear Force and Cooking Properties of Commercially Processed Ground Beef Patties. Food Quality and Preference, 7(1), 55-59

Blackmon, T., Miller, R.K., Kerth, C.R., & Smith, S.B. Ground beef patties prepared from brisket, flank, and plate have unique fatty acid and sensory characteristics. (2015). Meat Science, 103, 46-53. http://dx.doi.org/10.1016/j.meatsci.2015.01.004

Bourne, M. C., Sandoval, Ana M., Villalobos, & M., Buckle, T. S. Development of Standard Rating Scales in Colombia (1975). Journal of Texture Studies, 6, 43-52.

Bourne, M. C., Kenny, J. F., Barnard, J. (1978). Computer Assisted Readout of Data from Texture Profile Analysis Curves. Journal of Texture Studies, 9, 481-494.

Bowling, A. (2005) Handbook of Health Research Methods: Investigation, Measurements and Analysis : Approached to qualitative data collection in social science. McGraw-Hill Education. Pg. 215. Accessed: 11, May 2022.

Brown, W. E., & Braxton, D.. (2000). Dynamics of food breakdown during eating in relation to perceptions of texture and preference: a study on biscuits. *Food Quality and Preference*, *11*(4), 259–267. http://doi.org/10.1016/s0950-3293(99)00014-2

Byers, Peggy Y., & Wilcox, James R., (1991) Focus Groups: A Qualitative Opportunity for Researchers. The Journal of Business Communication, 28(1), 63-78

Calder, B.J. (1977) Focus Groups and the Nature of Qualitative Marketing Research. Journal of Marketing Research, 14, 353-364

Cross, H. R., Green, Curtis E., Stanfield, Marilyn, S., & Franks Jr., W. J. Effect of QualityGrade and Cut Formulation on the Palatability of Ground Beef Patties (1976). Journal of Food Science, 41.

Cross, H.R., Berry, B.W., & Wells, L.H., (1980a). Effects of fat level and source on the chemical lipid, sensory and cooking properties of ground beef patties. Journal of Food Science, 45, 71-76.

Cross, H.R., Nichols, J.E., & Kotula, A.W., (1980b). Effect of Grinding Method on Textural Properties of Cooked Ground Beef. Journal of Food Protection, 43(7), 555-557.

De Wijk, R. A., Engelen, L., & Prinz, J. F. (2003). The role of intra-oral manipulation in the perception of sensory attributes. Appetite, 40(1), 1-7. doi: 10.1016/s0195 6663(02)00172-1

De Wijk, R. A., Polet, I. A., Bult, J. H. F., & Prinz, J. F. (2008). Vibromyography of oral processing varies with type of semi-solid food and with sensory judgements. Physiology & Behavior, 95(3), 521-526. doi: 10.1016/j.physbeh.2008.07.028

De Wijk, R. A., Wulfert, F., & Prinz, J. F. (2006). Oral processing assessed by M-mode ultrasound imaging varies with food attribute. Physiology & Behavior, 89(1), 15 21. doi: 10.1016/j.physbeh.2006.05.021

Drewnowski, A. (1997). Taste Preferences and Food Intake. Annual Review of Nutrition, 17(1), 237-253. doi: 10.1146/annurev.nutr.17.1.237

Dunshea, F., Ha, M., Purslow, P., Miller, R., Warner, R., Vaskoska, R. S., . . . Li, X. (2021). Meat Tenderness: Underlying Mechanisms, Instrumental Measurement, and Sensory Assessment. Meat and Muscle Biology, 4(2). doi: 10.22175/mmb.10489

Egbert, W. R., D. Huffman, C.-M. Chen, and D. Dylewski. 1991. Development of low-fat ground beef. Food technology. 45(6): 64-73.

Fruin, M., & Van Duyne, F., (1961). Fat content, yield and palatability of Ground Beef. Journal of Diatetic Association, 39, 317-320.

Gilmore, L.A., Walzem, R.L., Vrouse, S.F., Smith, D.R., Adams, T.H., Vaidyanathan, V., Cao, X., Smith, S.B., (2011). Consumption of High-Oleic Acid Ground Beef Increased HDL-Cholesterol Concentration but Both High- and Low-Oleic Acid Ground Beef Decreases HDL Particle Diameter in Normocholesterolemic Men. The Journal of Nutrition, 33, 1003-1011

Gredell, D.A., McHenry, J.H., Worner, D.R., Legako, J.F., Engle, T.E., Brooks, C., Tatum, J.D., & Belk, K.E., (2018). Palatability Characterization if Fresh and Dry-Aged Ground Beef Patties. Meat and Muscle Biology, 2(1), 265-267 doi:10.22175/mmb2018.04.0007

Guinard, J.-X., & Mazzucchelli, R. (1996). The Sensory Perception of Texture and Mouthfeel Trends in Food Science & Technology Vol. 7, 213-218. doi: PII: S0924-2244(96)10025-X

Hutchings, J. B., & Lillford, P. J. (1988). The Perception of Food Texture – The Philosophy of the Breakdown Path. Journal of Texture Studies, 19(2), 103-115. doi: 10.1111/j.1745-4603.1988.tb00928.x

Jeltema, M., Beckley, J., & Vahalik, J. (2015). Model for understanding consumer textural food choice. Food Science & Nutrition, 3(3), 202-212. doi: 10.1002/fsn3.205

Jeltema, M., Beckley, J. H., & Vahalik, J. (2014). Importance if Understanding Mouth Behavior When Optimizing Product Texture Now and in the Future. Food Texture Design and Optimization.

Kerth, C.R., Harbison, A.L., Smith, S.B., Miller, R.K., (2015). Consumer sensory evaluation, fatty acid composition, and shelf life of ground beef with subcutaneous fat trimmings from different carcass locations. Meat Science, 104(2015) 30-36. doi: 10.1016/j.meatsci.2015.01.014

Kinnucan, H.W., Xiao, H., Hsia, C.J., & Jackson, J.D., (1997) Effects of Health Informationand Generic Advertising on U.S. Meat Demand. American Journal of Agricultural Economics, 79 (13-23).

Kokini, J. L., Kadane, J. B., & Cussler, E. L. (1977). Liquid Texture Perceived in the Mouth. Journal of Texture Studies, 8(2), 195-218. doi: 10.1111/j.1745-4603.1977.tb01175.x

Liu, L., & Hammond, E.G. (2000). A Research Note: The Role of Particles in the Perception of Flavors. Journal of Food Quality, 23(5), 521-528. doi: 10.1111/j.1745-4557.2000.tb00577.x

Liu, L., & Berry, B.W., (1998). Patty Formation Method, Thickness, and Weight Effects on Properties of Cooked Low- Fat Beef Patties. Journal of Muscle Foods, 9, (243-256).

Lusk, J.L., Parker, N., (2009). Consumer Preferences for Amount and Type of Fat in Ground Beef. Journal of Agricultural and Applied Economics, 41,1 (75-90).

Meilgaard, M., G.V. Civille, and B.T. Carr. 2016. Sensory evaluation techniques. 5th Ed. Boca Raton, FL: CRC Press, Inc.

Miller, R. K. (2020). Drivers of Consumer Liking for Beef, Pork, and Lamb: A Review. doi: 10.3390/foods9040428

Miller, R.K., (2022). The eating quality of meat: V. Sensory evaluation of meat. 9th Ed: Lawrie's Meat Science. Woodhead Publishing, Cambridge, MA

Miller, R.K., L.S. Papadopoulos, T.L. Wheeler, R.A. Gray, M.E. Dikeman, J.R. Claus,C. Owens-Hanning, W. Schilling, D.A. King, K.E. Belk, P. Bass, C.R. Calkins, M.F. Miller, S.D. Shackelford, and B. Wasser. 2022. Research Guidelines I: Cutting, Handling and Cookery Methods for Sensory or Texture Evaluation of Meat. Meat and Muscle Bio. (Accepted).

Muñoz, A. M. (1986). Development and Application of Texture Reference Scales. Journal of Sensory Studies, 1, 55-83.

Muñoz, A. M. (1988). Consumer Perceptions of Meat, Understanding These Results Through Descriptive Analysis. Meat Science, 49, S287-S295.

National Cattlemen's Beef Association.(2019). Beef It's What's for Dinner: Beef Remains Foodservice Mainstay. Retrieved from https://www.beefitswhatsfordinner.com/foodservice/menu-concepts-diner insights/beef-in-foodservice (Accessed March 28, 2022).

National Cattlemen's Beef Association (2021a). Beef It's What's for Dinner: An Overview of Ground Beef at Retail and Foodservice. Retrieved from: https://www.beefitswhatsfordinner.com/retail/sales-data-shopper insights/ground-beef-at-retail-and-foodservice (Accessed April 13, 2022).

National Cattlemen's Beef Association (2021b). Beef It's What's for Dinner: Hindsight 2020: Retail and Foodservice Trends Through the Pandemic. Retrieved from https://www.beefitswhatsfordinner.com/retail/sales-data-shopper insights/pandemic-market-trends (Accessed March 28, 2022).

Po, J. M. C., Kieser, J. A., Gallo, L. M., Tésenyi, A. J., Herbison, P., & Farella, M.. (2011). Time-Frequency Analysis of Chewing Activity in the Natural Environment. Journal of Dental Research, 90(10), 1206–1210. http://doi.org/10.1177/0022034511416669

Prinz, J., & Lucas, P. (1997). Mastication and swallowing: an optimization model. Proc R Soc Lond B, 264, 1715-1721.

Resurreccion, A.V.A., (2003) Sensory aspects of consumer choices for meat and meat products. Meat Science, 66, 11-20 doi: 10.1016/S0303-1740(03)00021-4

Roth, D.M., McKeith, F.K., Brewer, M.S., (1999). Processing Parameter Effects on Sensory and Instrumental Texture Characteristics of Reduced-Fat Ground Beef Patties. Journal of Muscle Foods, 10, 163-176.

Rust, R.T., & Cooil, B. (1994). Reliability Measures for Qualitative Data: Theory and Implications. Journal of Marketing Research, 31, 1-14

Sensory evaluation techniques. (2020) In Meat Quality Analysis: Advanced Evaluation Methods. Techniques, and Technologies.

Suman, S.P., & Sharma, B.D. (2003). Effect of grind size and fat levels on physico chemical and sensory characteristics of low-fat ground buffalo meat patties. Meat Science, 65, 973-976.

Szczesniak, A.S., (1975). General Foods Texture Profile Revisited- Ten Years Perspective. Journal of Texture Studies, 6, 385-409.

Troutt, E.S., Hunt, M.C., Johnson, D.E., Claus, J.R., Kastner, C.L., Kropf D.H. (1992a). Characteristics of Low0fat Ground Beef Containing Texture-modifying Ingredients. Journal of Food Science, 57(1), 19-24

Troutt, E.S., Hunt, M.C., Johnson, D.E., Claus, J.R., Kastner, C.L., Kropf D.H., Stroda, S. (1992b). Chemical, Physical and Sensory Characterization of Ground Beef Containing 5 to 30 Percent Fat. Journal of Food Science, 57(1), 25-29

Wilfong, T.A., McKillip, K.V., Gonzalez, J.M., Houser, T.A., Unruh, J.A., Boyle, E.A.E., O'Quinn, T.G., (2016). Determination of the brand and product identification on consumer palatability ratings of ground beef patties. Journal of Animal Science, doi: 10.2527/jas2016-0894

5. TABLES & FIGURES

Table 1. Fat level, processing method, patty formation and patty weight treatments for ground beef patties in Phase I

Fat Level, %	Processing Method	Patty Formation Method	Patty Weight, gm	Flight Number
7	Ground	Machine	226.8	1
27	Ground	Machine	226.8	1
20	Ground	Machine	226.8	2
20	Chopped	Machine	226.8	2
20	Chopped	Hand Pressed	113.4	3
20	Chopped	Ball, patty 'smashed'[a] during cooking	113.4	3

a = patties pressed to .64 cm on flat top grill

Table 2. Definition of food service and retail ground beef burger treatments used in Phase II.

Food Service Ground Beef			
Wayback Burgers			1
Five Guys			1
Koppe Bridge Single			1
Whataburger Single			2
McDonalds Quarter Pounder			2
Sonic Single			2
Freddys Single			2
Retail Ground Beef			
Raw Material	Packaging Form	Patty Formation Method	Flight Number
Round	Chub	Hand Pressed	3
Sirloin	Chub	Hand Pressed	3
Brisket	Lose	Hand Pressed	3
Chuck	Lose	Hand Pressed	4
Chuck	Chub	Hand Pressed	4
Chuck	Store Made	Machine	4

Table 3. Descriptive texture sensory attributes used to evaluate ground beef patties in Phases I and II.

Attribute	Definition	References
Surface Roughness	Feel surface with lips and tongue to evaluate surface roughness.	Jell-O= 0.0 Orange peel= 5.0 Original Pringles= 8.0 Hard granola bar= 12.0 Finn Crisp Rye Wafer= 15.0
Firmness	Force required to compress sample between 1. Tongue and palate, 2. Between molars.	Cream cheese= 1.0 Egg White= 2.5 Yellow American Cheese = 4.5 Olives = 6.0 Frankfurter= 7.0 Planters Peanut= 9.5
Springiness	The degree to which sample returns to original shape, or the rate with which sample returns to original shape (between molars)	Cream cheese= 0.0 Frankfurter= 5.0 Mini Marshmallow= 9.5 Jell-O= 15.0
Hardness	Force needed to compress with molars; force needed to compress between tongue and palate; force needed to bite through with incisors	Cream Cheese = 1.0 Yellow American Cheese = 4.5 Hebrew National Frankfurter = 7.0 Planters Peanut = 9.5 Almonds = 11.0 Life Savers = 14.5
Initial Juiciness	Amount of perceived juiciness that is released from the product during the first 2-3 chews	Mushroom = 6.0 Carrot = 8.5 Cucumber = 12.0 Apple = 13.5 Watermelon = 15.0
Chewiness	Length of time required to masticate product (at a constant rate of force) to reduce it to a consistency suitable for swallowing.	Marshmallows= 3.0 Nibs Twizzlers= 5.0 Tootsie Roll= 9.0 Starburst= 12.0 Haribo gummy bears= 14
Toothpacking	The degree to which product sticks on the surface of teeth after product is swallowed or expectorated.	Carrots=1.0 Mushrooms=3.0 Saltine crackers= 5.0 Graham Cracker=7.5 Cheese Puffs=11.0 Ju-Jubes Candy=15.0
Sustained Juiciness	Amount of perceived juiciness that is released form the product after 10-15 chews.	Mushroom = 6.0 Carrot = 8.5 Cucumber = 12.0 Apple = 13.5 Watermelon = 15.

Table 3. Descriptive texture sensory attributes used to evaluate ground beef patties in Phases I and II Continued.

Mouthcoating	Feel mouth and teeth with tongue after the product is swallowed or expectorated, evaluate for: number of particles left in the mouth; amount of oil film left on oral surfaces.	Half & Half = 2.0 Sara Lee All Butter Pound Cake = 3.0 Land O'Lakes unsalted butter =5.0 Land O'Lakes American Cheese = 8.0
Cohesiveness	The degree to which sample deforms, i.e. crumbles, cracks, or breaks 1. Between tongue and palate, 2. Between molars	Corn muffin= 1.0 Sara Lee's Pound cake= 4.0 Yellow American cheese= 5.0 Soft pretzel= 8.0 Dried raisin= 10.0 Starburst= 12.5 Freedent gum= 15.0
Cohesiveness of Mass	The degree to which chewed sample (15 chews) holds together in a mass.	Twizzlers= 0.0 Carrots= 2.0 Mushroom= 4.0 Frankfurter= 7.5 Yellow American Cheese= 9.0 Soft brownie= 13.0 Pillsbury dough= 15.0
Particle Size	Place sample between molars, bite down and evaluate the size of the crumb pieces after chewing, immediately before swallowing or expectorating	Boba Tea tapioca pearl= 8.0 Planters Peanut= 10.0
Particle Amount	Evaluate the relative number/ amount of particles in the mouth. Done after chewing, immediately before swallowing or expectorating	Starburst= 0.0 Yellow American Cheese= 1.0 Soft pretzel= 4.0 Mushroom= 6.0 Carrot= 7.0 Nibs Twizzlers= 8.0 Saltine crackers= 10.0 Granola bar= 14.0
Connective Tissue	The structural component of the muscle, as it relates to the tissue amount during mastication.	Brisket=4.0 Tenderloin=14.0

Table 4. Least squares means for Phase I ground beef patty descriptive texture attributes.

Attributes[1]	p-value[2]	Ground, Machine 97% lean	Ground, Machine 80% lean	Ground, Machine 73% lean	Chopped, Machine 80% lean	Chopped, Smashed 80% lean	Hand Pressed, Chopped 80% lean	RMSE
Surface Roughness	0.005	7.6^{c}	8.6^{bc}	8.0^{c}	8.4^{bc}	11.0^{a}	9.9^{ab}	1.30
Firmness	0.04	5.7^{bc}	5.5^{c}	5.4^{c}	6.3^{abc}	7.0^{a}	6.7^{ab}	0.89
Springiness	0.06	5.3	5.0	4.9	5.9	5.9	6.5	0.83
Hardness	0.10	5.8	6.1	5.5	6.3	7.0	7.0	0.91
Initial Juiciness	0.55	6.3	6.4	6.9	6.5	6.7	6.9	0.61
Mouthcoating	0.21	3.5	4.2	3.9	4.4	4.9	4.6	0.79
Connective Tissue	0.002	13.2^{a}	11.8^{ab}	13.7^{a}	8.7^{c}	7.5^{c}	8.8^{bc}	2.36
Cohesiveness	0.15	5.3	5.0	5.0	5.9	5.9	6.2	0.80
Cohesiveness of Mass	0.30	7.3	7.0	6.3	7.5	7.9	7.7	1.09
Particle Size	0.001	4.5^{b}	5.2^{b}	4.0^{b}	7.5^{a}	7.5^{a}	7.1^{a}	1.39
Particle Amount	0.37	5.8	5.9	6.1	5.8	6.0	5.1	0.72
Chewiness	0.004	4.4^{b}	5.2^{b}	4.0^{b}	7.5^{a}	7.8^{a}	6.9^{ab}	1.28
Toothpacking	0.42	3.2	2.7	2.9	3.0	3.1	2.8	0.34
Sustained Juiciness	0.42	5.9	6.1	6.7	5.9	6.3	6.4	0.73

[1] = Surface Roughness: 0 = none ; 15= extremely intense; Firmness: 0=none; 15=extremely intense; Springiness: 0=none; 15=extremely intense; Hardness: 0=none; 15=extremely intense ;Initial Juiciness: 0=none; 15=extremely intense; Mouth Coating: 0=_none;
15=extremely intense; Connective Tissue: 0=none; 15=extremely intense; Cohesiveness: 0=none; 15=extremely intense; Cohesiveness of Mass: 0=none; 15=extremely intense Particle Size: 0=none; 15=extremely intense; Particle Amount: 0=none; 15=extremely intense; Chewiness: 0=none;
15=extremely intense; Toothpacking: 0=none; 15=extremely intense; Sustained Juiciness: 0=none; 15=extremely intense;
[2] = p-value from analysis of variance table.
RMSE = Root Mean Square Error
[a,b,c] = Means on the same row with different letters are different ($P < 0.05$). Where no letters are present, differences were non-significant ($P > 0.05$) in analysis of variance

Table 5. Least squares means for Phase I ground beef patties Texture Profile Analysis attributes.

Treatment	Hardness 1(N)	Adhesion	Hardness 2(N)	Cohesiveness	Springiness	Gumminess	Chewiness
p-value[1]	0.0146	0.0113	0.0189	0.154	0.061	0.016	0.0004
Ground, Machine 97% lean	56.6^{a}	0.2^{b}	49.0^{ab}	5.3	5.3	29.2^{ab}	4.4^{b}
Ground, Machine 80% lean	38.4^{b}	0.2^{b}	33.3^{b}	5.0	5.0	20.8^{b}	5.2^{b}
Ground, Machine 73% lean	57.5^{a}	0.2^{b}	49.7^{a}	5.0	4.9	30.0^{a}	4.0^{b}
Chopped, Machine 80% lean	49.9^{ab}	0.2^{b}	43.9^{ab}	5.9	5.9	27.1^{ab}	7.5^{a}
Chopped, Smash 80% lean	31.0^{b}	0.3^{a}	26.8^{b}	5.9	5.9	17.1^{b}	7.8^{a}
Hand Pressed, Chopped 80% lean	53.4^{ab}	0.2^{b}	45.9^{ab}	6.2	6.5	30.7^{a}	6.9^{ab}
RMSE	12.60	0.04	11.2	0.8	0.83	6.67	1.28

[1] = p-value from analysis of variance table
RMSE = Root Mean Square Error
^{a,b,c} = Means on the same line with different letters are different ($P < 0.05$). Where no letters are present, differences were non-significant ($P > 0.05$) in analysis of variance.

Table 6a. Least squares means for Phase II retail ground beef patty descriptive texture attributes.

Attributes[1]	p-value[2]	Chuck, Loose	Chuck, Chub	Chuck, HEB	Brisket, Loose	Sirloin, Chub	Round, Chub	RMSE
Surface Roughness	< 0.0001	11.8^{a}	11.2^{ab}	10.0^{b}	8.0^{c}	8.5^{bc}	9.7^{b}	1.25
Firmness	0.0004	5.6^{b}	5.8^{ab}	5.0^{b}	4.9^{b}	5.5^{b}	5.6^{b}	0.74
Springiness	0.0001	5.6^{b}	5.6^{b}	4.3^{b}	4.3^{b}	5.3^{b}	5.1^{b}	1.06
Hardness	0.0002	6.1^{b}	6.2^{ab}	5.2^{bc}	4.5^{c}	5.7^{b}	5.9^{b}	0.75
Initial Juiciness	0.50	6.7	5.8	6.2	7.0	7.7	6.2	2.08
Mouthcoating	0.0002	4.6^{a}	3.8^{ab}	3.4^{bc}	3.4^{bc}	2.9^{bc}	3.5^{bc}	0.6
Connective Tissue	0.10	11.5	12.5	12.6	13.1	12.8	12.6	1.31
Cohesiveness	0.03	5.1^{b}	5.3^{ab}	4.6^{b}	4.6^{a}	5.4^{ab}	5.1^{b}	0.72
Cohesiveness of Mass	0.25	6.3	6.1	6.3	6.1	6.8	6.7	0.94
Particle Size	0.02	5.7^{a}	4.6^{ab}	4.4^{b}	3.8^{b}	4.0^{b}	4.1^{b}	0.86
Particle Amount	0.28	6.2	5.8	6.2	6.1	5.6	5.9	0.65
Chewiness	0.0001	5.2^{b}	5.0^{b}	4.3^{bc}	3.7^{c}	4.3^{bc}	4.7^{bc}	0.85
Toothpacking	0.53	2.8	3.1	3.1	3.3	3.1	3.0	0.39
Sustained Juiciness	0.0006	5.7^{ab}	5.8^{ab}	5.6^{ab}	6.3^{a}	5.1^{b}	6.1^{a}	0.69

[1] = Surface Roughness: 0 = none ; 15= extremely intense; Firmness: 0=none; 15=extremely intense; Springiness: 0=none; 15=extremely intense; Hardness: 0=none; 15=extremely intense ;Initial Juiciness: 0=none; 15=extremely intense; Mouth Coating: 0=_none;
15=extremely intense; Connective Tissue: 0=none; 15=extremely intense; Cohesiveness: 0=none; 15=extremely intense; Cohesiveness of Mass: 0=none; 15=extremely intense
Particle Size: 0=none; 15=extremely intense; Particle Amount: 0=none; 15=extremely intense; Chewiness: 0=none;
15=extremely intense; Toothpacking: 0=none; 15=extremely intense; Sustained Juiciness: 0=none; 15=extremely intense;
[2] = p-value from analysis of variance table. P-values apply to data extending from Table 6a to Table 6b.
RMSE = Root Mean Square Error
[a,b,c] = Means on the same row with different letters are different (P < 0.05). Where no letters are present, differences were non-significant (P > 0.05) in analysis of variance. Superscripts applies to extending from Table 6a to Table 6b.

Table 6b. Least square means for Phase II foodservice ground beef patties descriptive texture attributes

Attribute[1]	p-value[2]	Koppe Bridge	Freddys	5 Guys	Whataburger	Wayback	McDonalds	Sonic	RMSE
Surface Roughness	< 0.0001	8.5^{a}	9.4^{a}	8.9^{a}	9.0^{a}	8.6^{a}	8.5^{a}	8.0^{a}	1.25
Firmness	0.0004	6.3^{ab}	6.3^{ab}	6.0^{ab}	6.6^{ab}	5.7^{b}	6.7^{a}	5.5^{b}	0.74
Springiness	0.0001	6.8^{ab}	7.1^{a}	6.2^{ab}	7.0^{ab}	5.5^{b}	7.1^{a}	6.1^{a}	1.06
Hardness	0.0002	6.5^{ab}	6.4^{ab}	6.3^{ab}	6.4^{ab}	5.7^{b}	7.2^{a}	6.0^{b}	0.75
Initial Juiciness	0.50	5.4	4.4	5.7	5.2	7.3	6.1	5.7	2.08
Mouthcoating	0.0002	2.7^{c}	2.3^{c}	3.5^{ab}	2.9^{ab}	3.6^{ab}	3.7^{a}	3.0^{ab}	0.6
Connective Tissue	0.10	12.9	11.8	11.9	11.2	11.7	10.9	12.7	1.31
Cohesiveness	0.03	4.9^{b}	6.0^{ab}	5.1^{ab}	6.0^{a}	4.8^{b}	5.8^{ab}	5.0^{b}	0.72
Cohesiveness of Mass	0.25	6.0	7.2	6.1	6.7	5.6	7.0	5.7	0.94
Particle Size	0.02	4.8^{ab}	4.3^{b}	4.5^{b}	5.5^{a}	4.4^{b}	5.0^{ab}	4.2^{b}	0.86
Particle Amount	0.28	6.0	5.8	6.5	5.9	6.4	5.3	6.3	0.65
Chewiness	0.0001	5.2^{b}	5.8^{ab}	5.3^{b}	6.4^{a}	5.1^{b}	6.2^{ab}	4.9^{b}	0.85
Toothpacking	0.53	2.9	2.9	2.8	2.7	2.9	3.0	2.8	0.39
Sustained Juiciness	0.0006	4.7^{b}	4.5^{b}	5.2^{ab}	4.8^{ab}	5.5^{ab}	5.7^{a}	5.3^{ab}	0.69

[1] = Surface Roughness: 0 = none ; 15= extremely intense; Firmness: 0=none; 15=extremely intense; Springiness: 0=none; 15=extremely intense; Hardness: 0=none; 15=extremely intense ;Initial Juiciness: 0=none; 15=extremely intense; Mouth Coating: 0=_none;
15=extremely intense; Connective Tissue: 0=none; 15=extremely intense; Cohesiveness: 0=none; 15=extremely intense; Cohesiveness of Mass: 0=none; 15=extremely intense
Particle Size: 0=none; 15=extremely intense; Particle Amount: 0=none; 15=extremely intense; Chewiness: 0=none;
15=extremely intense; Toothpacking: 0=none; 15=extremely intense; Sustained Juiciness: 0=none; 15=extremely intense;
[2] = p-value from analysis of variance table. P-values apply to data extending from Table 6a to Table 6b.
RMSE = Root Mean Square Error
[a,b,c] = Means on the same row with different letters are different (P < 0.05). Where no letters are present, differences were non-significant (P > 0.05) in analysis of variance. Superscripts applies to extending from Table 6a to Table 6b

Table 7a. Least squares means for Phase II retail ground beef patties Texture Profile Analysis

Treatment	Hardness 1	Adhesion	Hardness 2	Cohesiveness	Springiness	Gumminess	Chewiness
p-value[1]	< 0.0001	0.44	< 0.0001	0.03	0.0001	0.0001	0.0001
Chuck, Loose	22.6^{c}	-6.7	13.5^{c}	5.1^{b}	5.6^{b}	2.4^{c}	5.2^{b}
Chuck, Chub	33.7^{bc}	4.4	26.0^{bc}	5.3^{ab}	5.6^{b}	20.5^{bc}	5.0^{b}
Chuck, HEB	37.0^{bc}	5.6	30.2^{b}	4.6^{b}	4.3^{b}	15.2^{c}	4.4^{bc}
Brisket, Loose	37.4^{b}	-8.0	29.9^{b}	4.6^{b}	4.3^{b}	24.4^{bc}	3.7^{c}
Sirloin, Chub	39.0^{b}	4.6	34.8^{b}	5.4^{ab}	5.3^{b}	18.0^{c}	4.3^{bc}
Round, Chub	34.1^{bc}	-5.2	27.2^{b}	5.1^{b}	5.1^{b}	17.6^{c}	4.7^{bc}
RMSE	9.89	32.28	10.81	0.72	1.06	13.06	0.85

[1] p-value from analysis of variance table. P-values apply to data extending from Table 7a to Table 7b.
RMSE = Root Mean Square Error
^{a,b,c} = Means on the same row with different letters are different ($P < 0.05$). Where no letters are present, differences were non-significant ($P > 0.05$) in analysis of variance.
Superscripts applies to extending from Table 6a to Table 6b

Table 7b. Least squares mean for Phase II foodservice ground beef patties Texture Profile Analysis

Attribute	p-value[1]	Koppe Bridge	Freddys	5 Guys	Whataburger	Wayback	McDonalds	Sonic	RMSE
Hardness 1	< 0.0001	59.2^{a}	40.4^{bc}	45.0^{b}	60.9^{a}	31.5^{c}	64.2^{a}	57.4^{ab}	9.89
Adhesion	0.44	9.2	9.7	45.2	-5.3	1.0	2.4	-0.9	32.28
Hardness 2	< 0.0001	53.8^{a}	37.3^{b}	49.3^{ab}	52.4^{ab}	27.0^{b}	56.4^{a}	49.9^{ab}	10.81
Cohesiveness	0.03	4.9^{b}	6.0^{ab}	5.1^{b}	6.0^{a}	4.8^{b}	5.8^{ab}	5.0^{b}	0.72
Springiness	0.0001	6.8^{ab}	7.1^{ab}	6.1^{ab}	7.0^{ab}	5.5^{b}	7.1^{a}	6.1^{ab}	1.06
Gumminess	0.0001	29.7^{bc}	19.0^{bc}	25.0^{bc}	55.4^{a}	12.2^{c}	36.8^{b}	27.5^{bc}	13.06
Chewiness	0.0001	5.2^{b}	5.8^{ab}	5.3^{b}	6.4^{a}	5.1^{b}	6.2^{ab}	4.9^{bc}	0.85

[1]p-value from analysis of variance table. P-values apply to data extending from Table 7a to Table 7b.
RMSE = Root Mean Square Error
^{a,b,c} = Means on the same row with different letters are different (P < 0.05). Where no letters are present, differences were non-significant (P > 0.05) in analysis of variance.
Superscripts applies to extending from Table 6a to Table 6b

Table 8. Characteristics of what a 'good burger' should be from focus groups of each Mouth Behavior classification

Chewers	Crunchers	Smooshers	Suckers
- Thick[b]	- Not too dry[a]	- Juicy[a]	- Juicy, not dry[a]
- Flavorful[a]	- Not too raw[a]	- Well seasoned[a]	- Thick or thin (depends on preference)[b]
- Not soggy bun[a]	- Not soaked through[a]	- A little crispy edge (a good chewy but 'not too chewy')[b]	- Melted cheese[c]
- Juicy[b]	- Texture and temperature differences across all parts[c]	- Not too big[a]	- 'Crunchy' edges[c]
- Not homogeneous texture [a]	- Charred outside soft inside[b]	- Doesn't fall apart in mouth	- Fluffy bun (brioche is perfect)[c]
- Not Rubbery[a]	- Cooked through[b]	- No gristle[a]	- Multiple condiments[b]
- Not Dry[a]	- Flavorful[b]	- Not congealed or sludgy/no residue or film[a]	- Seasoned before cooking[a]
- Not too greasy[a]	- Doesn't stick to teeth[a]	- Edible without condiments[c]	- Different every bite[c]
- Not too tender, not too tough (a little bit of fight)[c]	- Not chewy, crumbly, or chunky [a]	- Not too greasy [a]	- Not too chewy but doesn't fall apart[a]
- Not gristly[a]		- Not dry[a]	- Not crumbly[a]
- Right amount of salt[b]			- Not bland[a]

a = Must have
b = Optimizer
c = Delighter

Table 9. Demographic of Phase I qualitative workshop participants.

Phase I		
Attribute	**Age**	**Category**
F	18-24	Cruncher
F	25-34	Cruncher
M	25-34	Cruncher
M	18-24	Cruncher
M	55-64	Cruncher
M	35-44	Cruncher
M	25-34	Cruncher
F	25-34	Chewer
F	35-44	Chewer
F	55-65	Chewer
F	45-54	Chewer
M	55-65	Chewer
F	18-24	Smoosher
M	18-24	Smoosher
F	25-34	Smoosher
M	25-34	Smoosher
F	45-54	Smoosher
F	18-24	Sucker
M	18-24	Sucker

Table 10. Demographic of Phase II qualitative workshop participants.

Attribute	Phase II Age	Category
M	25-34	Cruncher
M	25-34	Cruncher
M	18-24	Cruncher
F	18-24	Cruncher
M	45-54	Chewer
M	35-44	Chewer
F	25-34	Chewer
F	25-34	Chewer
F	35-44	Chewer
F	18-24	Chewer
M	18-24	Chewer
F	45-54	Smoosher
F	18-24	Smoosher
F	25-34	Smoosher
M	55-65	Smoosher
M	18-24	Smoosher
F	18-24	Smoosher
F	25-34	Smoosher
F	18-24	Sucker
F	55-65	Sucker
F	18-24	Sucker

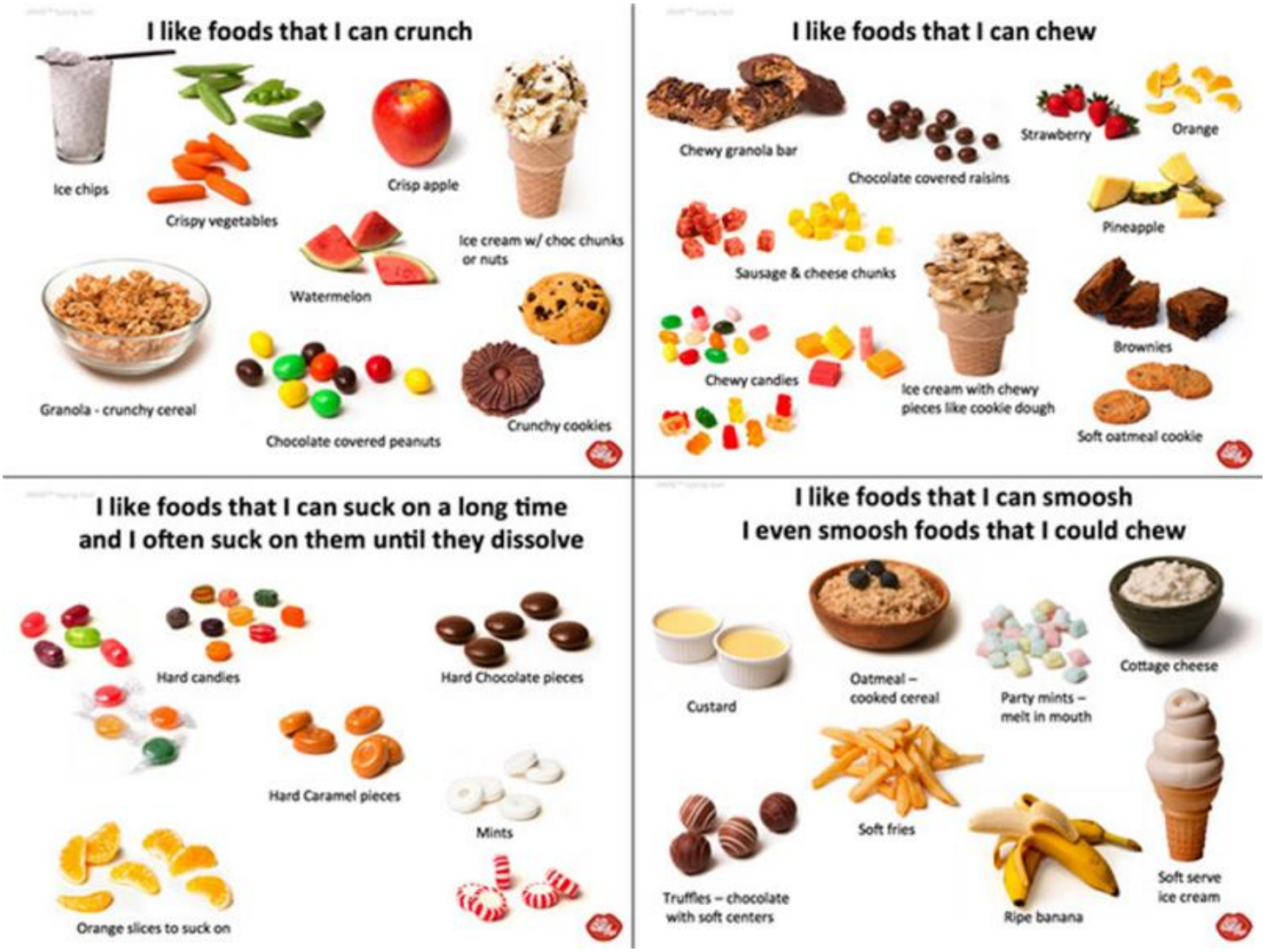

Figure 1 JBMB® graphic tool (Jeltema et al., 2015) used for identifying consumer classifications for mouth behavior for participants in Phase I and Phase II qualitative workshops.

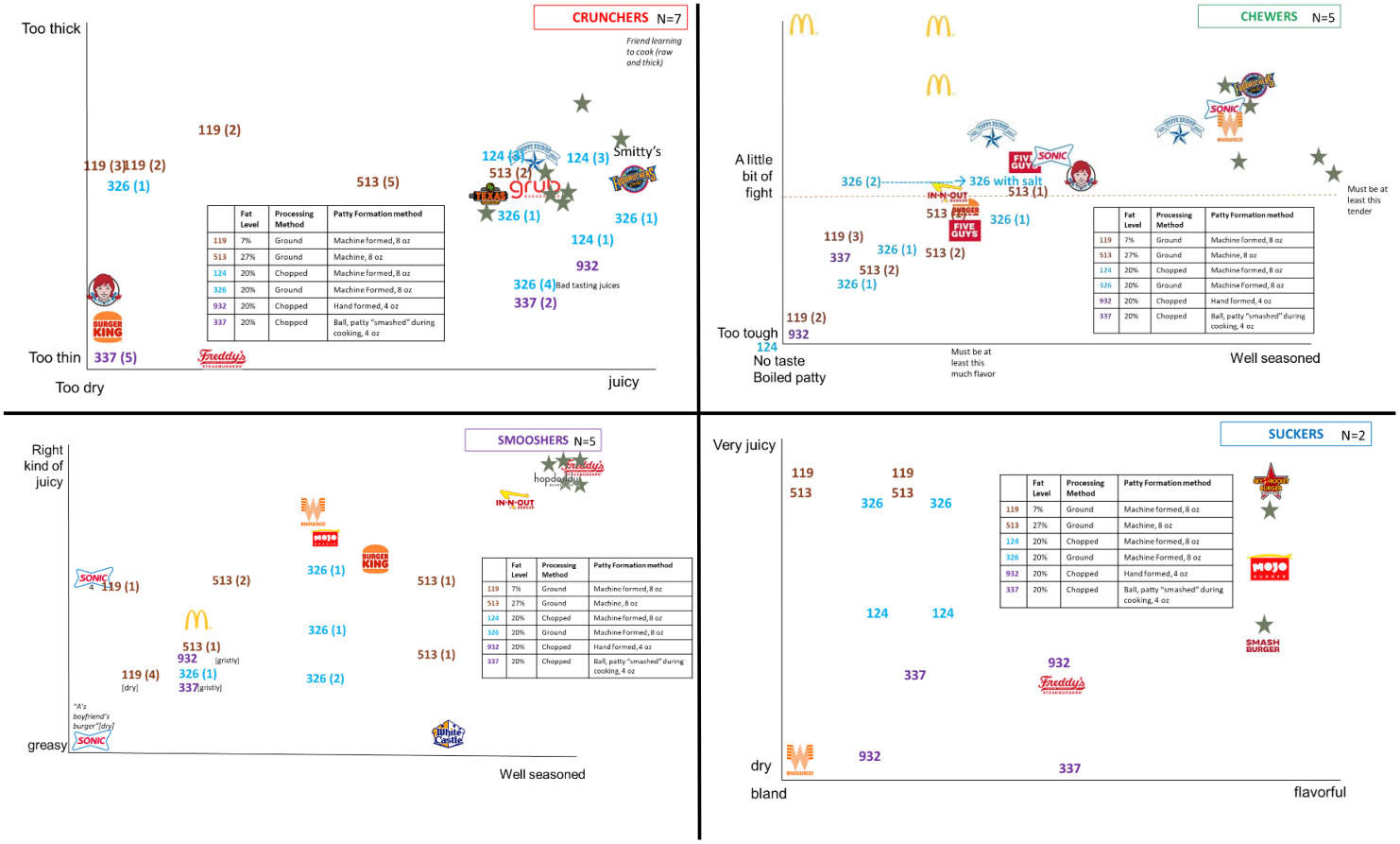

Figure 2. Ground Beef Phase 1 qualitative group landscape maps in relation to ideal (★) of each participant in the workshop sessions.

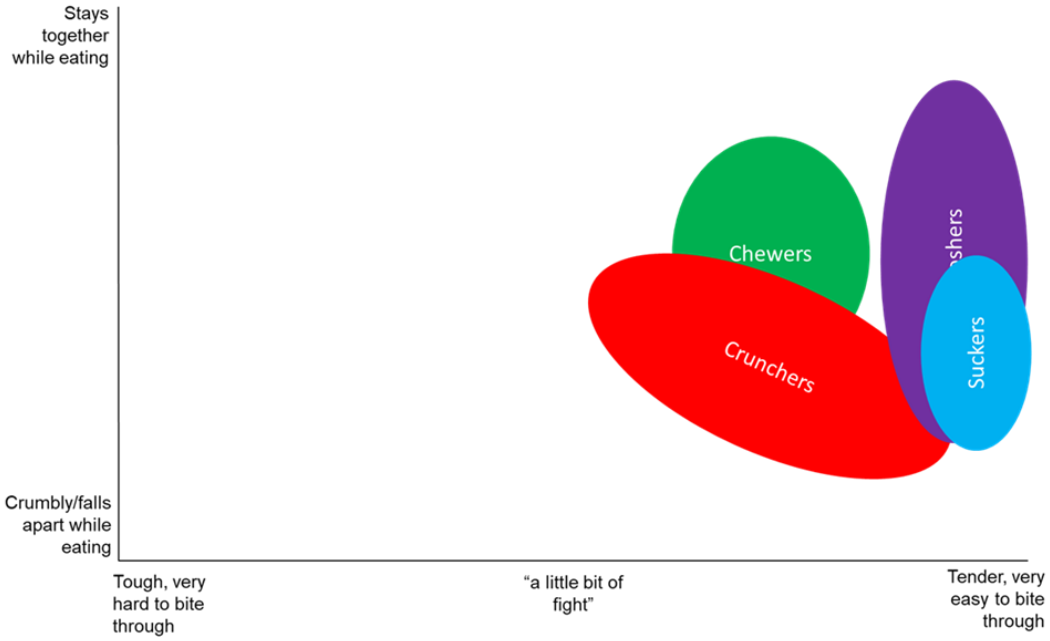

Figure 3. Ground beef Phase 1 raw qualitative group maps

3.

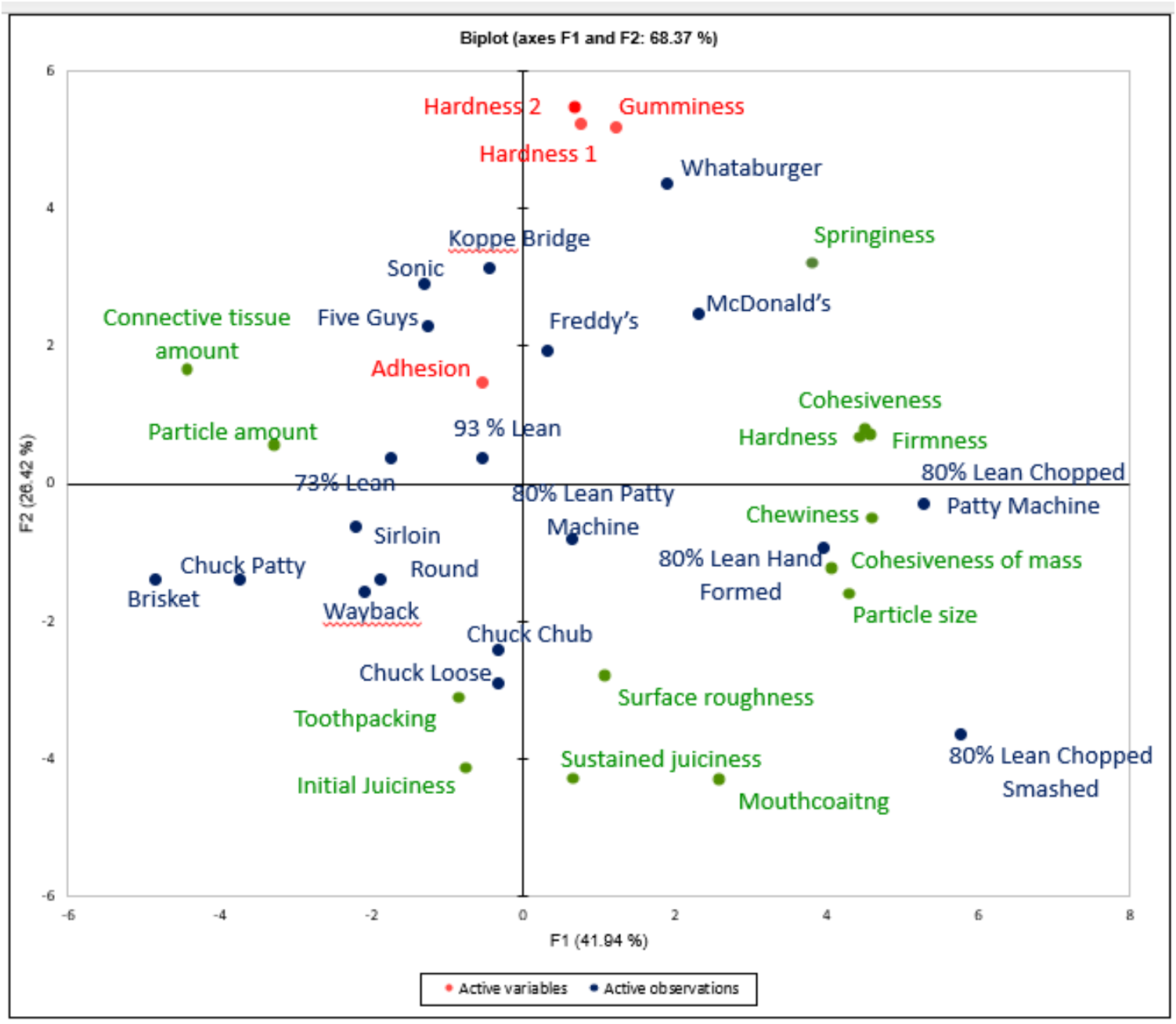

Figure 4. Principal component analysis bi-plot of Factor 1 (41.94% of variation) and Factor 2 (26.42% of variation) with treatments ( ), descriptive sensory texture attributes ( ), and Texture Profile attributes ( ).

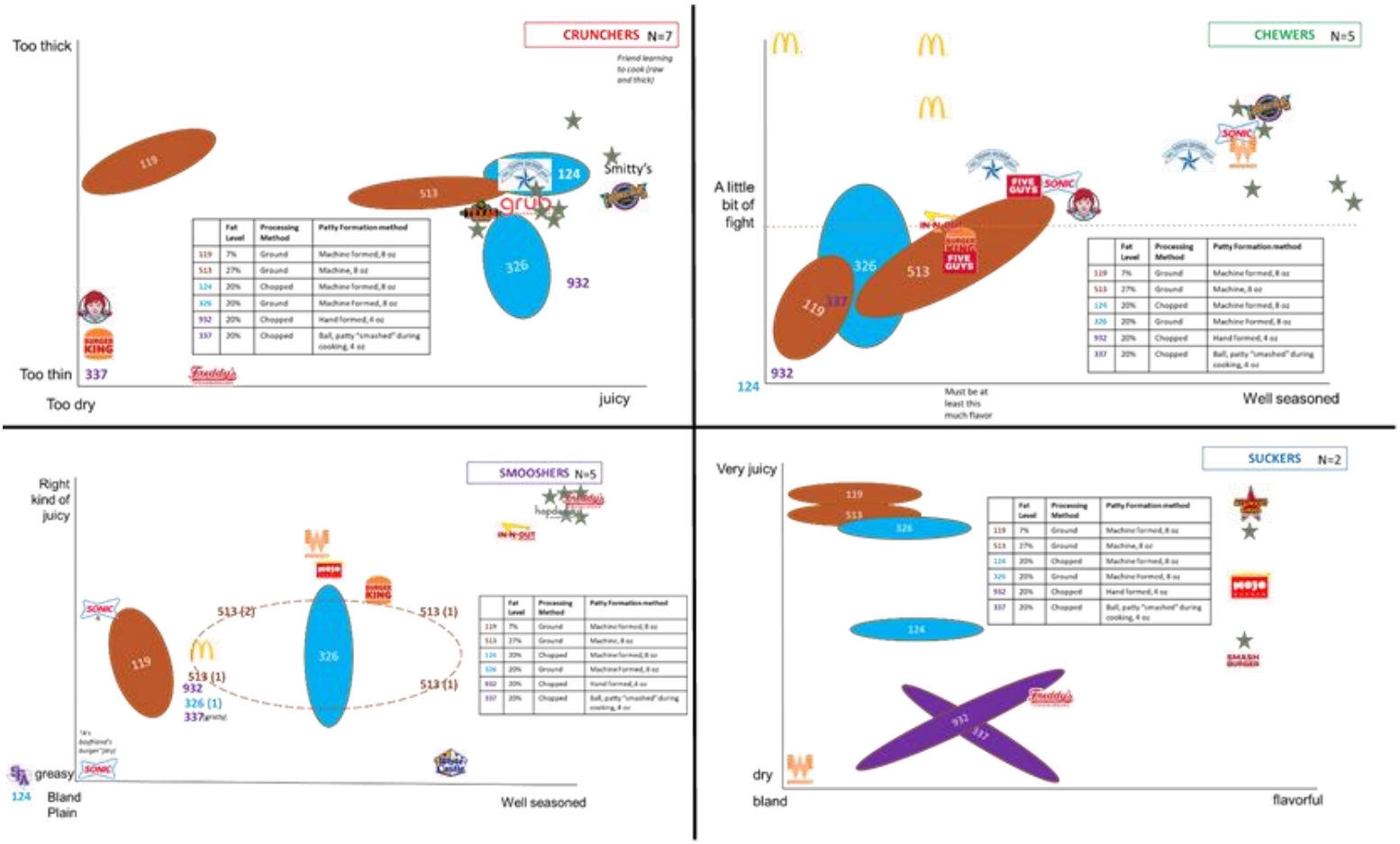

Figure 5. Phase II qualitative group 'ideal burger' landscape mapping

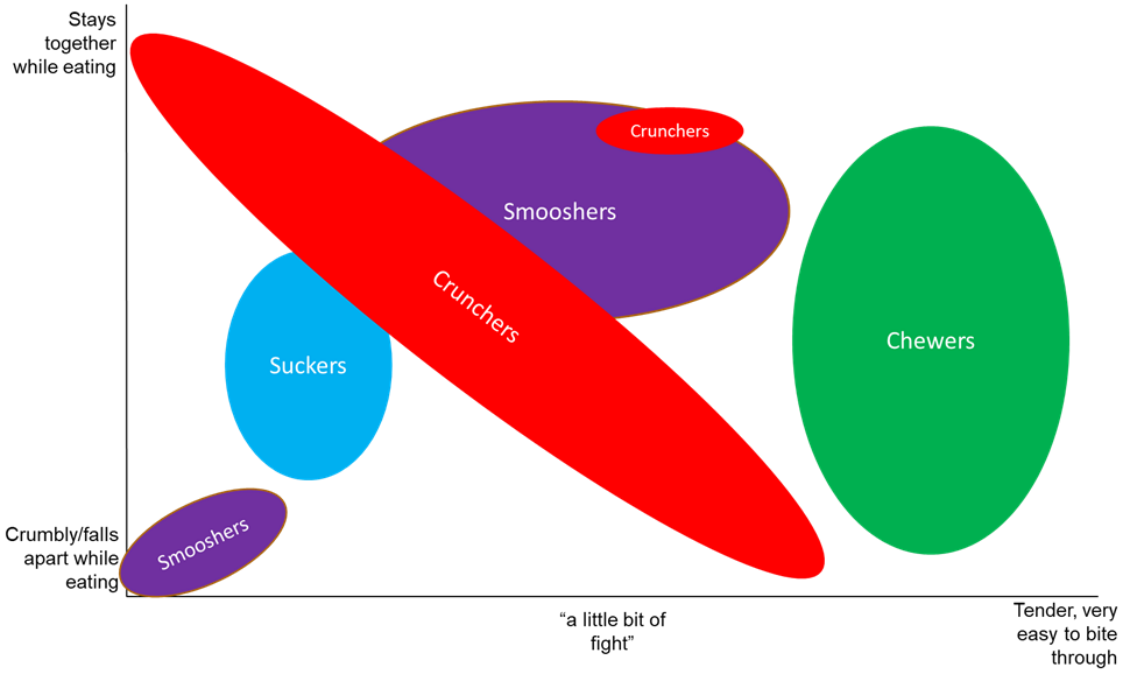

Figure 6. Phase II landscape map from each Mouth Behavior for casual dining patties (Koppe Bridge, Five Guys, Wayback).

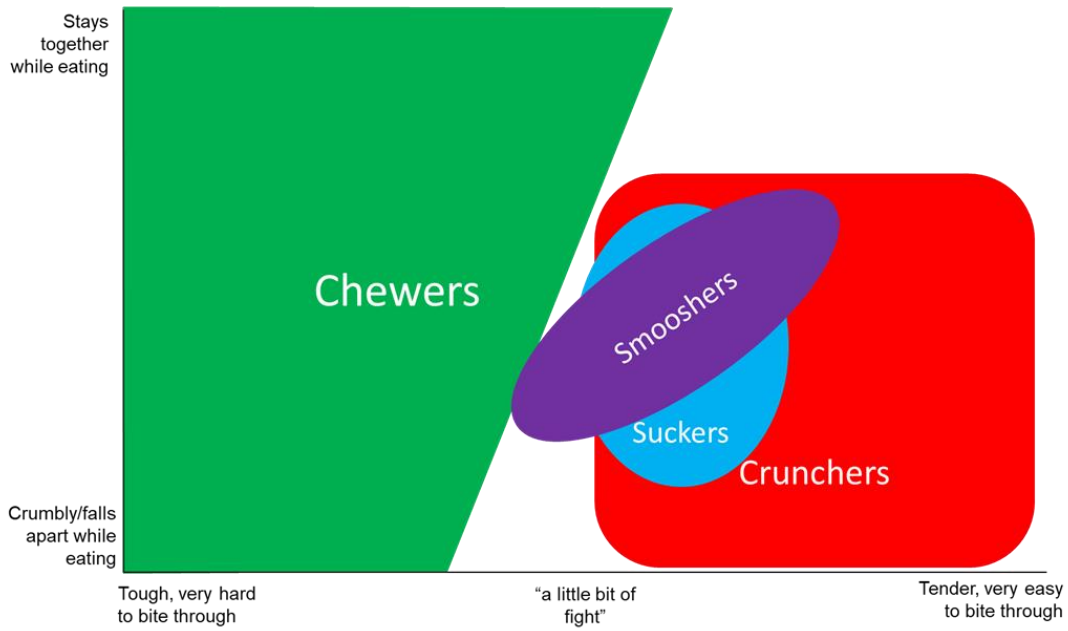

Figure 7. Phase II qualitative group landscape mapping of 'raw material' ground beef patties (round, brisket, sirloin).

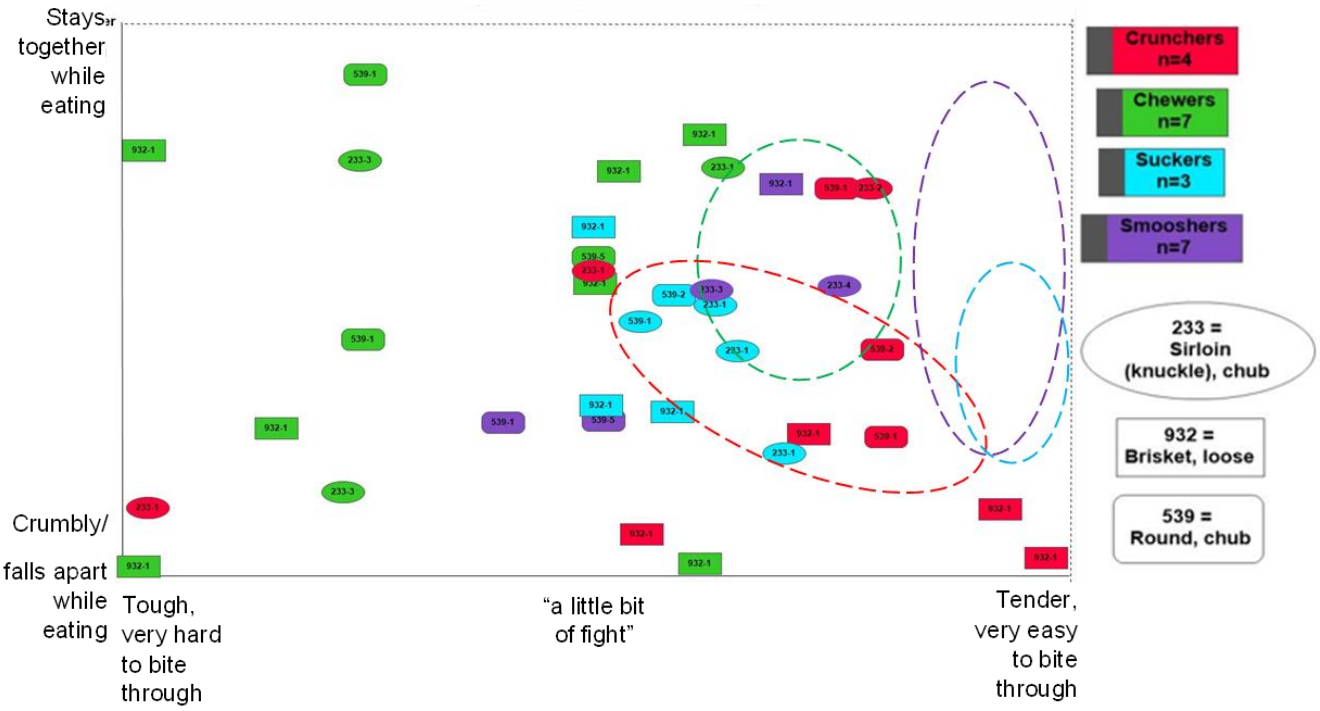

Figure 8. Phase II qualitative group 'raw material' raw mapping across Mouth Behavior groups compared to 'ideal burger'

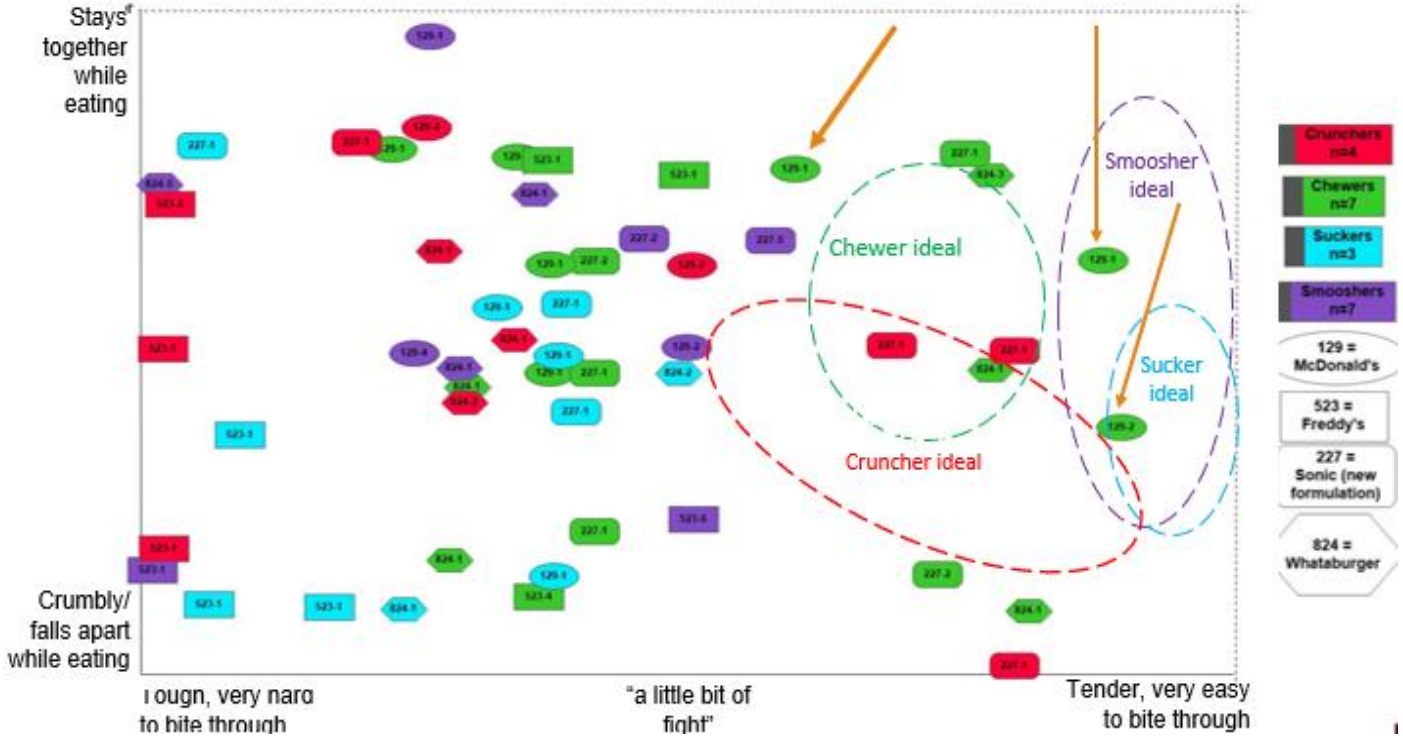

Figure 9. Phase II qualitative group 'fast food' mapping across Mouth Behaviors (McDonalds, Freddys, Whataburger, Sonic).

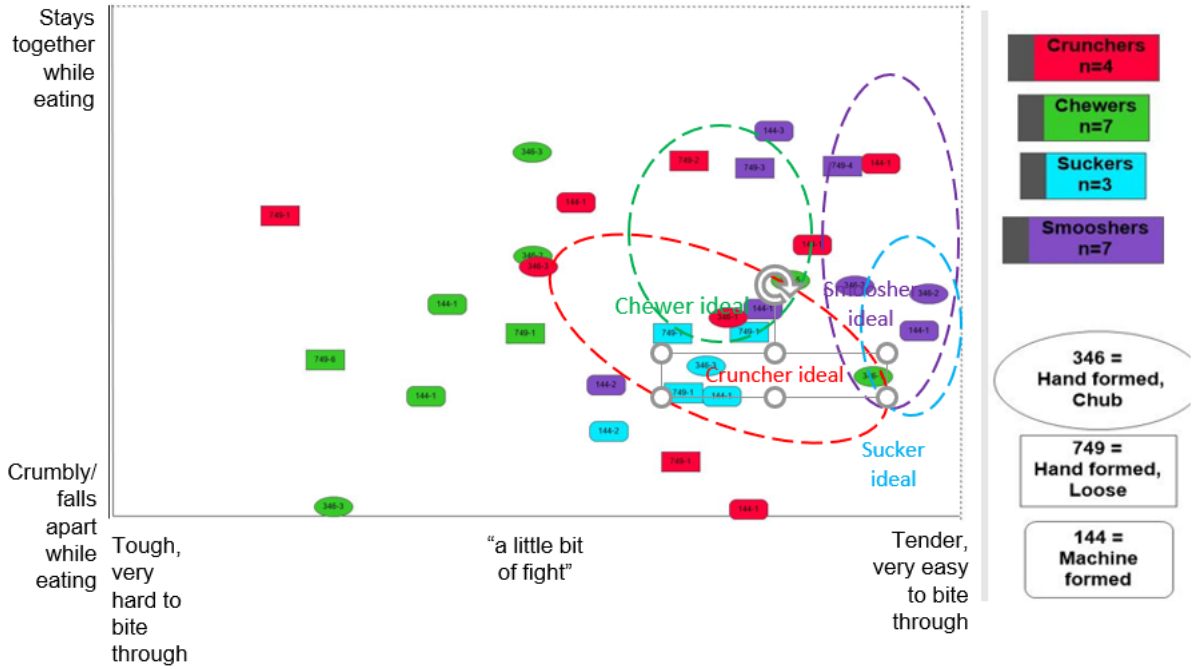

Figure 10. Phase II qualitative group raw mapping for ground beef chuck patties with different packaging materials